System of Environmental Economic Accounting

SEEA Experimental Ecosystem Accounting:

Technical Recommendations

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United Nations UNEP Convention on Biological Diversity NORWEGIAN MINISTRY OF FOREIGN AFFAIRS

Preface / Foreword

Key points

- Description of project and broad motivation (in addition to SDGs)
- Status of SEEA EEA TR in relation to SEEA EEA, to Global Strategy
- Process for developing SEEA EEA TR incl expert forum
- Links to other materials for testing of SEEA EEA
- Next steps at international level
- Connection to national work – implementation frameworks/plans, diagnostic tools, SEEA Implementation Guide,

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List of abbreviations and acronyms

BSU	basic spatial unit
CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CPC	Central Production Classification
CSIRO	Commonwealth Science and Industrial Research Organisation (Australia)
DEM	digital elevation model
EC	European Commission
EE-IOT	environmentally-extended input-output tables
EEZ	exclusive economic zone
ENCA QSP	Ecosystem Natural Capital Accounts: Quick Start Package
ESVD	Ecosystem Services Valuation Database
EU	ecosystem unit
Eurostat	Statistical Office of the European Union
FAO	Food and Agriculture Organization of the United Nations
FEGS	final ecosystem goods and services
FRA	FAO Forest Resource Assessment
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
GRI	Global Reporting Initiative
IIRC	International Integrated Reporting Council
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IRWS	International Recommendations on Water Statistics
ISO	International Organization for Standardization
IUCN	International Union for the Conservation of Nature
km^2	square kilometre
LCCS	Land Cover Classification Scheme
LPI	Living Planet Index
LUCAS	Land Use and Cover Area Survey
LULUCF	land use, land use change and forestry
m^2	square metre
m^3	cubic metre
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services

MEGS	Measuring Ecosystem Goods and Services
NBSAP	National Biodiversity Strategic Action Plan
NCP	National Capital Protocol
NEP	net ecosystem productivity
NESCS	National Ecosystem Services Classification System
NNI	Norwegian Nature Index
NPP	net primary productivity
NPV	net present value
NSDI	national spatial data infrastructure
OECD	Organisation for Economic Cooperation and Development
PIM	perpetual inventory model
PSUT	physical supply and use table
SANBI	South African National Biodiversity Institute
SCBD	Secretariat for the Convention on Biological Diversity
SDG	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SEEA EEA	System of Environmental-Economic Accounting Experimental Ecosystem Accounting
SIDS	small island developing states
SNA	System of National Accounts
SUT	supply and use tables
SWAT	Soil and Water Assessment Tool
TEEB	The Economics of Ecosystems and Biodiversity
UK	United Kingdom
UK NEA	UK National Ecosystem Assessment
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNSC	United Nations Statistics Commission
UNU-IHDP	University of the United Nations / International Human Dimensions on Poverty Programme
US	United States
US EPA	United States Environment Protection Agency
USLE	Universal Soil Loss Equation
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WCMC	UNEP World Conservation Monitoring Centre
WWF	World Wildlife Fund

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 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 System of Environmental-Economic Accounting (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 approach recognises that these individual resources function in combination within a broader system.

1.2 A prime motivation for ecosystem accounting is that separate analysis of ecosystems and the economy does not adequately reflect the fundamental relationship between humans and the environment. In this context, the SEEA Experimental Ecosystem Accounting (SEEA EEA) provides a platform for the integration of relevant information on ecosystem extent, ecosystem condition, ecosystem services and ecosystem capacity, with information on economic and other human activity and the associated beneficiaries (households, businesses and governments).

1.3 The integration of ecosystem and economic information is intended to mainstream information on ecosystems within public and private decision making and hence there must be a strong relevance of the information set to current issues of concern. The general nature of the ecosystem accounting described here is for application at a national level. That is, linking information on multiple ecosystem types and multiple ecosystem services with macro level economic and planning decisions. At the same time, it will prove highly relevant to apply ecosystem accounting approaches at the regional or lower levels. This may demonstrate more easily the potential for ecosystem accounting to aid in the development of responses to specific policy themes or issues. A reduced scale focus may be of particular interest in the development of pilot studies on ecosystem accounting.

1.4 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 (including changes in biodiversity) and the flows of ecosystem services. Often, measurement of these two aspects of ecosystems is undertaken in separate fields of research.
- Second, the SEEA EEA framework encompasses measurement in both biophysical terms (e.g. hectares, tonnes) and in monetary terms where flows of ecosystem services are ascribed monetary valuations through various market and non-market valuation techniques. The valuation of ecosystem services also supports the valuation of ecosystem assets.
- 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 the adoption of certain measurement boundaries and valuation concepts that are not systematically applied in ecosystem measurement. Their use 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 issues.

- 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. In principle, while 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. It is relevant then to balance the scope of the accounting exercise (sub-national, national, global) with the appropriate scale of analysis and information.

1.5 Building an integrated set of information concerning ecosystem extent and condition, ecosystem services and economic activity can provide a platform for discussion and integration between the various perspectives, disciplines and related initiatives that are involved in this area of work.

1.6 By its nature, ecosystem accounting is an inter-disciplinary undertaking with each discipline (statistics, economics, national accounts, ecology, geography, et al.) bringing its own perspective and language. However, in order to obtain the benefits from an integrated approach, institutional co-ordination is required to support the compilation and use of accounting solutions.

1.7 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 recognition 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 develop accounting for ecosystems using, as a starting point, the accounting approaches developed for recording economic activity and individual environmental stocks and flows (e.g. water, energy, timber resources, greenhouse gas (GHG) emissions).

1.8 Given its recent development, ecosystem accounting is considered to be an emerging area of work. While it shows considerable potential as an integrating framework, further discussion and testing of concepts and methods is required. These SEEA EEA Technical Recommendations are intended to support ongoing discussion and testing.

1.2 Scope and purpose of the SEEA EEA Technical Recommendations

1.2.1 Connection to the SEEA EEA

1.9 The SEEA Experimental Ecosystem Accounting: Technical Recommendations (Technical Recommendations) provides a range of content to support testing and research on ecosystem accounting. It complements the SEEA EEA endorsed by the United Nations Statistical Commission (UNSC) in 2013. The SEEA EEA describes a framework for ecosystem accounting and provided an initial platform for discussion and collaboration on ecosystem measurement issues.

1.10 Since the SEEA EEA's 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. Thus, advances in thinking on specific topics, for example on ecosystem capacity, have been introduced to ensure that the content is as up-to-date as possible in this rapidly developing field.

1.11 These Technical Recommendations should not be considered to reflect the final word on ecosystem accounting since further testing and discussion in this emerging field is required. Thus, they provide additional background, context and clarification to the concepts outlined in SEEA EEA with the intent of increasing understanding of the ecosystem accounting approach. A summary of the main differences and clarifications between the SEEA EEA and these Technical Recommendations is provided in Annex 1.

1.2.2 Connection to other materials

1.12 The Technical Recommendations also incorporate findings reflected in a range of other materials on ecosystem accounting that have developed over the past few years. Examples include Ecosystem Natural Capital Accounts: A Quick Start Package (ENCA QSP) (Weber, 2014); Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States (UNEP, 2015); Designing Pilots for Ecosystem Accounting (World Bank, 2014); and Mapping and Assessment of Ecosystems and their Services (MAES) (2^{nd} report) (Maes, et al., 2014). These materials have been developed by different agencies and in different contexts but have an important role to play in the testing of SEEA EEA by providing technical options and communicating the potential of a national accounting approach to ecosystem measurement. A short overview of these different documents is provided in Annex 2 and other initiatives are described in section 1.3.

1.13 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 will support the development of relevant estimates and accounts, especially in terms of describing methods and data sources. Also, these documents describe potential applications of accounting that can provide a useful focus for compilers.

1.14 As part of the broader ecosystem accounting project (in which developing these Technical Recommendations is one output), there have been a range of materials and outputs that have been developed that support the testing and research on ecosystem accounting. National testing plans have been described for seven countries and a range of entry level training materials have been developed. Also, research papers on important measurement topics have been prepared by ecosystem accounting experts. A full listing of these project research papers is included in Annex 3.

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

1.2.3 The audience for the Technical Recommendations

1.16 The primary audience of the Technical Recommendations are those people working on the compilation and testing of ecosystem accounting and those providing data to those exercises, perhaps as part of separately established ecosystem and biodiversity monitoring and assessment programs. Since ecosystem accounting is a multi-disciplinary exercise, and requires the integration of data from multiple sources, testing will require the development of arrangements involving a range of agencies including national statistical offices, environmental agencies and scientific institutes. The Technical Recommendations are intended to be applicable to all of these groups although it is accepted that different people will have different levels of understanding about different parts of the ecosystem accounting model.

1.17 The content should also assist those who will use the information that emerges from sets of ecosystem accounts in terms of understanding the broad ecosystem accounting model, the relevant definitions and terms, and the types of approaches to measurement. However, potential applications of ecosystem accounts and possible tools for analysis using ecosystem accounting are not the focus of this document.

1.2.4 The scope of the Technical Recommendations

1.18 All aspects of ecosystem accounting as described in SEEA EEA are within scope of the Technical Recommendations. However, more emphasis has been placed on measurement in biophysical terms than on issues concerning monetary 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 of land and ecosystem condition. The balance also reflects a pragmatic view that the valuation of ecosystem services and ecosystem assets requires a strong understanding of the relevant stocks and flows in biophysical terms. Consequently, considering the accounting issues in biophysical terms can be considered a necessary first step.

1.19 It is recognized that there is a substantial field of expertise and experience on the valuation of ecosystem services. It is less clear that there have been significant advances in linking this knowledge to the challenge of valuation for ecosystem 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.

1.20 Since the field of ecosystem accounting is quite new and is likely to advance quickly given the range of testing underway, the Technical Recommendations cannot be considered a final document but rather a summary at a point in time. However, it is intended that a process will be undertaken to update the SEEA EEA in the coming 3-5 years. This would take advantage of all relevant conceptual and practical development, and aim to put in place the first international statistical standard for ecosystem accounting. The active participation of the research and academic communities involved in ecosystem related measurement and analysis would be welcomed in this process. Also, on an ongoing basis it is proposed that relevant guidance be updated and shared.

1.3 Links between the Technical Recommendations and other ecosystem measurement related initiatives

1.3.1 International and national initiatives

1.21 As noted in Section 1.2, the content of the Technical Recommendations 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 SNA. Thus, the Technical Recommendations are based on national accounting conventions and accounting approaches to the organization of information.

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

1.23 The second reason is that the information set required for the compilation of a full set of ecosystem accounts is very diverse and not well coordinated at national level. On the whole, economic statistics are quite well coordinated by a small number of leading institutions (e.g. national statistics offices, central banks, taxation offices). The lack of organisation of the underlying information needed for ecosystem accounting has meant that ecosystem accounting is just one among a number of environmental information initiatives. These include work on the Framework for the Development of Environment Statistics (FDES), work on National Biodiversity Strategic Action Plans (NBSAPs) and work in the context of measuring sustainable development (e.g. indicators for the UN Sustainable Development Goals (SDGs)). For the Technical Recommendations and those compiling ecosystem accounts, it suggests that initial focus should be placed on gathering and adapting existing data before moving to the collection of additional data as data gaps and analytical priorities are established.

1.24 Finally, since ecosystem accounting is a relatively new field, it is natural that different approaches and perspectives are developing. There is thus a range of documents describing approaches that are essentially ecosystem accounting, even if some of the content is not fully aligned with the conceptual model described in the SEEA EEA. Since these documents provide useful background methods and data sources for SEEA based ecosystem accounting, Annex 2 provides a short summary of these documents.

1.25 In addition to these documents, there is an increasing body of work 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 (for example, the UNEP study The Economics of Ecosystems and Biodiversity (TEEB) (TEEB, 2010), by national and provincial governments, by non-government organisations (for example, work led by Conservation International in Peru) and by academia (for example, the work at Wageningen University, including Sumarga and Hein, 2013; Remme et al., 2014, Schroter et al., 2014).

1.26 Also, there are an increasing number of examples of projects and initiatives focused on the measurement of particular aspects of ecosystems. Various studies are underway on accounting for biodiversity, land, water and carbon. Sometimes this work is completed in awareness of the SEEA EEA framework, sometimes not. It is likely that these various studies are relevant in a SEEA EEA context, particularly with regard to connecting the measurement outcomes of ecosystem accounting work with policy discussion that is often framed around such themes as biodiversity, carbon, land, soil and water.

1.27 In combination, the initiatives noted in Annex 2 provide an information base to support ecosystem accounting. Inevitably, when drawing information from multiple sources, the results will need to be tailored and adjusted to suit the requirements of accounting and to ensure integration.

1.3.2 Corporate initiatives

1.28 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.

1.29 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 (i) integrating the costs of residual flows (emissions, pollutants, etc.) into current accounting structures or (ii) focused on reporting environmental and natural capital issues as a complement to the standard suite of accounts. This work may be placed within the broader contexts of corporate sustainability reporting and corporate social responsibility.

1.30 This 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 similar to ecosystem accounting.

1.31 Work on integration into standard accounting structures is being developed within the Natural Capital Protocol (NCP) project led 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 measurement approaches will be incorporated is unclear. Also, research funded by the Natural Capital Committee of the United Kingdom (UK) 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 broad logic of SEEA EEA.

1.32 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 the boundaries of 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.

1.4 Structure of Technical Recommendations

1.33 The Technical Recommendations are structured in the following way.

- Chapter 2 covers the general principles of ecosystem accounting with a summary of the ecosystem accounting model described in SEEA EEA and the paths that might be chosen to compile ecosystem accounts.
- Chapter 3 summarises the various accounting units and their classification.
- Chapter 4 describes the main types of ecosystem accounts.
- 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 wellbeing.
- Chapter 6 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.
- Chapter 7 provides an introduction to accounting for various thematic accounts related to ecosystems namely land, carbon, water and biodiversity.
- Chapter 8 summarises monetary valuation from an ecosystem accounting perspective.
- Chapter 9 updates the discussion in the SEEA EEA Chapter 6 on the integration of ecosystem and economic information via the accounting framework.

2. Main aspects of ecosystem accounting

Key points in this chapter

The core ecosystem accounting model from the SEEA EEA provides a robust framework for placing, in context, information on ecosystem assets, ecosystem services, the benefits generated from ecosystem services and well-being.

It is important to understand the analytical and policy questions of most relevance such that compilation can be focused in the appropriate areas.

There are five broad compilation steps within ecosystem accounting. Each step provides useful information for analytical and policy purposes.

There is no single path that must be followed in the compilation of ecosystem accounts. However, as a general observation, the initial focus is on measurement in physical terms and then on valuation in monetary terms.

Physical measures of ecosystem extent and condition, and measures of the supply of ecosystem services may be compiled in parallel since there will be a close relationship between the selection of indicators to measure ecosystem condition and the use of the ecosystem as reflected in the basket of ecosystem services.

The accounting structures presented in the Technical Recommendations can be adapted to support varying levels of detail – e.g. by providing information at different scales from municipal to national.

To gain the most benefit from the ecosystem accounting approach, it is important to continuously assess coherence between different ecosystem accounts. A number of iterations through the accounting system are likely to be appropriate.

Further, the true value of ecosystem accounting will emerge when accounts are compiled on an ongoing basis such that a time series of coherent information can be analysed and relationships and trends established.

2.1 Introduction

2.1 This chapter provides an overview of ecosystem accounting; relevant details are provided in the following chapters, and in associated training materials and research papers. The chapter complements the text in SEEA EEA Chapter 2 by providing additional descriptions of key elements of the ecosystem accounting model. In doing so, the section also provides some additional material to reflect the ongoing developments in ecosystem accounting.

2.2 The SEEA EEA model and key accounting principles

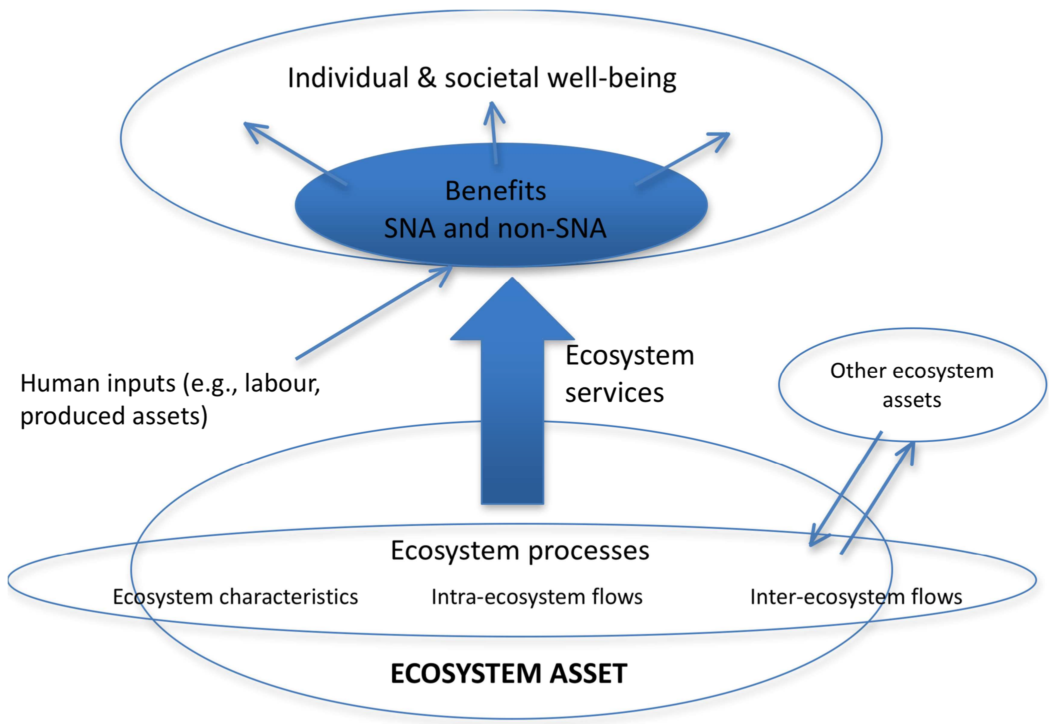
2.2.1 The ecosystem accounting model

2.2 The SEEA EEA ecosystem accounting model has five main components that are reflected in Figure 2.1. Starting at the bottom of Figure 2.1, the model is based around accounting for an **ecosystem asset (1)** that is represented by a spatial area. The delineation of the area that defines an ecosystem asset is required for accounting purposes and should be considered a statistical representation of ecosystems, which by their nature are not discrete systems.

2.3 Conceptually, ecosystem assets are represented by ecosystem units (EU). EU are contiguous areas of different types distinguished according to different characteristics including vegetation, climate, soil type, hydrology and use. To support the delineation of EU, the measurement of ecosystem services and the integration of multiple data sets, basic spatial units (BSU) should be delineated, often through the formation of a standard or reference grid. Generally, accounting will be undertaken at more aggregated level, for example at the level of a state or country, or in terms of broad ecological areas such as bioregions or river basins. These larger areas comprising multiple EU are known as geographical aggregations.

2.4 Each ecosystem asset has a range of relevant **ecosystem characteristics and processes (2)** 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 asset's area, characteristics and processes.

Figure 2.1 Ecosystem accounting model



Source: SEEA EEA Figure 2.2, UN et al 2014b

2.5 Each ecosystem asset generates a set or basket of **ecosystem services (3)** which, in turn, contribute to the production of **benefits (4)**. Benefits may be goods or services (products) currently included in the economic production boundary of the SNA, referred to as SNA benefits; or they may be benefits received by individuals that are not produced by economic units (e.g. clean air). These are referred to as non-SNA benefits. Both SNA and non-SNA benefits contribute to **individual and societal well-being (5)**.

2.6 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 are measurement challenges;

the core model reflecting the relationships between ecosystem assets, ecosystem services, benefits and individual and societal well-being remains strong.

2.2.2 Assets and services

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

2.8 By accounting for both of these components and presenting them in a single integrated model, two key advantages accrue:

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

2.9 There are a number of approaches to 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. Those that focus on ecosystem services tend to also incorporate monetary valuations. While this information is undoubtedly of value and relevance, the issue of why ecosystem assets are important for economic and human activity is commonly not considered quantitatively.

2.10 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 ignores significant issues of the complex, non-linear relationship between ecosystem assets and the services they generate.

2.11 The significance of the SEEA ecosystem accounting model, and the general relevance of accounting approaches, thus lies in: (i) requiring measurement of both assets and services; and (ii) recognizing the connection between these two key components. Indeed, the development of policy relevant information sets requires an overall understanding of an ecosystem's condition, interactions and connections such that suitable recommendations can be formed.

2.3 The steps in compiling ecosystem accounts

2.3.1 Introduction

2.12 In principle, ecosystem accounts will provide information that is relevant in a range of policy and analytical contexts. However, in the initial development and testing phase, it will likely be necessary to understand a more limited number of specific purposes or questions for which ecosystem accounts might be compiled. The type of policy question will help determine the scale of the accounts - either national or sub-national (e.g. water catchment, province, habitat type, etc.) - and the type of data needed. Over time, and building on the initial testing, the development of a more complete set of national level ecosystem accounts can be envisaged through progressive development, extension and integration. Further, the development of an initial set of ecosystem accounts is likely to spark awareness of additional potential applications.

2.13 Determining the appropriate scope and scale for a set of ecosystem accounts must be a matter of discussion at the country or provincial level. It is anticipated that the content of the Technical Recommendations will support that discussion, although it is recognised that other factors will need to be taken into account. Following the general principles of SEEA implementation (see SEEA Implementation Guide (UN, 2013)), the discussions should involve all relevant stakeholders, data users, account compilers and source data holders. Note that the information in the Technical Recommendations is appropriate for discussions on both the commencement of pilot studies and the establishment of nation-wide programs of work.

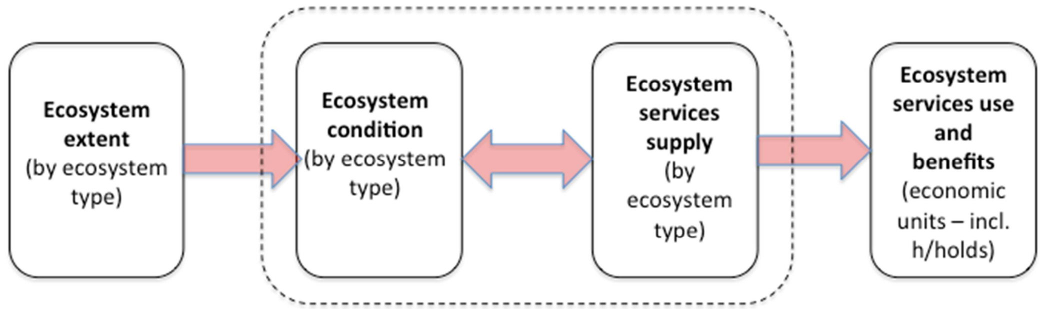
2.14 Generally, the compilation of ecosystem accounts will start using physical measures of stocks of ecosystem assets and flows of ecosystem services and associated benefits. From there, compilation would proceed to valuation and integration with standard economic accounts.

2.15 The conceptual model for ecosystem accounting shown in Figure 2.1 provides a general description of the relationships between the different stocks and flows. However, it does not provide a sense of how a compilation of ecosystem accounts might proceed. This section provides an overview of the steps involved in compiling ecosystem accounts. Later chapters in these Technical Recommendations provide more detail on the various types of accounts, related measurement issues and recommendations.

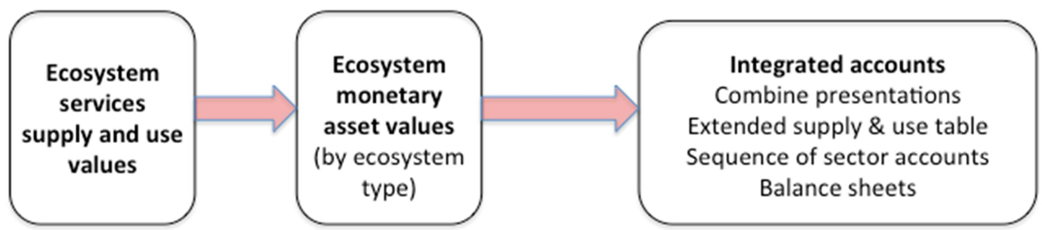
2.16 The broad steps in ecosystem accounting are shown in Figure 2.2. The first set of steps involves accounting in physical terms and the second set of steps is in monetary terms. While it is useful to see this sequencing, the reality of accounting is that there will be multiple iterations through the accounts and further, that the precise starting point may vary. By way of example, Annex #4 shows the steps applied in the UK for the development of ecosystem accounts for broad habitat types. Other projects will likely follow a different sequencing. Whatever sequence is adopted, the reality of accounting exercises is that iteration will be required in order to develop a coherent integration of data across the various accounts.

Figure 2.2 Broad steps in ecosystem accounting

a. Steps in physical terms



b. Steps in monetary terms



2.3.2 Summary of compilation steps

2.17 Within the general considerations noted above, the following paragraphs describe the main steps that must be incorporated within any pathway. The sequence of steps used is reflected in the structure of the Technical Recommendations.

2.18 Step 1: For ecosystem accounting, the first important step is to delineate the ecosystem assets that are to be the focus for the accounts. In principle, these areas should cover the entirety of a country's terrestrial area (including inland waters) and, as appropriate, relevant coastal and marine areas – perhaps extending to a country's exclusive economic zone (EEZ). Chapter 3 discusses the issues of delineating and classifying ecosystem assets for ecosystem accounting purposes.

2.19 Information on the total area of different types of ecosystem assets, often measured in hectares, is presented in an **ecosystem extent account**. This account presents an opening and closing area by type of ecosystem, together with information on the additions and reductions in area. A key aim with this account is to measure the change over time in the composition of ecosystem types within a country. The ecosystem extent account is described in Chapters 4 and 6 with relevant information also in the discussion of land accounts in Chapter 7.

2.20 Step 2: Using the breakdown of ecosystem types 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 state of an ecosystem, and over time, will provide information on trends in ecosystem degradation or enhancement. The set of relevant characteristics will depend both on the type of ecosystem (i.e. indicators for forests will likely be different compared to 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.

2.21 Chapters 4 and 6 discuss the compilation of ecosystem condition accounts in more detail. Chapter 7 discusses the compilation of information on land, carbon, water and biodiversity using accounting approaches since these data may be relevant in monitoring the condition of many ecosystems.

2.22 Step 3: The next step involves the measurement of **ecosystem services in physical terms**[1]. This is completed by considering each ecosystem asset in turn and determining the relevant ecosystem services and appropriate indicators. This task should be conducted using a classification of ecosystem services, such as the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013). A classification can provide a checklist to ensure appropriate coverage.

2.23 This step involves the estimation of both the supply of ecosystem services from each ecosystem asset and the use of those services by various beneficiaries. Together, the information on supply and use are used to compile an **ecosystem services supply and use table**. 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. The possible approaches to measurement are discussed in Chapter 5.

2.24 Step 4: There are many examples of the valuation of ecosystem services and it is a necessary step for certain types of integration with the standard national accounts, such as adjusted gross domestic product (GDP) and extended measures of net wealth.

2.25 There are two main targets for valuation in ecosystem accounting. The first target is 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**. In some cases, particularly for provisioning services, it may be relevant to use broad scale national level measurements of output as a starting point for estimating ecosystem service values, whereas for other services, particularly regulating services, ecosystem specific measurements will be required.

2.26 The second target is the valuation of ecosystem assets. This is done by estimating the net present value (NPV) of the future flow of all ecosystem services from each ecosystem asset. There are, of course, many challenges in this step (discussed further in chapters 8 and 9). A particularly important one is estimating the future flow of ecosystem services and hence the extent to which current ecosystem services supply can be maintained. This requires an assessment of ecosystem capacity which reflects the connection between ecosystem condition and ecosystem services.[2]

2.27 The value of ecosystem degradation will be related to the change in the net present value of ecosystem assets. Opening and closing values for ecosystem assets and changes in those values over an accounting period are presented in an **ecosystem monetary asset account**.

[1] In this context, "physical" means "non-monetary" and measurement in physical terms encompasses ecosystem services that reflect flows of materials and energy, flows of services related to the regulation of an ecosystem, and flows related to cultural services. (SEEA EEA para 3.2)

[2] The measurement of ecosystem capacity may be facilitated by the description of baseline scenarios, i.e., describing expected changes in ecosystem condition given relevant business-as-usual assumptions.

2.28 Step 5: The final step involves the use of information on ecosystem services, ecosystem assets and ecosystem degradation from the accounts described above, to integrate environmental and economic data and augment the current, standard national accounts. This may be done in a number ways including:

i. The compilation of combined presentations where data on ecosystem condition and services in physical terms are presented alongside standard economic data, such as value added, employment, and costs of environmental restoration.

ii. The full extension of the ecosystem services supply and use table in monetary terms to also include all products. This approach can be used to show the integration of ecological and economic supply chains.

iii. The compilation of an extended sequence of accounts where standard economic measures such as GDP, national income, and national saving are adjusted for the cost of ecosystem degradation. Adjusted measures may also be derived by institutional sector and industry.

iv. The estimation of a national balance sheet in which the value of ecosystem assets is incorporated with the value of other assets and liabilities to derive extended measures of national wealth.

2.29 There are challenges in all of these areas that are discussed at more length in Chapter 9 on **integrated ecosystem-economic accounts**.

2.30 Alongside the compilation of ecosystem accounts, it will be relevant to compile thematic accounts such as accounts for land, carbon, water resources and species diversity. These accounts organise data on themes that are commonly of interest from a policy perspective. At the same time, they will each have linkages to some aspects of ecosystem measurement and data from thematic accounts may directly support the compilation of ecosystem accounts.

2.31 Eventually the complete cross-reading of ecosystem and thematic accounts is what should ensure consistency of the whole accounting system. The key aspects of national accounting approaches to measurement are summarised in Annex 5. Annex 5 has been included to provide an overview of the key elements of the national accounting approach that underpins the compilation of ecosystem accounts described here. This material is highly relevant to those who have not practised national accounting and should provide a context in which what constitutes ecosystem accounting can be understood.

2.3.3 Key considerations in compiling ecosystem accounts

2.32 Six key considerations emerge in understanding the set of ecosystem accounts as presented in the Technical Recommendations. First, it is a set of accounts with each account containing specific pieces of information applicable to one part of the ecosystem accounting model outlined in Chapter 2. There is not one single "ecosystem account" and it would be inconsistent with accounting principles to force information on all stocks and flows into a single account while attempting to also retain notions of internal consistency and coverage.

2.33 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 accounts that can be highlighted by structuring the information appropriately.

2.34 Indeed, in some cases, the same information may be contained in two accounts, as it is relevant in both contexts. For example, the accumulation of biomass for accessible timber will be relevant in the measurement of the supply of ecosystem services and also in understanding the change in the ecosystem asset, i.e. the forest. This does not represent double counting but rather the appropriate placement of information to reflect different accounting identities.

2.35 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 particularly relevant for accounts concerning ecosystem services.

2.36 Fourth, the accounting 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 EU types (e.g. forests) within a given geographical aggregation. In practice, it may be most relevant to provide finer detail only for some specific EU types (e.g. by type of forest). The accounting principle of working from the outside-in (see Annex 5) implies that rearrangement of information inside a boundary is perfectly appropriate and the level of detail should be determined based on analytical and policy requirements and with regard to data availability.

2.37 Fifth, the accounts described in this chapter present information for one accounting period, usually one year. The length of the accounting period determines the points chosen to measure the opening and closing stocks. Flows are measured in terms of observed changes between the opening and closing of the accounting period.

2.38 Most commonly however, the interest in accounting information stems from the presentation of time series of information, i.e. for multiple accounting periods. Presuming that time series of accounts are compiled, including, for example, accounts for two accounting periods 5 years apart, 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 of concept. Compilers should feel free to restructure the accounts described here in such a way to best suit the presentation and analysis of data, in reference to the associated policy questions.

2.39 Sixth, the structure of accounts will generally represent a level of detail suitable for presentation and analysis of outputs from accounting. 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 necessary for underlying information to be compiled at different, usually lower, levels of aggregation before entry into the accounts.

2.40 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 EU 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 are managed separately. Making this distinction is essential if changes to the source of the input data are to be managed effectively, without affecting the integrity of the time series of data contained in the accounts themselves. Indeed, changes to input data should be considered a normal and common situation.

2.41 With all this in mind the ecosystem accounts described in Chapter 4 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 understanding the relationship between ecosystems and the economy in their country. However, to support ongoing dialogue and international comparison, it is essential that these structures, classifications, concepts and resulting indicators are coherent with the core presented in the Technical Recommendations. If variations are used, these should be described and presented with the accounts.

2.42 The design of the accounts will benefit from further testing and discussion in terms of both the relevant compilation approaches and the most appropriate levels for analysis and communication of results.

2.3.4 What constitutes ecosystem accounting?

2.43 Given that there are a number of accounts within scope of the ecosystem accounting system, a reasonable question 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. 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 provides a framework for discussing the relationship between the economy and the environment.

2.44 Second, in the context of this comprehensive approach, it must be accepted that all of the accounts described above cannot be completed at once. As compilation takes place and understanding increases, the set of ecosystem accounts will become more advanced and complete. However, at each point along the way, the accounts that have been compiled will be relevant for particular policy purposes and analysis. Thus, it is not necessary to complete the full set of accounts for the information to become relevant.

2.45 Based on current experience, a reasonable first level of attainment in terms of ecosystem accounting would be the compilation of accounts in physical terms for ecosystem extent, ecosystem condition and ecosystem services supply and use. These three accounts form the basis for the remaining accounts and, in their own right, cover the key elements of the ecosystem accounting model in Figure 2.1.

2.46 In compiling the ecosystem condition account and the ecosystem services supply and use table in physical terms, a challenge is the derivation of meaningful aggregates that support a broad assessment across ecosystems. For ecosystem services, aggregation is possible using monetary valuation techniques. It is in this context that valuation and, ultimately integration with the standard economic accounts, may have most relevance. It is often assumed that valuation in monetary terms is an accounting requirement. 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.

3. Spatial infrastructure and definition of units for ecosystem accounting

Key points in this chapter

Ecosystem accounting requires the delineation of areas within a country into mutually exclusive units that represent ecosystem assets.

Ecosystem units (EU) are the spatial areas that form the conceptual base for accounting and the integration of relevant statistics.

Basic spatial units (BSU) support the delineation of EU and the integration of multiple datasets. For ecosystem accounting, BSUs are assumed to be internally homogenous in terms of their biophysical properties. BSUs may be delineated through the formation of a spatial grid covering the extent of a country.

Accounts will generally be produced for relatively large administrative areas, such as a provinces, states or countries; or in relation to a large ecological areas such as bioregions or river basins. These larger areas that are used for accounting and reporting are referred to as geographical aggregations.

The delineation of EU will require the use of multiple data sources. As a starting point for delineation, land cover data, grouped into relatively broad land cover types may be appropriate.

Testing of methods for the delineation of EU and the formation of BSUs is required. A focus should be placed on determining the appropriate scale of information required for integration of data and for accounting and policy use.

3.1 Introduction

3.1. The SEEA EEA applies the definition of ecosystems from the Convention on Biological Diversity (CBD) – "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). Ecosystems are not straightforward to delineate spatially for measurement purposes. In ecological terms, they may be defined at a range of spatial scales, and hence it is often difficult to identify clear boundaries and they may overlap in spatial terms. For statistical and accounting purposes, it is necessary to clearly differentiate ecosystem assets as discrete units. Hence, the boundaries described here should be considered a statistical abstraction from an ecological reality.

3.2. Ideally, in ecosystem accounting, there is consideration of all ecosystems within a country. To support this scope, it is necessary to delineate all areas within a country such that there are no gaps or overlaps – i.e. an approach that is mutually exclusive and collectively exhaustive. A key objective in delineating areas is to be able to classify a country into different types of ecosystems. Different types of ecosystems will supply different ecosystem services. Hence, understanding the multiple and changing structures of different types of ecosystems is an important aspect of ecosystem accounting.

3.3. Different types of spatial areas need to be delineated to co-ordinate and present the information required for ecosystem accounting. For this purpose, a framework covering three types of spatial areas has been developed. The purpose of the framework 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 economic units (businesses, households and governments) are distinguished by their types of economic activity and legal structure. These economic units can then be grouped into relevant types, such as industry classes and institutional sectors. Second, the spatial framework and the associated classifications provide a basis for structuring and presenting data on ecosystem extent, condition, and ecosystem services.

3.4. This chapter outlines the approach taken in SEEA EEA to delineate spatial areas for the purpose of ecosystem accounting, building on the discussion in SEEA EEA Section 2.3. The conceptual and practical aspects of delineating spatial areas are described in section 3.2. In section 3.3 a summary of data sources, classifications and methods is provided. In section 3.4 key measurement issues are described and section 3.5 provides recommendations for testing and areas for ongoing research.

3.2 The framework for delineating spatial areas for ecosystem accounting

3.5. The conceptual model for ecosystem accounting involves the integration of three types of areas. First, areas representing ecosystem assets which lie at the heart of the conceptual ecosystem accounting model. Second, small areas that can be used to integrate the detailed geo-spatial data that is required for ecosystem accounting. Third, larger areas that represent aggregations of smaller areas and will correspond to the level of spatial detail likely to be reflected in ecosystem accounts. Each of these three types of areas is described in this section.

3.2.1 Ecosystem Units (EU)

3.6. Conceptually, for accounting purposes, each area representing a different type of ecosystem is considered to represent an ecosystem asset. Each of these individual areas is considered an EU. Ecosystem assets are considered to be bounded spatially with each asset comprising all of the relevant biotic and abiotic components within those bounds that are required for it to function and to supply ecosystem services. An EU can be considered to reflect the spatial boundary for accounting and statistical purposes that supports measurement of the CBD's definition of an ecosystem quoted above.

3.7. The EU is the conceptual unit that underpins the ecosystem accounting model. It is the EU that represents the ecosystem that supplies a mix of ecosystem services and which can be considered to have a condition in terms of a combination of structure, function and process. In principle, an EU will be differentiated from neighbouring EUs by the extent to which the relationships between biotic and abiotic components within an EU are stronger than the relationships with components outside of the EU.

3.8. EUs are contiguous areas representing individual ecosystems. In practice, it may be relevant to analyse accounting variables, such as ecosystem condition and ecosystem service supply, at a more aggregated level reflecting information for EUs of the same type. For example, ecosystem account users may be interested in information on the ecosystem services supplied by all EUs of type "deciduous forest", rather than in services from individual patches of deciduous forests.

3.9. Ideally, EU will be delineated based on various characteristics including vegetation structure and type, physiognomy, climate, hydrology, soil characteristics and topography. These characteristics may be used alone or in combination. The choice will be dependent on the country and the data available.

3.10. Additionally, it may be relevant to use information on land management as part of the delineation of EUs. This may be particularly helpful in understanding the flows of ecosystem services that are most likely from a particular area. For example, it may be useful to distinguish between protected forests that are not logged and other, ecologically similar forests in which logging in permitted. It is also noted that maps that delineate land within a country according to different land management regimes (for example protected areas and water catchments) may be readily available and can be used to support the establishment of spatial areas for ecosystem accounting.

3.11. In terms of delineation using ecological characteristics, the breadth of data covering the characteristics noted above may not be available to specify EU sufficiently well across all areas within a country. Therefore, where various ecological data are not available, a land cover based delineation of EUs can be used as a starting point. This raises the practical question of which land cover types should be considered and at what level of detail.

3.12. For land cover based EUs, it is recommended that the most coarse level of aggregation should be based on the interim land cover classification of the SEEA Central Framework which has 15 types/classes as shown in Table 3.1.[3] Note that a class for sea and marine areas has been incorporated to ensure appropriate coverage for all of a country's area that may be included within ecosystem accounting. (For a more detailed description see the SEEA Central Framework, Annex 1, Section C.)

3.13. Each of these 15 types may be used to represent a type of EU. Generally, across a country, there will be a number of different areas of the same EU type. For example, there will be different areas of forest in different parts of a country. Each separate forest is considered a separate EU but is classified to the same EU type.

3.14. The use of high level land cover information as a starting point for ecosystem accounting is likely to be amenable to measurement in most countries at the national level. Data and analysis at this aggregated level of detail will also be useful to convey broad trends in the changing structure of ecosystem types.

3.15. However, the use of a limited number of EU types will also limit the sophistication of the questions that can be answered using the accounting information. Ideally, and as appropriate within a country, more detailed classifications should be integrated with the broad land cover classes such that a nested or hierarchical set of EU types is developed. This could be done progressively as the understanding of ecosystem accounting develops and as the availability of information increases.

3.16. The availability of more detailed EU type information would also support a more straightforward link to ecosystem services supply. For example, ecological detail concerning the type of perennial crop, or the hydrological properties of a forest,

[3] The SEEA EEA proposed a set of 16 classes for land cover/ecosystem functional units. These classes were developed as an application of the interim Land Cover classes presented in the SEEA Central Framework by combining land cover information with information on land use. Since there may be various ways in which land use and land cover information may be combined, it is now considered that for the task of attributing land cover characteristics to the BSU level and hence for delineating broad EUs, the starting point should be the land cover classification of the SEEA Central Framework.

would facilitate identifying and analysing the ecosystem services supplied by those EUs.

3.17. As the number of different EU types increases, the sizes of EUs will generally decrease. For example, individual areas of forest will be larger than areas of different types of forest, for example, classified according to species or altitude. While additional detail may be useful for better understanding the changing composition of types of ecosystems, this outcome may be problematic for deriving other measures of ecosystems, for example ecosystem services, since information may not be available in relation to detailed types of EU. Further, as the size of EU becomes smaller, often the accuracy of the information attributed to it will also reduce (depending on the data source). In practice, a balance must be found between the number of EU types that are identified and the availability of information.

3.18. To support the improvement of accounts over time and the integration of data, it is recommended that the classification used for EU types is nested. That is, finer level classes providing more detail should sit within broader classes, perhaps of land cover type, eco-region or biome. Further, use of a common set of land cover types at the highest level in all ecosystem accounting work would support cross country comparison and support exchange of methods.

Table 3.1 Land cover classes

Description of classes
Artificial areas (including urban and associated areas)
Herbaceous crops
Woody crops
Multiple or layered crops
Grassland
Tree-covered areas (forests)
Mangroves
Shrub-covered areas
Shrubs, and/or herbaceous vegetation, aquatic or regularly flooded
Sparsely natural vegetated areas
Terrestrial barren land
Permanent snow and glaciers
Inland water bodies
Coastal water bodies and intertidal areas
Sea and marine areas

Source: SEEA Central Framework Table 5.12 (UN et al., 2014a)

3.2.2 Basic spatial units (BSU)

3.19. While EU represent the underpinning conceptual unit for accounting and statistical purposes, the delineation of EU in practice is unlikely to be completed directly from available information. Further, much of the information that needs to be attributed to EU or to types of EU, will not be available at the EU level directly. Consequently, another type of spatial area is needed to support compilation. For ecosystem accounting, this area is termed a basic spatial unit (BSU).

3.20. A BSU is a small spatial area that is a geometrical construct. The purpose of delineating BSUs is to provide a fine level frame to which a range of different information can be attributed. Once different data have been integrated to the same spatial scale then many aggregation and integration possibilities emerge.

3.21. The most common approach to delineating BSUs is to form a grid of appropriate coverage and cell-size (ideally <100m) that is overlayed on a large area or country. This forms a *reference grid.* In this context, a BSU corresponds to a *grid-cell* in geo-information disciplines and a *grain* in landscape ecology.

3.22. A reference grid, and its constituent BSU, is used to ensure spatial data quality, for example in terms of ensuring consistent coverage and structure by stopping shifting boundaries, removing gaps, etc.

3.23. It is also necessary to establish and agree on a reference coordinate system or datum. A datum is a set of reference points on the earth's surface against which position measurements are made, and (often) an associated model of the shape of the earth to define a geographic coordinate system. A reference coordinate system based on a common spatial projection is important for accounting purposes to ensure all spatial datasets can be combined for analysis. Ecosystem accounting relies on being able to specify the spatial location of EUs and requires the integration of different spatial data sets. In these contexts, a reference grid with an agreed datum is an essential tool for spatial analysis and reporting. It is necessary that all spatial data layers, including grid and vector data are converted to the same reference coordinate system for analysis.

3.24. Where a reference grid is established, a key question is what size the grid squares should be for ecosystem accounting purposes. A general principle for the reference grid is to use a grid size that is as small as possible within computational capabilities. It is recommended that grid squares of 100m be considered the maximum size. Grid squares down to 10m and smaller are now possible in some countries, but whether delineation at that level of detail is required or appropriate for ecosystem accounting should be informed by the use of the accounts for decision making. In most cases, grid square sizes ranging between 25m and 100m will be suitable.

3.25. Once a reference grid delineating BSUs has been established, attention must turn to the attribution of information to the BSUs. Note that when attributing information to a single BSU, it is assumed that, within the boundary of a BSU, its structure and processes are homogenous. In principle, a range of information can be attributed to each BSU, including EU type, land cover, soil type, elevation and other biophysical information.

3.26. Spatial data are available in two formats – grids and vectors. With grid data, it is likely that different types, or spatial layers, of information that will be used for accounting will be produced using different grid sizes. For example, satellite data are often mapped using 30m grids, or perhaps 250m grids when mapping larger areas or for national analysis.

3.27. It is also possible to use vector data for the ecosystem extent account, and as analytical basis for the data analysis of the other accounts. This has been tested in the Netherlands, where five different maps depicting land cover, vegetation and land use have been combined to create a vector map of the ecosystem units.

3.28. The smallest EUs measure 10 to 20 square meters, but the size of the EU goes up to several hectares in some cases. It is assumed that the individual units are homogenous in terms of ecosystem type, and ecosystem service flows are calculated for each EU. The use of a vector format can be useful for the analysis of linear elements in the landscape, in particular narrow elements which may not be covered accurately using a raster map, such as roadsides, hedgerows or streams.

3.29. Generally, individual spatial data sets have been stored in vector format due to their smaller file size. However, combining vector data sets is computationally intensive and requires assumptions be made about the process adopted for adjusting overlapping areas between data layers. More recently, there has been a move to the use of raster data since computational capabilities are no longer limiting. By adopting a reference grid, and converting all vector data to raster format, the time required to analyse many data layers can be significantly reduced.

3.30. Once information is attributed to the BSUs of the reference grid, it is possible to aggregate BSUs. One particular objective is to delineate EUs by combining contiguous BSUs that have the same or similar characteristics (e.g. the same vegetation type). In practice, the formation of a comprehensive set of BSU, often in the form of a reference grid, is the path that will be taken to delineating EU rather than a direct form of delineation. Other types of aggregations are considered in the next section.

3.2.3 Geographical aggregations

3.31. Conceptually, it is possible to develop a set of ecosystem accounts for an individual EU, such as an individual forest, wetland or farming area. This would be akin to developing accounts for individual businesses. However, aside from the measurement challenges this might entail if applied to all EUs within a country, the general ambition of ecosystem accounting in the SEEA is to provide more general guidance as to the changes in ecosystem related stocks and flows.

3.32. To provide this larger picture of ecosystems, it is necessary to consider aggregations of EUs that both provide information (i) at a scale relevant for policy monitoring and analysis, and (ii) at a scale where the accuracy of the information is considered acceptable.

3.33. At the most aggregated level, this involves accounting at the national level, i.e. covering all EUs within a country but it may also be relevant to create aggregations (i) of EUs within specific sub-national administrative areas; (ii) of EUs within hydrologically defined areas within a country (such as river basins); and (iii) for other areas of policy interest (such as protected areas). Commonly, these geographical aggregations will reflect contiguous areas, such as administrative areas or river basins, but this is not a requirement for accounting purposes.

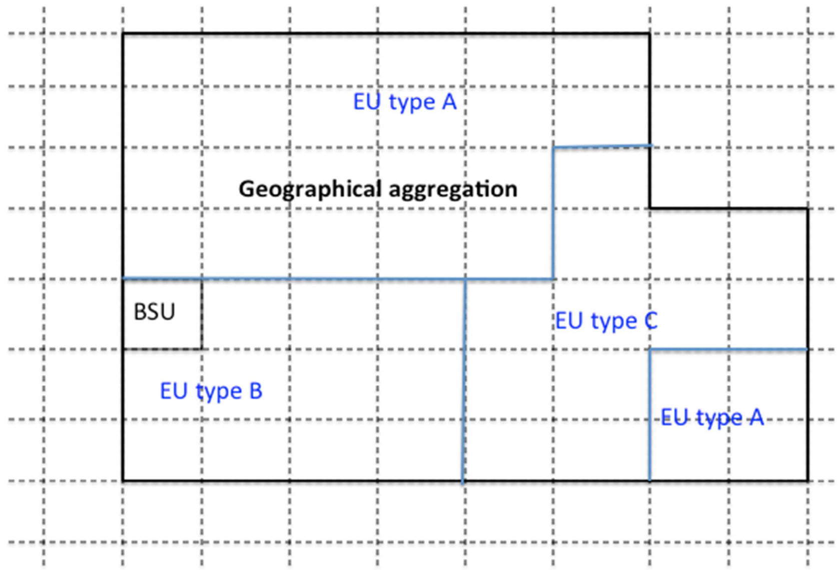
3.34. Within each of these geographical aggregations there will be multiple types of EU, e.g. combinations of forests, rivers, agricultural areas, etc. The resulting account structures, as described in Chapter 4, will be such that measures of ecosystem extent, ecosystem condition and ecosystem services, will present information for aggregations reflecting types of EU. For example, for a given sub-national administrative area, an ecosystem extent account would show the changing total area of each type of EU. It would not show the changing area of each individual EU.

3.35. There is no single classification structure for geographical aggregations. However, it is important to ensure that a single account covers all EUs within a country or large administrative area (e.g. state or province) boundary in a mutually exclusive way. Thus, there may be a national-level ecosystem account that is structured to reflect river basins; and another national level ecosystem account that is structured to reflect sub-national administrative areas. In all cases, the sum of the areas of all component geographical aggregations must equal the total area being accounted for. It is also important that the reference grid provide coverage of the geographical aggregations.

3.36. In some cases, ecologically, a single EU may cross administrative and national boundaries. For example, large forests and lakes that cross the boundary of neighbouring countries. In these cases, the EU should be delineated such that they remain within the geo-political boundaries. In other cases, a single EU may be classified to different geographical aggregations, for example to a river basin and to an administrative region. Incorporating a single EU into these different geographical aggregations will be relevant depending on the question being addressed.

3.37. The relationships between EU, BSU and geographical aggregations are shown in Figure 3.1.

Figure 3.1 Relationships between spatial areas for ecosystem accounting



Source: (adapted from SEEA EEA Figure 2.4 (UN et al., 2014b)

3.38. In practice, a balance must be struck between providing a highly detailed typology of EUs and providing information that can be readily translated to support trend analysis at an aggregate level and which is of suitable accuracy. Approaches to delineating spatial units are described in section 3.3.

3.39. The framework for delineating spatial units described above focused on ecological characteristics. It is also possible to delineate spatial areas using characteristics such as land ownership and land management. Since all data layers will be snapped to a reference coordinate system, it is possible to combine these non-ecological layers in different ways for accounting purposes. For instance, it is possible to combine information on land tenure (ownership) with EU and river basin information to understand the tenure of EUs within each river basin. The potential to utilise land management information in the delineation of EU has also be noted earlier in the chapter.

3.40. In many countries, cadastres are well established, administratively defined units that are delineated on the basis of land ownership. Information from cadastre-based datasets can be attributed to BSUs and, consequently, linked to information on EUs, economic activity, land use and other socio-economic information.

3.41. The use of cadastre-based information is likely to be meaningful in terms of understanding the link to policy initiatives, particularly in those countries where land is under private ownership. However, it is not recommended that land ownership data be directly applied to delineate EU since this information may raise sensitivities in many countries.

3.3 Data sources, classifications and methods for delineating spatial units

3.42. The delineation of spatial units will involve the use of a range of spatial information relating to:

- Land cover and land use
- The topography of the country (coastline, digital elevation model (DEM), slopes, river basins and drainage areas)
- Vegetation, habitats and species composition
- Soil resources
- Meteorological data
- Bathymetry (for coastal areas)
- Administrative boundaries
- Population, built-up areas and settlements
- Transport and communication (roads, railways, power lines, pipelines)

3.43. Using these types of information, it is possible to construct maps for a given country outlining different EUs as objects in the landscape. Object based classification tools for spatial data can facilitate the mapping process. In practice, it will be necessary to put in place a common spatial infrastructure and reference grid that ensures the data can be integrated in a common spatial framework.

3.44. All spatial layers must have the same area coverage (in terms of information) as that of the reference grid. It some instances, layers may have only been partially populated with data. In these cases, the unpopulated areas of each spatial layer need to be classified as either "no data" or "unclassified', or the data need to be modelled in some way, to ensure consistent coverage and reporting.

3.45. With these data sources and tools in place, there is a range of choices available for delineating the spatial units needed for ecosystem accounting, depending on scale (i.e. the level of spatial detail) and thematic detail (the number of classes in the classification). The following considerations are relevant, beyond those described in section 3.2.

3.46. First, there is no standardised method for delineating EUs. The approaches used will depend, in part, on the extent to which information is available that can be attributed to the BSU level and hence be grouped to form EUs, or whether individual EUs can be directly mapped. Wherever possible, it is recommended that ecological principles are followed since EUs are considered the units that function to supply ecosystem services. Habitat/biotope and vegetation classification methods are expected to offer the most suitable inputs for EU delineation.

3.47. The most obvious choices for geographical aggregations are nationally defined statistical areas since they permit integration with national level economic, social and demographic data. Statistical areas will also commonly correspond best to the level of coverage of government decision-making. Depending on the decision making context, other boundaries will also be relevant including river basins, ecozones, landscapes and view-scapes, water provisioning areas, flood/storm protection areas and protected areas (e.g. national parks).

3.48. In all instances, geographical aggregations must provide exhaustive and mutually exclusive coverage of a country or sub-national area to ensure a clear reference area for ecosystem accounts. For example, reporting for river basins should still be undertaken with complete coverage of the country so that the total area of all river basins is equal to the total area of the country.

3.49. There may be times when decision making and policy needs requires a focus on select types of EU, for example wetlands. In compiling accounts for these purposes, it is appropriate for the account to show not only forest areas but also the "residual" non-wetland areas to ensure that the sum is still equal to the total area of the country.

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

3.50. Approaches to delineating spatial areas for ecosystem accounting are still developing and there are a number of issues that should be kept in mind.

3.51. First, there are a number of methods that can be used to delineate spatial units through the integration of several data sources. The choice of method should take into consideration the policy and decision making requirements.

3.52. Second, the framework including BSU, EU and geographical aggregations has been developed in the context of terrestrial areas. Some work has commenced on the application of the model to marine areas (e.g. South Africa (Driver, 2012), Mauritius (Weber, 2014b), UK (UK NEA, 2011)) and to river systems (e.g. South Africa (Driver, 2012) and Australia (Victorian DSE, 2013)). Further 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 – which may have specific ecological properties and supply specific ecosystem services. Particularly for linear features, further testing is needed to assess whether the solution may lie in providing data at higher resolution or whether an alternative approach is needed.

3.53. Third, for EUs, 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 and use table – are all structured based on data by type of EU. Since each EU represents an ecosystem asset, measures of condition should be able to be developed at the EU 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 testing and research.

3.54. A related point is the extent to which the EUs are consistent with ecological factors. If the EU are to represent ecosystem assets for accounting purposes, it is reasonable to suppose that they would also reflect spatial areas that ecologists would consider to be appropriate functional units.

3.55. Fourth, ideally the delineation of spatial units should take into account the need to scale information both upwards and downwards, particularly in relation to the attribution of information to the BSU level. Delineating units in a manner that requires a heavier burden of assumptions to support scaling would likely reduce the general quality of the accounts.

3.56. Fifth, it is likely to be the case that the delineation of spatial units will involve the use of remote sensing data including satellite data. This is an important step forward but is not without its challenges, particularly in the context of compiling a consistent time series for accounting purposes. Further, there is the related challenge of uncertainty in spatial interpretation and the need for validation and ground truthing. These challenges are not unique to ecosystem accounting but developing methods for adapting remote sensing data for ecosystem accounting purposes is an important area for testing.

3.5 Recommendations

3.5.1 Recommended activities and approaches for testing

3.57. Based on the approach described in this chapter a number of points emerge as being steps that countries can focus on in testing and experimentation in ecosystem accounting. A clear theme in these recommendations is that work to establish the spatial units required for ecosystem accounting should be undertaken within a broader context of work to establish a national spatial data infrastructure that would support integration of environmental and socio-economic data.

3.58. The starting point is the need to develop a reference grid/coordinate system and a common spatial projection (i.e. grid size). This is required to ensure all data layers no matter what their source can be snapped to a common basis and be combined to produce statistics and accounts. Further, all data layers must be fully populated for the country or area of interest. As noted above if they are not then unpopulated areas of the layer need to be classified as "no-data" or unclassified.

3.59. Work on the delineation of spatial units should be undertaken at the national level as part of the development of a national spatial data infrastructure (NSDI). Even where the initial intent is to develop ecosystem accounts for a sub-national region, there will be significant gains in articulating a national approach to the delineation of spatial units. In particular, it will ensure that any initial work can be integrated into subsequent larger scale measurement and it is likely that there are some production efficiencies in undertaking the delineation task for all areas within a country at the same time.

3.60. The development of an NSDI requires hardware with sufficient processing, storage and back-up capacity, geographic information system (GIS) software[4], and integration of the following recommended data layers:

- Official country boundaries, official administrative and statistical boundaries for collection of official statistics (in a shapefile of polygons)
- A common geographic projection, compatible with an international projection (e.g. WGS 84)
- A reference grid with a common projection, applied as a BSU structure, and used to organise and manage spatial data consistently and allocate all spatial input datasets[5] (it may also be used to prepare data cubes for storing and extracting data)
- Elevation and topography data, based on a Digital Elevation Model (DEM). If no detailed country-level data are available the global ASTER dataset[6] can be used. The DEM data are important to distinguish the elevation and slope of the BSU.
- Land cover data
- Additional data layers as available including
    - Land management/use
    - Vegetation type
    - Soil and geology data

[4] Freeware, such as QGIS, or commercial - ArcGIS

[5] It is recommendable to identify the grid size of highest resolution that will be applicable. This needs to be consistently nested into lower resolution sizes.

[6] http://asterweb.jpl.nasa.gov/gdem.asp

- Hydrological data related to rivers, lakes, streams, coastal and marine areas
- Data on urban infrastructure, including cities, villages, industrial zones, and transport (rail, road), that is needed for assessing ecosystem condition and understanding ecosystem use (e.g. relevant for mapping fragmentation and other impacts)

3.61. Most likely the delineation of spatial units will rely, in the first instance, on the use of land cover information. This will provide a strong starting point for the compilation of ecosystem accounts. Over time, it is recommended that land cover information be combined with information on other characteristics such as hydrology, soil, vegetation types and road networks, to support delineation of EUs.

3.62. As part of the development of an NSDI and, ultimately a national register or listing of ecosystem units, it will be important to understand spatial areas that have already been delineated by government agencies for administrative purposes, for example land management, river basin and catchment management and nature conservation purposes. In some cases these existing spatial boundaries may provide a suitable starting point for ecosystem accounting.

3.63. Further, it is relevant to develop an understanding of the hierarchy of ecosystem/landscape/eco-region/biome units that are relevant for the country. This can be done in reference to existing products (e.g. World Wildlife Fund (WWF) eco-regions) and rules to convert (aggregate/disaggregate) between them (particularly between EU and geographical aggregations). Overall, testing and experimentation should reveal what are the most relevant data sources for the delineation of units for ecosystem accounting ensuring that the outcome provides a spatially exhaustive coverage of a country.

3.64. One area for testing is assessing the appropriate scale of analysis for different analytical purposes. In particular it will be important to test whether data should be maintained at the scale at which they are collected or transformed to a common spatial scale for subsequent compilations. Also, the effect of the size of the BSU in terms of measures of ecosystem condition and ecosystem services is an important area for testing.

3.65. Other key aspects in testing and experimentation are:

- Assessing the accuracy and uncertainty in the use of remote sensing data for ecosystem accounting purposes. This will normally require use of ground-truthing (point) data.
- Establishing appropriate quality control criteria and assessment protocols
- The use of soil science to delineate spatial units, for example the potential role of soil classifications and links to the SEEA Central Framework.
- Criteria for, and testing, other intermediate spatial units (such as landscapes, viewscapes and river units)
- Linking levels of spatial units with specific information that may be attributed to a unit for certain types of analysis.
- Understanding how spatial units are treated in various ecosystem services models.

3.66. It is important to recognise that the ecosystem accounting approach will be most useful when developed over a period of time. Indeed, given the potential complexity of the accounts, a step-by-step approach and learning by doing are required. In addition, data will be more useful when both spatial and intertemporal (trend) analyses are possible.

3.5.2 Issues requiring ongoing research

3.67. In addition to testing the delineation of spatial units at country level, there are some issues that require more substantive research and investigation. These include:

- The delineation of units for freshwater, coastal and marine ecosystems
- The treatment of airsheds, hydrological networks and other connective phenomena within the spatial units framework
- The treatment of subterranean ecosystems (such as caves and ground water systems)

3.68. The creation of units that are closely linked to ecological principles to aid ecologically focused analysis. While some ongoing research is required, overall, the work on the delineation of spatial units for ecosystem accounting is largely a matter of testing and application of the principles as outlined in SEEA EEA and expanded on in this chapter.

4. The ecosystem accounts

> **Key points in this chapter**
>
> There are three main types of ecosystem accounts: accounts for ecosystem assets, accounts for ecosystem services and integrated accounts which presented ecosystem accounting information with standard economic and national accounts data.
>
> Thematic accounts on themes such as land, biodiversity, carbon and water provide important context and supporting information for ecosystem accounts.
>
> The structure of ecosystem accounts follows the general structures of supply and use tables and asset accounts as described in the SEEA Central Framework and the SNA.
>
> There are important connections between the different ecosystem accounts which permit the description of a single integrated picture of ecosystems.
>
> In compilation, there is a progression in compilation from extent accounts, to condition and ecosystem services accounts in physical terms, to ecosystem services supply and use tables in monetary terms, to full integrated accounts.
>
> The appropriate structure and detail for the ecosystem condition requires further consideration following testing.
>
> It is possible to compile the accounts at different levels of detail. It may be appropriate, as a starting point, to compile information at a broader level within the proposed accounts, and then, over time, add finer levels of detail as relevant for policy and analysis.

4.1 Introduction

4.1 The presentation of the main ecosystem accounts helps to frame much of the discussion concerning data sources and compilation methods that follows in the remainder of Technical Recommendations. This chapter describes the set of nine ecosystem accounts as shown in Table 4.1. The different accounts have been grouped as to whether they are accounting for ecosystem assets, for ecosystem services or relate to the integration of ecosystem accounting data with the standard economic accounts. While each account stands alone, there are also important connections between the accounts. These connections reflect the accounting relationships between stocks and flows.

4.2 The designs and structures of the accounts listed in Table 4.1 reflect, or are adaptations of, the accounting structures of the SNA and the SEEA Central Framework. Further testing of appropriate structures is still required, building on the descriptions provided here.

Table 4.1: The ecosystem accounts

Accounts for ecosystem assets	Ecosystem extent account
	Ecosystem condition account
	Ecosystem monetary asset account
Accounts for ecosystem services	Ecosystem services supply and use table – physical terms
	Ecosystem services supply and use table – monetary terms
Integrated accounts*	Combined presentations
	Extended supply and use table
	Sequence of accounts for institutional sectors
	National and sector balance sheets

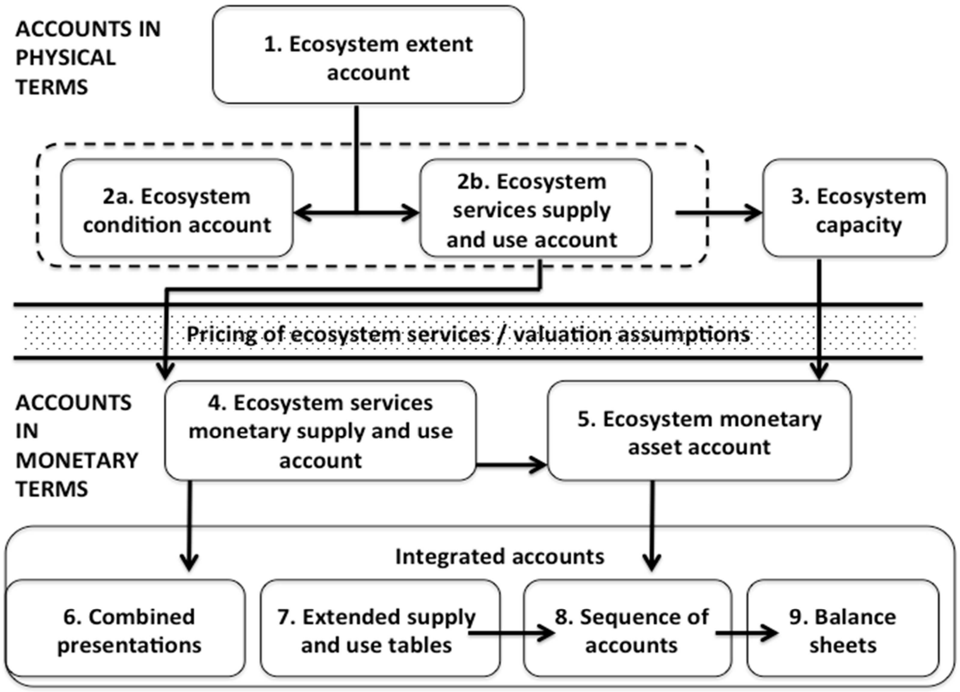
* These accounts reflect the integration of ecosystem accounting based information with information from the standard set of national accounts

4.3 From a SEEA perspective, one ambition is to integrate information on ecosystems with the standard national accounts. However, it is clear that achieving this ambition requires iterations through a series of steps. On the whole, these steps reflect following a path from the ecosystem extent account and ecosystem condition account, on to the measurement of the supply and use of ecosystem services in physical terms, then the valuation of ecosystem services in monetary terms, followed by the valuation of baskets of expected future flows of ecosystem services to value ecosystem assets, and finally, the integration of these data into the standard economic accounts. This sequence is shown in Figure 4.1.

4.4 From a purely theoretical accounting perspective, this transition through the various accounts is quite logical. However, in practice it is better to consider each account as reflecting one module within an integrated system. Consequently, it is possible to start the compilation process at different points and work iteratively among the accounts such that a consistent and single picture emerges.

4.5 It should not be expected that all accounts will be compiled in the initial stages and developing a comprehensive coverage of all of the accounts within the ecosystem accounting framework will take some time.

Figure 4.1 Connections between ecosystem accounts



NB: The dotted line around boxes 2a and 2b indicates that the development of these two accounts may often be completed in parallel, and iteration between them is appropriate in developing a single best picture.

4.6 Special mention must be made of thematic accounts. These accounts cover themes such as land cover, carbon, water and species diversity[7] and are linked to ecosystem accounting in two ways. First, they are accounts that record information on themes that are of particular policy interest and hence can play an important role in monitoring developments in, for example, carbon emissions, water scarcity and biodiversity loss. The connection to ecosystem accounting in this context comes from recognising that, by understanding the dynamic of the links between ecosystem assets and ecosystem services, policy options that are aimed at these themes may be better informed and targeted.

4.7 Second, the information in the thematic accounts may be a source of information for the compilation of ecosystem accounts, especially for the estimation of ecosystem extent and condition and the measurement of ecosystem services.

4.8 Each of the thematic accounts has a structure that is described in the SEEA Central Framework or has a similar asset account based structure (as is the case for carbon and species diversity accounts that are described in the SEEA EEA). Other potential thematic accounts include accounts for soil resources, nutrients, air, timber resources and fish resources. Chapter 7 provides a more complete introduction to four thematic accounts - land, water, carbon and species diversity.

[7] Following the CBD definition, biodiversity can be considered in terms of genetic, species and ecosystem diversity. The assessment of ecosystem diversity is supported by the compilation of ecosystem extent accounts. Genetic diversity has not been a focus of ecosystem accounting to this point.

4.2 Ecosystem extent accounts

4.9 The starting point for ecosystem accounting is most likely organizing information on the extent or area of different ecosystem types within a country. This is important for four reasons. First, the task of defining the ecosystems of interest for accounting purposes is by no means straightforward and a balance between scale of analysis, available data and policy questions will need to be found. It is very appropriate to start this discussion by examining the most conceptually straightforward issue of the definition of ecosystem assets and the delineation of their extent.

4.10 Second, the organisation of information required to establish an ecosystem extent account is likely to be a good entry point for establishing the national level spatial infrastructure, i.e. NSDI, 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 are a first application in this process.

4.11 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. This may be challenging because distinguishing changes in ecosystem type over time is difficult, especially where the changes are relatively local. It is also likely to be more complex as the number of ecosystem types increases. The challenge may be met by using higher aggregations of ecosystem types – for example using only 4 or 5 highest level classes, but, in turn, this may limit the type of analysis that can be undertaken.

4.12 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. For example, ecosystem extent accounts should provide an assessment of ecosystem diversity at a national level. Commonly, higher level extent accounts will be based primarily on land cover information. Ideally, it will be the case that all countries will be able to report changes in ecosystem extent at a common level of detail on a regular basis.

4.13 The structure of a basic ecosystem extent account is shown in Table 4.2. The structure of the rows reflects the basic logic of asset accounts as described in the SEEA Central Framework with an opening extent (in hectares or km2), closing extent, additions and reductions. The columns reflect the chosen classification for ecosystem types. The proposed structure here uses high level EU types based on the interim land cover classification in the SEEA Central Framework. Additional sub-classes may be added depending on the ecosystem types of most relevance within a country.

Table 4.2 Ecosystem extent account (hectares)

	Type of Ecosystem Unit															
	Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas	TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Opening extent																
Additions to extent																
Managed expansion																
Natural expansion																
Upward reappraisals																
Reductions in extent																
Managed regression																
Natural regression																
Downward reappraisals																
Net change in extent																
Closing extent																

4.14 The alignment of the high level EU types with the SEEA Central Framework land cover classes recognizes that the use of land cover information is the most likely starting point for ecosystem accounting in practice. To maintain consistency over time as ecosystem accounting develops, it is recommended that any more detailed classification of ecosystem unit types be "nested" within these higher level land cover classes.

4.15 From an accounting perspective, it is important to recognize that the total area of a country is unlikely to change over an accounting period and hence the total area recorded in the right hand column should be the same for the opening and closing stock. This number should remain irrespective of the number of different types of EU that are introduced into the table.

4.16 Ecosystem types of national interest may not coincide with one or more of the 15 high level classes. For example, no singular definition of wetlands can be applied at an aggregate country level, especially from the perspective of land cover. It is likely that, in most countries, the majority of wetlands are within EU type 9 but areas of wetlands may also be present in other land cover types, e.g. grasslands. Where relevant for analysis, a separate aggregation of finer level ecosystem types may be compiled, but for international comparison, data should also be presented according to the 15 high level classes.

4.17 Information in an ecosystem extent account would be usefully presented in maps using different colours for different types of EU. In the ecosystem extent account presented in Table 4.2 there is no requirement that the areas of each type of ecosystem be contiguous. That is, the total area of, for example, grassland, will occur in various "patches" across a country and the data in Table 4.2 represents an aggregation of all of the different patches. Mapping the information can more readily highlight issues of fragmentation of ecosystem types and possible connections between ecosystem types that are not apparent when the information is presented in a traditional table format.

4.3 Ecosystem condition accounts

4.18 A central feature of ecosystem accounting is organizing biophysical information on the condition of different ecosystem assets across a country. The ecosystem condition account in Table 4.3 is compiled in physical terms using a variety of indicators for selected characteristics.

4.19 Generally, it will be relevant to compile these accounts by type of EU within a relevant geographical aggregation (as shown in Table 4.3). This is so because each type of EU (e.g. tree-covered areas, grasslands, mangroves, etc.) will have distinct characteristics that should be taken into account in assessing condition. This approach also recognizes that much information on ecosystem condition is available by type of ecosystem rather than in reference to landscape scales or administrative boundaries. Consequently, harnessing available scientific information and expertise may be more readily achieved through a focus on EU types.

4.20 There is a range of measurement issues and challenges in the compilation of ecosystem condition accounts. Indeed, it is reasonable to conclude that there is still much to learn about the structure and compilation of these accounts. Particular issues concern the selection of characteristics for different ecosystem types, the relevant indicators for different characteristics, the potential to aggregate across different characteristics to derive an overall measure of condition for a single EU, the aggregation of condition measures for multiple EUs of the same type, and the approach to recording changes in ecosystem condition over time. These issues are discussed in more detail in Chapter 6. Chapter 6 also provides recommendations for testing and research related to ecosystem condition accounts.

4.21 The structure of the ecosystem condition account in Table 4.3 is focused on recording information at a single point in time, i.e. it presents information on the condition of different types of ecosystem assets at one time and does not show changes in condition over time. Each characteristic shown in Table 4.3 uses one column. In practice, it may be that each characteristic is best measured using more than one indicator in which case, multiple sub-headings for each characteristic would be needed. In some cases, multiple indicators may be combined to form an overall index of condition for a single characteristic. By way of example, for the ecosystem type of inland water bodies and the characteristic of water, indicators of river flow and pollutant levels may be relevant.

Table 4.3 Ecosystem condition account – end of accounting period

Type of Ecosystem Unit	Ecosystem characteristics						
	Vegetation	Water resources	Soil	Carbon	Biodiversity	Air	…
Artificial surfaces							
Herbaceous crops							
Woody crops							
Multiple or layered crops							
Grassland							
Tree-covered areas							
Mangroves							
Shrub-covered areas							
Regularly flooded areas							
Sparse natural vegetated areas							
Terrestrial barren land							
Permanent snow and glaciers							
Inland water bodies							
Coastal water and inter-tidal areas							
Sea and marine areas							

4.22 Underpinning these accounts will be information from a variety of sources. In some cases, source data may itself be organized following accounting approaches. Examples include information concerning land cover, water resources, nutrients, carbon and biodiversity. Accounts about these themes are discussed in Chapter 7.

4.4 Ecosystem services supply and use table

4.4.1 Introduction

4.23 The supply of ecosystem services by ecosystem assets and the use of these services by economic units, including households, is one of the most important aspects of ecosystem accounting. These are the flows that reflect the link between ecosystems and economic and human activity. The supply and use table records the actual flows of ecosystem services supplied by ecosystem assets and used by economic units during an accounting period. The data relate to a given geographical aggregation and should be structured by type of ecosystem service. The table may be compiled in both physical and monetary terms.

4.24 To interpret the supply and use table, it is important to distinguish between economic units and ecosystem assets in relation to the supply and use of ecosystem services. Following the ecosystem accounting model described in Chapter 2, only ecosystem assets can supply ecosystem services that are then received by economic units.

4.25 This distinction may seem quite abstract. For example, in the case of agriculture or forestry related ecosystem services, it may seem that it is the farmer or forester as the economic unit that supplies the ecosystem service. However, for accounting purposes, in these instances, the farmer and forester should be seen as supplying benefits (crops, timber, etc.) that are produced by combining inputs from other economic units (fuel, fertiliser, etc.) and inputs from ecosystem assets (i.e. the ecosystem services). Consistent with this explanation, ecosystem assets cannot produce or use benefits (or products in the case of the supply and use account shown below).

4.26 The structure of the supply and use account is shown in Table 4.4. The various quadrants, labelled A – H reflect the following information.

- A: No data are recorded in this quadrant as in concept economic units cannot supply ecosystem services.
- B: In this quadrant the supply of ecosystem services by type of EU is recorded.
- C: This quadrant is the equivalent of the standard physical supply and use table showing the supply of products by different economic units. This reflects the production of benefits to which the ecosystem services contribute. The scope of products is all goods and services produced in an economy.
- D: No data are recorded here as, in concept, EUs cannot supply products.
- E: Here the use of ecosystem services by types of economic units is recorded. This includes both the use of ecosystem services as input to further production and the use of ecosystem services as final consumption.
- F: At this stage, it is not anticipated that data would be recorded here as it represents the use of ecosystem services by other EUs – i.e. intermediate ecosystem services. If these flows were to be recorded then the supply of ecosystem services in quadrant B would need to have an equivalently larger scope.
- G: This quadrant is the equivalent of the standard physical supply and use table showing the use of products by different economic units.
- H: No data are recorded here as, in concept, EUs cannot use products.

4.27 As described, the structure of the ecosystem services supply and use table incorporates flows of products. This supports the joint presentation of data on both the ecosystem services used by economic units, and the products (SNA benefits) to which those ecosystem services contribute. In terms of the quadrants of Table 4.4, the output of products such as livestock would be recorded in the first column of quadrant C (under agriculture) and the use of ecosystem services (e.g. grass consumed directly by livestock) would be recorded in the same column in quadrant E. (The original supply of those ecosystem services would be recorded in quadrant B.) As desired, quadrant G could record inputs of products such as fertilizer or veterinary costs. In effect, each column pertaining to type of economic unit can be used to record key elements of a production function that includes ecosystem services as inputs.

4.28 The basic structure of the account comes from the design of physical supply and use tables (PSUT) in the SEEA Central Framework. There are two principle alterations. First, rather than showing just one column representing the environment, there are multiple columns each representing a type of EU. In effect, each EU is considered a unit supplying ecosystem services.

4.29 Second, in the SEEA Central Framework PSUT there are three types of flows – natural inputs, products and residuals. In the ecosystem services supply and use account there are just two – ecosystem services and products. In some cases, the flows relating to natural inputs are replaced by flows relating to provisioning services – e.g. the harvest of biomass from natural forests. However, particularly for regulating and cultural services, there are additional flows that are not recorded in a standard PSUT table, for example air filtration services and opportunities for recreation.

Table 4.4 Ecosystem services supply and use table

ECOSYSTEM SERVICES SUPPLY TABLE

		Type of economic unit							Type of Ecosystem Unit															
	UNITS	Agriculture, forestry and fisheries	Electricity, gas supply	Water collection, treatment and supply	Other industries	Households	Accumulation	Rest of the world - Imports	Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas	TOTAL SUPPLY
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Ecosystem services																								
Provisioning services																								
Regulating services					A											B								
Cultural services																								
Products					C											D								

ECOSYSTEM SERVICES USE TABLE

		Type of economic unit							Type of Ecosystem Unit															
	UNITS	Agriculture, forestry and fisheries	Electricity, gas supply	Water collection, treatment and supply	Other industries	Households	Accumulation	Rest of the world - Exports	Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas	TOTAL USE
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Ecosystem services																								
Provisioning services																								
Regulating services					E											F								
Cultural services																								
Products					G											H								

4.30 Residual flows are not ecosystem services but reflect physical flows from economic units into the environment. In cases where the residual flows comprise waste or pollution, ecosystems may play a regulating and filtering role in reducing the impact of residual flows on ecosystem condition. In these cases, a flow of regulating services from ecosystems to economic units should be recorded in quadrant B. These flows of regulating services will be related to the residual flows but are a different concept.

4.31 The accounting for residual flows is described in Chapter 3 of the SEEA Central Framework. This accounting treatment could be modified and appended to the supply and use table shown above. Thus, relevant residual flows might be recorded as being supplied by different economic units (immediately below block C) and then shown as being used/received by different ecosystems (immediately below block H). The addition of this information may assist in conveying a broader picture. However, care should be taken since, as noted above, information concerning residuals is related but different from ecosystem services and hence there is no defined accounting relationship to be conveyed by including both residual flows and ecosystem services in a single table.

4.32 Another difference from the PSUT is that, generally, a PSUT will follow the flows of a single type of resource or material – e.g. energy or water. In the ecosystem services supply and use account there are multiple services and products. Thus, in terms of balancing the table, the focus should be on ensuring that the supply and use for each row is balanced, i.e. for each ecosystem service. Indeed, in physical terms this is the only balance that can be determined.

4.33 Although the supply of ecosystem services is shown as only emerging from ecosystems (quadrant B), there may be interest in attributing the supply of services to particular economic units. For example, ecosystem services that are inputs to the production of farming outputs might be attributed to agricultural businesses. This alternative presentation could be recorded in quadrant A. Note however, that while this recording is likely to be reasonably straightforward for provisioning services, it will be more difficult to attribute the supply of regulating services to specific economic units.

4.34 The potential extent of this supply and use table is all products within the production boundary. One way of seeing this table is thus as an extended supply and use table that contains flows of all products between industries, as well as flows of ecosystem services. Viewing the account in this way is consistent with the idea, inherent in the ecosystem accounting model, of expanding the SNA production boundary to include the supply and use of ecosystem services. The table facilitates recording this additional supply and use. In Table 4.4, this potential expansion to incorporate a full supply and use table would imply expanding (considerably) the quadrants of the tables labelled C and G. A longer description of this proposed extended supply and use table, including its distinction from environmentally extended input-output tables (EE-IOT)[8], is presented in Chapter 9.

4.35 The current focus for the compilation of the ecosystem services supply and use table is on flows of final ecosystem services – i.e. those ecosystem services where there is a direct interaction with economic units or people. Conceptually, the design of the ecosystem services supply and use account can also be applied to record the flows of ecosystem services between different ecosystem units – so-called intermediate services. An example is water regulation services from an upstream forest provided to a reservoir from which drinking water is subsequently abstracted. In principle, these flows could be recorded as being supplied by ecosystem units in quadrant B (i.e. total supply recorded in quadrant B would increase) and recorded as used by other ecosystem units in quadrant F.

4.4.2. The ecosystem services supply table

4.36 A likely challenge in compiling the supply table will be attributing the supply of ecosystem services to a specific EU. This is unlikely to be an issue for provisioning services, but it may be of concern for regulating services and some cultural services in cases where the service is provided through a combination of ecosystem types.

4.37 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 supplied from different EU types for their country or target geographical 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,

[8] For an introduction to EE-IOT see SEEA Applications and Extensions (UN, 2014)

particularly regulating services such as carbon sequestration, the same service will be supplied by more than one EU type. Also for some ecosystem services the service will be supplied as a result of the combined production of neighbouring EU types. For example, cultural services supplied in a mixed landscape setting. In these cases, some allocation between EU types will be required.

4.38 It will be relevant to use this initial table as a discussion document to obtain input from various experts. It is important that the development of such a table is informed by people experienced in considering the link between ecosystems and economic and human activity. This should ensure that commonly overlooked services are not ignored.

4.39 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[9], in contrast to the "bottom-up" measurement of selected ecosystem services for specific ecosystem types.

4.40 The proposed ecosystem services supply table (Table 4.4) has columns reflecting the various ecosystem types and rows reflecting the range of different ecosystem services, in this case classified following CICES. In this table there is no direct recording of the beneficiaries or users of ecosystem services, this takes place in the ecosystem services use table. It will be relevant to also compile information on the combination of EU type, ecosystem services and beneficiaries at the same time.

4.41 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 for testing and research are also discussed in Chapter 5.

4.42 The ecosystem services supply table shown in Table 4.4 can be compiled in physical terms and in monetary terms, when valuation is possible. When compiled in physical terms each ecosystem service will be measured using a different unit of measurement. One consequence is that there can be no aggregation of ecosystem services over different ecosystem service types because the relative importance of individual ecosystem services cannot be immediately determined. Aggregation within a single row to obtain a total flow from all types of ecosystem units is possible. In practice, for some services, compilation may involve using aggregate, country or geographical area level information for a single ecosystem service and then allocating that information to the EU type level.

4.43 The ecosystem services supply table can be compiled in monetary terms, usually by applying appropriate prices to the physical flows of each ecosystem service. Direct measurement of values may be possible for some provisioning services. The ecosystem services supply table shown in Table 4.4 can then be extended with additional rows to record the total flows of ecosystem services. The estimation of prices for ecosystem services is discussed in Chapter 8.

4.4.3 The ecosystem services use table

4.44 An important difference between the supply and the use tables is that the focus of the use table is on the link between ecosystem services and different types of beneficiaries, while the supply table focuses on the supply from types of EU. Beneficiaries include economic units classified by industry, government sector and

[9] For an explanation of the "outside-in" approach of accounting see Annex 3.

household sector units, following the common conventions of organising the national accounts.

4.45 The focus on beneficiaries arises because, while the supply of ecosystem services can be directly linked to a spatial area (e.g. to an EU), there is no requirement that the location of the beneficiary is the same as the location of the area from which the ecosystem service is supplied. This is especially the case for regulating services but also for some cultural services.

4.46 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 global. 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).

4.47 Given the lack of a definitive spatial link, the structure of the ecosystem services use table must be guided by possible uses and analysis of data. The choice made here, is to structure the ecosystem services use table showing the allocation of the total supply of each ecosystem service to the various economic units. This allocation provides the first sense of a link to the national accounts datasets.

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

4.49 In monetary terms, entries for the total use of ecosystem services can 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.

4.50 The presentation of the tables 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 supply and use estimates should take place in an iterative fashion. For example, measures of provisioning services are likely to be estimated based on measures of 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.

4.5 Ecosystem monetary asset account

4.51 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 a particularly useful way of structuring relevant information about changes in the asset base.

4.52 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 recorded in a single account. For example, all timber resources can be measured in both cubic metres and in a common currency unit.

4.53 For ecosystem assets, their measurement in physical terms (as undertaken in the ecosystem condition account) is a more complex process, requiring the integration of data on a range of characteristics each with different units of measure. Consequently, at this stage, the ecosystem condition account is envisaged as reflecting estimates only in terms of the opening and closing condition for an accounting period. Defining entries for additions and reductions in condition requires further consideration.

4.54 Accounting for ecosystem assets in monetary terms would appear more tractable, since a single unit of currency is used. However, the complexities in accounting for the changes in assets remains.

4.55 In the ecosystem monetary asset account, the opening and closing stocks of ecosystem assets are estimated using the net present value of the future stream of each ecosystem service – covering provisioning, regulating and cultural services. It is assumed that the individual services are mutually exclusive and can be aggregated.

4.56 Assuming that the net present value for each type of service is separable, it is possible to consider the total value and changes in value for each ecosystem service flow separately. For provisioning services, such as timber extraction, accounting for the additions and reductions is conceptually straightforward. In this case, the value of provisioning services will reflect a resource rent. Therefore accounting for the changing value of provisioning services is equivalent to the advice provided in the SEEA Central Framework and the SNA on accounting for individual environmental assets. Applying this approach is possible since the underlying physical flows (e.g. of timber resources) can be accounted for using a single metric.

4.57 For regulating and cultural services, the link to underlying physical flows may be less clear. For regulating services, the issue is that the supply of the service does not only depend upon the extent and condition of the ecosystem, but also upon other driving factors that will not be stable over time. For example, air filtration is a function of the extent and type of vegetation and its leaf area index, but it is also influenced by air pollution levels that can be spatially and temporally heterogeneous. Thus, the higher the concentration of atmospheric particulate matter, the higher the amount of particulate matter that is captured by the vegetation.

4.58 In addition, most regulating services depend upon a variety of ecosystem components and processes, with each of them providing only limited information on the capacity of the ecosystem to supply the service over time. Recording additions and reductions in ecosystem assets for regulating services is thus likely to involve different types of indicators for different services. These indicators may reflect ecosystem characteristics, such as leaf area index per BSU in the case of air filtration or the density of pollinators in the case of pollination, or they may reflect outputs of the ecosystem, for instance, amount of water made available for irrigation throughout the year in the case of the water regulating service provided by upland forests. Establishing accounting entries for changes in ecosystem assets related to regulating services is therefore not straightforward.

4.59 For cultural services, it may also be challenging to find appropriate physical indicators for quantifying the services in terms of the underlying ecosystem assets. Cultural services can involve a passive (enjoying without visiting through information obtained from various media) or active (visiting) interaction with an ecosystem. Thus describing the link between the condition of the ecosystem in physical terms and its capacity to supply individual cultural services is difficult to define in general terms. For example, in the case of recreation, a natural park may physically allow access to large number of people, but at some point the recreational experience gained per individual will decline because of overcrowding. It is however, hard to quantify this decreasing marginal return.

4.60 Overall, policy-relevant physical indicators about ecosystem assets can be defined for most provisioning services, but for many regulating and cultural services such physical indicators are more difficult to define. The challenge to define physical indicators also impacts on the ability to develop estimates of changes in assets in monetary terms.

4.61 It is therefore envisaged that, in the first phases of ecosystem accounting, ecosystem monetary asset accounts should focus on estimating the opening and closing value of the stock of ecosystem assets. This estimation can be followed by applying the standard national accounting technique of net present value, where the opening and closing stock value of an ecosystem asset can be estimated by using assumptions about the future flows of ecosystem services and discounting these flows to provide a current, point in time, estimate of their value.

4.62 The relevant accounting structure is shown in Table 4.5. The entries in the rows have been simplified to very basic asset account entries. If more detail is required to account for changes in assets, particularly those related to provisioning services, then additional entries similar to those from the SEEA Central Framework could be incorporated. In the columns, different presentations are possible given that the data are in monetary terms. That is, a single asset account may relate to an individual ecosystem asset (e.g. a specific grassland), to a type of ecosystem (e.g. all tree-covered areas), or to an administrative region or country.

Table 4.5 Ecosystem monetary asset account (currency units)

	Type of Ecosystem Unit															
	Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas	TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Opening stock of ecosystem assets																
Additions to stock																
Reductions in stock																
Revaluations																
Closing stock of ecosystem assets																

4.63 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 and assumptions about the future. That is, the focus is on the measurement of the value of ecosystem assets as distinct from ecosystem services. In measurement terms, this represents an increase in uncertainty given the general challenges of net present value based estimation.

4.64 Nonetheless, such estimates are useful for making decisions about alternative uses of ecosystem assets since they provide a consistent basis for comparison. In addition, estimates in monetary terms can be integrated with valuations for other types of assets to provide more complete assessments of net wealth.

4.65 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 the use of ecosystems by economic units. This should be seen as quite distinct from the change in the net present value of the asset.

4.66 In national accounting terms, the concept of ecosystem degradation has a specific role. It represents the capital cost that should be attributed to a user of an ecosystem asset in generating an income stream. Thus, degradation should not include changes in the value of the asset that arise for other reasons. In particular, reductions in asset value due to unforeseen events, that are not part of the use of the asset in production (e.g. due to natural disasters), are not considered part of degradation for accounting purposes. Further, it is possible that the value of an asset changes solely due to changes in prices. These are considered revaluations for accounting purposes and are separately recorded.

4.67 These distinctions are reflected in Table 4.5 where the series of entries between opening and closing stock are characterised for different types of assets. Note that for ecosystems, depletion will be a subset of degradation, in that depletion refers only to the loss of future income associated with provisioning services from an ecosystem – e.g. timber resources from a forest. Degradation will encompass losses from provisioning services and other ecosystem services. An important aspect in the table is that there is a consistency of treatment in the accounting framework between consumption of fixed capital (depreciation of produced assets), depletion and degradation.

Table 4.6 Accounting entries for depletion and degradation

<table>
<tr><td></td><td colspan="5">Accounting entry</td></tr>
<tr><td>Type of asset</td><td>Opening stock</td><td>Transactions</td><td>Other changes in volume</td><td>Revaluations</td><td>Closing stock</td></tr>
<tr><td>Produced assets
(incl. cultivated biological resources e.g. plantations, livestock)</td><td></td><td>Gross fixed capital formation (investment)
Depreciation</td><td rowspan="3">Primarily physical appearance and disappearance of assets
- discoveries
- catastrophic losses
- reappraisals of stock</td><td rowspan="3">Changes in value between opening and closing stock solely due to changes in prices of assets</td><td></td></tr>
<tr><td>Natural resources</td><td></td><td>Depletion</td><td></td></tr>
<tr><td>Ecosystem assets</td><td></td><td>Degradation</td><td></td></tr>
</table>

4.68 However, within this accounting construct, further consideration of exactly how ecosystem degradation should be defined is required, building on the discussion of this issue in SEEA EEA Chapter 4. Relevant issues, discussed further in section 6.4 and 9.5, include:

i. the treatment of complete changes (conversions) in the use of an ecosystem – for example from a forest area to an agricultural area;

ii. the treatment of situations where economic activity, including household consumption, has an indirect and potentially delayed impact on ecosystem conditions – for example, the impacts arising from human-induced climate change;

iii. the treatment of declines in condition of ecosystems that are not direct suppliers of final ecosystem services – for example, remote forests.

4.69 Another consideration is the role of capacity in the measurement of degradation. Recent discussion (see Hein et al., 2015) suggests that the change in capacity may represent an appropriate measure of ecosystem degradation but further consideration of this alternative and the associated accounting implications is required. (See section 6.4 for further discussion)

4.6 Integrating ecosystem accounting information with standard national accounts

4.70 The discussion of the ecosystem services supply and use account highlighted the potential for information on ecosystem services to be integrated with information presented in standard supply and use or input-output tables. However, aside from this potential, the accounts described in the previous sections do not involve integration of information on ecosystem assets or services with the standard national accounts. Since one of the motivations for the development of ecosystem accounting is integration with the standard national accounts, this section introduces how this step might be achieved. A more complete discussion is presented in Chapter 9 and the text in SEEA EEA Chapter 6 is also of particular relevance.

4.71 Building on the SNA framework, there are two main types of accounts that can be adapted to integrate ecosystem accounting information. The first is integrated institutional sector accounts and the second is balance sheets. Institutional sector 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), and transactions in financial assets and liabilities.

4.72 The intent from an ecosystem accounting perspective is to integrate estimates of ecosystem services in monetary terms and estimates of ecosystem degradation (as a cost of capital equivalent to consumption of fixed capital) into the standard sequence of accounts. The type of presentation that emerges from this integration is shown in Table 4.6, taken directly from SEEA EEA Annex A6.

4.73 SEEA EEA Table A6.1 presents simplified versions of two models (A and B). In the example, presented for a farm, a single ecosystem asset provides a mix of ecosystem services (total of 110) of which 80 are used by the farmer and 30 are the final consumption of households.[10] All SNA production of the farmer (200) is recorded as final consumption of households. For simplicity, no other production, intermediate consumption or final consumption is recorded. It is to be noted that in the generation of ecosystem services, there is no recording of "inputs" from the ecosystem. Such recording is not required for the purposes of developing a sequence of accounts focused on economic units.

[10] The allocation is based on the assumed composition of the ecosystem services. Thus, the value of 80 for ecosystem services may be considered inputs to agricultural production and the value of 30 may be considered regulating services, such as air filtration, used by households.

4.74 In both models, the rise in GDP occurs in relation only to the final consumption of ecosystem services that relate to non-SNA benefits. Many ecosystem services will be indirectly included in measures of final consumption when they are used by enterprises in the production of standard SNA outputs (e.g. food, clothing, recreation).

4.75 Measures of GDP may be adjusted for both consumption of fixed capital and ecosystem degradation, thus providing degradation adjusted net domestic product.

4.76 In drafting the SEEA EEA, there was no clear choice about the structure of the sequence of accounts with a decision needed on whether (i) ecosystems should be treated as producing units in their own right; or (ii) treated as assets owned and managed by existing economic units. At this stage, no decision on this issue has been made. However, discussion on other issues in ecosystem accounting suggests treating ecosystem assets as producing units is the preferable option, on balance. This would imply a sequence of accounts akin to Model A in Table 4.7. The largest as yet unresolved issue in compiling a sequence of accounts is the attribution of ecosystem degradation to economic units. This is a topic that will remain on the research agenda. The second type of accounts are balance sheets, in which the opening and closing values of ecosystem assets in monetary terms, as recorded in the ecosystem monetary asset account, are integrated with the values of asset and liabilities recorded in the standard balance sheet of the SNA. Such an integration would lead to the derivation of extended measures of national and sector net wealth.

4.77 The integration of ecosystem asset values would seem a relatively straightforward step. However, for a variety of reasons, it is likely to be quite complex. There are two main challenges that are described at more length in SEEA EEA Chapter 6. First, in a full SNA and SEEA Central Framework balance sheet, there will already be values recorded for natural resources, such as timber and fish. Since the value of these resources is embedded in the value of ecosystem assets it will be necessary to appropriately ensure the removal of double counting of these resources. This will also apply to various cultivated biological resources such as orchards and vineyards.

4.78 Second, in many countries, the value of land will be recorded on the SNA balance sheet estimated in terms of its market price. Since there is a generally well-established market in land, balance sheet values may be obtained more directly than by using net present value techniques as applied in resource accounting. It is likely to be the case that the market values of land, particularly agricultural land, will capture the value of some ecosystem services, to some extent. However, they are unlikely to capture a full basket of ecosystem services, particularly those that have clear public good characteristics and longer term benefits. Also, the land value may well reflect aspects that are not ecosystem services in nature – for example, the location and the value of alternative uses.

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

Table 4.7 Simplified sequence of accounts for ecosystem accounting

	Model A				Model B		
	Farmer	Household	Ecosystem	Total	Farmer	Household	Total
Production and generation of income accounts							
Output – Products	200			200	200		200
Output – Ecosystem services			110	110	30		30
Total Output	200		110	310	230		230
Int. consumption – Products	0		0	0	0		0
Int. consumption –Ecosystem services	80		0	80	0		0
Gross value added	120		110	230	230		230
Less Consumption of fixed capital (SNA)	10			10	10		10
Less Ecosystem degradation (non-SNA)			15	15	15		15
Degradation adjusted Net Value Added	110		95	205	205		205
Less Compensation of employees – SNA	50			50	50		50
Degradation adj. Net Operating Surplus	**60**		**95**	**155**	**155**		**155**
Allocation and use of income accounts							
Degradation adj. Net Operating Surplus	60		95	155	155		155
Compensation of employees		50		50		50	50
Ecosystem transfers	80	30	-110	0	-30	30	0
Disposable income	140	80	-15	205	125	80	205
Less Final consumption – Products		200		200		200	200
Final consumption – Eco. serv.		30		30		30	30
Degradation adjusted net saving	**140**	**-150**	**-15**	**-25**	**125**	**-150**	**-25**

Source: SEEA EEA Table A6.1 (UN et al., 2014b)

5. Accounting for flows of ecosystem services

Key points in this chapter

In ecosystem accounting, ecosystem services are considered to reflect the contribution that ecosystems make to the benefits received by economic units and people from the environment. It is therefore important to distinguish clearly between ecosystem services and benefits.

Generally, most focus for national level accounting is on final ecosystem services. All final ecosystem services have a direct link between ecosystems and economic units.

Intermediate ecosystem services are important for understanding relationships and dependencies between ecosystems and can be incorporated into the ecosystem accounting model.

The use of a classification of ecosystem services, such as CICES, is an important aspect in compiling estimates of ecosystem services flows.

In almost all cases it will be necessary to undertake modelling to estimate flows of ecosystem services. The modelling may be either spatial or temporal involving a dynamic systems approach.

In measuring the supply of ecosystem services it will be useful to also consider the use of ecosystem services by different beneficiaries including households, business and governments.

In some cases, biodiversity may be considered a cultural ecosystem services but generally, biodiversity is best considered as a characteristic of ecosystem assets that can be degraded or improved over time, and which underpins the supply of ecosystem services.

5.1 Introduction

5.1. Ecosystem services are the glue that enables the connection to be made between ecosystem assets on the one hand and 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. However, recognition of the potential role of the ecosystem services concept in an accounting context has followed the development and testing of the concept in other disciplines. As a result, the reality is that there are multiple definitions, alternative measurement boundaries and classifications, and a wide array of measurement methods available in relation to ecosystem services. The SEEA EEA attempted to chart a course through the various discussions on ecosystem services. It made a range of choices about the definition and measurement of ecosystem services for accounting purposes.

5.3. This chapter summarises the main points from the SEEA EEA concerning ecosystem services, discusses possible refinements to the SEEA EEA discussion, and describes the main measurement issues and remaining challenges.

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 SNA production boundary. This boundary sets the scope for the measurement of GDP and related measures of production, income and consumption. It is noted that this means that ecosystem services related to illegal activity or subsistence production are included in scope since both of these types of activity are included in the production boundary of the SNA.

5.5. An important part of the rationale for measuring ecosystem services is that much economic production (for example in agriculture, forestry and fisheries) utilizes inputs directly taken 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. Thus, 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 ecosystem assets as suppliers, whose contribution was previously not explicitly recognised. Defining the contribution of ecosystems is particularly important in valuation but also relevant in ensuring that physical measures of ecosystem service flows are consistently described and appropriate indicators chosen.

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 functioning 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 would be 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. From an accounting perspective, the distinction is meaningful since

- it allows description of the relationship between final ecosystem service flows and existing flows of products currently recorded in the SNA
- it recognizes the role of human inputs in the production process and that the contribution of final ecosystem services to benefits may change over time (e.g. due to changes in the methods of production)
- it helps in identifying the appropriate target of valuation since the final ecosystem services that contribute to marketed products (e.g. crops, timber, fish, tourism services) will only represent a portion of the overall value of the corresponding benefits.

5.9. For these reasons, the principle of distinguishing between final ecosystem services and benefits is appropriate for accounting. It is also consistent with the approach taken in TEEB (2010), Boyd and Banzhaf (2012), Haines-Young and Potschin (2013) and the UK National Ecosystem Assessment (NEA) (2011), although the precise definitions and terms applied for final ecosystem services and benefits vary in the different cases.

5.10. In practice, particularly at large scales, the explanation and application of this distinction can be challenging. The issues arise differently for provisioning services, regulating services and cultural services. For provisioning services, the challenge is fully describing the various ecosystem services involved in supplying cultivated biological resources [11]. These outputs, including crops, plantation timber, and aquaculture, are considered benefits produced as a combination of final ecosystem services and human inputs. Further, since the balance of inputs between final ecosystem services and human inputs will vary by production process (e.g. between irrigated and rainfed agriculture), it means that using a measure of output from production as a measure of the ecosystem service will be misleading.

5.11. For regulating services, there are generally no direct human inputs consumed in the production of benefits, although there may be costs incurred in maintaining an ecosystem such that the supply of regulating services can be supported. Consequently, the quantity of final ecosystem services may be equal to the quantity of the benefit, as in the case of, for example, carbon sequestration services supplied by a forest. However, in other cases, there is a distinction between final services and benefit. For example, in the case of air filtration services, the benefit is reduced risk (to the local population) of respiratory and cardio-vascular diseases through cleaner air. The ecosystem service in this example is the capture of air-borne pollutants.

5.12. The challenge is to appropriately describe 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 that reflect the contribution of the ecosystem to the production of the benefit – i.e. what is the ecosystem doing?

5.13. For cultural services, the contribution of ecosystems is relatively passive in that it is commonly the ecosystem providing opportunities for people to engage in activities, learning experiences and the like. Costs may be incurred to facilitate people benefiting from these services, such as the construction of cycling or hiking paths, visitor facilities, etc. Often, cultural services are conceptualised in terms of the benefits that people receive from the engagement and hence the challenge for ecosystem accounting is to distinguish the contribution that represents the ecosystem service among the various benefits.

5.14. Distinguishing final and intermediate ecosystem services: The distinction between final and intermediate services reflects the principles of national accounting where aggregate production is measured by netting out flows along the supply chain. This ensures that double counting of outputs that become inputs to subsequent production 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 ecosystem services, i.e. inputs to the supply of other ecosystem services.

5.15. While straightforward in theory, the complexity of ecosystems means that it can be difficult to make this distinction in practice. Further, at an aggregate level a focus on only final ecosystem services is appropriate but this may not be the case when considering the contribution of individual ecosystems. This is especially so if an ecosystem's primary function is to support neighbouring ecosystems. A typical

[11] Cultivated biological resources is a term from the SNA that supports the distinction between biological resources (e.g. timber, fish, animals, etc.) the growth of which is considered the output of a process of production – i.e. cultivated; and those whose growth is the result of natural processes – i.e. natural biological resources.

example would be the services provided by upstream forests in regulating downstream water abstraction.

5.16. In the SEEA EEA, the flows between ecosystem assets, if recorded, were described as inter-ecosystem flows and in turn these flows were equated with intermediate services. (UN et al., 2014b, 2.29) However, recording only the tangible, physical flows between ecosystems (e.g. of water) does not serve to highlight the true nature of the dependencies among ecosystems. Indeed, there are many ecosystem services both final and intermediate for which there are no movements in physical terms. For example, the regulation of water flows by a forest does not require that there is a movement of materials between ecosystems (other than the water itself). Of course, the actual measurement of the ecosystem service may rely on actual and modelled physical flows.

5.17. For intermediate services, the accounting issue is not that flows of services between ecosystem assets cannot be recorded in the system. Rather, the issue is that there are potentially many different intermediate services that all require large amounts of data to record them in the accounts.

5.18. 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. Possible criteria to determine a measurement boundary for accounting include those services considered critical for ecosystem functioning and ecosystem services supply, and services affected by ecosystem management.

5.19. The following observations are relevant to advancing this discussion and supporting testing.

- 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, where the contribution of these services is embodied in the mature animal that is an input to final ecosystem services, commonly in a separate ecosystem. For example, the habitat services provided by mangroves as nurseries for fish that are subsequently caught in open seas.
- 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, i.e. they can be described in the context of an ecological production function.
- It would be appropriate, for accounting purposes, to ignore the services flowing 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. With smaller ecosystem assets (in terms of area) there will be an increased likelihood of intermediate services being recorded.
- The recording of intermediate services would seem most useful for the purposes of supplying 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 importance of different ecosystems within a country is likely to be very relevant for management purposes.

- Increasing the measurement scope to include only certain intermediate services causes no specific issues in terms of accounting structure. The changes needed would be to recognize only 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. In concept, these may be treated as imports and exports of ecosystem services.

5.20. <u>The treatment of other environmental goods and services:</u> 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 flows we receive in the form of mineral and energy resources: flows of 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.

5.21. Since the focus of the SEEA EEA is on accounting for ecosystems, these various flows are not incorporated in the ecosystem accounting model. Many of these flows are accounted for 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 relevant to consider incorporating measures of abiotic services to consider the full range of benefits from a defined area. The extension of the accounting tables to consider this aspect has not been developed at this stage.

5.22. <u>The link between biodiversity and ecosystem services:</u> On the whole, the perspective taken for ecosystem accounting in the SEEA EEA is that biodiversity is a feature most directly relevant in measurement of the condition of ecosystem assets. This is distinct from an alternative conception that biodiversity is an ecosystem service supplied by ecosystem assets. Thus, measures of biodiversity, whether of ecosystem diversity or species diversity (the inclusion of genetic diversity measures has not yet been examined), are considered to relate primarily to the stocks component in the accounting model. This approach is consistent with a view that biodiversity can be degraded or enhanced over time, an attribute that only applies to stocks and not to flows (i.e. ecosystem services). The exact nature of the relationship between biodiversity and ecosystem condition is a matter of some uncertainty. Indeed, given that biodiversity is a many layered concept it would be possible to consider that biodiversity might be the asset that is the focus of accounting rather than ecosystem assets. This issue is discussed further in section 7.5.

5.23. At the same time, it is recognised that there are some aspects of biodiversity, especially species diversity, that can supply final ecosystem services. This includes, for example, the value of recreational services from wildlife related activities, where people gain benefit from experiencing the diversity of nature. In addition, people may appreciate, and therefore value, elements of biodiversity as such, for example when they take an interest in the conservation of endemic and/or iconic species. In this latter case, specific elements of biodiversity (e.g. related to the conservation of species) could be considered representing a 'final use' of biodiversity. Given these potential links to both ecosystem assets and ecosystem services, it is relevant to recognise that measures related to biodiversity may be appropriate indicators in a variety of accounts, including ecosystem condition accounts and ecosystem services supply and use tables.

5.24. The treatment of ecosystem disservices: Ecosystem disservices arise in cases where the interaction between ecosystems and humans is considered to be “bad”. Usually this refers to the effects of things such as pests and diseases that emerge from ecosystems and 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.

5.25. Unfortunately, accounting principles do not work well when trying to make a distinction between products that may be considered as either “goods” and “bads”. Indeed, accounting, as distinct from economics, does not focus on the welfare effects of use, and focuses instead on the activity associated with the generation of products and the associated patterns of consumption. As a consequence, all flows between producers and consumers have positive values in the accounts, irrespective of their possible welfare effects. The positive values also reflect that, in accounting, values must be able to be separated into price and quantity elements. It is difficult to envisage either prices or quantities being negative and thus recording negative estimates of value is not possible.

5.26. A related matter is the treatment in ecosystem accounting of negative externalities, such as carbon emissions, where economic and human activity leads to declines 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.

5.27. For both disservices and negative externalities, work is ongoing to outline the appropriate treatment in the context of the ecosystem accounting model. It is also noted that the SEEA Central Framework provides accounting approaches for recording flows of emissions and other residuals to support measurement in these areas.

5.3 The classification of ecosystem services

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

5.29. The classification included in the SEEA EEA is the CICES, version 3 (Haines-Young and Potschin, 2013). It was considered an interim version. Subsequent releases have been made with the latest being CICES version 4.3 and consultation on the CICES is ongoing.

5.30. CICES has been adopted for work on the European Union’s MAES project (Maes, et al., 2014) but alternative approaches to the classification of ecosystem services have also been developed. 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 United States Environmental Protection Agency (US EPA) on final ecosystem goods and services (FEGS) (Landers and Nahlik, 2013) and the associated National Ecosystem Service Classification System (NESCS) (Landers and Nahlik, 2012). This work places attention on the links between ecosystem types and the classification of beneficiaries from the final services supplied by those ecosystem types.

5.31. 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 relative significance of ecosystem services. In effect, a classification can operate as a checklist and be applied in initial discussions by considering each EU type and noting those ecosystem services that are considered most likely to be generated from that EU. The resultant "baskets" of services for each EU 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.

5.32. One finding from work on ecosystem services is that the choice of words used to describe an ecosystem service can have a 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 material in the selection of measurement approaches and in valuation. 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.

5.33. There is common misunderstanding of the role of classifications with regard to the distinction between final and intermediate ecosystem services. Put simply, it is not the case that ecosystem services must be neatly classified between those that contribute directly to economic and social beneficiaries and those that support the ongoing functioning of ecosystems. For example, when water is abstracted from a lake it would be considered final if the beneficiary was a household but intermediate if consumed by a wild deer.

5.34. A similar situation arises in economic statistics. The classification of products (e.g. following the international standard CPC) includes, appropriately, a large number of products that may be considered either 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.

5.35. Given this, for accounting purposes, 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 intermediate ecosystem services reflecting the operation of an ecosystem, and the "final" ecosystem services that are contributions to economic and social beneficiaries.

5.36. 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

5.37. 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 measurement (including ecosystem condition and the ecosystem's capacity to generate services) or ecosystem services measurement. In this chapter, the focus is on ecosystem services.

5.38. The intention here is to provide some general guidance on the types of biophysical modelling approaches that can be used to analyse ecosystem service flows, as distinct from models that can be used to understand ecosystem processes (e.g. nutrient cycling, energy flows). In the scientific literature, a wide range of different modelling approaches has been described in the fields of ecology, geography, and hydrology. Many of them are potentially relevant to ecosystem accounting depending upon the environmental characteristics, 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. This chapter provides an overview of the different approaches, and their main uses for the biophysical modelling of ecosystem services.

5.39. 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 6.4), 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.

5.4.2 Overview of biophysical modelling approaches

5.40. The two most relevant forms of modelling are spatial and temporal modelling techniques. Spatial modelling is required to produce maps of ecosystem services for a complete EU or geographical aggregation, including at 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.

5.41. Within the general GIS packages, spatial modelling tools include the use of look-up tables, and the application of statistically based approaches such as Maxent (Philips, et al., 2006). There is also a range of geostatistical interpolation techniques, such as "kriging", that use statistical algorithms to predict the value of un-sampled pixels on the basis of values for nearby pixels in combination with other characteristics. The basic interpolation methods use simple interpolation algorithms, for instance nearest-neighbour interpolation, but there are more sophisticated geostatistical tools that also consider 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. Examples of the applications of these approaches and related technical references can be found in, for example, Sumarga and Hein (2013), Remme, et al. (2014) and Schröter, et al. (2014).

5.42. In ecosystem accounting, temporal modelling is required to estimate 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 spatial models. A dynamic systems approach is based upon modelling a set of state (level) and flow (rate) variables in order to capture the state of the ecosystem over time, including relevant inputs, throughputs and outputs. 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).

5.43. 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.

5.44. 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), although 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 (Soil and Water Assessment Tool) and SedNet from the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO). These models are both temporally and spatially explicit, and use 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

5.45. SEEA EEA Annex A3 provides some stylised figures to help articulate the measurement required to estimate flows of ecosystem services. The figures 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.

5.46. It will generally be helpful for measurement purposes to distinguish clearly between provisioning, regulating and cultural services. For this task the use of a classification of ecosystem services, such as CICES, can serve as a useful checklist. Further, it is likely to be useful to consider the measurement of ecosystem services in relation to broad ecosystem types such as forests, wetlands, and agricultural areas. (Note that the use of broad ecosystem types may also be useful in accounting for change over time and reducing uncertainty in spatial measurement.)

5.47. A useful structuring of indicators is presented in Chapter 5 of the European Union's MAES project report (Maes et al., 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.

5.5.2 Data sources

5.48. Data sources will be different in each country. It is suggested that important national data holders be engaged in the process of compiling the accounts. They will be able to advise on data availability and quality. The following list suggests some government departments (using generic titles) and the data they may hold:

- National Statistical Offices: Agricultural production (crops and livestock); health statistics (incidence of environmentally-related diseases); Population data
- Departments of Natural Resources: Timber stock and harvest; biomass harvest for energy; water supply and consumption; natural disaster statistics (floods, landslides, storms); land cover (to estimate carbon stock and sequestration); remote sensing (to estimate primary production);
- Water management and related agencies: Water stocks and flows, abstraction rates, hydrological modeling
- Departments of Agriculture: Erosion potential, biomass harvest;
- Departments of Forestry: Forest stock and harvest; carbon sequestration;
- Departments of Environment and Parks: Iconic species habitats, visitors to natural areas

5.49. Local academic and government researchers may have conducted studies for specific regions of the country or for specific services. As well, international organizations (e.g. UNEP, SCBD, World Bank) may have conducted studies on specific locations or services. These should also be reviewed and considered for integration into the ecosystem services supply and use table.

5.50. Databases storing research on ecosystem valuation will also include information on the physical aspects of the ecosystems they value. For example, if the fish harvest in one lake is estimated to be 500 tonnes per year, the research is likely looking to estimate the economic value of those fish. For the purposes of the ecosystem services supply and use table, it is useful to know that 500 tonnes per year was harvested from a specific lake.

5.51. Two broad based ecosystem valuation databases that should be investigated for country-specific (or region-specific) data are the EVRI (Environmental Valuation Reference Inventory, at www.evri.ca) and the ESVD (Ecosystem Service Valuation Database at http://www.fsd.nl/esp/80763/5/0/50) that emerged from the TEEB 2010 study. Other service-specific or region-specific databases or projects should also be investigated.

5.52. Depending on the resources, including time, available, it may be feasible to collect new data. New data collection activities could include:

- Ecological field studies to determine location-specific production functions for ecosystem services. Such studies could, for example, collect data on water purification services of wetlands.
- Socio-economic surveys could be conducted on a national scale to better understand how people and businesses use ecosystem services (e.g., water withdrawals, visits to recreational sites)
- Case studies could be conducted on target populations (e.g., households near forest areas) to better understand their use of ecosystem services (e.g., biomass for fuel, food gathering, sources of water).

5.53. 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 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 supply 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 relate to common spatial areas and the same time periods should be made.

5.5.3 Measuring the supply of ecosystem services

5.54. The measurement of provisioning services can generally be linked to measures commonly available in statistical systems. Data on the production of crops, livestock, other agricultural products, forestry products and fisheries products are all of direct relevance in the estimation of provisioning services. It is relevant to recall however, that the crops and agricultural products themselves are considered benefits in the SEEA EEA model, and the ecosystem services are the contributions to the production of those benefits.

5.55. 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, if sub-national accounts are to be compiled, to allocate national or regional level estimates to the spatial areas being used for ecosystem accounting using spatial modelling techniques.

5.56. 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 non-use cultural services is more problematic and is considered further in section 5.6.

5.57. For regulating services, some specific suggestions for measurement using bio-physical models are suggested in Table 5.1). These suggestions are intended as guide only.

Table 5.1: Ecosystem services metrics and mapping methods for selected ecosystem services

Ecosystem Service	**Potential metric**	**Description**
Carbon storage	Ton of carbon (or carbon-dioxide) per hectare or square kilometre.	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 low 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 remote sensing 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 and the capacity to map above ground carbon stock globally is increasing with the launch of the Sentinel radar satellites.
Carbon sequestration	Ton of carbon (or carbon-dioxide) sequestered per year, per hectare or per square kilometre.	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 using remote sensing images. However, care needs to be taken that the relationship 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. It will be relevant to understand estimation approaches used in the compilation of IPCC based greenhouse gas inventory estimates for the LULUCF.
Maintaining rainfall patterns	mm water evapotranspiration per hectare per year, mm	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.

	rainfall generated per hectare per year.	Reductions in rainfall in the Western Sahel and the Murray Darling 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.
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 is also necessary to define the benchmark against which the reduction in risk can be assessed. It may not always be necessary 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 in the current ecosystem state compared to a situation with no plant cover	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 requires large datasets, preferably with daily time-steps, of nutrient concentrations in various sampling stations along the river course.

5.5.4 Recording the beneficiaries of ecosystem services

5.58. 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, including beneficiaries that are both resident in a country and those in the rest of the world.

5.59. Other groupings of economic units that might be considered include

- Industry groupings whereby individual establishments or businesses are grouped into those that undertake similar activities such as agriculture or manufacturing.
- Allocation of use of ecosystem services by household income levels
- Distinguishing between rural and urban use of ecosystem services
- Distinguishing between those services that are used locally, nationally or globally.

5.60. To the extent that these alternative groupings of users can be identified during the data collection stages, there is the potential to develop information sets relevant to a broader range of policy questions.

5.61. When measuring the supply of ecosystem services and mapping out the supply across ecosystem types (e.g. forests), it is likely to be useful to consider the link to beneficiaries. This approach has been extensively applied in the development of FEGS and NESCS by the US EPA (Landers and Nahlik, 2012 and 2013).

5.62. 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 Recommendations

5.63. Since the release of the Millennium Ecosystem Assessment (MA) in 2005 (MA, 2005) there has been an explosion in the number of studies on ecosystem services. The studies have focused on many aspects of definition and measurement and have involved researchers from a range of disciplines. Subsequent work in the context of the TEEB Study (2010), the MAES initiative (Maes, et al., 2014) and the Inter-governmental Platform on Biodiversity and Ecosystem Services (IPBES) have reinforced the potential of the ecosystem services approach in understanding the relationship between humans and the environment. Ecosystem accounting has built upon this work and research.

5.64. From an official statistics perspective, the number of alternative estimates and the variety of methods and definitions presents a conundrum. The challenge from a national-level, statistical and accounting perspective is how to draw the knowledge together to form a comprehensive and coherent data set on trends in ecosystem service flows. The descriptions in the SEEA EEA should be seen as a first attempt to support this type of data coordination.

5.65. For countries seeking to undertake pilot studies in ecosystem accounting, the most appropriate initial advice is that there is a large body of work on which estimates of ecosystem services flows can be based. At the same time, it is unlikely that estimates of ecosystem services for specific ecosystems in each country will have been developed in a relatively standardised way. Consequently, it is the role of the ecosystem accountant to bring together the available expertise and research. Advancing the measurement of ecosystem services is a matter for testing rather than research.

5.66. It is recommended that the ecosystem accounting model be used to build an understanding of the gaps in information, either because certain ecosystem services have not been measured or because ecosystem services from certain ecosystem types have not been measured. The accounting model can play an important role in identifying data gaps.

5.67. This may be done by determining a list of priority ecosystem services based on existing national land and water management, and nature conservation practices. For this task:

- The US EPA FEGS-CS and associated NESCS can be applied as analytical tools as they contain a broad set of 'origin points' of services, linked to types of ecosystems and beneficiaries

- CICES can be used as check-list, and as a framework to facilitate international comparability.

5.68. Once a set of priority services has been determined it will be relevant to quantify and map the ecosystem services in terms of both ecosystem services supply (from ecosystem units) and use (by beneficiaries, including businesses, households and governments).

5.69. Data relating to flows of provisioning services may be available from national agriculture, forestry, fishery and water agencies. Ideally, these data would be sourced from accounting frameworks such as the SNA or SEEA Central Framework. Data for some regulating services may be obtained from thematic accounts, such as for carbon sequestration.

5.70. If no data on observed ecosystem flows is available, new data collection/generation (including inventories, remote sensing, spatial modelling and other sources) may be required. Data collection should be developed in a way that provides consistent estimates across the different service types (e.g. of similar detail, quality, error and uncertainties), as well as correctly embedded in the ecological and land use processes. Alternative modelling tools include:

- For soil and water-related process and service modelling tools consider USLE and associated models, and SWAT, SedNet, HEC and others
- For carbon-related process and service modelling tools consider CASA (Potter, et al, 2012)
- For biodiversity and other process and service modelling tools consider MAXENT

5.71. Depending on the nature of the data gaps, the use of benefit transfer functions can be considered and cautiously tested. Generally, it will be important to develop an understanding of uncertainties when defining, classifying, quantifying and mapping ecosystem services and to prepare validation/quality control data and protocols.

5.72. Notwithstanding the priority for testing to be the focus of current activity, there are some areas of research that would support this testing work. Primary among these is resolution of issues concerning the definition and classification of ecosystem services. This work has advanced well and the relevant boundary issues are quite well delineated. However, further consultation leading to decisions or treatments is needed to put in place a classification of ecosystem services that is, at least, appropriate for ecosystem accounting purposes.

5.73. The second key area of research is articulation of the role of intermediate and supporting services in ecosystem accounting. A related task is specifying what are best called ecological production functions or value chains – i.e. the sequence of ecosystem processes and characteristics, possibly across ecosystem types, that leads to the supply of a final ecosystem service. Although it is not anticipated that a complete catalogue of all such production functions would be established in the short to medium term, research in this direction would be of direct benefit to applying ecosystem services and ecosystem accounting measures to policy questions.

Chapter 6: Accounting for ecosystem assets

Key points in this chapter

Three main dimensions are considered in the measurement of ecosystem assets: ecosystem extent, ecosystem condition and expected ecosystem service flows.

Ecosystem extent can be measured in straightforward fashion in terms of the area of different ecosystem units.

Ecosystem condition is more challenging to measure requiring the selection of relevant characteristics and then selection of appropriate indicators and metrics of each characteristic.

For some characteristics in certain ecosystem types, condition metrics are well established.

A key challenge for ecosystem accounting is developing a full coverage of measures in a manner that support aggregation and comparison.

Reference condition approaches are one technique for developing measures that can be monitored over time and can be compared across ecosystem types and across countries.

Determining reference conditions for multiple ecosystem types and more than one country is not straightforward.

Testing is required, especially regarding ecosystem condition measurement.

Ecosystem capacity is emerging as an important concept in ecosystem asset measurement.

Ecosystem capacity provides a link between ecosystem services and ecosystem assets and supports the assessment of sustainability in ecosystem use and trade-offs between different baskets of ecosystem services.

6.1 Introduction

6.1. 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 achievable. 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.

6.2. This chapter builds on the initial discussion of accounting for ecosystem assets in Chapter 4 of the SEEA EEA. When that chapter was drafted, there were many concepts and ideas about how ecosystem assets might be described and measured, 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.

6.3. This chapter assumes that ecosystem assets are represented by spatial areas called EU, as outlined in Chapter 3. EU represent ecosystem assets while geographical aggregations are combinations of EU for the purpose of reporting and analysis. Note that a geographical aggregation could be an aggregation of specific EU types (e.g. deciduous forests), or a geographical aggregation could be all EUs aggregated within a specific ecological boundary (e.g. a river basin) or an administrative boundary (e.g. a country or local government area).

6.4. It may be intuitively appealing to consider that certain geographical aggregations are assets in their own right, for example all forests within a country. However, from a stricter accounting and measurement perspective it will be more consistent and useful to consider only EU as ecosystem assets. This approach is more strongly aligned 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).[12]

6.5. The treatment of EU as being ecosystem assets does not imply that individual EU themselves are the appropriate level of reporting for ecosystem accounting purposes. In national economic accounting, reporting takes place at the industry (e.g. manufacturing) or institutional sector level (e.g. households) rather than at the level of individual economic units. Similarly, it is likely that accounts will be structured to present different types of EU within a single geographical aggregation, e.g. a country. A key issue for further research is the level of detail at which accounts can provide accurate information, as a function of landscape properties and the quality of input data.

6.2 Dimensions in the measurement of ecosystem assets

6.6. 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 provides a linking point in the measurement of ecosystem assets and ecosystem services.

6.7. The measurement of each of the dimensions of ecosystem assets must take into account the appropriate scale of analysis. This is likely to be considerably affected by the number of different types of EU that are used. Where accounting is undertaken using the 15 classes of land cover to represent the types of EU, this will provide a broad and relatively coarse sense of changes in ecosystem assets. For a range of analytical purposes, it is likely to be necessary to incorporate additional EU types and hence provide a richer understanding of the structure and changes in the structure of ecosystem assets within a country.

6.8. This section introduces the different dimensions of ecosystem assets noted above, with an extended discussion on the measurement of ecosystem condition in section 6.3 and a discussion on ecosystem capacity in section 6.4.

6.9. The most straightforward measurement 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 asset types at an aggregate level. For example, these accounts will support the derivation of indicators of ecosystem diversity.

[12] Some studies consider that biodiversity, habitats, individual species or individual ecosystem services are "assets". Since the objective in ecosystem accounting is to consider the ecosystem as an integrated, functioning unit, the focus is on EU as assets rather than specific characteristics.

6.10. 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, often hectares, this permits aggregation and comparison at larger scales. Thus comparisons can be made between the relative proportions of different ecosystem asset types and the changes in these proportions over time. It is not as straightforward to undertake this type of comparison for the condition of ecosystem assets.

6.11. 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 6.3, requires the selection of specific characteristics and then measurement of relevant indicators pertaining to those characteristics.

6.12. Once indicators are measured, the task from an accounting perspective is to develop methods that support comparison and aggregation. Being able to understand the relative significance of different ecosystem assets is core to the 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 step is provided in section 6.3.

6.13. The third dimension concerns *expected ecosystem services flows*. The concept of expected ecosystem services flows is an application of standard capital accounting to the area of ecosystems. It stands somewhat distinct 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.

6.14. 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.

6.15. The concept relates to the actual flows of ecosystem services that are considered most likely to occur in future accounting periods. It does not reflect the sustainable yield of ecosystem services, unless a sustainable yield is expected. Rather, the actual (or observed) flow refers to the quantity of ecosystem services (measured in terms of tonnes, m3, number of visitors, etc.) that flow from an ecosystem asset to a beneficiary during an accounting period. The actual flow is different from estimates of flows of ecosystem services that are based on consideration of alternative scenarios (e.g. if prices for resources were higher or population distributions were different) or under different assumptions (e.g. if the ecosystem asset is used sustainably).

6.16. Given this definition, 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. In terms of the asset as a whole, some mixture or basket of ecosystem services must be assumed for estimation to take place.

6.17. Ultimately, from an ecosystem accounting perspective, the main 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 in its own right and in comparison with other ecosystem assets.

6.18. 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, e.g. produced assets. The measurement of ecosystem extent and ecosystem condition in monetary terms is not possible (at least not directly) and hence the focus for the valuation of ecosystem assets is on the valuation of expected ecosystem service flows.

6.19. In the SEEA EEA, the valuation of ecosystem assets is undertaken by deriving the net present value of all future expected ecosystem service flows from an asset. There is a range of conceptual and practical challenges in valuation including (a) developing future scenarios of condition; (b) modelling the capacity to supply services under those conditions; (c) determining the expected basket of ecosystem services given that capacity; and (d) selecting appropriate discount rates.

6.20. Progress toward the full valuation of ecosystem assets is a medium to longer term objective. A more complete discussion of the relevant valuation issues is presented in Chapters 8 and 9.

6.3 Compiling measures of ecosystem condition

6.3.1 Introduction

6.21. The intent of an ecosystem condition account is to bring together a range of information about the 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 monitoring on, for example, carbon, water, timber, soil, species diversity, landscape characteristics (such as fragmentation or relative attractiveness), ecosystem resilience and integrity.

6.22. In the SEEA EEA, the general ambition in accounting for ecosystem condition is to bring together the relevant pieces of information to provide an overall assessment of the various ecosystem characteristics. The general tone of the SEEA EEA was that this was a two-step process whereby individual indicators for different characteristics were defined and then weighted together. Discussion since the release of SEEA EEA has highlighted the following points that provide a broader context for the measurement of ecosystem condition.

6.23. First, it is relevant to recognise different motivations for the measurement of ecosystem condition which each requires the use of a different measurement approach. There are two main motivations:

a. That ecosystem condition indicators can be used to indicate the general condition, state or health of an ecosystem and the relevant trends in condition. These indicators may reflect policy priorities (e.g. preservation of native habitat); ecosystem functioning (e.g. deposition levels of acidifying compounds versus critical loads for such compounds); or the capacity of ecosystems to generate one or more services (e.g. attractiveness of the landscape for tourism).

b. That spatial information concerning ecosystem condition is needed for the measurement and modelling of ecosystem services supply. For example, to analyse erosion risks and the ecosystem service of erosion control, it is necessary to have information on, among other things, slope, slope length and soil type. By themselves, indicators of these characteristics are not necessarily policy relevant, and so they may not change in the time frames relevant for ecosystem accounting.

6.24. For the compilation of the ecosystem condition account, the focus in the Technical Recommendations is on condition indicators that are relevant for conveying information on the state and trends in ecosystems. These may include condition indicators that reflect the capacity of an ecosystem to supply ecosystem services, thus enabling a connection to be made between ecosystem condition and ecosystem service flows.

6.25. Second, although it is clear that assessment of the condition of an ecosystem asset must involve consideration of a set of ecosystem characteristics, there is no definitive set of characteristics that can be determined a priori, even for a given ecosystem type. In part, this reflects that the assessment of condition should take into consideration, or implicitly place emphasis on, the likely uses of an ecosystem asset. Since there is a range of possible uses of an ecosystem, there will also be a number of combinations of ecosystem condition indicators. Determining the appropriate set of characteristics is a particularly important task for testing in ecosystem accounting.

6.26. In general, the types of indicators being considered in the measurement of ecosystem condition focus on measuring ecosystem process and function. However, there are two other groups of indicators that may be relevant in the measurement of ecosystem condition, or at least will be relevant in ecosystem measurement more generally.

a. The first group concerns the recording of relatively fixed characteristics of ecosystem assets such as measures of soil type, slope, altitude, climate and rainfall. Such measurements will provide important context for measures of condition and also may be important inputs in the modelling of ecosystem services.

b. The second group are more difficult to label but pertain to measures of impacts or pressures on the environmental state, for example, measures of pollution, emissions or waste. They were labelled “enabling factors” in SEEA EEA in the sense that, without the presence of these flows, there would be no associated ecosystem service being delivered. Accounting for these flows is described in the SEEA Central Framework although more spatial detail will be required for ecosystem accounting purposes. While primarily needed for measuring regulating services, they will also be relevant in the assessment of ecosystem condition. For example, in understanding the drivers for change in condition over time. Finally, this group of indicators will also be of particular interest from a policy monitoring perspective.

6.27. Third, in some cases, it maybe useful to compile composite indicators where a range of indicators is combined to reflect different elements of ecosystem condition. Having determined a suitable set of indicators, there is no natural, apriori weighting of the indicators that might be used to estimate the overall condition of an ecosystem asset. Rather, a measure of the overall condition requires a view to be taken on the relative importance of the different ecological processes involved, or the different purposes for use of an ecosystem asset. It would be possible to give each indicator equal weight, or perhaps to determine weights via surveys of ecosystem users, but this does not overcome the underlying issue.

6.28. It will be useful to compare condition indicators to benchmark or reference conditions. This approach is discussed at more length later in this chapter. Condition indicators may also be attributed to in specific classes on the basis of an assessment against standard criteria. This is sometimes done with classes reflecting different levels of soil fertility or land suitability for a specific purpose.

6.3.2 Different approaches to the measurement of ecosystem condition

6.29. There are three broad approaches that can be tested. The first is a "top-down" approach where indicators for a small set of generally applicable ecosystem characteristics across a country, are combined to form an overall condition measure. The combination uses assumptions on the relative importance of each characteristic and correlations among them.

6.30. This is the approach adopted for the ENCA QSP (Weber, 2014) where indicators of carbon, water, biodiversity and ecosystem potential are measured for all ecosystem types in a country and then combined to form a single index, the ECU, using carbon as the primary weighting variable.

6.31. The second approach is a "bottom-up" approach in which different characteristics are determined for different ecosystem types and perhaps, also for different uses of ecosystem types. This is the approach that has been used by SANBI in South Africa (Driver, 2012), MEGS in Canada (Statistics Canada, 2013), in the Norwegian Nature Index (Alasken, et al., 2012) and the Wentworth Group in Australia (Cosier and McDonald, 2010)[13]. In theory, it may be possible to combine the various indicators of the different characteristics to provide aggregate measures of condition but this step is not generally taken. Perhaps the closest to undertaking this step is the work of the Wentworth Group through their development of the "econd" as a reference condition based indicator and in the aggregate indexes of the Norwegian Nature Index.

6.32. The third approach is a variation on the bottom-up approach and involves selecting the condition indicators through a direct link to the basket of ecosystem services for a given ecosystem asset. This is the approach used in the UK NEA (2011) and relates to the concept of measuring ecosystem capacity (see section 6.4) where the ability for an ecosystem asset to continue to produce a given ecosystem service is a function of the ecosystem condition. An extension of this approach is that the relative importance of different condition measures could be determined on the basis of relative value shares of ecosystem services (i.e. those services with a higher share of total supply of ecosystem services in monetary terms received higher weight).

6.33. All three approaches are plausible ways forward for the measurement of ecosystem condition. Testing is required to understand whether there is a significant difference in the results from the use of different approaches, and which approaches might be most appropriate for ecosystem accounting purposes. This issue is discussed further in section 6.5.

6.34. To support the measurement of condition, it is likely to be useful to prepare data relating to drivers of change in ecosystem condition. Information on population growth, climate change related variables, economic growth and similar indicators will help to provide a broad context for measuring and interpreting ecosystem condition.

6.3.3 Developing indicators of individual ecosystem characteristics

6.35. The SEEA EEA points to a number of different characteristics and indicators (see for example Table 2.3).

6.36. The development of indicators to assess condition for particular purposes for particular ecosystem types, is a relatively well developed area of research. For a given characteristic, often the research enables the relative importance of the different

[13] Note that the ENCA QSP approach also supports the use of additional indicators beyond an initial standard set.

factors to be weighted to provide an appropriate composite index. The issue is not whether indicators of specific characteristics of ecosystem condition can be measured, but rather which characteristics are relevant and how the indicators might be combined.

6.37. 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 flows, there may be significant spatial variability that must be considered.

6.38. However, there will be some situations in which this may make little conceptual sense or imply assumptions in downscaling that are not appropriate. For example, in measuring ecosystem condition for the purpose of providing habitats, fragmentation and connectivity are key factors. These factors are measureable only at a multiple ecosystem asset or landscape level. Attribution of information on fragmentation and connectivity to the BSU level is possible, but the information remains meaningful only at the EU and/or landscape level.

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

6.40. It is not expected that the development of various individual indicators for each ecosystem type would require 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. In this regard, a key element of accounting is monitoring change over time and hence a focus on those characteristics that reflect changes in ecosystem condition is an important consideration. Based on assessments of the various projects referred to above, it seems 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.

6.41. In terms of data sources, these will vary depending on the indicator selected. In the areas of carbon, water and species diversity, a range of potential data sources is introduced in Chapter 7. The ENCA QSP also 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.

6.42. 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 the ecosystem or key processes within it; (iii) data availability; and (iv) the possibility to generate new data cost effectively.

6.43. Compilers are encouraged to consider the work described in the project research papers, the outcomes from testing in different projects, and most importantly, to engage with national experts on ecosystems and biodiversity measurement noting that there may be 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.

6.3.4 Aggregate measures of condition

6.44. Given that indicators of individual characteristics are available (as just described), the next question for ecosystem accounting concerns the aggregation of indicators to obtain overall measures of ecosystem condition for a single ecosystem asset and for multiple ecosystems. As noted in the introduction to this section, the development of overall measures of the condition of ecosystem assets remains a challenge in measurement terms.

6.45. In considering aggregation, the main objective in ecosystem accounting is to provide decision makers some macro-level information that supports understanding the relative state and importance of different ecosystems. Usually, there will be a limited set of resources available to influence ecosystem condition and capacity and hence choices must be made among a range of investment options.

6.46. Ideally, macro-level information would give a sense of the overall condition of each ecosystem relative to each other and also relative to relevant thresholds. For example, there may be more concern about an ecosystem whose condition was considered relatively close to collapse.

6.47. In moving from individual indicators of specific characteristics to information on relative overall condition, a continuum of information can be described. Moving along the continuum reflects the use of additional information and assumptions. In general terms, as the range of ecosystem types increases, it is likely to be more difficult to make comparisons.

6.48. The continuum is as follows:

i. At the most basic level, there will be information on individual characteristics that can be measured directly. For example, the pH level of soil or the cubic metres of biomass in a forest can both be measured in absolute terms. Looking at these measures over time can provide information on the ecosystem's condition.

ii. For some characteristics, it may be necessary to compare the chosen metric with a known baseline, standard or threshold, to be able to infer something about ecosystem condition. For example, measures of water or air quality will rely on both direct measures of pollutants and an understanding of how the estimate compares to a relevant standard.

iii. At the third level, still for a single characteristic, a composite indicator could be formed whereby a number of indicators (related to the same characteristic) are weighted together (as discussed in the previous section). For this composite indicator to be meaningful, it is necessary that the different indicators are measured or interpreted in relation to a common baseline or standard. Note that for many characteristics, in different ecosystem types, measurements at these first three levels are well developed in the literature.

iv. At the fourth level, the aim is to consider, within a specific ecosystem, some combination of indicators, each relating to a different characteristic. Two issues arise, first the selection of characteristics, and second the means of comparison. The first issue has been discussed in the previous section. The solution to the second issue, as proposed in the SEEA EEA, is the use of reference conditions, whereby indicators for each characteristic are compared to the same reference condition for that ecosystem.

v. At the final level, assuming that measures of ecosystem condition exist for each ecosystem (i.e. at level four), it is necessary to find a means of comparing different ecosystem types. Again, the use of reference conditions is a possible way forward where, in this case, all ecosystems are compared to a single reference condition. An extension at this level would be comparisons between countries.

6.49. Given the desire in accounting for macro-level information, it is particularly in the last two levels that the challenges in measurement and interpretation arise. A focus is thus on the extent to which a single reference conditions can be used to both compare within ecosystems, and to compare across ecosystems.

6.50. Assuming that an appropriate reference condition can be determined, the next step is to normalise each indicator. This is commonly done using the reference condition reflecting a "score" of 100 and the actual condition being between 0 and 100. A related approach used by SANBI (Driver, 2012), among others, is to grade ecosystems on a scale of A – E (or similar), with A representing a characteristic associated with a reference or near reference condition ecosystem and E representing a characteristic within a heavily degraded ecosystem.

6.51. 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 government agencies, research bodies and universities that can be used or built upon to support this type of assessment. The use of reference conditions is well known in the ecological literature and it should be considered as an adaptation for ecosystem accounting purposes rather than reflecting the use of an entirely new measurement approach.

6.52. While the use of reference conditions is well known and practiced, the precise choice of a reference or benchmark condition for accounting purposes requires further testing. A short summary of the issues is provided in the following sub-section.

6.53. As noted earlier in this section, the second step of weighting together indicators of the different characteristics is more complex and less developed. The ambition is not new from a statistical perspective (consider for example the Human Development Index (UNDP, 2014)) but, as for socio-economic indicators, the weighting of different ecosystem condition indicators is a matter of debate.

6.54. 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, or take into account various thresholds and non-linearities which may apply in aggregating indicators that relate to different aspects of condition.

6.55. At this stage, no clear pathways forward have emerged but there are a number of areas for testing and research described below in section 6.5.

6.3.5 Determining a reference condition

6.56. As noted above, determining an appropriate reference condition is not straightforward and can be the matter of considerable debate. The discussion here provides a short summary of the key points from an ecosystem accounting perspective.

6.57. A common starting point for determining a reference condition is application of the idea of natural or pristine condition where the reference condition reflects the condition of the ecosystem asset if it had been unaffected by human activity. In many cases the application of this reference condition is done by selecting a point in time at a pre-industrial stage. In Australia, for example, the year 1750 is commonly used.

6.58. A positive feature of this approach is that it places all ecosystem assets on a common footing and "distance from natural" can be interpreted relatively equivalently irrespective of the type of ecosystem. That is, it is possible to compare ecosystems that are either extremely diverse, such as rainforests, or much less diverse such as deserts.

6.59. Unfortunately, what constitutes a natural ecosystem can lead to significant debate particularly in those countries where human influence on the landscape has been evident for thousands of years. For example, almost all of Europe may be considered to have been forested at one point in time, but the use of this as a reference condition for the current mix of ecosystem types may not be appropriate.

6.60. Another concern that arises is that the reference condition can be mistakenly interpreted as a target or optimal condition. A clear distinction should be made between reference and target conditions. A reference condition should be used solely as a means of estimating relative condition and comparing across ecosystem characteristics and ecosystem types. Target conditions, on the other hand, should be developed through participatory processes, taking into account economic, social and environmental considerations. For example, in urban areas where the actual condition would be likely very low or zero relative to a reference condition of the previous natural state of that area, it would be inappropriate to suggest that the target condition should be the natural state. This would imply a social choice of relocating an urban area. On the contrary, it would be expected that information on the actual and reference condition would be useful input to a discussion of target conditions.

6.61. For accounting purposes, it may be sufficient to simply select the condition at the beginning of the accounting period as a reference condition and measure the actual condition relative to that point in time. A variation on this approach is to select the condition at the point in time at which the accounts commence.

6.62. The difficulty with this approach is that ecosystems that may have been heavily degraded in the past will be compared from the same starting point as those that have not been degraded at all – i.e. both would be given a reference condition of 100.

6.63. On balance then, some degree of discretion in the selection of a reference condition is required. In making a decision, an important consideration is the question of scale of analysis. In general, it will be more challenging to determine a reference condition as the scale of analysis gets larger since there are more factors affecting the analysis to take into account. Thus, if the intent is to only measure the condition of a specific characteristic (e.g. soil condition) of a specific ecosystem (e.g. open grasslands) then the choice of reference condition may be made taking only that characteristic and ecosystem type into account.

6.64. However, where there is a desire to compare multiple characteristics and multiple ecosystems, then a relevant reference condition will not be readily apparent. For some countries, it may be that a pre-industrial time point gives an appropriate reference condition, since there is a point in the not too distant past where a relative common understanding of change from a reference condition can be understood. As noted though, such a choice will likely not be appropriate where the current landscape mix of ecosystem types has, to varying degrees, been evident for centuries. Assuming a national level reference condition can be determined, a remaining challenge is to find a reference condition that allows comparison across countries. Given the diversity of landscape development patterns this choice is not at all obvious.

6.65. Pending further testing of different reference conditions, it is recommended that in the development of ecosystem condition accounts for a given country, that a point in time be selected, preferably at least 30 years previous, to allow the development of the relevant metrics of current condition and the application of the reference condition approach. For the measurement of change over time within a country, this is a pragmatic starting point and ensures that discussions focus on perhaps the more challenging measurement issue of actually selecting the indicators and maintaining ongoing time series. Using a relatively distant reference point, rather than the beginning of the accounting period, will better support the assessment of distance from thresholds for ecosystem assets.

6.66. Where comparison across countries is required, then it will be necessary for the measurement community to test options that are both meaningful for comparison purposes and also feasible for implementation. One point for testing would be the potential for a country to use one reference condition domestically, but to use a different reference condition for international comparison.

6.4 Developing the concept of ecosystem capacity

6.4.1 Defining ecosystem capacity

6.67. Earlier in this chapter, it was noted that the SEEA EEA describes three main ecosystem asset concepts: ecosystem extent, ecosystem condition and expected ecosystem service flows. Ecosystem capacity was the main ecosystem asset concept not dealt with in SEEA EEA. 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 for two reasons:

- First, there was 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 supply of individual ecosystem services. Notions of threshold effects, resilience, ecosystem dynamics and other non-linear factors are important to consider.
- Second, since the concept of capacity was considered to relate to the overall ecosystem asset, a requirement in measuring capacity was defining an expected basket of ecosystem services. Discussion on how such a basket should be defined was not conclusive.

6.68. Since the release of SEEA EEA in 2013, it has become increasingly apparent that the concept of ecosystem capacity is a central one for explaining the ecosystem accounting model and applying the model in practice. This is especially the case in relation to developing information sets that can support the discussion of sustainability. An initial definition of ecosystem capacity is – the ability of an ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum yield or use level that does not negatively affect the future supply of the same or other ecosystem services (Hein et al., 2015).

6.69. In the context of developing this definition, the following points have emerged. They are listed here to frame an ongoing discussion about ecosystem capacity in the context of ecosystem accounting and to encourage further dialogue on this topic. In particular, it discusses issues in applying the concept of capacity to different types of ecosystem services, i.e. provisioning, regulating and cultural services.

i. Ecosystem capacity is a function of ecosystem extent and condition and maintaining condition is an essential feature in the measurement of capacity.

ii. The supply of one ecosystem service can reduce the ecosystem's capacity to supply other ecosystem services. For instance, timber harvesting may reduce recreational opportunities in a forest. A distinction is therefore needed between (a) an ecosystem asset's capacity to supply an individual ecosystem service, i.e. there is a measure of capacity corresponding to each ecosystem service within the basket; and (b) an ecosystem asset's capacity to supply a basket of ecosystem services as a whole.

iii. Ideally, to take into account the systemic nature of ecosystem service supply, each individual service capacity measure will be a function of the overall ecosystem asset condition, thus bringing together the two conceptualizations just outlined.

iv. For ecosystem accounting, ecosystem capacity should be considered in relation to a current basket of ecosystem services and a specific ecosystem asset. It can be related to the sustainable flow of ecosystem services under current ecosystem conditions and ecosystem uses, and with respect to the current basket of ecosystem services. Estimates of ecosystem capacity may relate to flows of ecosystem services that are lower, higher or equal to actual, observed flows. In most cases, defining sustainable ecosystem use levels requires specific consideration of extractive ecosystem uses (e.g. logging, fishing), and involves analysing the basket of ecosystem services under the assumption that these extractive uses are brought to a sustainable level.

v. Each individual service capacity may be considered as a sustainable yield or flow relevant to the specific ecosystem service and taking into account the use levels of other ecosystem services supplied in by the ecosystem. The capacity measure should therefore reflect the estimated stream of annual service flows 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 remain unchanged over the accounting period.

vi. For ecosystem accounting, capacity is related to the actual basket of ecosystem services supplied. Thus, capacity requires the presence of users of ecosystem services. Capacity therefore differs from the ability of an ecosystem asset to supply ecosystem services independently from the potential use of those services by beneficiaries. This could be labelled theoretical or potential ecosystem supply (e.g. Bagstad et al., 2014). It may also differ from the basket of ecosystem services that would be obtained under optimal ecosystem management, which could be labelled 'the capability of an ecosystem to supply services'. Both theoretical/potential supply and capability are relevant concepts for ecosystem management but would not necessarily underpin ecosystem accounting estimates.

vii. In cases where high levels of use of the ecosystem asset take place, e.g. through high levels of extraction or pollution, it is expected that the condition of the asset will fall and hence that actual flows of ecosystem services will be higher than the sustainable flow. This set of circumstances would reflect ecosystem degradation.

6.70. Considering capacity as being measurable in terms of 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 remain significant challenges in understanding the links between measures of capacity for individual services and overall ecosystem condition.

6.71. An interim step may be the measurement of the potential of an ecosystem to supply ecosystem services, without requiring a link to be made to the likely use of ecosystem services by beneficiaries. However, for some ecosystems, particularly remote ecosystems, measures of such potential or "theoretical" supply may provide a significant overstatement of the availability and value of ecosystem services for economic and human activity.

6.72. Suggestions for taking this work forward in an ecosystem accounting context are described in section 6.5.

6.4.2 Linking ecosystem capacity and ecosystem degradation

6.73. From an accounting perspective, an important and emerging aspect of ecosystem capacity measurement 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 as a result of economic and other human activity (SEEA EEA 4.31). This aligns with the approach in the SEEA Central Framework for the definition of depletion of natural resources and in the SNA for consumption of fixed capital (depreciation) of produced assets. Table 4.6 presents the linkages between these accounting entries.

6.74. The emerging idea is that while ecosystem degradation is clearly related to declining condition, it should be defined more specifically as reflecting a decline in ecosystem capacity as a consequence of human activity (in line with the accounting definition of degradation). Thus ecosystem degradation would be measured as the decline in ecosystem capacity over an accounting period, or in other words, the decline in the ecosystem asset's ability to supply ecosystem services due to a decline in ecosystem condition. This would mean that, at the beginning and end of the accounting period, an assessment would be needed as to the future flow of ecosystem services if, from that point forward, the supply of ecosystem services did not lead to a decline in condition.

6.75. Standard concepts of depreciation and depletion are developed in relation to assets with finite lives and hence, the measurement of the capacity for sustainable supply of capital services does not arise explicitly. As a result, how a capacity based definition of degradation can be incorporated in a manner that remains consistent with the accounting principles of the SNA and SEEA Central Framework requires further investigation.

6.76. Overall, the role of measures of ecosystem capacity in an accounting context requires further discussion. As indicated in the SEEA Central Framework, discussion of depletion, in an accounting setting it is necessary to measure the depletion and degradation of renewable biological resources with reference to the potential for infinite regeneration. This issue does not arise in accounting for produced assets or non-renewable resources since, for accounting purposes, it is sufficient to assume that over some period of time the asset will be completely used up.

6.77. In determining the appropriate asset life for renewable resources, the concept of capacity may be particularly relevant since it supports consideration of the effects of current activity on the long term usefulness of the asset. Further, in the context of measuring degradation, the emerging conceptual discussion is that ecosystem degradation occurs when actual ecosystem service flows (in particular, provisioning services) exceed the ecosystem's capacity to supply that service. Therefore, where capacity can be quantified, it can be used in accounting as a measure to analyse whether flows of ecosystem services can be sustained in the future (see Schröter, et. al., 2014).

6.78. While ecosystem degradation may be most appropriately measured in terms of changes in capacity, degradation will also be reflected in measures of changes in ecosystem condition and, depending on how the ecosystem is used, in flows of ecosystem services (since the expected flow of ecosystem services will ultimately decrease over time as a result of ecosystem degradation).

6.79. There have been proposals to develop asset accounts for ecosystem capacity At this point, an ecosystem capacity account has not been defined. Instead, the emphasis is placed on the measurement of ecosystem capacity for individual services such that there can be a more complete understanding of the extent to which current patterns of use differ from patterns of use that would leave the condition of the ecosystem asset unchanged.

6.80. From an ecosystem accounts compilation perspective, the need for further discussion on ecosystem capacity in no way limits the potential to compile most other ecosystem accounts. 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 have been discussed.

6.5 Recommendations

6.5.1 Recommended steps for testing and experimentation on ecosystem assets

6.81. As described in Chapter 4, the compilation of an ecosystem extent account is the likely starting point for all ecosystem accounting work. In the process of compiling an extent account, the relevant spatial units should be clearly identified, and it will be possible to develop maps and tables showing the changes in composition of ecosystem extent in a continuous, spatially- and temporally-explicit way at the country level. These information should be consider important outputs of ecosystem accounting in their own right and can be linked to relevant socio-economic data such as population change, production and income data, employment information to provide a sense of the potential of accounting for environmental assets.

6.82. Consistent with the advice provided in Chapter 4, at a minimum ecosystem extent accounts should be developed at the level of the top level land cover types as described in the SEEA Central Framework land cover classification. However, wherever possible and as appropriate, finer level breakdowns of these land cover types should be developed including integrating this with existing ecological classifications. An important outcome from testing the measurement of ecosystem extent is determining the level of detail needed to provide broad trends in changes in ecosystems at the country level.

6.83. Specific advice concerning the measurement of ecosystem extent is to measure the extent[14] of the EU identified (and mapped) following recommendations in Chapter 3. An important (and still challenging) consideration is the choice of an appropriate spatial resolution to ensure balanced representation of dominant versus smaller ecosystem units. In this context is it necessary to:

- Apply land cover/use change to measure the extent of ecosystems, with additions and reductions, in spatially- and temporally-explicit way
- Report, where appropriate, the extent measures in a way that allows international comparability, for example, by aggregating to the global biome/ecoregion defined by WWF, and also reclassifying and aggregating the ecosystem types to match the 15 land cover classes from the SEEA Central Framework

[14] Change in volume, length or other physical measures may be more relevant for ecosystem like rivers and lakes

- Combine area (raster or vector-polygon) measurements and linear (vector) measurements for the smallest features, such as streams and hedgerows to prevent double counting of areas. Key principles are to maintain the same total national area and ensure that no gaps are left.
- Consider special area-corrections where coastal lines have a high fractal dimension, and in mountain slopes terrains.

6.84. The measurement of ecosystem condition following the concepts in the ecosystem accounting model is a complex task due the need to consider multiple ecosystems and multiple characteristics. At the same time, there is sufficient research in the general area of condition measurement to suggest that the testing of different approaches in pilot ecosystem accounting projects is quite possible and should be pursued.

6.85. An initial question in taking this work forward is whether a top down or bottom up approach should be used. In the initial phases of testing it is recommended that a top down approach be used following the steps just below. Over time, it may then be appropriate to expand the set of indicators for different ecosystem types within the same spatial units architecture.

- Measure the main ecosystem characteristics/stocks on land including soil, biomass (composed of C, N, P and others), species/habitats abundance and conservation, and water. These can be estimated applying the models recommended in Chapter 5.
  - Carbon, nutrients and biodiversity measures will be applicable to virtually all ecosystems, while water- and soil-related ones for terrestrial ecosystems.
  - Cross-cutting estimates related to land, water and forest should be consistent with the national accounts developed for the Central Framework
- Choose an appropriate reference period for the condition measure, or alternatively use the ‘opening stock’
- Apply measurement of condition with reference to the supply and use of ecosystem services
- Record and report on the variability and sources of error in the data.

6.86. Beyond top down approaches, and where resources are available, it is likely to be more ecologically well founded if bottom up approaches can be tested – i.e. developing measurement specific characteristics for different ecosystem types.

6.87. An important observation is that a broader set of characteristics can be considered than included in the ecosystem condition account described in the SEEA EEA. Thus, in addition to the characteristics of vegetation, biodiversity, soil, water and carbon, it is recommended that consideration also be given to developing condition indicators for air and ecosystem integrity and health (including for example indicators of fragmentation, naturalness, and ecosystem diversity).

6.88. While the table provides a good starting point for a testing program, it is not intended that every indicator proposed in the table be tested in all countries. In the planning phase there are two important steps that should be taken. First, for each ecosystem type a connection should be made between the common uses of the ecosystem and the most relevant characteristics – i.e. not all characteristics will be relevant in the measurement of condition of all ecosystem types. It is noted that answering these questions would be supported by understanding the relevant ecosystem services that are likely to be supplied from a given ecosystem. Second, an assessment must be made regarding data availability for the different indicators.

6.89. To support the comparison of different ecosystems types within a country it is recommended that a single reference condition approach be used. Different principles for determining a reference condition can be applied, including the principle of naturalness. However, given the difficulty of applying this principle in a number of countries and the practical issue of defining naturalness, it is recommended that, as a starting point for ecosystem accounting, a single reference point be selected, preferably at least 30 years previous. This will allow the development of the relevant metrics of current condition and the application of the reference condition approach.

6.90. For the measurement of change over time within a country this is a pragmatic starting point and ensures that discussions focus on the more challenging measurement issue of actually selecting the indicators and maintaining ongoing time series. Where available, it is also likely to be relevant to understand target conditions and hence understand the movement towards or away from the desired state.

6.91. On the whole, these recommendations are ones that can be tested in applications at country and regional level. One area for research is the development of overall indexes of condition for ecosystem assets either based on aggregation of indicators for selected characteristics or using some alternative approach, for example isolating a key characteristic in ecological terms. Further research is also required on the choice of reference condition for ecosystem accounting purposes.

6.5.2 Recommendations in relation to ecosystem capacity

6.92. For ecosystem capacity, it is increasingly evident that this concept has an important role to play in ecosystem accounting, both in terms of interpreting the links between ecosystem services and ecosystem condition and in terms of the definition of ecosystem degradation.

6.93. Given that a definition of ecosystem capacity is still emerging, the advice here is that the measurement of ecosystem capacity should be considered to be a topic of ongoing research but with a very high priority. The principle aims in the short term should be (i) to reach a common understanding of the definition of ecosystem capacity and its relationship to other related concepts; (ii) to articulate the role of ecosystem capacity within the accounting system, primarily with respect to defining ecosystem degradation.

6.94. To support this research into ecosystem capacity, it would be beneficial for those countries and agencies undertaking testing of ecosystem accounting to consider questions relating to the links between flows of ecosystem services and measures of ecosystem condition. These links should, in any event, be a part of any testing since it is generally accepted that the measurement of condition must integrate information on the management and use of ecosystems and that modelling the flows of ecosystem services, particularly regulating services, will involve the use of information on ecosystem condition.

6.95. One way in which these relationships might be developed and tested is to undertake analysis for different scenarios of future conditions. Such information and methods are likely to be of direct interest for policy purposes in any event and may be usefully defined to support an understanding of ecosystem capacity.

6.96. Finally, it is observed that understanding and measuring capacity will benefit from a more complete articulation of the “cascade” model that links ecosystem structure, composition and function to ecosystem processes and flows of ecosystem services. Understanding these connections which are relevant in a number of parts of the ecosystem accounting model should be seen as an important aspect of testing.

7. Thematic accounts

Key points in this chapter

Thematic accounts are standalone accounts on topics of interest in their own right and also of direct relevance in the measurement of ecosystems and in assessing policy responses.

Thematic accounts include accounts for land, carbon, water and species diversity.

Land accounts can focus on land use, land cover and land ownership. The development of land accounts provides a platform for measurement and is commonly the basic entry point for ecosystem accounting.

In water accounting measurement at the river basin level is important for ecosystem assessment. Working at this level will require the use of hydrological models but this work can also underpin the estimation of relevant ecosystem services such as water filtration and soil retention.

Accounting for stocks of carbon can provide a strong base for co-ordinating information on carbon and complements measurement within the Inter-governmental Panel on Climate Change (IPCC) framework and the UN REDD+. The data can support measurement of ecosystem condition and ecosystem services such as carbon sequestration and storage.

Accounting for biodiversity considers both ecosystem and species diversity. Biodiversity is considered primarily a characteristic of ecosystem assets rather than an ecosystem service. In accounting terms this permits recognising declines or improvements in biodiversity over time and links to the capacity of ecosystems to supply ecosystem services.

In all cases - land, water, carbon and biodiversity - there is a broad range of information and measurement methodologies available. The challenge for ecosystem accounting is the assessment and integration of these data and methods within the SEEA EEA framework.

7.1 Introduction

7.1. The ecosystem accounts described in Chapter 4 provide a coherent coverage of information pertaining to ecosystem assets and ecosystem services. At the same time, from both an analytical and a measurement perspective, it can be challenging to focus only on a systems perspective. More commonly, our view of ecosystems, and our policy responses, are framed using themes that concern specific aspects of the economic – environment relationship. Four main themes that are evident are land, water, carbon and biodiversity. This chapter provides an introduction to accounting in relation to these themes.

7.2. The incorporation of a thematic focus in the context of ecosystem accounting provides two benefits. First, it enables a closer link to be drawn between the compilation of ecosystem accounts and the likely areas of policy response – for example in terms of land management, management of river basins, carbon emissions policy and maintenance of protected areas. Second, often the data that are used to understand trends in thematic areas can also be used to compile ecosystem accounts.

7.3. It is relevant to note that while measurement in each of the four main themes is relatively well advanced, the work on the SEEA has highlighted the potential to use accounting approaches to (i) improve the co-ordination of data and (ii) recognise links between the themes.

7.4. In the case of two themes – land and water – the SEEA Central Framework and the SEEA Water provide the conceptual grounding for accounting. 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 developing. SEEA EEA section 4.5 introduces relevant ideas for accounting for biodiversity but more testing is needed.

7.5. Accounts for land, water, carbon and biodiversity 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 thematic accounts to support discussion of environmental-economic issues. In particular, information from the thematic accounts, when presented in the context of ecosystem measures, can provide a more tangible hook for users when making links between ecosystems and policy choices.

7.6. This chapter provides a summary of the relevant accounting issues for each of these four areas.

7.2 Accounting for land

7.2.1 Introduction

7.7. Accounting for land, particularly land cover, will be a common starting point for compilers of ecosystem accounts, given the focus on terrestrial ecosystems. A distinction is made here between land accounting and ecosystem extent accounts. Land accounting is considered to encompass compilation of a variety of accounts utilising different classifications of land including land use/management, land cover, and land ownership. In applying these classifications links to standard SNA classifications of industry (ISIC) and institutional sector. Land accounting will include standard asset account structures and also change matrices and tables that cross classify land. These various aspects of land accounting are covered in the SEEA Central Framework Chapter 5. Ecosystem extent accounts on the other hand are a specific account recording the area and change in area of different EU types. Ideally, EU types would be nested within a land cover classification, hence providing a link between land accounts and ecosystem extent accounts.

7.8. As part of the accounts compilation process, the information from land cover accounts can be used to help define the relevant spatial areas, 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.

7.9. From an analytical and policy perspective, information on land cover can, at a national scale, provide important information on trends in deforestation, desertification, urbanisation and similar forms of landscape change. As recognised in ecosystem accounting, understanding these types of changes is not sufficient for understanding the effects on ecosystem condition or flows of ecosystem services but it is a relevant starting point.

7.10. The total area of a country may also be classified according to land use or land ownership criteria. An interim land use classification is provided in the SEEA Central Framework (Table 5.11 and Annex I). Land ownership may be classified by institutional sector (corporations, government, households) or by industry (agriculture, manufacturing, retail, etc.). In some cases, a reasonably clear connection can be made between different classifications of land – for example there will often be a clear link between tree-covered areas and forestry. However, it is not possible for a simple integration of land cover and land use classes to be described.

7.11. Information on land use and land ownership will be important in understanding the connection between ecosystem assets and the beneficiaries of ecosystem services. For that reason, it is recommended that, where possible, accounts for land use and land ownership be compiled following the advice in the SEEA Central Framework. A useful output for ecosystem accounting may be a table which cross-classifies land cover and land use at a given point in time. Such a table would highlight the relative significance of different land cover types to specific uses.

7.12. Land accounts can also provide an important tool to link environmental and socio-economic data, essentially providing a means by which policy can be placed in a spatial context. A key link here is recognising that implementation of policy to maintain and restore ecosystem condition is likely to require the involvement of land holders. Hence, understanding the connection between land ownership, current use and the relevant ecosystems can provide the means by which decisions on appropriate policy interventions can be made.

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

7.14. The basic structure of a land account follows the structure of an asset account as described in the SEEA Central Framework. That is, there will be an opening stock, additions and reductions in stock and a closing 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 and land use accounts.

7.15. In addition to an asset account, information on land cover and land use may be organised in the form of a change matrices which show how, over an accounting period, the composition of land has changed. An example of such a matrix for land cover is provided in the SEEA Central Framework, Table 5.14 (UN et al., 2014a).

7.2.2 Relevant data and source materials

7.16. In terms of data requirements, a distinction has to be made 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.

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

7.18. Materials to support land accounting include the SEEA Central Framework, the SEEA EEA and the ENCA QSP. The ENCA QSP in particular has an extensive discussion of land cover accounting and associated data sources and methods.

7.19. Additional support and guidance is available in looking at country examples and case studies. Relevant examples include the work of the European Environment Agency (Weber, 2011), the Australian Bureau of Statistics (2015), Statistics Canada

(2013), the Victorian Department of Sustainability and Environment (2015) and in Mauritius (Weber, 2014).

7.2.3 Key issues and challenges in measurement

7.20. There is a range of measurement challenges in land accounting. An immediate challenge is being able to integrate the various data to produce harmonised geo-databases and, for accounting purposes, measures of change over time. This requires careful consideration of scale and classification in combining different data sets.

7.21. In general terms, higher levels of detail will be better but will also have higher resource costs. Balancing the resources available with the degree of accuracy required will be important. A relevant issue in this context is understanding approaches to the validation of data, particularly since much data will be derived from remote sensing, including satellite imagery. Ideally, some degree of sampled ground truthing should be undertaken.

7.22. An integrated approach involving sampled reference points to measure land use and land cover across Europe, the Land Use and Cover Area Survey (LUCAS) has been developed in recent years by Eurostat. This approach may provide additional ideas for measurement approaches at national level.

7.23. The approach to classifying land is particularly important for communicating messages on the changing composition of land at national level. For land cover, there is now an ISO standard[15] that underpins the Land Cover Classification Scheme (LCCS version 3) as developed by the FAO (FAO and GLCN, 2009). This provides a structure by which each type of land cover around the world can be consistent classified. It thus provides a way of linking the various classifications that are in use in different countries and regions.

7.24. While this provides a base level classification tool, more varied have been the approaches to the formation of higher level classes that can be used to summarise detailed classes in meaningful ways. There are a number of options, one of which is the interim land cover classification presented in the SEEA Central Framework. Definition 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 would underpin greater alignment in ecosystem accounting discussions and applications.

7.25. With regard to the classification of land use, the SEEA Central Framework describes an interim land use classification based on work on agriculture, forestry and fisheries land use by the FAO, and UNECE work on the classification of land use for all economic activities.

7.2.4 Recommended activities and research issues

7.26. It is recommended that countries develop land accounts as an integral part of a suite of national environmental-economic accounts. In their own right, land accounts provide important information on environmental trends. Also, their compilation requires the organisation of spatial data which in turn provides the inputs

[15] ISO 19144-2:2012 specifies a Land Cover Meta Language (LCML) expressed as a UML metamodel that allows different land cover classification systems to be described based on the physiognomic aspects.
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=44342

for the delineation of spatial units and ecosystem accounting. Finally, a focus on land provides a platform for integrating environmental and socio-economic data.

7.27. A number of relevant areas for testing in relation to land accounting are presented in chapters 3 and 6 in relation to the delineation of spatial units and the compilation of ecosystem extent accounts. In terms of areas for research, the main issues concern (i) finalising appropriate classifications for land cover and land use beyond the interim classifications of the SEEA Central Framework; and (ii) determining the best approaches to account for linear features, such as rivers, beaches and hedgerows.

7.3 Accounting for water related stocks and flows

7.3.1 Introduction

7.28. Water is a fundamental resource. It is essential for all life and underpins the production of food, fibre and energy in many countries. The management of water, including taking into account cross-boundary flows (e.g. in relation to the Nile River), and the joint ownership of surface water bodies (e.g. in relation to Lake Victoria), is an important focus for many governments around the world.

7.29. Accounting for stocks and flows of water is a key feature of both the SEEA Central Framework and the SEEA EEA. While both of these documents promote accounting for water at the river basin level, this is the focus in ecosystem 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.

7.30. Accounting for water is relevant to ecosystem accounting in a number of ways. First, water is a key feature of ecosystems and hence the measurement of the stocks and changes in stocks of water resources is a relevant aspect in the measurement of ecosystem condition.

7.31. Second, there are a number of ecosystem services which relate directly to water. These include the provisioning service of water when it is abstracted for use (irrigation, drinking, hydropower), the regulating role of water in filtering pollutants and other 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.

7.32. 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 – (a) the supply and use of water and (b) the asset account for water. They provide the basis for accounting for water.

7.3.2 Relevant data and source materials

7.33. 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 also SEEA Water (UN, 2012b) and the associated International Recommendations on Water Statistics (IRWS) (UN, 2012a). Chapter 6 of the ENCA QSP has much relevant information.

7.34. There is a wide range of data sources, including global data sets that might be considered for use in water accounting. To date, over 50 countries have trialled the development of SEEA based water accounts. Consequently, there is an increasing body of knowledge and experience in water accounting that can be drawn on.

7.3.3 Key issues and challenges in measurement

7.35. 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). The ability to recognise these areas and hence better understand the stocks and flows of water resources is important.

7.36. On a related note, integrating information on groundwater within the ecosystem accounting framework requires further consideration given that generally the ecosystem accounts have considered surface water resources. The same comment also applies in the case of information on stream flow and water yield. While these are not standard SEEA accounting items, indicators on these aspects of the hydrological system may be relevant in understanding the system and more completely assessing ecosystem condition.

7.37. 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, understanding water flows is relevant in measuring the service of soil retention in the upper reaches of river basins. SEEA EEA largely ignored flows between ecosystems but further reflection suggests that incorporating certain intermediate ecosystem services is required.

7.38. A general challenge in water accounting from a national accounts perspective is that, often, national level data on water resources are not overly meaningful. Instead, information at a river basin level is required. While it may be straightforward to propose measurement at this level of detail, developing estimates at a river basin level will be resource intensive. Further, in some situations, sub-annual data may be needed to understand the dynamics of seasonal fluctuations in water supply and water use. Such information may be overlooked if working with annual or long-term averages.

7.3.4 Recommended activities and research issues

7.39. The main conclusion in relation to accounting for water resources is that there is a wide array of information and examples of water accounting in practice to support countries that wish to start work in this area. Further, there are many datasets that can provide a starting point for compilation. Testing the compilation of water accounts should therefore be given a very high priority.

7.40. A few areas in which further research might be conducted include accounting for dependencies between ecosystem units within river basins (including flows of intermediate ecosystem services), advancing discussion on the valuation of water resources and accounting for water quality at a broad scale.

7.4 Accounting for carbon related stocks and flows

7.4.1 Introduction

7.41. Carbon has a central place in ecosystem and other environmental processes and hence accounting for carbon stocks and transfers between them 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 to reproduce or summarise the content of those materials.

7.42. Accounting for carbon in the SEEA commenced in the context of accounting for carbon in forests and for greenhouse gas emissions. With the development of the SEEA EEA, the scope of carbon accounting has been broadened and, as described in the SEEA EEA, ideally it encompasses carbon stocks and flows and their changes for all parts of the carbon cycle and all carbon pools. Thus it covers geocarbon, biocarbon, atmospheric carbon, carbon in the oceans and carbon accumulated in the economy. In practice, the focus of carbon stock accounting at this stage is on biocarbon and geocarbon.

7.43. The measurement of stocks and transfers of carbon can support discussion of many policy relevant issues. These issues include the analysis of greenhouse gas emissions, sources of energy, deforestation and land use change, loss of productivity and biomass, and sources and sinks of carbon emissions. Since carbon is also a common focus of policy response, for example carbon taxes, its direct measurement is of high relevance.

7.44. In ecosystem accounting, information on stocks and flows of carbon can be used in two main areas. First, as part of the measurement of ecosystem condition. One broad approach is to use changes in net ecosystem carbon balance (net primary production less human appropriation) as an indicator of ecosystem condition. This single indicator can capture changes in soil, vegetation and other biomass. Second, information on carbon stocks and flows relates directly to the ecosystem services of carbon sequestration and carbon storage.

7.4.2 Relevant data and source materials

7.45. 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, involves the collection of (i) data on land vegetation/cover and the rates at which different land/vegetation cover types sequester and store carbon in above and below ground biomass; (ii) data on the carbon content of soils; and (iii) information on sub-soil fossil fuel resources. A particularly relevant source is information compiled by countries as part of reporting to the IPCC.

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

7.47. A number of aspects of carbon accounting are also reflected in the SEEA Central Framework. For example, air emission accounts will include flows of GHG emissions; and mineral and energy resource asset accounts will record stocks and changes in stocks of sub-soil fossil fuel resources. For SEEA EEA purposes, it is relevant to compile such accounts at a finer level of spatial detail.

7.48. The ENCA QSP provides a detailed discussion on accounting for changes in biocarbon at national scale including a discussion about global datasets and measurement challenges. Of particular relevance, is the work undertaken on the measurement of carbon through the FAO Forest Resource Assessment (FRA) (FAO, 2015) which is conducted every five years. The FRA asks for estimates of carbon stock for forests including above and below ground carbon stocks. These data may provide a useful starting point for compiling a time series of carbon accounts.

7.4.3 Key issues and challenges in measurement

7.49. Compared to other areas of measurement, the measurement issues in relation to carbon are relatively limited, although challenges exist in using point measurements for estimation of large scale areas. 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 measure carbon stocks accurately across the wide variety of vegetation and soil types since different carbon content ratios will apply in different situations. Related to this, the sourcing of information via either remote sensing or using local sources requires balancing between coverage and accuracy.

7.4.4 Recommended activities and research issues

7.50. Given the high policy relevance of carbon and the comparably large resources currently directed at measuring stocks and flows of carbon at national level, it is recommended that countries support the development of carbon accounts. The preparation of these accounts can provide information on broad trends in environmental change and also provide insight into the requirements of bringing data together from a variety of sources.

7.5 Accounting for biodiversity

7.5.1 Introduction

7.51. Biodiversity (the diversity of ecosystems, species and genes) plays an essential role in supporting human well-being. Biodiversity maintains functioning ecosystems that in turn deliver ecosystem services such as food, the regulation of our climate and aesthetic enjoyment.

7.52. The SEEA EEA provides a framework to measure and link ecosystem service flows supported by biodiversity and other characteristics (e.g. soil type, altitude) with the economy and other human activities. It also allows comparison and integration of data on ecosystem services with other economic and social data. Biodiversity accounts can help build an understanding of the relationship between biodiversity and economic activity by integrating data in a spatially explicit manner.

7.53. On the whole, the perspective taken for ecosystem accounting in the SEEA EEA is that biodiversity is a feature that is directly relevant in measurement of the condition of ecosystem assets. Measures of biodiversity, whether of ecosystem diversity or species diversity (the inclusion of genetic diversity measures has not yet been examined), are considered to relate primarily to the stocks component in the accounting model. This approach is consistent with a view that biodiversity can be degraded or enhanced over time, an attribute that applies only to stocks and not to flows (i.e. ecosystem services). In this context, the connection between biodiversity and ecosystem functioning may often be difficult to make. This is related to both to the limitations of ecosystem dynamics models as well as data gaps for many ecosystems world-wide.

7.54. In the framing of the SEEA EEA, species diversity may be considered as a characteristic of an individual or connected EUs, and ecosystem diversity would emerge from assessment of the diversity of EU types. People may appreciate and therefore value specific elements of biodiversity, for example when they take an interest in the conservation of endemic and/or iconic species. This is reflected, for instance, in the creation of protected areas in many countries. However, these species can only survive in the long-term when the overall condition of the ecosystems in which they occur is maintained.

7.55. In order to reflect the multi-layered relation between biodiversity, ecosystem functioning, ecosystem services and the human appreciation of ecosystems, a range of biodiversity asset indicators should be considered. Species indicators may be selected on the basis of the importance of species for specific ecosystem processes, for being indicative of ecosystem quality or functioning, or because the species represent specific aspects that people appreciate in biodiversity, such as the occurrence or abundance of endemic and/or iconic species.

7.56. Integrated accounting for aspects of biodiversity is still developing and experimentation on biodiversity accounting by countries is less advanced than for water or carbon accounting. To advance work, a paper was commissioned as part of the project - project research paper #10 (UNEP-WCMC, 2015). This section summarizes the findings of that paper.

7.5.2 Why account for biodiversity?

7.57. To deliver sustainable development, national accounting systems need information on the foundation for sustainable economic growth provided by ecosystems and their services. Biodiversity accounting provides a methodology to help understand the contribution of biodiversity (both ecosystem and species diversity) to human well-being and the economy, by explicitly considering its role as a determinant of the condition of ecosystem assets that are essential for the supply of ecosystem services.

7.58. Biodiversity data is incorporated into the SEEA EEA framework via a thematic, species diversity account and also in the ecosystem extent account that can support analysis of ecosystem diversity. The species diversity account provides information that can be used in the measurement of the condition of ecosystem assets. The spatial nature of the accounts allows statistics on biodiversity to be examined against economic and social statistics in a spatially consistent manner.

7.59. Notwithstanding the connection made here between biodiversity measurement and the measurement of ecosystem assets, there are situations in which measures of biodiversity can be indicators of flows of final ecosystem services. For example, the value of recreational services from wildlife related activities, where people gain benefit from experiencing the diversity of nature. In these circumstances, it is relevant to recognise that measures related to biodiversity may be appropriate indicators in a variety of accounts, including ecosystem condition accounts and ecosystem services supply and use tables.

7.60. Biodiversity accounting also provides opportunities for the harmonization of national level biodiversity data alongside other reporting mechanisms, such as the CBD through the implementation of National Biodiversity Strategies and Action Plans (NBSAPs) and reporting on the SDGs.

7.5.3 Assessing ecosystem and species diversity

7.61. Assessments of biodiversity generally consider ecosystem and species diversity due to the cost and complexity of assessing genetic diversity. However, that is not to say that genetic diversity is not important and could not be integrated into an accounting framework in the future.

7.62. Ecosystem diversity may be assessed using information on ecosystem extent as described in Chapter 6. Extent measures are based on data on land cover, land use, habitat and other ecosystem data, commonly sourced from satellite remote sensing. Within the SEEA EEA framework, these data inputs also provide spatial information for delineating ecosystems (as assets) on the basis of common characteristics. Many countries have their own ecosystem classification standards and methods for mapping them, and work is progressing towards an internationally accepted ecosystem classification.

7.63. Species diversity is the focus of this section, in part due to the availability of data and also because species measures can be used to approximate the status of biodiversity, in the form of biodiversity indicators. Development of a biodiversity account using species data should move beyond simple counts of the number of species (the species richness) and include the population size of each species (the species abundance) as this provides more information on the status of species.

7.64. Developing measures of species diversity is resource intensive and has methodological challenges. A complete inventory of a country's species is not possible and so species to be included in a biodiversity account will need to be prioritized. When selecting species, the broader the representation of taxonomic groups (e.g. plants, birds, mammals etc.), the better the account will estimate overall biodiversity. In addition, some species (e.g. keystone species) are better indicators of biodiversity and ecological condition than others.

7.5.4 Suitability of assessment approaches for biodiversity accounting

7.65. Biodiversity data needs to meet the following criteria to be suitable for informing biodiversity accounting. It should:

- Be available at a spatial resolution suitable for accounting. This allows data to be mapped to individual ecosystem units.
- Be temporally relevant. This informs net changes in the stock of biodiversity between the opening and closing of accounting periods.
- Be comparable to a common reference condition. This allows the comparison of biodiversity measures against a benchmark indicative of a balanced state and aids aggregation of different types of biodiversity data.
- Be possible to aggregate the measures to provide a composite indicator of the condition of biodiversity relevant to ecosystem functioning (e.g., via the Simpson Index or aggregation using a common reference condition). The change in this composite indicator between accounting periods provides an indication of the net biodiversity balance.
- Be comparable over space and time. This allows direct comparison of biodiversity stocks in different ecosystem types.

7.66. When measuring ecosystem diversity, remote sensing and associated mapping of land cover, use, habitat or other characteristics can provide data that meet most of these criteria for informing biodiversity accounting. To best support integration, this work should be undertaken in the context of the spatial areas defined for ecosystem accounting.

7.67. The International Union for the Conservation of Nature (IUCN) Red List of Ecosystems (Keith, et al., 2013) will, in due course, meet these criteria by generating measures of ecosystem condition based on risk of ecosystem collapse. The spatial resolution will be high enough for national accounting (anticipated to be at least equivalent to a 250m resolution. The first global assessment (scheduled for 2025) will provide a baseline which may then be used as a reference condition. Assessments are likely to be repeated on a 5-year basis. The application of the quantitative categories and criteria will ensure consistency and comparability between countries and over time.

7.68. In regard to organizing species diversity data, three main approaches are noted here. First, the IUCN Red List of Threatened Species (IUCN, 2014) which measures extinction risk. Application of the IUCN Red List categories and criteria ensures consistency in assessment over space, over time, and between assessors. While originally designed for global assessments, methods are available to allow disaggregation of the Red List Index to national levels. Downscaling of the global Red List to national levels can be complemented with national red lists, where these exist. It is suggested that both the global Red List and national red lists are used to ensure as broad and relevant a coverage as possible.

7.69. Second, the Norwegian Nature Index (NNI) (Certain and Skarpaas, 2010; Alasken, et al., 2012) uses indicators from a variety of species groups and major ecosystem types that measure deviation from a reference state. The NNI produces a single 'value' that provides information on ecosystem condition. The methodology involves a series of aggregations, first within spatial units, and then across spatial units. The NNI incorporates expert judgment, monitoring-based estimates, and model-based estimates, so the method can be used in both data rich and data poor areas.

7.70. Third, the Living Planet Index (LPI) (WWF, 2014) aggregates species population trend data from different sources and across multiple spatial scales. The methodology involves a series of aggregations in order to avoid bias induced by including only well-known taxonomic groups and well-studied locations. With systematic monitoring of species abundance, the data lends itself for incorporation in a biodiversity account. For those countries that lack this systematic data, the methodology can still yield a single 'value' to support assessment of ecosystem condition.

7.5.5 Implementing biodiversity accounting

7.71. A key starting point for biodiversity accounting is to identify biodiversity-related policy priorities to help determine what information should be compiled, covering plants, animals and to a lesser extent fungi. Guidance on the selection process is provided below. This step will also establish the required resolution of data (both spatial and temporal) necessary to address these priorities.

7.72. Establishing an inventory of all existing monitoring data will help identify any 'data-gaps' for national biodiversity accounting. Countries should consider their reporting obligations to regional processes and biodiversity-related conventions/agreements, such as the CBD or the Ramsar Convention. Identifying data gaps could inform a protocol for further data gathering (e.g., via monitoring or modelling approaches).

7.73. An initial step in the biodiversity accounting process is to delineate ecosystem assets spatially (e.g. by type of EU) on the basis of similarities in ecological and ecosystem characteristics. This can be considered the foundation of a biodiversity account in the broadest sense, as it provides information on ecosystem diversity. Capturing further information on ecosystem diversity on the basis of ecological variations within EU can improve these accounts further. Additional biodiversity accounts can then be developed at the type of EU level. In order to facilitate analysis and reporting, information on biodiversity can be aggregated across EU to larger scales (e.g., across administrative boundaries or ecological features, such as river basins). Testing is required on the characteristics and scales that are most appropriate for the delineation of spatial areas for biodiversity accounting.

7.74. For the construction of 'species accounts' coverage should be based on policy priorities. For example, a focus may be on economically important species (e.g. game species) or species associated with ecosystem functioning (e.g. keystone species).

7.75. More than one biodiversity account may be required in order to answer the range of biodiversity relevant policy questions. For instance, information on biodiversity relevant to ecosystem functioning may require a different accounting structure than information on species extinction risk. In creating a species account, analysts should consult with ecologists to ensure meaningful data is collected and collated.

7.76. Building on these comments, a number of approaches to biodiversity accounting may be followed that vary in complexity and resource requirements. They are presented here as three tiers of accounts.

- 'Tier 1' accounts capture information on the ecosystem characteristics used to define different types of EU (or important areas of biodiversity habitat) and measure their extent. These measures can be weighted using input indicators of species diversity.
- 'Tier 2' accounts capture information on species richness, extinction risk and potentially other characteristics (e.g. species health) for ecosystem and other spatial areas.
- 'Tier 3' accounts capture information on species abundance within ecosystem units and other spatial areas.

7.77. While primary monitoring data is the ideal for assigning biodiversity information to ecosystem units, this is unlikely to be available at the spatial resolution required for ecosystem accounting. A number of approaches exist for upscaling or downscaling data on biodiversity. These include habitat modelling, land use modelling, species-area curves and expert judgment approaches. A portfolio of these approaches will be required to inform biodiversity accounting. It is important however, that any application of these approaches is supported by regular updating of primary monitoring data.

7.5.6 Limitations and issues to resolve

7.78. In their present state, the majority of potential global datasets do not provide the temporal or spatial resolution necessary to inform national biodiversity accounting. Further, developing biodiversity accounts that are globally comparable is likely to be challenging, particularly when relative measures of biodiversity are employed. This is because a consistent reference condition is required.

7.79. While a single biodiversity indicator can provide an overall indication of ecosystem condition, it is unlikely to be useful in informing the link to ecosystem service supply. This is because there will be different aspects of biodiversity that will be relevant to different ecosystem services. Consequently, a broad suite of biodiversity indicators is likely to be required. For those species considered to provide an ecosystem service in their own right, (e.g. for their existence or aesthetic enjoyment) information in a species diversity account can inform ecosystem service supply estimates directly.

7.80. Ultimately, the value of the contribution of biodiversity to ecosystem service supply would be extremely useful to record in the ecosystem accounting framework. There exist various market and non-market based valuation techniques to generate a lower bound for this value. However, this will only be possible for a subset of ecosystem services for which ecological production functions can be described.

7.5.7 Recommendations for testing, refining and validating

7.81. More testing is required of suitable spatial scales for biodiversity accounting. This should be supported with further testing of the modelling and other approaches for generating spatially explicit information on biodiversity via various downscaling and upscaling approaches. A range of options has been presented in this section. Protocols for validation and calibration of these approaches should also be explored.

7.82. Selecting the appropriate scale has significant implications for the aggregation of biodiversity information. Thus, further research and testing of methods to aggregate ecosystem and species data and condition indicators across ecosystem units is required. This should consider the implications of ecotones (as areas of high biodiversity on ecosystem borders) and the diversity among different ecosystem types across larger spatial areas.

7.83. The asset accounts for biodiversity proposed in the SEEA EEA allow for causes of addition and reduction in the stocks of species diversity to be recorded. There are obvious benefits to establishing such a clear causal relationship. However, completing these entries would require additional data collection and may often be difficult to complete in a balanced manner. The possibilities for undertaking this work would benefit from testing in a specific case study, possibly via linkages to land ownership or land use. At this stage, it is recommended that countries focus on the development of time series of biodiversity reflected as a sequence of opening and closing positions.

7.84. Biodiversity is considered as an indicator of condition in the ecosystem condition account. Improvements and reductions in condition are also recorded in the condition account. However, there exist multiple drivers of biodiversity loss and so a supplementary account for drivers of change in ecosystem condition could be a possibility for testing. This would also provide a suitable structure for capturing factors such as habitat fragmentation and invasive species.

7.85. The link between biodiversity and ecosystem service delivery is complex. There will often be time lags between changes in biodiversity and changes to the supply of ecosystem services. Furthermore, capturing information on the importance of biodiversity to ecosystem functional redundancy and resilience is challenging due to non-linear and threshold effects. Given the importance of biodiversity to ecosystem functioning and sustaining ecosystem service provision, measurement of ecosystem functional redundancy and resilience is a key issue to be addressed in the ecosystem accounting framework. Further research is required in this regard, potentially via research on the capacity of ecosystems to deliver services.

7.6 Other thematic accounts and data on drivers of ecosystem change

7.86. 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 to be relevant across many ecosystem types. Other data areas, 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 much further development is required)
- Nutrient flows and balances for nitrogen and phosphorous (accounting described in the SEEA Agriculture, Forestry and Fisheries (FAO, forthcoming) and in OECD/Eurostat manuals (e.g. Eurostat and OECD, 2013))
- GHG emissions and residual flows (e.g. solid waste, wastewater) (accounting described in the SEEA Central Framework)
- Data on production and use of outputs from agricultural, forestry and fisheries activity (accounting described in the SEEA Agriculture, Forestry and Fisheries (FAO, forthcoming))
- Data on tourism and recreation (some coverage of accounting in Tourism Satellite Accounts) (UN et al., 2010)
- Population data.

7.87. In other contexts some of these data are considered indicators of "drivers" of changes in ecosystem condition and the supply of ecosystem services. That is, many of these types of data point to the changing extent of human interaction with the environment. Information on drivers is likely to be of particular relevance in (i) understanding changes in condition for specific ecosystems; (ii) developing appropriate assumptions about future flows of ecosystem services; (iii) assessing ecosystem capacity; and (iv) valuing ecosystem assets.

7.88. Particular note is made here on the relevance of accounting for GHG emissions and other residual flows such as solid waste. These flows are not ecosystem services within the ecosystem accounting model but given the potential negative impact of these flows on environmental condition there may be significant interest in how residual flows may be incorporated. In practice, the most straightforward first step would be presenting information on flows of emissions and residual flows by type of economic unit by spatial area where possible, alongside information on changes in environmental condition for the same areas. Subsequently, analysis may be able to determine linkages between changes in condition and the residual flows and the associated economic units.

7.89. A more complete integration of residual flows into the ecosystem accounting model would require a more complete understanding of dependencies between ecosystems. In particular, it would require incorporation of the atmosphere as a type of spatial "area", whose condition is affected by economic activity, including for example, forest fires. Where there is a decline in condition then it would be possible, within the ecosystem accounting model, to assess the effects on flows of ecosystem services and other environmental services, such as the provision of clean air space for air transport. The extension described here will however, require much further consideration.

7.90. 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 covered by the accounts listed above will be required.

7.91. Further, particularly for the measurement of ecosystem services, it will be necessary to use models of ecosystem processes to estimate the relevant flows. These models will require additional data, usually 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 platform for data integration.

8. Valuation in ecosystem accounting

Key points in this chapter

The estimation of monetary values for ecosystem services and ecosystem assets can be undertaken for a variety of purposes. It is essential that the purpose of valuation is well understood.

In ecosystem accounting, the primary purpose of valuation is the integration of ecosystem accounting information with information in the standard national accounts. For this purpose the valuation used in ecosystem accounting needs to be consistent with the valuation concept used in the national accounts.

The purpose of integration leads to the application of the valuation concept of exchange values – i.e. those values that reflect the price at which ecosystem services and ecosystem assets would be exchanged between buyer and seller if a market existed.

The use of the exchange value concept implies that some valuation techniques commonly used in the valuation of ecosystem services are not appropriate. However, quite a number of techniques are relevant or may be adapted for use in accounting.

The focus on exchange values is not intended to suggest that valuation for other purposes is not appropriate. For example, valuation that takes into account changes in welfare is central to much economic policy and analysis. However, such values should not be used directly in accounting.

In ecosystem accounting, the valuation of ecosystem services is the starting point for the valuation of ecosystem assets. A clear distinction should be made between these to objects of valuation.

Further testing on valuation methods is required, especially in the context of ecosystem accounting.

Research is needed to understand the connection between exchange and welfare based valuations and the extent to which different valuation techniques may be adapted to estimate exchange values.

8.1 Introduction

8.1. The issue of valuation can complicate the discussion of ecosystem and natural capital accounting. This occurs for many reasons. For some, the concerns about valuation relate to the implication that a "dollar value" is placed on all environmental assets and services and that this is both inappropriate and misleading. For others, the measurement concerns are too great and the environment is considered too complex to consider that useful measures in monetary terms might be compiled. Finally, there are differences concerning the purposes, concepts and techniques in relation to monetary valuation.

8.2. As in 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.

8.3. One general conclusion is that valuation in monetary terms requires careful consideration of the *purpose* of the valuation. Alternative purposes include accounting purposes and the assessment of changes in welfare between alternative scenarios. Once the purpose is defined, the appropriate valuation *concept* can be selected and from this, the relevant valuation *method and technique* can be applied. Often the discussion in environmental valuation moves directly to discussion of method and technique without recognising that different purposes for valuation, and hence different concepts may be relevant.

8.4. A fundamental aspect of valuation in an accounting context is that the first step is the valuation of individual ecosystem services. In general, this will require 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).

8.5. Valuing ecosystem assets requires considering the future flows of ecosystem services that are expected to be supplied by the ecosystem asset. Generally, this will mean that a basket of ecosystem services needs to be assumed and priced, with the value of the ecosystem asset then equal to the net present value of the future flows of expected ecosystem services. In general, information on the current uses of the ecosystem and the current basket of services supplied provides the starting point for establishing the expected flow of 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 implementation of ecosystem accounting.

8.6. 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 section provides a summary of recommendations in relation to valuation based on current practice and knowledge and a summary of the key issues requiring further research. Issues related to the valuation of ecosystem assets and the valuation of ecosystem degradation are discussed in Chapter 9.

8.2 Valuation principles for ecosystem accounting

8.7. 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 significance or importance. 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 a way in which non-monetary valuation may be conducted is described in Maynard et al, 2014)

8.8. Monetary valuation in the SEEA EEA is applied to the valuation of ecosystem services and 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, usually the date to which the balance sheet relates, is equal to the NPV of the future flows of ecosystem services that are expected to occur. The application of the NPV 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 ecosystem assets in such a way that the value of all ecosystem services is captured.

8.9. 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 distinct but related tasks.

8.10. The relevant valuation concept for ecosystem accounting is exchange values. If there were observable markets in individual ecosystem services, an exchange value would reflect the prices paid by consumers of ecosystem services to the relevant producers (i.e. the ecosystem assets). Since transactions with ecosystems are not observable, these exchange values must be estimated using one of a variety of valuation techniques.

8.11. Some ecosystem services can be reasonably closely connected to activities in markets. This is generally the case for provisioning services where ecosystem services that contribute to the production of food, fibre, fuel and energy can be valued using prices for the relevant benefits. Here a close connection can be made to the values used in the SNA to estimate production and consumption. One description of these types of ecosystem services is that they their values are "near-market" (Nordhaus, 2005).

8.12. On the other hand, some ecosystem services contribute to benefits that are not closely connected to existing markets – so called "far-market" services. Often these are ecosystem services that may be considered to provide public goods – the contribution of ecosystems to flood protection is one example. In these cases, determining valuation techniques is more complicated.

8.13. Some techniques used to value ecosystem services 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.

8.14. While values that incorporate welfare effects may be very useful for assessing differences between available choices, these welfare values are not of direct applicability 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. At the same time, it is possible within the same measurement framework, to estimate prices based on either exchange or welfare valuation concepts. They should be considered alternative rather than competing valuations.

8.3 Relevant data and source materials

8.15. The SEEA EEA Chapter 5 suggests a logic in the valuation process such that the first step is 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 concept 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.

8.16. 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 the approaches and an updated summary of valuation techniques is provided in Table 8.1.

8.17. In terms of implementation, valuation exercises generally 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. Information on physical flows of ecosystem services is thus of direct relevance.

8.18. In terms of estimating prices, usually it is necessary to find studies that have estimated a price for the relevant ecosystem service in a particular ecosystem type. There are a number of databases that hold relevant studies, including the Ecosystem Services Valuation Database (ESVD) that has built on the original work of the TEEB study, the Environmental Valuation Reference Inventory (EVRI) database, 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).

8.19. Additional support for applying valuation in national accounting contexts can be found in materials from the UNEP Ecosystem Services Economics unit, the materials developed as part of the TEEB study, work being undertaken within the World Bank WAVES project and the discussion of valuation in the context of the IPBES.

8.20. It is noted however, that generally these materials are not explicit about the valuation concept being applied. Hence, it is often unclear as to whether the approaches and recommendations are suitable for ecosystem accounting purposes in terms of measuring exchange values. In particular, since much of the work on environmental valuation has been led by environmental economists, the focus is often on the valuation of externalities (and associated shadow prices) or the estimation of welfare effects between alternative scenarios. More work is required to understand further how these approaches can support valuation in an accounting context. 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 assets and intermediate inputs from market price of outputs (benefits).	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, cost function and profit function methods	Prices obtained by determining the contribution of the ecosystem to a market based price using an assumed production, cost or profit function.	In principle analogous to resource rent but generally focused on the valuation of regulating services. May be difficult to estimate the 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. a house block including the dwelling and the land) 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, unless there are large sample sizes.	**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 assets 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; (ii) that it is a least-cost treatment; and (iii) that it would be expected that society would replace the service if it was removed. (Assumption (iii) may be tested using stated preference methods.)
Damage costs avoided	Prices are estimated in terms of the value of production losses or damages that would occur if the ecosystem services were reduced or lost due to ecosystem changes (e.g. as a result of pollution of waterways).	May be challenging to determine the value of the contribution/impact of an individual ecosystem service.	**Appropriate** under the assumptions (i) that the estimation of the damage costs reflects the specific ecosystem services being lost; (ii) that the services continued to be demanded; and (iii) that the estimated damage costs are lower than potential costs of abatement or replacement.
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	**Inappropriate** since it does not determine a price for an individual ecosystem service.

		context also.	
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. Finally, some travel cost methods include a value of time taken by the household which would be considered outside the scope of the production boundary used for accounting purposes.	**Possibly appropriate** depending on the actual 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. 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. However, the creation of meaningful demand functions and estimating hypothetical markets may be challenging.

8.4 Key challenges in valuation

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

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

8.23. By way of example, in the case of timber harvest there will commonly be a price for the logged timber – perhaps a roadside price. This price should be sufficient to cover the costs of felling (labour, fuel, equipment, etc.). It should also cover any payments that are made to the owner of the forest for the right to harvest the timber. These are commonly referred to as stumpage prices. The price of the ecosystem services in this case is not the roadside price after felling, but the stumpage price, equivalent to the residual after deducting the costs of extraction. In effect the forest owner, in setting a stumpage price, is setting a price on the ecosystem services.

8.24. Unfortunately, in some cases, this residual may be very small or negative (for example, in the case of abstracted water or open access fishing). Consequently, the implied price of the ecosystem service is very low, zero or negative. A number of different cases can be identified. For example in the case of water the resource rent is often near zero as there is commonly no competitive market for distributed water. In the case of open access fishing the lack of defined property rights is the key driver. In recreational hunting the costs are often higher than the potential sale price of the game meat but this will reflect the recreational value of the activity.

8.25. Depending on the situation different valuation approaches may be possible, for example using replacement costs in the case of water (Remme et al. 2014) or hunting costs in the case of recreational hunting (Remme et al. 2014). Most problematic is determining an approach in the case of common pool / open access resources. Note that the benefits produced in these instances (e.g. fish or water) still have market prices, but the ecosystem services are implicitly valued at near zero. A clear resolution of this matter is required since the value obtained using residual or resource rent techniques do not seem to not reflect the broadening of the production boundary that underpins the ecosystem accounting approach.

8.26. A second aspect concerning the target of valuation is the distinction between the valuation of ecosystem services and the valuation of ecosystem assets (and the related issue of valuing ecosystem degradation). 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. These issues are discussed in Chapter 9.

8.27. <u>Valuation of intermediate services.</u> The focus of valuation in the SEEA EEA, and in the majority of other studies, is on final ecosystem services. This focus supports understanding the interactions with beneficiaries (economic units including households). However, if the valuations of final ecosystem services are attributed to specific ecosystems it may imply that ecosystem assets that supply final ecosystem services have a particularly high value, relative to ecosystem assets that do not supply final services directly. Where there are important dependencies between ecosystem assets in the supply of a final ecosystem service, ignoring the value of intermediate services may provide misleading information on the relative importance of certain ecosystem assets. The description and measurement of ecological production functions is an important pathway in understanding these connections.

8.28. <u>Consistency in the use of valuation concepts and techniques.</u> 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 values in the standard national accounts.

8.29. It is quite reasonable and at times necessary to compile estimates using alternative valuation concepts. Thus, welfare valuations are highly relevant when comparing alternative scenarios. However, these valuations should not be directly compared with the value of other assets from the national accounts since the underlying valuation concept is different.

8.30. 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.

8.31. Scaling and aggregation. Often, studies on the valuation of ecosystem services are undertaken for 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.

8.32. 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 – but by no means all - cultural services (such as those relating to economic activity in tourism and recreation). However, in the area of regulating services such connections to marketed benefits are unusual. Indeed, for regulating services it can be difficult to appropriately define and measure the actual physical flow of the service because 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.

8.33. 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, in principle, are captured 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 values (based on the utility derived from knowing that someone else is benefiting from the ecosystem) and bequest values (based on the 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 from the perspective of ecosystem services. Further, there is an open question of the extent to which non-use values can be captured within an exchange value concept.

8.34. 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 – including, for example, agricultural land. Depending on the circumstance, values of land will incorporate the value of some ecosystem services. However, 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, such as the prospects for property development or the capitalisation of farm subsidies. 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 for the estimation of total net wealth.

8.35. 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 separately valued using the general approach outlined here and the relative contribution of biodiversity and resilience is unlikely to be identifiable. Further consideration on how these aspects of ecosystem may be valued is required.

8.36. 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 measurement of ecosystem services and ecosystem assets in physical terms; (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; and (iv) uncertainty regarding future prices and values of ecosystem services.

8.5 Recommendations

8.37. There remains a substantial amount of work to be conducted to advance valuation in the context of ecosystem accounting. At one level there is a need to continue the discussion about the role of valuation both in general terms and with respect to accounting. The main challenge is to provide the appropriate context for the discussion since commonly there are many misunderstandings of the relevant points. A key issue is understanding the different purposes of valuation and the types of questions that may, or may not, be supported using information in monetary terms.

8.38. At a second level, there is a need for understanding and explaining the concept of exchange values for accounting purposes and the development, or adjustment of, valuation techniques to support the estimation of this valuation concept. A possible path forward on this is to distinguish better between the relevant valuation techniques as to: (i) when the ecosystem services can be relatively easily linked to existing market prices and (ii) when the ecosystem services relate to public goods. These two principal approaches involve different challenges.

8.39. In the case of ecosystem services that can be relatively easily linked to market prices, an important part of the information required for valuing the service may already be in the national accounts. This may be the case for provisioning services or tourism. For these services, valuation serves to specify the contribution of the ecosystem to the related benefits included in the national accounts in monetary terms. Following Table 8.1, for such services a unit resource rent-based valuation approach may in many cases be appropriate. The SNA (2008) provides detailed guidance on how intermediate inputs, labour and fixed capital should be costed.

8.40. The SEEA-EEA approach involves the combination of tabular and mapped information. Producing maps for ecosystem services that are valued based on information that is in the national accounts generally involves spatial allocation. In some cases this is straightforward, as in the case of forests providing the opportunity to harvest timber to a logging company. In other cases, some modelling of spatial interactions between ecosystem users and the ecosystem is required, as in the case of allocating the resource rent generated in the tourism sector to (natural) ecosystems.

8.41. In the case of public services, including most regulating services, that are not captured in the national accounts spatial, physical models for the ecosystem services involved provide the basis for valuation. Significant uncertainty pertains to both the physical models (as discussed in Chapters 5 and 6) and the unit values for the ecosystem services. Different regulating services require different valuation methods. Replacement costs methods can be applied, based on the least-cost alternative, if it can reasonably be assumed that the service would indeed be replaced if lost. This method is relevant, for instance, for the flood protection service of coastal or riparian ecosystems in densely populated areas. In case it cannot be assumed that the service would be replaced, an avoided damage cost method may be appropriate (see Table 8.1). Hedonic pricing is another valuation method with which there is ample experience. It can be used to value for example the amenity service, as in the case of eliciting the incremental value of houses with a view or close to a greenspace.

8.42. Other valuation methods have as yet been less frequently applied, but offer the potential to broaden the pallet of valuation methods available for SEEA-EEA. For instance, the Simulated Exchange Value approach and the Travel Cost Method can be used to reveal demand curves for tourism and recreation which would allow a more comprehensive inclusion of tourism and recreation in the ecosystem accounts. Well-functioning Payment Schemes for Ecosystem Services may indicate partial market equilibrium demand and supply for ecosystem services, and associated market prices, but it needs to be examined under what conditions the prices paid for ecosystem services in a PES truly reflect exchange values.

8.43. In general, there is a need for further efforts to estimate exchange values of ecosystem services in practice, for a basket of ecosystem services, at a broad, macro scale. There are some examples of work heading in this direction (see for example Remme et al., 2014; Sumarga and Hein, 2013) but more testing is required. In some cases (hedonic pricing, replacement costs, avoided damage costs) there is ample experience in the environmental economics literature that can be built upon, in other cases, e.g. simulated exchange values and using the travel cost method and prices from PES schemes in the context of accounting, there is a need for further research before such valuation approaches can become standardized.

9. Integrating ecosystem accounting with standard economic data

Key points in this chapter

Full integration of ecosystem accounting information with the standard national accounts comprises many steps and is the end point of measurement of ecosystem condition and ecosystem services in physical and monetary terms.

Four broad types of integration can be described: combined presentations, extended supply and use tables, institutional sector accounts and balance sheets. Each of these types of integration provides information suited to answering different policy and analytical questions.

Combined presentations bring together information on ecosystems and the economy without requiring the estimation of ecosystem services and assets in monetary terms. For example, information of physical flows of ecosystem services to agriculture can be compared to agricultural value added from the national accounts.

Extended supply and use tables support the analysis of extended supply chains and the integration of ecological production functions.

Institutional sector accounts provide the means by which standard aggregates of income and production can be adjusted for ecosystem degradation – i.e. the cost of using up ecosystem capital.

Balance sheets provide the framework for extended measures of wealth incorporating the value of the full range of ecosystem services; standard economic accounts only incorporate values related to provisioning services.

Aside from combined presentations, the other types of integration require ecosystem data to be estimated in monetary terms. Thus the measurement challenges outlined in chapter 8 apply.

In addition, there are some specific measurement issues concerning the valuation and attribution of ecosystem degradation and the application of net present value techniques in the measurement of ecosystem assets.

There are other approaches to the integration of ecosystem and economic data, including wealth accounting and full cost accounting. These have a similar intent to the SEEA based approaches but apply some different measurement concepts and boundaries.

9.1 Introduction

9.1. The integration of ecosystem accounting information with standard economic data is a key driver for 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 of the SNA. Indeed, for some, the prime ambition of developing the SEEA is deriving adjusted measures of national income and economic activity 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 and testing of the SEEA EEA is that calculating 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 a series of issues as outlined in the SEEA EEA and in these Technical Recommendations. These issues concern spatial units, scaling and aggregation, ecosystem services, ecosystem condition, ecosystem capacity and valuation.

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 compilation steps (described in section 9.2) and also requires a range of assumptions on the nature of the required valuation and integration. Compilers should recognise that some of these accounting matters remain the subject of ongoing discussion.

9.4. While the ambition to complete a full integration of ecosystem accounting information continues, it is important to recognise that there are various means by which ecosystem accounting data can be combined with economic data. Section 9.3 describes the use of combined presentations that are valuable in this context.

9.5. This chapter builds on the text provided in SEEA EEA Chapter 6 and summarises some of the key points in integrating ecosystem accounting data with standard economic data.

9.2 Steps required for full integration with the national accounts

9.6. 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 approaches outlined by national accountants (see for example, Harrison 1993 and Vanoli 1995). However, the question of exactly how the integration should be undertaken has never been fully resolved.

9.7. As explained in SEEA EEA and also in recent literature (e.g. Edens and Hein, 2013; Obst et al, 2015) 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 inherent in the SEEA EEA.

9.8. Through the concept of ecosystem services the following (generalised) steps toward full integration emerge. The precise ordering of these steps will vary in practice, and iteration between the steps is to be expected.

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

ii. Identify and measure the supply of ecosystem services from each ecosystem asset and determine the relevant beneficiaries

iii. Measure the condition of each ecosystem asset

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

v. Estimate the monetary value of all ecosystem services

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.

9.9. It is clear from this list, which itself is somewhat stylised, that the full integration of ecosystem accounting information into the standard national accounts (step viii) is not straightforward. At the same time, maintaining 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 providing direction for ecosystem accounting.

9.10. A significant challenge in working through these eight steps, is the requirement for aggregation across ecosystem services and ecosystem assets. Aggregation requires a range of assumptions about the relationships between different ecosystem services and different ecosystem assets. In particular, there is often an implicit assumption, that separate estimates for different services and assets can be summed. The reality is that such a summation will tend to abstract, to some degree, from the inherent complexity of the underlying ecosystem functions and processes. (In the same way as the national accounts is an abstraction of the underlying economic system.) The question for compilers and analysts is whether the abstraction that is represented in ecosystem accounts is appropriate in terms of making better informed decision on the use and management of ecosystems.

9.11. The measurement issues relating to the initial steps outlined above have been described in earlier chapters in these Technical Recommendations. 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

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

9.13. 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 use of common classifications and accounting principles.

9.14. Two examples with respect to ecosystem accounting are (i) the provision of information for specific ecosystem assets (spatial areas) regarding changes in condition of the asset combined with information on the expenditure on environmental protection on those assets; and (ii) information on the flows of ecosystem services generated by an ecosystem asset combined with information on economic activity associated with that asset. Examples in this second case would be showing data on flows of ecosystem services from a forest alongside data on employment in the forestry industry or comparison of agriculture related ecosystem services to agricultural income. Such comparison may give an insight into the relative significance of ecosystem flows to various beneficiaries.

9.15. Specifically in relation to ecosystem degradation, a common link is made to potential restoration costs. That is, for a given decline in ecosystem condition what would be the costs involved in restoring the ecosystem to the original condition.

Information on restoration costs is likely to be of particular relevance in the management of ecosystems and in understanding the degree of investment in ecosystems that might be needed to maintain or improve condition.

9.16. Over time, as information is gathered on the actual expenditure on restoring ecosystem assets, this may be complemented with information on flows of ecosystem services, and a more complete picture of the relationships between ecosystem condition and ecosystem services should emerge. Indeed, one of the key roles of the ecosystem accounting model is to facilitate the organisation of information of this type and thus support more detailed analysis in the future.

9.17. SEEA EEA Chapter 6 provides some additional comments in relation to combined presentations. The key point is that there is considerable flexibility in the design of combined presentations. While they do not represent a full integration of information in accounting terms, they may support a more informed discussion of the relationship between ecosystems and economic activity. Further, they may help underpin the presentation of indicators for monitoring trends in ecosystem related outcomes.

9.4 Integrated ecosystem-economic accounting structures

9.18. Chapter 4 introduced three types of integrated accounts in the context of the broad suite of ecosystem accounts. In this section, those three types of accounts – extended ecosystem supply and use tables in monetary terms, the full sequence of institutional sector accounts and balance sheets are described in more detail.

9.4.1 Extended supply and use tables (SUT)

9.19. Extended supply and use tables (SUT) represent 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 SUT is to present the information on the supply and use of ecosystem services as extensions to the standard national accounts SUT table.

9.20. Building on the discussion in Chapter 4 concerning ecosystem services supply and use tables, and as reflected in Table 4.4, 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 SUT table is broader and hence the size of the SUT must increase. This can be done through the addition of new rows (representing the ecosystem services).

9.21. The requirement here is to ensure that these ecosystem services are distinguished clearly from the products that are already within the standard SUT – 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 rows for both the ecosystem services and the new benefits need to be incorporated.

9.22. Conceptually, it is possible to extend the SUT further to incorporate both final and intermediate ecosystem services. However, 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. However, it is also the case that from an analytical perspective there is little gain. The focus of the extended SUT is on the link between the economy and ecosystems and this requires only links to final ecosystem services. Put differently, from a production perspective, the intermediate services would net out in accounting terms and are, in effect, embodied in the final ecosystem services. The analysis of intermediate services, and hence flows between ecosystems, may be better analysed using data from the basic ecosystem services SUT.

9.23. The second key aspect of the extended SUT 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 SUT 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 supply and use account. However, there may be interest in adding columns by type of EU (ensuring aggregation to national level) or by specific geographical areas within a country.

9.24. A related extension is environmentally-extended input-output tables (EE-IOT). These tables are regularly 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.

9.25. For EE-IOT, information on environmental flows (e.g. GHG emissions by industry) is 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. The additional information may be in physical or monetary form even while the standard input-output data remain in monetary form. Thus, using EE-IOT techniques, it is possible to analyse selected ecosystem services without developing a full extended SUT.

9.26. For the extended SUT envisioned here, the ecosystem services are fully integrated within the standard SUT reflecting the extension of the production boundary. This is an important development.

9.27. An important result of integrating the flows of ecosystem services in extended SUT is that it is clear how the commonly discussed topic of "double counting" is managed. 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 through to final use via 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.

9.28. Table 9.1 is a stylized supply and use table and is divided into three parts. Part A reflects a standard recording of timber production, 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).

9.29. Part B extends this recording to include the flow of the provisioning service of timber from the ecosystem asset (a 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 due to the inclusion of the production of ecosystem services. This reflects the increase in the production boundary and demonstrates how the accounting framework deals with the challenge of double counting.

9.30. Part C introduces a second ecosystem service, air filtration, which is supplied by the ecosystem asset. Again total production is increased, but in this case value added also rises because the additional production is not an input to existing, i.e. SNA, 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

Source: Obst et al, 2015

9.4.2 Integrated ecosystem accounts: full sequence of institutional sector accounts and balance sheets

9.31. It is also relevant to integrate ecosystem information into the broader sequence of institutional sector 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 is summarised in the SEEA Central Framework, Chapter 6. The focus in these accounts moves away from information on production and consumption and instead focuses on the institutional sector level (i.e. corporations, governments, households) and measures of income, saving, investment and wealth.

9.32. 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.

9.33. Chapter 6 of SEEA EEA describes a possible sequence of accounts where there is integration of information on ecosystem degradation. (Table 4.6 in Chapter 4 of these Technical Recommendations shows the sequence of accounts proposed in the SEEA EEA.) The SEEA EEA treatment is not definitive however, and there is no clear resolution of the way in which degradation might be allocated.

9.34. The appropriate allocation of degradation requires 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 after the impact occurred, and may be unknown to the relevant units. In addition, it is not necessarily clear in what way the loss of benefits incurred by 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.

9.35. 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.

9.36. From an implementation perspective, it should be recognised that the compilation of a sequence of institutional sector accounts and balance sheets is not straightforward. It relies on compilation of aggregated data for ecosystem services and ecosystem assets in monetary terms and hence information from all of the accounts described elsewhere in these Technical Recommendations will be required before a sequence of accounts can be compiled. In that sense, the completion of these accounts should be considered of lower priority in the short term.

9.5 Key integration issues

9.5.1 Measurement of net present value

9.37. The valuation of ecosystem assets, and the estimation of associated changes in the value of ecosystem assets, requires the derivation of net present values for the flows of ecosystem services. Setting aside the issues discussed in other chapters on the measurement of the flows of ecosystem services in physical terms (chapter 5) and the estimation of relevant prices (chapter 8); there remain other measurement considerations in estimating NPV.

9.38. First, it is necessary to understand the likely asset life of the ecosystem. That is, an understanding is required of the length of time that ecosystem services will be supplied into the future. This cannot be done independently for each ecosystem service. In many cases, the supply of regulating and cultural services will be competing with the supply of provisioning services. It is likely that the estimated asset life for provisioning services provides the relevant lower bound for the asset life assumption. Where an ecosystem asset is being used sustainably, i.e. with no decline in ecosystem condition, the asset life will be infinite.

9.39. Second, the derivation of NPV requires describing the likely future flows of ecosystem services. This flow may be affected by many considerations, in particular ecosystem condition. It may be useful to separately consider future flows in physical terms and future changes in prices. A common assumption in national accounting for both of these factors is to assume that the unit resource rent stays constant over the remaining asset life. This may be considered a default basis for estimation, although it would be considerably better if some assessment of possible future trade-offs between different services was taken into account.

9.40. Third, a discount rate is required. The choice of discount rate is an area of much discussion. Economists are by no means clear on what discount rates might be appropriate and there are a number of factors to take into consideration. SEEA Central Framework Annex A5.2 provides a useful summary. Perhaps the key issue for ecosystem accounting is clearly articulating the intended valuation concept. Where integration with existing national accounts estimates of income and assets is required, then an exchange value concept is appropriate. Consistent with this choice, the use of a market based discount rate is appropriate. Where a societal based valuation is required, then other considerations are relevant. Generally, social discount rates are lower than market based discount rates and the resulting NPV estimates will be higher.

9.41. There is an important link between the choice of approach to estimating future flows of ecosystem services and the choice of discount rate. Where it is assumed that the prices of ecosystem services will remain constant over the asset life, it is necessary to use a discount rate in real terms, i.e. after adjusting for inflation. Conversely, where the future path of ecosystem services prices is directly estimated and included in the calculations, then a nominal discount rate should be used.

9.5.2 Allocation of ecosystem degradation to economic units

9.42. 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 treatment recognises that the "using up" of natural resources is a cost against the future income of the extractor, and one that should be attributed to the extractor.

9.43. Depletion due to natural resource extraction is a component of ecosystem degradation. However, in concept, degradation is broader since it also incorporates the cost of reducing the future supply of other ecosystem services, such as regulating and cultural services. 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.

9.44. A number of alternative approaches to dealing with this 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) and time (i.e. when the impacts become evident after the activity occurred). Due to both of these factors, the relevant 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, attributing the overall impacts is complex, since physical degradation of an ecosystem is likely to impact on the supply of multiple ecosystem services that are received by various beneficiaries.

9.45. 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 benefits/services of the asset (in the generation of output and income).

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

9.5.3 Valuation of ecosystem degradation

9.47. Together with the 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.

9.48. A commonly discussed alternative approach to valuing ecosystem degradation is the use of restoration (maintenance) costs. Such approaches were suggested in the original 1993 SEEA (UN, 1993). Under this approach, an estimate is made of the expenditure that would be required to restore an ecosystem to its condition at the beginning of the accounting period. This line of thinking is sometimes extended to consider that the accumulated, unpaid restoration costs represent a liability – an ecological debt.

9.49. Generally, restoration cost approaches are not well accepted by the environmental economic community (see for example, Barbier, 2013) who prefer to see degradation valued as the change in the value of the associated benefits and income flows. In accounting terms as well, recent work suggests that restoration costs are not equivalent to what is undertaken in estimating depreciation of fixed capital (Obst and Vardon, 2014; Obst et al., 2015). Importantly, the extension of the accounting framework to integrate the value of ecosystem services allows a different perspective on degradation to be supported within the accounting framework.

9.50. Notwithstanding concerns about the use of restoration cost approaches for the valuation of degradation, the estimation of potential restoration costs can provide valuable information for policy purposes. Estimation of these costs can provide a sense of scale to degradation discussion, especially where the discussion revolves around the resources required to maintain condition. It may also be analytically useful to compare the estimated restoration costs with the actual expenditures on ecosystem maintenance. When these costs and expenditures are tracked against actual changes in ecosystem condition, some useful information for policy purposes seems likely to emerge.

9.51. A more recent suggestion for the valuation of ecosystem degradation concerns ecosystem capacity. The suggestion involves estimating the net present value of the future flow of services linked to an ecosystem's capacity. This is distinct from the net present value of the flow of services that are expected to occur, which may be higher or lower than capacity. The difference will depend on difference in the expected asset life under either scenario and, where the difference in asset life is large the choice of discount rate may have a significant effect on the results. The change in the NPV of 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 but further investigation of the national accounting aspects of this approach is required.

9.5.4 Integrating balance sheet valuations

9.52. 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.

9.53. 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 supplying this assumed basket on the future condition of the ecosystem asset.

9.54. It is possible to estimate future service flows using biophysical models that estimate future conditions according to assumed scenarios (e.g. an extraction profile). Advances in recording and understanding the links between ecosystem condition and ecosystem services will, over time, improve these estimates.

9.55. 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 outputs. Similar logic would apply in the case of forests.

9.56. However, as explained at some length in SEEA EEA section 6.4.2, untangling the overlap in valuations is likely to be complex. For example, in the valuation of agricultural land, part of the market value currently on the balance sheet will reflect the contribution of ecosystem services. To avoid double counting, a reconciliation is needed between the total market value and the value of agricultural land derived summing the NPV of a basket of ecosystem services.

9.57. An intermediate step may be the compilation of an ecosystem monetary asset account as described in Chapter 4. This account shows the opening stocks, additions and reductions in stocks and closing stocks for ecosystem assets in a standalone 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.

9.58. In comparing the values of ecosystem assets with values currently incorporated into SNA balance sheets, it is important to recognise the different underlying 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[16]. The effects of these two differences on the total value of environmental assets will vary from country to country.

9.5.5 Application of integrated approaches for individual ecosystem assets

9.59. A final challenge in the area of integrating the accounts arises when applying the accounting approach at the level of an individual ecosystem asset. 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, instead plays a supporting role in supplying intermediate services to neighbouring ecosystems. In this situation, an ecosystem asset may be recorded as having zero monetary value and its value becomes embodied in the value of the neighbouring ecosystems. While at an aggregate, national level 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.

9.6 Alternative approaches to integration

9.60. If the 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.

9.61. A well-developed approach, usually referred to as wealth accounting, has developed as a branch of economics since the mid-1970s. 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 (2011) and by UNU-IHDP and UNEP (2014). Their methods vary in the detail but they are broadly similar approaches.

9.62. 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.

9.63. Given the purpose of wealth accounting, the conceptual approach to integration is quite appropriate. However, in practice, often values for produced assets from the standard national accounts based on exchange values are combined with valuations for other capitals based on welfare valuation concepts. 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.

9.64. 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 as a possible extension in the ENCA QSP and has also been suggested for use at the corporate

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

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 was discussed earlier in this chapter.
- 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 social 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. This 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 counter-intuitive.

9.65. 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.

9.66. The final integrating approach noted here is that of full cost accounting. This is an accounting approach that has developed in corporate accounting. The intent behind full cost accounting is to estimate and record the broader costs of a company's impacts 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.

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

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

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

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

9.7 Recommendations

9.71. From a national accounting perspective, the full integration of ecosystem accounting information into the standard national accounts and the derivation of adjusted estimates of GDP and other measures of economic activity represents somewhat of a required outcome from SEEA. While recognising the need for some final work on the allocation of degradation, the adoption of ecosystem accounting has demonstrated that a full integration is conceptually possible.

9.72. At the same time, there are numerous challenges in measurement that must be worked through. These particularly concern the aggregation of stocks and flows across ecosystem services and ecosystem assets. These are important challenges to be confronted through testing and on-going research. This chapter has described some specific issues concerning integration but the measurement issues raised in other chapters are equally relevant in working towards a complete integrated accounting dataset.

9.73. While work continues on developing these full links between ecosystem and economic data, there are other options that can be pursued. Combined presentations, as described in SEEA EEA Chapter 6 and here in section 9.3, are important tools for presenting data that support a comparison and discussion of environmental and economic issues. It is strongly recommended that countries work towards the development of combined presentations of data. Work in this area is likely to be considerably supported by a focus on presenting data at meaningful spatial level.

9.74. As work within a country proceeds on ecosystem accounting, it is important that any related or similar work on the integration of environmental and economic data is placed in context. Generally, it is not a question of data being in competition, but rather it is a case of different data being suited for specific purposes. Explaining the link between different measurement approaches and different policy questions is an important role for national statisticians.

Annex 1: Clarifications on SEEA EEA

Introduction

These Technical Recommendations build directly on the conceptual framework for ecosystem accounting described in the SEEA EEA. For the most part, they provide additional explanation and direction for compilation. However, there are some areas in which a clarification of the conceptual model is described. This reflects the ongoing discussion and consideration of ecosystem accounting since the completion of the SEEA EEA in 2013. There are five areas in which conceptual clarifications are introduced. These areas are described in this annex.

The treatment of spatial units

The treatment of spatial units for ecosystem accounting has been advanced and clarified in a number of ways in the Technical Recommendations (see Chapter 3 for details). In the first instance, while three types of spatial area have been retained, the labels have changed. BSU remain Basic Spatial Units, but LCEU have been re-labelled Ecosystem Units (EU) and EAU have been labelled geographical aggregations.

More significantly, the EU is now clearly the core spatial area concept for ecosystem accounting representing the ecosystem asset that supplies ecosystem services. The Technical Recommendations clarify that the delineation of EU will, ideally, involve the use of a range of criteria, including land cover, vegetation type, soil type, hydrology, and potential land management or use. These criteria can be used to define various EU types. At the highest level of aggregation EU types should aggregate to the 15 land cover classes of the SEEA Central Framework thus helping to align datasets and also provide a starting point for ecosystem accounting work.

Concerning BSU, it has now been clarified that these may be formed in various ways but that the use of a reference grid, delineated using a common reference system or datum is the most useful approach. Within a reference grid both raster and vector data can be more readily combined.

Account labelling and structure

The SEEA EEA included a range of accounts but, on reflection, the structure and naming conventions were not well developed. In the Technical Recommendations (Chapter 4), there are three key developments:

i. A distinction has been drawn between ecosystem accounts and thematic accounts. Ecosystem accounts are those covering specifically stocks and changes in stocks of ecosystem assets, flows of ecosystem services, and accounts that integrate ecosystem information with the standard national accounts. Thematic accounts are for specific topics including land, carbon, water and biodiversity. Data from thematic accounts may be used in compiling ecosystem accounts and may also provide important context for the analysis of ecosystem accounting information.

ii. Some of the ecosystem accounts have been relabelled – most notably the ecosystem monetary asset account which was formerly simply the ecosystem asset account.

iii. In terms of account structure most retain a similar approach as in SEEA EEA. The exception is the supply and use table for ecosystem services which now has a more articulated framing that builds on the physical supply and use tables of the SEEA Central Framework.

The measurement of ecosystem services

The focus for ecosystem accounting on final ecosystem services as contributions to the production of benefits remains unchanged. However, there are two aspects surrounding this focus that have been clarified in these Technical Recommendations.

First, there is a clearer explanation that the incorporation of final ecosystem services in the accounting model can be seen as an extension in the production boundary of the SNA. Thus, in a national accounting context, the integration of final ecosystem services leads to an expansion in measures of output. Where the ecosystem services contribute to the production of SNA benefits there is a corresponding increase in intermediate consumption and hence value added is unaffected.

This expansion of the production boundary has a range of "natural" implications for national accounting. These include the broadening of measures of income and hence the associated value of assets that supply the services. Also, it is consistent to extend standard supply and use tables through the additional of rows reflecting the "new" final ecosystem services. Additional columns are also added reflecting the ecosystem assets and "new" producing units.

Second, there is a clearer recognition of the potential to record intermediate ecosystem services reflecting flows between ecosystem assets. In an accounting sense, these flows net out in the production of final ecosystem services and hence recording them has no impact on value added. However, recognising that they may be recorded in the system, supports a better conceptualisation of the connections between ecosystem assets and hence illustrates the potential of ecosystem accounting to recognise the contributions of possibly remote ecosystems.

At the same time, there is the practical reality that there are a very large number of potential intermediate services. Consequently, it is not anticipated that at this stage there should be significant focus on these flows.

Ecosystem condition

The concept of ecosystem condition remains the same as in the SEEA EEA. However, on reflection, there was a certain naivety concerning the measurement of condition and hence some important framing of this issue has been included. This framing introduces the notion of top-down and bottom-up approaches to measurement, recognises that some indicators of condition may relate to fixed characteristics as distinct from variable ones, and there is important clarification on the issue of measuring condition from small to larger scales. On this last point, a continuum is described from the definition of indicators for individual characteristics for a single ecosystem type, up to the potential to define comparable indicators across ecosystem types with multiple characteristics.

A more general point is that it is also recognised more explicitly that the measurement of condition will depend on the current pattern of land use/management and the associated mix of ecosystem services. In turn, this is likely to affect the way in which ecosystem units are delineated.

Ecosystem capacity

In the SEEA EEA, ecosystem capacity was mentioned but not defined. In the discussion through the development of the SEEA EEA, the relevance of the concept was recognised but no agreement could be found on how it might be best described in an accounting context. Since the release of the SEEA EEA, it has become increasingly clear that the concept of ecosystem capacity that links the concepts of ecosystem condition and ecosystem services is in fact quite fundamental in an accounting context. Most importantly, the concept of ecosystem capacity can be directly linked to the measurement of ecosystem degradation, itself a fundamental variable in national accounting.

These Technical Recommendations (Chapter 6) therefore provide a more thorough description of the concept of ecosystem capacity, propose a definition and outline some associated measurement thoughts. As yet, no final position has been reached regarding the definition and measurement of this concept and research is continuing on this topic.

Annex 2: Summary of various National Capital Accounting initiatives

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

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 and applied in Europe (European Environment Agency, 2011) and in Mauritius (Weber, 2014b), 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 – it is in effect a top down approach. Ecosystem services are not measured directly in what might be termed a bottom up approach. A consequence is that the measurement requirements in ENCA QSP are reduced relative to 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 approach may seem inappropriate from an ecological perspective but the intention is to provide a quick and broad assessment.

The core of the ENCA QSP lies in the measurement of ecosystem condition and the assessment of ecosystem capability. It does however, articulate a number of potential extensions. These include recording different economic sectors accountability for ecosystem degradation (in physical units), the compilation of an ecological balance sheet and discussion of the recording of ecosystem restoration costs. There is no valuation of ecosystem services nor valuation of ecosystem assets as outlined in the SEEA EEA.

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 (World Bank, 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 with 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 Small Island Developing States 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 remains the object of the testing and in this regard the WAVES guidance material should usefully complement these Technical Recommendations as well.

c. *UNEP Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States (SIDS) (UNEP, 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. Mapping and Assessment of Ecosystems and their Services (MAES)

The European Union's MAES project is a large measurement project working towards completion of Action 5 of the European Union 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 on "Indicators for ecosystem assessments under Action 5 of the European Union Biodiversity Strategy to 2020" (Maes, et al. 2013). In this report it documents the establishment of six pilot studies 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.

Annex 3: Listing of project research papers

1. Compilation of data, tools and methods (Bordt, 2014)
2. Water and ecosystem accounting (Vardon, 2014a)
3. Carbon and ecosystem accounting (Vardon, 2014b)
4. Linkages between ecosystems asset and service accounts (Hein, 2014a)
5. Guidelines for biophysical modelling and mapping (Hein, 2014b)
6. Land and ecosystem condition and capacity (Bordt, 2015a)
7. Spatial units, scaling and aggregation (Bordt, 2015b)
8. Land accounts and ecosystem extent (Ivanov, 2015)
9. Functional approach to ecosystem accounting (Eigenraam, 2015)
10. Experimental Biodiversity Accounting within the SEEA EEA framework (UNEP-WCMC, 2015)

Annex 4: UK guidance for ecosystem accounts scoping studies

Natural Capital Project Board

Guidance for developing ecosystems accounts based on Broad Habitats

UK Department of Environment, Food and Rural Affairs and Office for National Statistics

June 2014

This note sets out the steps involved in conducting scoping studies and compiling initial accounts for a particular Broad Habitat, based on our experiences so far and the World Bank's report on designing ecosystem accounting pilots[17].

1. **Define extent.** Define the different ecosystems/habitats covered within the Broad Habitat category and assess the available and likely future availability of measurements of the extent of each habitat
2. **Identify key services**. Identify the key services these ecosystems provide and their importance and status by reference to the prioritisation criteria
3. **Establish relevant characteristics**. Identify what characteristics are key to the delivery of those services (this might best be done in consultation with experts)
4. **Assess data sources**. Assess the availability (including expected future availability) of non-monetary information on those characteristics and those services, and the degree to which spatially disaggregated data is important for the accounts and its availability
5. **Propose asset account structure**. Conclude on the services which should be included in the initial accounts and hence on the structure of the non-monetary asset accounts in terms of recording specific habitats separately and the relevant characteristics for those habitats
6. **Propose services account structure(s)**. Conclude on the units and structure of the non-monetary services accounts for each of these habitat types
7. **Spatially disaggregated accounts**. Conclude on the scope for spatially disaggregated non-monetary asset and services accounts and the process by which they should be compiled and maintained
8. **Assess valuation options**. Explore options for the valuation of those services (and hence the asset value relating to those services)
9. **Provide proof of concept**. Set out illustrative accounts on the basis of the data obtained so far and make recommendations about a) how to best fill data gaps b) when to update and c) how to reconcile with other accounts
10. **Unresolved issues**. Set out any unresolved (specific or cross-cutting) issues arising which need further consideration, and report any potential policy applications identified in the course of the study
11. **Resource requirements**. Assess the resources and time required to compile the proposed accounts and resolve outstanding issues

[17] https://www.wavespartnership.org/sites/waves/files/documents/PTEC2%20-%20Ecosystem.pdf

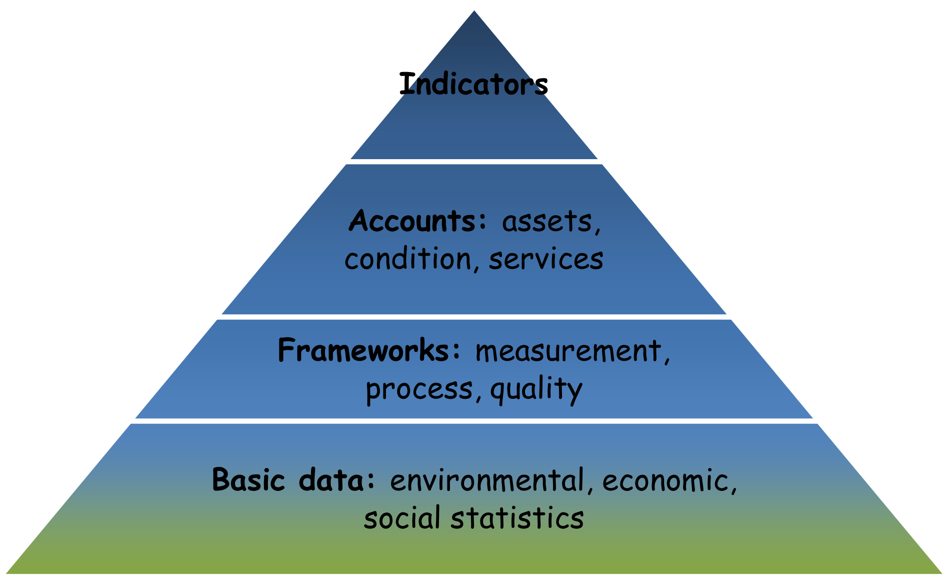
Annex 5: Key features of a national accounting approach to ecosystem measurement

Introduction

A5.1 This section explains 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.

A5.2 To place accounting frameworks in context it is relevant to consider the information pyramid (Figure A3.1). This pyramid has as its base a full range of basic statistics and data from various sources including surveys, censuses, scientific measurement 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 A3.1 Information pyramid



A5.3 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 concept 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.

A5.4 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.

A5.5 The following sub-sections focus on the approach that national accountants take to providing the single best picture.

Key features of a national accounting approach

A5.6 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 focused on defining survey questions, determining sample sizes, collecting and processing data, etc. These important tasks are assumed to be completed by experts in specific subject matter areas, relevant methodologists and 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.

A5.7 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 encapsulate 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.

A5.8 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.

A5.9 Building on these two key aspects there are some related national accounting compilation principles that should be recognised.

i. *The maintenance of time series is fundamental.* Perhaps the most important principle is that in creating the "single best picture" it is not sufficient for each data point to stand alone in time. Hence changes over time must be considered as part of the picture. 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 is linking information from different sources and over time, and hence various methods may be applied to consistently measure the same concept.

ii. *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, is conducted in volume terms (i.e. after removing price effects). Again the single best picture ambition requires balancing these different perspectives at a component and aggregate level.

iii. *The need for revisions.* Without a time constraint on the integration of data and the release of results it is likely that 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 in the knowledge that it will be revised in due course when additional information comes to hand.

iv. *Accounting is iterative.* Fundamentally, the process of integrating data for accounting is not a single, one-off 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. Such joint resolution is an important aspect in mainstreaming different data as part of an overall picture.

A5.10 One overall consequence of a national accounting approach to compilation 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.

A5.11 One benefit of a focus on concepts is that countries will tend to focus their resources on measuring those aspects within the accounting framework 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 choice of data and 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 over the past 25 years is a good example of this evolution in compilation approaches even as the underlying concepts remain stable.

Applying the national accounting approach to ecosystem accounting

A5.12 In most cases, including for 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 and reconciliation with other datasets.

A5.13 A national accountant, on the other hand, is not compiling such a dataset but rather is seeking to undertake the integration. In many respects this is a role that must, at some point, be undertaken by a data user, analyst or decision maker. That is, at some point interpretations and judgements are needed concerning data from different sources that may suggest different trends. Within the scope of macro-economic analysis, national accountants make such judgements about relative data quality using the rigour of the national accounting framework. The alternative would be a situation where each economic analyst made their own judgements possibly using varying definitions of economic aggregates and measurement scope.

A5.14 The application of a national accounting approach within ecosystem accounting extends this national accounting compilation approach to 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, to present the single best picture.

A5.15 One consequence is that for ecosystem accounting it is necessary but not sufficient to have data for a particular ecosystem type 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 and 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 and significant, but this should not detract from the ambition to measure the whole.

A5.16 In putting national accounts based 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.

A5.17 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.

A5.18 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.

Principles and tools of national accounting

A5.19 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. 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 Central Framework.

A5.20 <u>Accounting identities.</u> The accounting system relies on a number of identities – that is, expressions of relationships between different variables.

There are two relationships of particular importance in ecosystem accounting. First, there is the supply and use identity in which the supply of a product (or, in this case, an 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.

A5.21 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 (e.g. through natural growth or extraction) aligned with the series of point-in-time estimates of ecosystem condition that underpin the balance sheets.

A5.22 Frequency 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 across a set of SEEA based accounts is one year. This supports alignment with economic data that are usually compiled on this periodicity. Flows are measured such that all activity that takes place during the selected accounting period is recorded. Stocks are measured at the opening and closing dates of the accounting period.

A5.23 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.

A5.24 For the measurement of some ecosystem characteristics and services the use of an annual frequency may not be ideal. For example at larger scales changes in ecosystem extent may only be detectable over periods of three to five years. In the other direction, measurement of changes in water resources may require sub-annual data to detect seasonal variation. As appropriate it is relevant to record and present specific data using these alternative frequencies such that decision making and analysis can be best supported. At the same time, a single frequency is required for the integration of all data, including economic data, and it is for this purpose that annual recording is proposed. This frequency also ensures a regular presentation of ecosystem accounting data to decision makers and supports the mainstreaming of environmental information that is a core ambition of the SEEA.

A5.25 In addition to these key principles there are a few common tools and methods that national accounts apply. These are

A5.26 Benchmarking, interpolation and extrapolation. Among the range of different data sources there will usually be a particularly high quality source in terms of coverage and quality. Commonly such a source will provide a benchmark estimate at a point in time or for a given accounting period. Using this information as a base, it is then common to use indicators to extrapolate this information to provide more up to date estimates (a process known as "nowcasting") 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 initial estimates for a particular variable and may be subsequently adjusted through the balancing and integration process.

A5.27 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 extent of a national accounts framework would be very resource intensive. Further, since the estimates for an individual time series 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.

A5.28 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 consumption of fixed capital (depreciation) which are commonly derived using the so-called perpetual inventory model (PIM) that requires estimates of capital formation and assumptions regarding asset lives and depreciation rates.

A5.29 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. Chapter 5 of the EEA TG considers the role of biophysical modelling in ecosystem accounting and the general issue of spatial imputation where information estimated in one location is applied in other locations. Such modelling and imputation may be relevant in the measurement of ecosystem extent, ecosystem condition and ecosystem services. 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. At the same time, a balance must be found concerning the proportion of data that are modelled within the overall dataset. Excessive reliance on modelled rather than directly collected data may raise questions about the accuracy of the information.

A5.30 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 on data quality. 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.

A5.31 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. 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.

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.

A5.32 A final area concerns the treatment of uncertainty in accounting contexts. SEEA EEA Chapter 5 provides an overview of several areas of uncertainty that may affect information used in ecosystem accounting. By its nature, accounting aims to provide a single best picture and in this context it would seem to ignore issues of uncertainty. Three 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.

A5.33 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 with further consideration of how uncertainty can be usefully reflected within an accounting context would be welcome.

A5.34 Third, accounting does not provide a model for forecasting future changes in systems. The national accounts 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.

A5.35 In the same way, ecosystem accounting is not designed to provide a model of how the ecosystem behaves that can be used to forecast ecological outcomes. 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.

A5.36 The inappropriateness of the national accounts as a forecasting model must be distinguished from the use of future data in the derivation of some national accounting estimates. A particular example is the use of information on future flows of services in the measurement of ecosystem capacity and ecosystem asset net present values. While it is true that net present values require information on future flows, ideally this information should be obtained from specific data sources, models and expert opinion. Where such inputs are not available, national accountants will commonly make assumptions about the future flows (usually based on past history) such that a net present value can be estimated. However, this is quite different from concluding that the national accounts framework provides a model that can be used for forecasting.

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