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SEEA Revision

SEEA Experimental Ecosystem Accounting

Consultation Draft

REVISION OF THE SYSTEM OF ENVIRONMENTAL - ECONOMIC ACCOUNTING (SEEA)

SEEA Experimental Ecosystem Accounting

CONSULTATION DRAFT

The following text has been drafted for consultation as part of the process of finalising SEEA Experimental Ecosystem Accounting. The descriptions of various concepts and measurement issues are a work in progress and are subject to change. The material should not be considered definitive and should not be quoted.

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Chapter 1: Introduction

1.1 What is ecosystem accounting?

1.1 Ecosystem accounting is an approach to the assessment of the environment through the measurement of ecosystems, and measurement of the flows of services from ecosystems into economic and other human activity.

1.2 These two primary measurement objectives are integrated within an accounting framework that uses as its starting point the statistical standard for measuring the relationship between the economy and the environment, the System of Environmental – Economic Accounting: Central Framework (SEEA Central Framework). The use of an accounting framework enables measures of ecosystems and measures of flows from ecosystems to be seen in relation to each other and also in relation to a range of other environmental, economic and social information.

1.3 Significantly, ecosystem accounting has a focus beyond the relationship between ecosystems and the standard measures of economic activity to encompass links to other human activity. Thus, it also incorporates accounting for the many unpriced services from ecosystems used in other human activity such as the purification of water, the filtration of air, and the amenity and cultural benefits of landscapes. The extended focus allows ecosystem accounting to organise information relevant to the assessment of trade-offs between different uses of ecosystems.

1.4 Ecosystem accounting considers the interaction of individual environmental assets as part of natural processes in a spatial area to provide a range of services. Therefore, it involves two particular extensions to the economic accounting in the System of National Accounts (SNA). First, ecosystem accounting involves accounting in physical terms, i.e. accounting for the stocks and flows related to ecosystems in terms of their quantity and quality. While ecosystem accounting may be undertaken in monetary terms this is not required. Second, ecosystem accounting involves accounting for relatively detailed, sub-national, spatial areas that can be aggregated to a national territory.

1.5 These extensions require the use of a cross-disciplinary approach to measurement. The development of the accounting framework, the establishment of the relevant statistical infrastructure, and the organisation of information are key tasks that cannot be completed within a single agency.

1.2 What is the SEEA Experimental Ecosystem Accounting?

Status of SEEA Experimental Ecosystem Accounting

1.6 The System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting describes the state of knowledge on accounting for ecosystems. It introduces an accounting framework that may be used to commence and support work on ecosystem accounting and to facilitate the exchange of experiences in the testing of various aspects of ecosystem accounting. There is sufficient evidence to support the development of an experimental accounting framework and there is growing evidence of the possibility of implementing ecosystem accounting at a national level.

1.7 SEEA Experimental Ecosystem Accounting provides a synthesis of measurement concepts from a number of disciplines while aiming to retain flexibility for ongoing research. It is certainly the case that through testing and experimentation there will be improved understanding and development of the accounting framework. However, without a synthesis of various concepts and terms, the ability to communicate effectively across multi-disciplinary programs of work in this area would be significantly diminished. Indeed, the participants in the various disciplines are well aware of the need for further harmonisation in terminology and definitional coverage even though the number of core concepts is, in reality, not extensive.

1.8 Thus the effort made in this document is to provide a synthesis of current knowledge and discussion accepting that choices on terms and conceptual scope have been made in some cases. It is clear that significant gains in the integration of various measurement approaches can be obtained through the use of an environmental-economic accounting perspective, especially for the organisation of information to assess macro level trends related to ecosystems. Further, the various understandings of ecosystems and their connection to economic and other human activity are remarkably compatible.

1.9 The synthesis in SEEA Experimental Ecosystem Accounting reflects that ecosystem accounting is a new and emerging field of measurement and hence this work is considered experimental. Nonetheless, ecosystem accounting builds on well-established disciplines including ecosystem science, ecological economics, and official statistics, especially national and environmental-economic accounting.

1.10 The importance of accounting for ecosystems in physical (i.e. non-monetary) terms is a key feature of the SEEA Experimental Ecosystem Accounting. There is a significant amount of information in physical terms that can be organised within an accounting framework to support analysis and monitoring. The organisation of physical information is the focus of Chapters 2, 3 and 4. Approaches to accounting for ecosystems in monetary terms (Chapters 5 and 6) are also described recognising that this area of measurement raises additional complexities and is dependent on the availability of information in physical terms.

1.11 In a number of areas it is clear that further advancement of concepts and theory are required, and in all areas the development and testing of methods is needed. To this end a research agenda for ecosystem accounting is discussed in Section 1.7.

Background to SEEA Experimental Ecosystem Accounting and links to the SEEA Central Framework

1.12 The SEEA Experimental Ecosystem Accounting has been developed within the broader process of revising the SEEA-2003 – a process initiated by the United Nations Statistical Commission (UNSC) in 2007. The primary objective of the SEEA revision process was the establishment of a statistical standard for environmental-economic accounting. At its 43rd meeting in February 2012, the UNSC adopted the SEEA Central Framework as an initial international statistical standard for environmental-economic accounting. The SEEA Central Framework is a multi-purpose, conceptual framework that describes interactions between the economy and the environment, and the stocks and changes in stocks of environmental assets. It provides a structure to compare and contrast source data and allows the development of aggregates, indicators and trends across a broad spectrum of environmental and economic issues.

1.13 During the SEEA revision process it became clear that there were some aspects of the SEEA-2003 that could not be advanced and agreed to at the level of an internationally agreed standard. Consequently, these aspects, primarily relating to accounting for ecosystems and their degradation, were set aside in the finalisation of the SEEA Central Framework. At the same time, recognising the increasing relevance and interest in the measurement of ecosystems, their degradation, and the flow of ecosystem services, UNSC supported the development of SEEA Experimental Ecosystem Accounting, the process being managed through the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA). It is not intended that SEEA Experimental Ecosystem Accounting constitutes an international statistical standard but rather it is to provide an accounting framework for multi-disciplinary research.

1.14 The accounting framework described in SEEA Experimental Ecosystem Accounting complements the accounting for stocks and flows of environmental assets presented in the SEEA Central Framework. Rather than focusing on the various individual environmental assets (e.g. timber resources, land, water resources), SEEA Experimental Ecosystem Accounting takes the perspective of ecosystems and, in effect, assesses how individual environmental assets interact as part of natural processes in a spatial area to provide a range of services for economic and other human activity.

1.15 By taking a more holistic view, information organised following SEEA Experimental Ecosystem Accounting is able to provide an indication of impacts (both positive and negative) of economic and other human activity on the environment and can highlight the trade-offs between alternative uses of ecosystems. The assessment of systemic impacts on the environment is not possible using the accounting structures of the SEEA Central Framework which instead provides greater focus on the pressures on the environment as a result of economic activity through the use of natural inputs or through the release of residuals.

1.3 Policy relevance of ecosystem accounting

1.16 The policy relevance of ecosystem accounting for environmental assessments is very broad, real and increasing. A general motivation is that ecosystem accounting can provide information for tracking changes in ecosystems and linking those changes to economic and human activity. A particular motivation for the development of ecosystem accounting stems from the concern that economic and other human activity is leading to an overall degradation of ecosystems and, consequently, there is a reduced capacity for ecosystems to continue to provide the services that people are dependent on.

1.17 In combination with the accounts of the SEEA Central Framework, information on the extent to which ecosystems are impacted by economic and other human activity from ecosystem accounting can be used to evaluate and number of policy issues including; the potential for alternative patterns of consumption, production and accumulation: alternative uses of energy and the extent of decoupling of economic growth; the effectiveness of resources spent to restore and enhance ecosystems: and more generally the trade-offs between alternative uses of ecosystems.

1.18 The assessment of trade-offs between alternative land uses and part of landscape management is likely to be a particularly powerful application of the ecosystem accounting framework. The usefulness in this area stems from the connections made in the framework between changes in ecosystems and economic and other human activity.

1.19 Increasingly, policy in different areas of public concern is being considered in a more integrated, multi-disciplinary fashion with economic, social and environmental factors being assessed in determining appropriate policy responses. In this regard the integrated structure of the ecosystem accounting, and the SEEA generally, is of particular relevance. For ecosystem accounting the potential for combined presentations of economic data, and scientific and other physical data is a particular feature.

1.20 Through its measurement of ecosystems, SEEA Experimental Ecosystem Accounting provides insights into how ecosystems may be conceptualised as a form of "capital" which may then be considered in relation to other measures of capital including economic, human, social and environmental capital.

1.21 For many environmental concerns the policy response is developed and implemented at a specific local level, for example in the management of river basins, fisheries or protected areas. Since ecosystem accounting requires the development of spatially specific datasets it can form a basic tool for the assessment of integrated policy responses at that level of detail.

1.22 As part of an international measurement process, the development of the SEEA Experimental Ecosystem Accounting may provide a base to build information sets for use in assessing cross-border ecological cycles and their global environmental challenges.

1.23 In this context, it is recognised that stocks and flows of carbon and changes in biodiversity are central elements in understanding the operation of ecosystems. The significance of carbon and biodiversity has seen the development of two important international environmental policy frameworks, the Convention on Biodiversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC). The broad and integrated nature of the SEEA Experimental Ecosystem Accounting and its underlying accounting approach are of direct relevance in the organisation of data for assessing changes in these areas and putting the relevant information in a socio-economic context. Equally, the measurement of ecosystems requires data on biodiversity and carbon and hence there is strong potential for data integration across a range of important environmental areas.

1.4 Objectives and challenges in ecosystem accounting

Accounting objectives

1.24 The over-arching objective of developing an accounting structure is the integration of environmental and economic information to inform policy discussion and environmental management. Within this, the more specific objectives in establishing an accounting structure are:

(i) Organising information on the environment from a spatial perspective describing, in a coherent manner, linkages between ecosystems and economic and other human activity

(ii) Applying a common and coherent set of concepts, classifications and terminology

(iii) Allowing connections to be made to environmental-economic information compiled following the SEEA Central Framework thus aiding the understanding of the contribution of ecosystem services to economic production, consumption and accumulation, the attribution of the degradation, restoration and enhancement of ecosystems to economic units, and the development of more comprehensive measures of national wealth.

(iv) Identifying information gaps and key information requirements.

1.25 In order to meet the various accounting objectives, there are some specific considerations that are the focus of the SEEA Experimental Ecosystem Accounting. These are:

(i) The objects of measurement – the ecosystems – need to be defined from a statistical perspective;

(ii) Measurement units for the assessment of ecosystem assets need to be described;

(iii) The definition of, and relationships between, ecosystem assets and ecosystem service flows with consideration of appropriate measurement scope and coverage;

(iv) The structure of relevant accounts needs to be outlined including links to the accounts described in the SEEA Central Framework; and

(v) The use of valuation techniques needs to be explained.

Measurement challenges

1.26 A full articulation of ecosystem accounting will, inevitably, require the use of much detailed data. However, although this is a new area of accounting, it is the case that a large amount of relevant information may be available from existing data sources. Of course, some of the data may be proxies of the “ideal” measures, the data are likely to be initially incompatible with each other, and overall a significant amount of work may be required to organise and integrate the information. These challenges however, do not invalidate the use of accounting frameworks to compile coherent and structured information. A significant opportunity exists to take advantage of emerging spatially specific datasets and related analytical techniques.

1.27 Central to the success in meeting these various accounting objectives is the involvement of a wide-range of professional communities, most notably scientists, economists and official statisticians. While all of these communities come from different perspectives, each group has an important role to play in developing the appropriate accounting framework and in populating that framework with meaningful information.

1.28 In practical terms, for the development of national level ecosystem accounting, it is highly unlikely that any single agency or organisation can effectively cover all of the information requirements for a set of ecosystem accounts. This is particularly the case for the collection of the range of scientific and other environmental information which may be very localised.

Consequently, the development and testing of ecosystem accounting will require the involvement of multiple disciplines across agencies. The types of agencies that are likely to be involved include national statistical offices (NSO); government scientific and meteorological agencies; departments of environment, agriculture, forestry and fishing; and government geographical and geo-spatial information agencies. The establishment of appropriate institutional co-ordination and management arrangements is essential if the work is to be routinely implemented.

1.29 Further, given the new and emerging status of ecosystem accounting there is strong potential to harness the research capability of the academia to develop and test aspects of the ecosystem accounting framework that is proposed. This is especially true in the area of standardising and accrediting scientific information for use in national level ecosystem assessments. This issue is discussed at more length in Section 2.5.

1.5 The role of national statistical offices

1.30 There are a number of aspects of ecosystem accounting as described in the SEEA Experimental Ecosystem Accounting that warrant the involvement of national statistical offices (NSO). The actual role an individual NSO might play will depend on the scope of the activities it has traditionally been involved in. For example, some NSO have strong traditions in relation to working with geographic and spatial data, and others have a history of development and research. NSO with these types of experience may be able to play leading roles in the development of ecosystem accounting.

1.31 Those NSO without this experience may still play an important role. Government agencies leading ecosystem accounting research are encouraged to utilise the expertise of NSO in the following areas that are common roles played by all statistical offices.

1.32 First, as organisations that work with large and various datasets, NSO are well placed to contribute their expertise in the collection and organisation of data from a range of different sources.

1.33 Second, a core part of the role of NSO is the establishment and maintenance of relevant definitions of concepts and classifications. The area of ecosystem accounting has many examples of similar concepts being defined differently and there are known to be multiple classifications of ecosystem services and ecosystem types. In many cases each new study develops its own concepts and classifications. The SEEA Experimental Ecosystem Accounting is a first attempt to give stronger guidance in this important measurement discipline and the ongoing involvement by NSO in this area of work would be beneficial.

1.34 Third, beyond the organisation of information, NSO have capabilities to integrate data from various sources to build coherent pictures of relevant concepts. Most commonly NSO focus on providing coherent pictures in relation to socio-economic information and this capability can be extend to also consider environmental information. Given the multi-disciplinary nature of ecosystem accounting data integration is an important requirement.

1.35 Fourth, NSO work within broad national and international frameworks of data quality that enable the assessment and accreditation of various information sources and the associated methodologies in a consistent and complete manner.

1.36 Fifth, NSO have a national coverage. The focus of the SEEA Experimental Ecosystem Accounting is on the provision of information that permits analysis at the national level rather than site or ecosystem specific information that is more commonly available. Creating national economic and social pictures is a relatively unique role undertaken by NSO and the understanding of scaling data is implicit in creating these pictures. Ecosystem accounting could benefit substantially from consideration of how standard statistical techniques used for official statistics may be applied, in particular in the context of geo-spatial statistics.

1.37 Sixth, NSO can present an authoritative voice by virtue of the application of standard measurement approaches, data quality frameworks and their relatively unique role within government.

1.38 All of these factors suggest that there is a role for NSO in the development of ecosystem accounting under a variety of possible institutional arrangements.

1.6 The key disciplines in ecosystem accounting

1.39 While ecosystem accounting is a new and emerging field of measurement, its foundation in ecosystem science, ecological economics, and national accounts is strong. Research in these foundation areas continues to deal with the ever increasing complexity of economic activity and our ever increasing understanding of the world in which we live. At the same time there are some core understandings of ecosystem science, ecological economics and national accounts that are accepted and hence form a base for ecosystem accounting.

Core principles of ecosystem science

1.40 An ecosystem can be broadly described as a “dynamic complex of biotic communities interacting with each other within their non-living environment interacting as a functional unit”[1]. The operation of ecosystems involves ecosystem processes such as the capture of light, energy and carbon through photosynthesis, the transfer of carbon and energy through food webs, and the release of nutrients and carbon through decomposition. Biodiversity affects ecosystem functioning, as do the processes of disturbance and succession. The principles of ecosystem management suggest that rather than managing individual species, natural resources should be managed at the level of the ecosystem itself.

1.41 Ecosystems contribute to the generation of a variety of goods and services upon which people depend. These contributions are known as ecosystem services. Single ecosystems will usually generate a number of different ecosystem services. In general terms, the capacity of an ecosystem to provide ecosystem services depends on the area covered by an ecosystem (its extent), and the condition of the ecosystem. This capacity is modified through human behaviour both positively and negatively. Commonly, through land use conversion, certain types of ecosystems have been replaced by different ecosystems supplying a different set of ecosystem services, as in the case of forest converted to cropland.

1.42 Ecosystems are often subject to complex, non-linear dynamics involving negative or positive feedback loops. These complex dynamics include, for example, the presence of multiple

[1] Convention on Biological Diversity

steady states, irreversible change or stochastic (random) behaviour. It is now recognised that many types of ecosystems are influenced, and often dominated by complex dynamics, including temperate and tropical forests, rangelands, estuaries, and coral reefs. Resilience is an important property of ecosystems in this regard. Resilience indicates the propensity of ecosystems to withstand pressure or to revert back to its previous condition following a disturbance.

Core principles of ecological economics

1.43 Ecological economics is a field of research that cross a number of traditional disciplines and considers the interdependence and co-evolution of human economies and natural ecosystems over time and space. One of the distinguishing features of ecological economics is its treatment of the economy as a sub-system within the ecosystem and consequently it has an interest in the preservation of ecosystems on which the economy is dependent.

1.44 Issues such as intergenerational equity, the irreversibility of environmental change, the uncertainty of long-term outcomes, and sustainable development are common areas of focus for ecological economists. Underpinning the analysis of these issues is a view of the relationship between the economy and the environment as being a system of flows involving energy, natural inputs and resources, and pollutants and residuals.

1.45 From an accounting perspective ecological economics captures many relevant concepts including those relating to ecosystem capital and a flow of services. By using a broad conceptualisation of services, ecological economics is able to consider trade-offs between the generation and use of different services in a more comprehensive fashion. Further, by considering the relationship between ecosystem capital and services flows, the potential for ecosystems to continue to provide services into the future becomes a direct point of analysis. Such analysis involves consideration of the carrying capacity of the environment.

1.46 Ecological economics also considers the valuation of ecosystem services, most commonly in a welfare context to assess broader social costs and benefits of different policy choices. A broad and expanding set of approaches exist to undertake valuation of these unpriced services.

Core principles of national accounts

1.47 At the heart of national accounting is the ambition to record, at a national, economy-wide level, measures of economic activity and associated stocks and changes in stocks of economic assets. The accounting approaches are described at length in the System of National Accounts (SNA). The SNA is the international statistical standard for national accounting, first released in 1953 and most recently updated and released jointly in 2008 by the United Nations, the European Commission, the International Monetary Fund, the Organisation for Economic Co-operation and Development (OECD) and the World Bank. The SNA provides the conceptual underpinnings of the SEEA Central Framework.

1.48 Following the SNA, economic activity is defined by the activities of production, consumption and accumulation. Measurement of each of these activities over an accounting period (commonly one year) is undertaken within the constraint of a production boundary which defines the scope of the goods and services considered to be produced and consumed.[2] Accumulation of these goods and services in the form of economic assets (for example, through the construction of a house) is recorded in cases where production and consumption is spread out over more than one accounting period. Further, non-produced economic assets may be accumulated (for example, through the purchase of land). At its core, national accounts is the reporting of flows relating to production, consumption and accumulation, and stocks of economic assets.

1.49 Central to the measurement of economic activity and economic assets is the recognition of economic units – i.e. the different legal and social entities that participate in economic activity. At the broadest level these entities are categorised as enterprises, governments and households. The economy of a given territory is defined by the set of economic units (referred to in the SNA as institutional units) that are resident in that territory.

1.50 The national accounts thus aim to organise and present information on the transactions and other flows between these economic units (including flows between units in different territories), and on the stocks of economic assets owned and used by economic units.

1.51 There are strong similarities between national accounting and the accounting that is undertaken for an individual business. However, the main distinctions are that (i) national accounting requires consideration of the accounting implications for more than one business (thus the recording must be consistent for both parties to a transaction without overlaps or gaps); and (ii) national accounting operates at a far larger scale in providing information for a country and encompassing a wide variety of types of economic units that play quite distinct roles in an economy.

Creating linkages between disciplines

1.52 Placing ecosystems in a national accounting context requires these disciplines to consider measurement in new ways. For ecologists, this requires creating clear distinctions between ecosystem assets and service flows within an ecosystem and to differentiate between those aspects of ecosystems that provide direct benefits to economic and other human activity and those aspects of ecosystems that, effectively, support the provision of these benefits.

1.53 For national accountants, it is necessary to consider the set of goods and services produced and consumed in the context of the set of benefits provided by ecosystems and also to see the ecosystem as a complex, self-regulating system that, while influenced by economic activity, also operates outside of traditional economic management regimes.

1.54 For ecological economists, it is necessary to consider their conceptual models concerning the links between ecosystems and the economy in a strict accounting sense, and to consider the complexities of integrating new measures of assets and services with traditional economic measures.

1.55 Fundamentally, ecosystem science, ecological economics and national accounting are disciplines that recognise the significance of systems and the mass of relationships that

[2] This boundary also defines the measurement scope for the most widely known national accounts aggregate, Gross Domestic Product (GDP).

comprise their fields of interest. Ultimately, it is the aim of SEEA Experimental Ecosystem Accounting to present a system based approach to recording the relationships between ecosystems, the economy and society that is useful for public policy making and environmental management.

1.7 Structure of the SEEA Experimental Ecosystem Accounting

1.56 Chapter 2 "Principles of ecosystem accounting" presents the model of ecosystem operation that underpins the accounting framework and places the model in the context of ecosystems, ecosystem services, and ecosystem assets. These various parts of the model are subsequently described in greater detail in later chapters. Chapter 2 also presents a model of statistical and reporting units for ecosystem accounting, and discusses some general measurement issues that apply to all areas of ecosystem accounting.

1.57 Chapter 3 "Accounting for ecosystem services in physical terms" discusses the measurement of ecosystem services highlighting key issues of scope and coverage, presenting a common classification of ecosystem services, proposing basic accounting structures for recording flows of ecosystem services, and describing a range of examples of the measurement of ecosystem services in physical terms.

1.58 Chapter 4 "Accounting for ecosystem assets in physical terms" considers measures of ecosystem assets in physical terms comprising measures of ecosystem extent, condition, and expected ecosystem service flows. It explains approaches to measuring ecosystem assets, the organisation of this information into ecosystem asset accounts, and the measurement challenges involved in making overall assessments of ecosystems. Chapter 4 also highlights some specific areas of accounting, namely carbon accounting and accounting for biodiversity, and the relationship of these specific areas to ecosystem accounting.

1.59 Chapter 5 "Approaches to valuation for ecosystem accounting" introduces the general concepts of value that may be utilised in ecosystem accounting and outlines the principles of valuation that are applied in the SEEA. Building on these concepts and principles, the chapter describes a range of methods for valuation of ecosystem services and discusses their consistency with the valuation principles. The chapter also considers a range of measurement issues including aggregation and scaling estimates for individual ecosystem services and individual ecosystems.

1.60 Chapter 6 "Accounting for ecosystems in monetary terms" introduces how estimates of ecosystem services, ecosystem assets and ecosystem degradation in monetary terms can be integrated with information in the traditional national accounts, including via a sequence of accounts and via wealth accounts. This chapter also highlights the way in which standard monetary transactions associated with ecosystems can be recognised and recorded, with particular mention of the treatment of payments for ecosystem services.

1.8 Research agenda

1.61 The intent of SEEA Experimental Ecosystem Accounting is to provide a synthesis of the developments in ecosystem accounting. Many of these developments are recent and in that sense many aspects of SEEA Experimental Ecosystem Accounting are part of ongoing research and development work in various related disciplines.

1.62 An annex outlines a targeted research agenda for ecosystem accounting focusing on those areas that are considered in most need of further investigation in order to advance ecosystem accounting as a whole. It is expected that the investigation of the issues on the research agenda may be undertaken in joint fashion across disciplines and in conjunction with ongoing research programs.

1.63 In addition to advancing a research agenda it is important that experience be gained through the testing of the accounting framework outlined in SEEA Experimental Ecosystem Accounting. To this end it is expected that the concepts and terminology described here will support testing efforts and facilitate the sharing of experiences in ecosystem accounting.

Chapter 2: Principles of ecosystem accounting

2.1 An overview of ecosystems

2.1 "Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."[3]They change as a result of natural processes (e.g. succession, natural disturbances such as a storm) and because of human actions - either through deliberate management or through human disturbances such as the extraction of natural resources, the introduction of invasive exotic species, or pollution.

2.2 Traditionally, ecosystems have been associated with more or less 'natural' systems, i.e. systems with only a limited degree of human influence. However, a wider interpretation has become more common, based on the recognition that human activity influences ecosystems across the world.

2.3 Different degrees of human influence can be observed. For instance, in a natural forest or a polar landscape, ecosystem processes dominate the dynamics of the ecosystem and there are likely to be fewer impacts from human management of the ecosystem or from human disturbances. At the other end of the spectrum, in a greenhouse or in intensive aquaculture ponds, ecosystem processes have become dominated by human management, and ecosystems close to human settlements may be significantly affected by human disturbances such as pollution.

2.4 Assessment of ecosystems should consider their ecology and location. Key characteristics of the ecology of an ecosystem are (i) its structure (e.g. the food web within the ecosystem); (ii) its composition, including biotic (flora and fauna) and abiotic (soil, water) components; (iii) its processes (e.g. photosynthesis or the recycling of nutrients in an ecosystem), and (iv) its functions (e.g. resilience). Key characteristics of its location are (i) its extent; (ii) its configuration (i.e. the way in which the various components are arranged and organised within the ecosystem); and (iii) the landscape forms (e.g. mountain regions, coastal areas) within which the ecosystem is located.

2.5 An important broad characteristic of ecosystems, related to its ecology and location, is its biodiversity. There are therefore important connections between ecosystems and biodiversity.

2.6 Ecosystems can be identified at different spatial scales, for instance a small pond may be considered as an ecosystem, as may a tundra ecosystem stretching over millions of hectares. In addition, ecosystems are interconnected commonly being nested and overlapping, and they are subject to processes that operate over varying time scales.

2.7 For accounting purposes ecosystems are defined in relation to spatial areas with each area considered an ecosystem asset. Thus, ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.

2.8 It is widely recognised that ecosystems are subject to complex dynamics. The propensity of ecosystems to withstand change, or to recover to their initial condition following disturbance

[3] Convention on Biological Diversity (2003)

is called ecosystem resilience. The resilience of an ecosystem is not a fixed, given property, and may change over time, for example, due to ecosystem degradation (e.g. timber removal from a forest) or ecosystem enhancement (e.g. through management of wetlands). These complex dynamics make the behaviour of ecosystems as a function of management and natural disturbances difficult to predict.

2.2 Key conceptual relationships in ecosystem accounting

2.9 In common with all accounting systems, ecosystem accounting is founded on relationships between stocks and flows. The stocks in ecosystem accounting are represented by spatial areas each comprising an *ecosystem asset*. Each ecosystem asset has a range of *ecosystem characteristics* – such as land cover, biodiversity, soil type, altitude and slope, etc – which describe the ecology and location of the ecosystem.

2.10 In the SEEA Central Framework, measurement of ecosystem assets sits as part of the measurement of environmental assets. "Environmental assets are the naturally occurring living and non-living components of the Earth, together comprising the bio-physical environment, that may provide benefits to humanity."[4] Environmental assets are considered from two complementary perspectives either as individual environmental assets such as mineral and energy resources, timber resources, land, and water resources; or as ecosystems where many individual components are considered to function together within spatial areas.

2.11 Chapter 5 of the SEEA Central Framework describes the accounting relevant for individual environmental assets. SEEA Experimental Ecosystem Accounting discusses accounting for the second perspective on ecosystem assets. While there is significant overlap in the coverage of ecosystem assets and individual environmental assets, there are two types of differences. First, some individual environmental assets, particularly mineral and energy resources, are not assets that interact as part of ecosystem processes and hence are not considered part of ecosystem assets. Second, the accounting for individual environmental assets in the SEEA Central Framework only considers their role in providing material and energy inputs to the economy. In accounting for ecosystem assets, a broader range of flows from the individual assets and their joint functioning is considered.

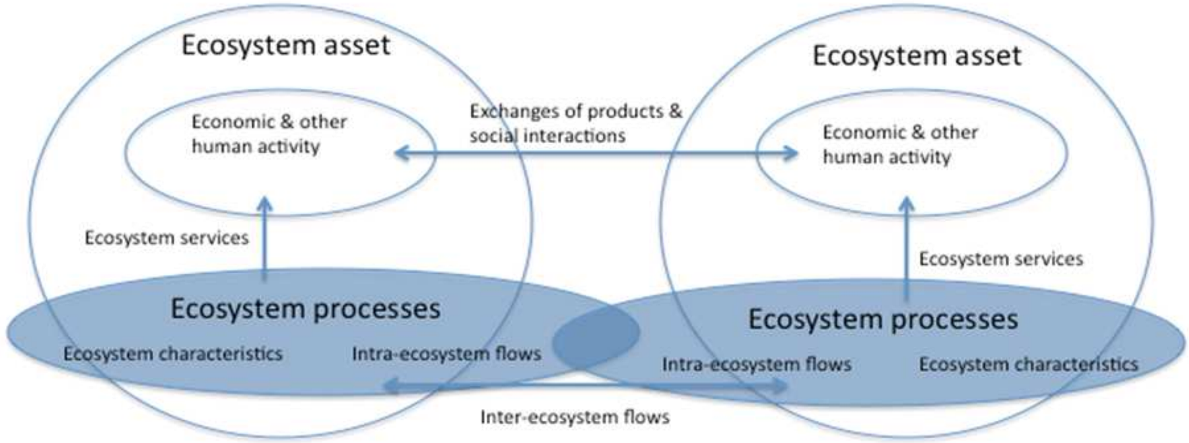
2.12 The flows in ecosystem accounting are of two types. First, there are flows within and between ecosystem assets that reflect ongoing ecosystem processes – these are referred to as *intra-ecosystem flows* and *inter-ecosystem flows*. The recognition of inter-ecosystem flows highlights the dependencies between different ecosystem assets (e.g. wetlands are dependent on flows of water from further up the river basin).

2.13 Second, there are flows reflecting that people, through economic and other human activity, take advantage of the multitude of resources and processes that are generated by ecosystem assets – collectively these flows are known as *ecosystem services.* Ecosystem services are generated from the combination of ecosystem characteristics, intra-ecosystem flows and inter-ecosystem flows.

[4] SEEA Central Framework 2.17

2.14 Figure 2.1 presents the basic relationships of the stocks and flows relevant in ecosystem accounting. The key feature of the figure is that each ecosystem asset represents a distinct spatial area with economic and human activity taking place within that area. Thus the model recognises the strong spatial relationship between ecosystems and economic and human activity. The model also recognises the strong connections between ecosystem assets both in terms of ecosystem processes and in terms of exchanges of economic products and other social interactions that cross spatial boundaries.

Figure 2.1 Basic model of ecosystem stocks and flows



2.15 From a measurement perspective, ecosystem accounting focuses (i) on the flows of ecosystem services to enable improved understanding of the relationship between ecosystems and economic and other human activity; and (ii) on the stock and changes in stock of ecosystem assets to enable an understanding of changes in ecosystems and their capacity to generate ecosystem services in the future. In general, there is no direct focus on intra- and inter-ecosystem. Instead, the impact of changes in these flows are captured implicitly in measures of ecosystem assets and ecosystem services.

2.16 The remainder of this sub-section summarises this basic model. Additional detail relating to the definition and measurement of ecosystem services and ecosystem assets is presented in the remaining chapters.

2.2.1 Ecosystem services

A model for ecosystem services[5]

2.17 Ecosystem services are important in the ecosystem accounting framework since they provide the link between ecosystem assets on the one hand, and the benefits used and enjoyed by people on the other. Hence they are at the intersection of the relationship between ecosystems and human activity which is the focus of the environmental-economic accounting described in the SEEA.

[5] The model of ecosystem services developed for SEEA Experimental Ecosystem Accounting is based on a large literature related to this topic. An annotated bibliography is included in Annex 1.

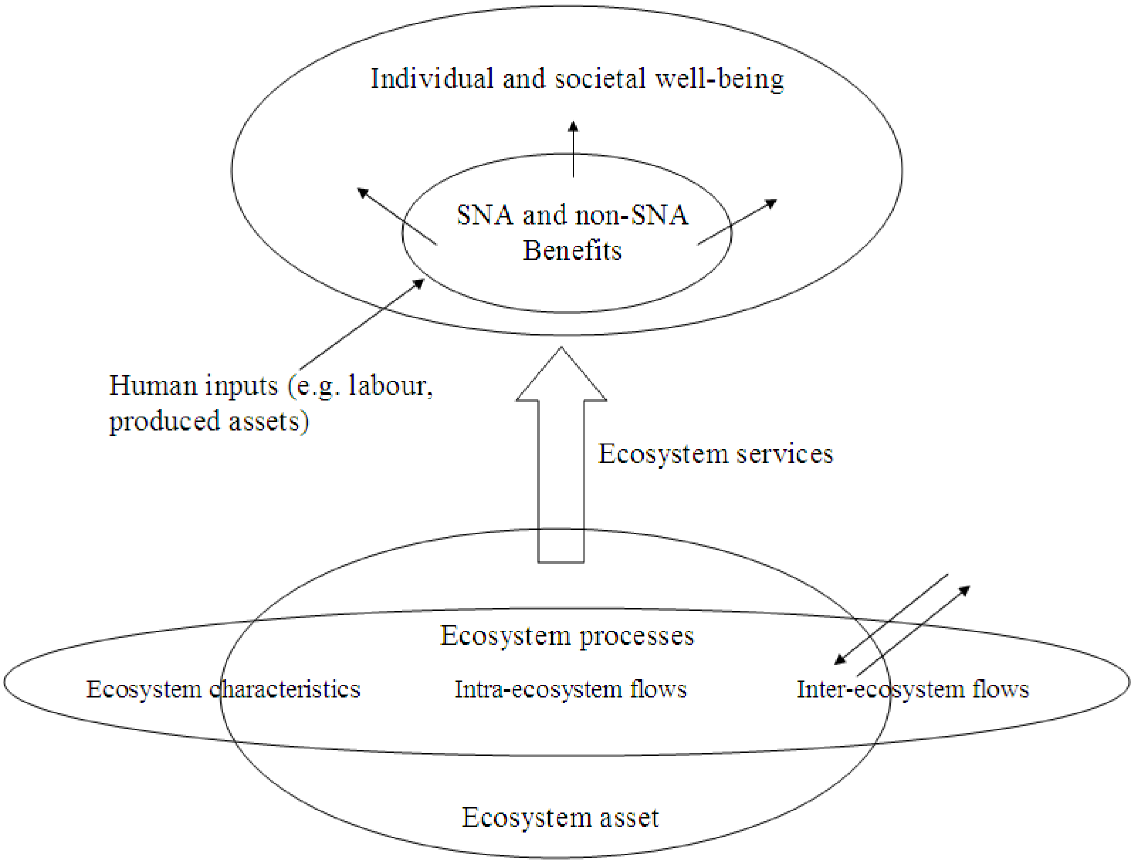
2.18 A range of definitions and interpretations of ecosystem services have been used in various contexts from site specific case studies to large national and global assessments of ecosystems. For accounting purposes it is most useful to consider ecosystem services in the context of a chain of flows that connect ecosystems with well-being. The overall model is shown in Figure 2.2.

2.19 Starting at *individual and societal well-being*, the chained approach recognises that well-being is influenced by the receipt of *benefits*.[6] In the context of ecosystem accounting, benefits comprise

(i) The products produced by economic units (e.g. food, clothing, shelter, entertainment, etc). These are referred to as *SNA benefits* as the measurement boundary is defined by the production boundary used to measure GDP. This includes benefits produced by households for their own consumption.[7]

(ii) The benefits that accrue to individuals that are not produced by economic units (e.g. clean air and water). These benefits are referred to as *non-SNA benefits* reflecting that the receipt of these benefits by individuals is not the result of an economic production process defined within the SNA. A distinguishing characteristic between these two types of benefits is that, in general, SNA benefits can be bought and sold on markets whereas non-SNA benefits cannot.

Figure 2.2 General model of flows related to ecosystem services



[6] The relationships between benefits and well-being are not the focus of the SEEA and hence are not articulated.

[7] SNA benefits as defined for ecosystem accounting do not incorporate flows of operating surplus, interest, rent and dividends that may also be considered benefits in a broader economic context.

2.20 In SEEA Experimental Ecosystem Accounting, ***ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity***. As can be seen in Figures 2.1 and 2.2 this definition excludes some flows that are considered ecosystem services in other contexts, in particular intra- and inter- ecosystem flows that relate to ongoing ecosystem processes, commonly referred to as supporting services. While these flows are not considered ecosystem services, they are not ignored in the accounting model and are considered as part of the measurement of ecosystem assets.

2.21 The model of ecosystem services takes no direct account of so-called ecosystem “disservices” such as pests and disease. To some extent these effects will be reflected in reduced flows of some ecosystem services (e.g. lower flows of environmental regulation services). Chapter 3 discusses this issue further.

2.22 Defining ecosystem services as “contributions” highlights that ecosystem services are only one part of a broader set of inputs that are combined to provide the benefits. For example, the benefit of clean drinking water is, most commonly, the end result of the water abstracted from an ecosystem and the use of human inputs of labour and produced assets (e.g. pipes, wells, filtration equipment, etc). These combinations of inputs may be considered instances of joint production and are a feature in the production of SNA benefits.

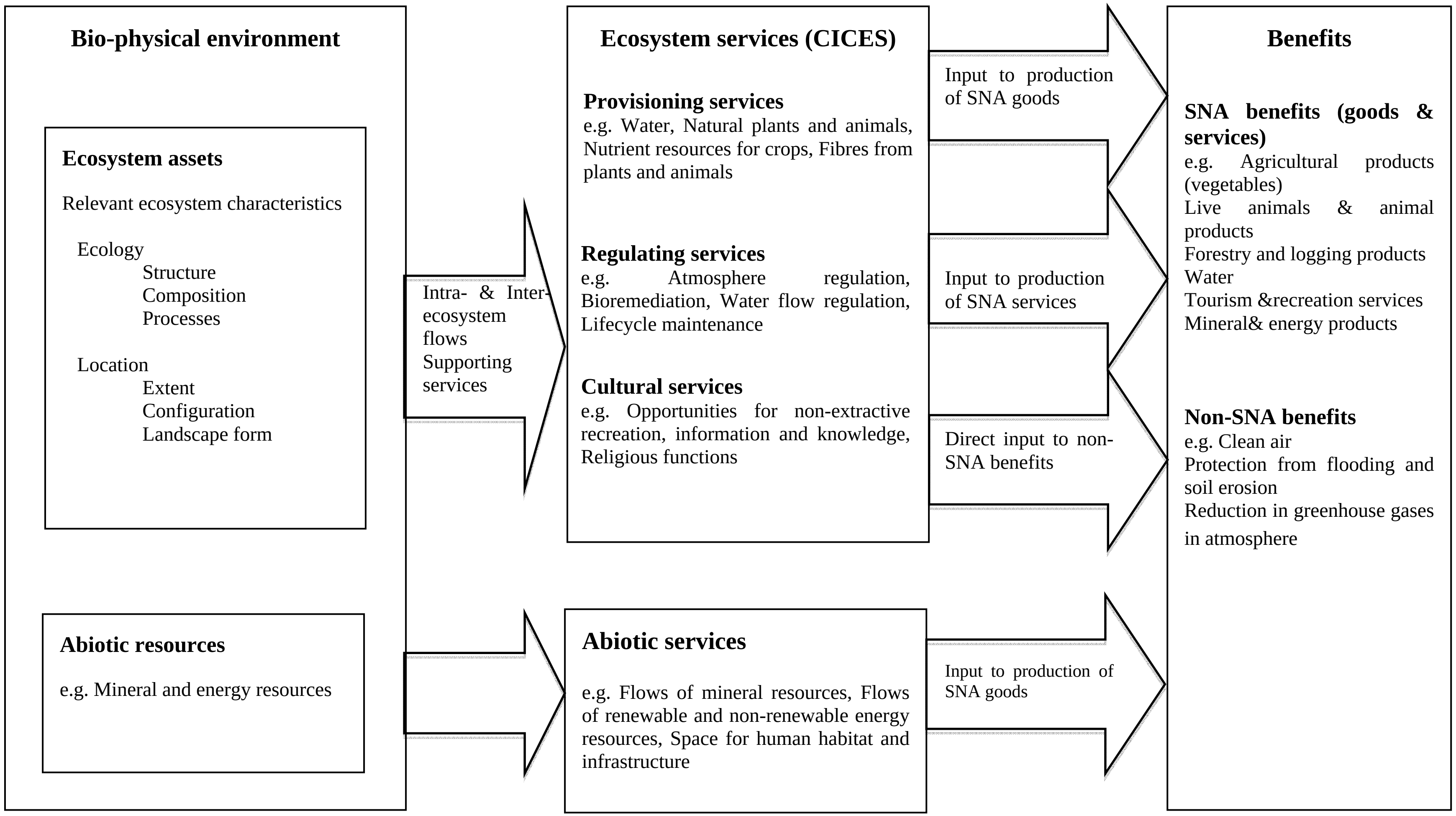
2.23 For non-SNA benefits there are usually few human inputs in their generation and hence the ecosystem service and the associated benefit may, in effect, be equivalent (e.g. the benefit of clean air from the ecosystem service of air filtration by trees and other plants).

2.24 Ecosystem services do not relate only to cases of harvest or extraction of materials from ecosystems. Ecosystem services also relate to the general functioning of the ecosystem (e.g. air filtration services from trees providing clean air) and to the characteristics of an ecosystem (e.g. the physical structure and composition of mountain landscapes providing wonderful views). Thus the term “services” is used here in an all-encompassing manner covering these various ways in which humans relate to ecosystems.

2.25 Ecosystem services do not represent the complete set of flows from the environment. Important examples of other environmental flows include the extraction of mineral and energy resource, energy from the sun for the growing of crops and as a renewable source of energy, and the movement of wind and tides which can be captured to provide sources of energy. More broadly, the environment provides the space in which economic and other human activity takes place and the provision of space may be conceptualised as an environmental flow. Collectively, these other environmental flows are referred to as *abiotic services*. The relevant boundary issues are discussed further in Chapter 3.

2.26 The final step in the series of flows related to ecosystem services is the recognition that ecosystems do not function only to generate ecosystem services. Therefore, the multitude of ecosystem flows and characteristics that constitute a functioning ecosystem must also be accounted for. This is done by accounting for ecosystem assets.

Figure 2.3 Broad model of flows in ecosystem accounting



2.27 One way of reflecting the relationships between ecosystem services and the other relevant measures concerning ecosystems is presented in Figure 2.3. This figure places ecosystem services in the context of the bio-physical environment, ecosystem assets, ecosystem processes, ecosystem characteristics, abiotic services and benefits. The figure highlights the variety of relationships and connections between the physical earth and the benefits used in economic and other human activity. Chapter 3 provides more detail regarding the relevant measurement boundaries that need to be defined to ensure appropriate accounting for ecosystem services.

2.2.2 Central concepts in measuring ecosystem assets

2.28 ***Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.*** Ecosystem assets are measured from two perspectives. First, ecosystem assets are considered in terms of *ecosystem condition* and *ecosystem extent*. Second, ecosystem assets are considered in terms of *expected ecosystem service flows*. In general terms, 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.

2.29 There will not be a neat or simple relationship between these two perspectives, rather the relationship is likely to be non-linear and variable over time. Consequently, a variety of measures of ecosystem assets is needed for a complete assessment.

Ecosystem condition and ecosystem extent

2.30 ***Ecosystem condition reflects the overall quality of an ecosystem asset, in terms of its characteristics.*** The assessment of ecosystem condition involves two distinct stages of measurement with reference to both the quantity and quality aspects of the characteristics of the ecosystem asset. In the first stage it is necessary to select appropriate characteristics and associated indicators of changes in those characteristics. The selection of characteristics and indicators should be made on scientific basis such that there is assessment of the resilience, vigour and organisation of the ecosystem asset. Thus, movements in the indicators should be responsive to changes in the resilience, vigour and organisation of the ecosystem as a whole.

2.31 In the second stage, the indicators are normalised to a common point in time. The chosen point in time reflects a reference condition. There are a number of conceptual alternatives to determine a reference condition that are described in Chapter 4. The use of a common reference condition for all indicators within an ecosystem may allow an overall assessment of the condition of the ecosystem asset.

2.32 Measures of ecosystem condition are generally compiled in relation to key ecosystem characteristics (e.g. water, soil, carbon, vegetation, biodiversity) and the choice of characteristics will generally vary depending on the type of ecosystem asset. There will not usually be a single indicator for assessing the quality of a single characteristic.

2.33 ***Ecosystem extent reflects the area of an ecosystem asset.*** For an ecosystem as a whole the concept of extent is generally considered in terms of area, e.g. hectares, for particular types of land cover. Changes in the mix of different land covers within a defined spatial area may be important indicators of changes in ecosystem assets.

Expected ecosystem service flow

2.34 ***Expected ecosystem service flow is an aggregate measure in physical terms of all future ecosystem service flows from an ecosystem asset for a given basket of ecosystem services.***[8]The expected flows must be based on an expected basket of provisioning, regulating and cultural services from an ecosystem asset. Generally, the basket of ecosystem services would be based on current patterns of use.

2.35 Because the generation of some ecosystem services involves the extraction and harvest of resources, and since ecosystems can regenerate, it is necessary to form expectations on the amount of extraction and the amount of regeneration that will take place, and on the overall "sustainability" of human activity in the ecosystem. To form these expectations information concerning likely changes in ecosystem condition is required.

2.36 More broadly, there are likely to be relationships between the condition of an ecosystem asset, its pattern of use, and the expected basket of ecosystem services. Thus while ecosystem condition may be assessed without considering measures of ecosystem services, the measurement of ecosystem assets in terms of their capacity to generate ecosystem services must involve assessment of ecosystem condition.

Changes in ecosystem assets

2.37 Measures of ecosystem condition and extent, and measures of expected ecosystem service flows are all stock measures at a point in time. In accounting, they are most commonly measured at the beginning and end of the accounting period. Often however, there is greater interest in measuring changes in ecosystem assets. Following the logic of the asset accounts described in the SEEA Central Framework, accounting entries may be defined which reflect the different additions to and reductions in an ecosystem asset over the course of an accounting period.

2.38 In some cases the measurement of changes in ecosystem assets is a relatively straightforward exercise. Of interest may be changes in ecosystem extent, commonly reflected in changes in land cover. Changes in ecosystem condition and expected ecosystem services flows (calculated as differences between beginning and end of period stocks) may also be of interest, particularly if assessed over a number of accounting periods.

2.39 However, for accounting purposes, there is most interest in recording and attributing the changes over an accounting period to various causes. In the context of ecosystem accounting there is interest in changes due economic and human activity as distinct from natural causes, and changes due to extraction distinct from regeneration. Two particular accounting entries in this context are ecosystem degradation and ecosystem enhancement. A description of these and other changes in ecosystem assets is provided in Chapter 4.

[8] This concept is akin to the concept of the productive capital stock as developed in the context of multi-factor productivity analysis. The productive capital stock is the measure of an asset at a point in time in terms of the aggregate number of efficiency units of capital services that an asset is expected to deliver over its lifetime.

2.3 Units for ecosystem accounting

2.3.1 Introduction

2.40 In order to undertake measurement of ecosystems in a co-ordinated way and to subsequently compare and analyse information across time and between ecosystems, there must be a clear focus for measurement. Boundaries for specific ecosystems are generally drawn on the basis of relative homogeneity of ecosystem characteristics, and in terms of having stronger internal functional relations than external ones. However, these boundaries are often gradual and diffuse and a definitive boundary between two ecosystems may be difficult to establish. Further, ecosystems may be very small or very large and operate at different spatial scales.

2.41 Statistical units are the entities about which information is sought and about which statistics are ultimately compiled. It is the unit that provides the basis for statistical aggregates and to which tabulated data refer. The statistical units of ecosystem accounting are spatial areas about which information is collected and statistics are compiled. The statistics pertain to the characteristics of the ecology and location of an ecosystem (see para 2.4) and its services. In compiling accounts, it may be necessary to collect information about biological components (e.g. trees, animals, etc.), but statistical units for the measurement of these characteristics are not articulated here. For a country or region the total area is generally subject to little change and the main interest of ecosystem accounting lies in assessing changes within a total area.

2.42 The units model consists of three different types of units: basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU). The following sub-sections describe each type of unit. The BSU, LCEU and EAU do not delineate an ecosystem per se although the LCEU may fit most closely with common conceptions of an ecosystem. However, ecosystems are multi-faceted and depending on the purpose of analysis may be delineated spatially in different ways.

2.3.2 Basic spatial units

2.43 A basic spatial unit (BSU) is a small spatial area. Ideally, BSU should be formed by delineating tessellations (small areas e.g. 1 km^2), typically by overlaying a grid on a map of the relevant territory, but they may also be land parcels delineated by the cadastre. Grid squares, ideally each one being a BSU, are delineated to be as small as possible given available information and landscape diversity.

2.44 Each BSU should be attributed with a basic set of information. The most common starting point for this attribution process will be information on the location of the unit and land cover. This basic information is then extended with information relevant to the purpose of the account being compiled. For example, relevant information may include ecosystem characteristics such as soil type, groundwater resources, elevation and topography, climate and rainfall, biodiversity, the degree of connection to related areas, current land uses, location relative to human settlement, and the degree of accessibility to the area by people.

2.45 This set of information may be extended to include information on the generation of different ecosystem services from the BSU such that the BSU can represent the level at which all relevant information for ecosystem accounting is assimilated and organised. Since ecosystem services are often generated over areas larger than a single BSU a method is required to attribute information to the BSU level. This issue is discussed in Chapter 3.

2.46 If possible, information on any associated economic units, e.g. land owners should be attributed to each BSU (which may be straightforward when using land parcels and the cadastre). This range of information recognises that while each BSU is a mutually exclusive area, it exists within a number of systems that operate at varying spatial scales. The link to economic units is discussed further in sub-section 2.3.6.

2.3.3 Land cover/ecosystem functional units

2.47 The second type of unit is the land cover/ecosystem functional unit (LCEU). For most terrestrial areas an LCEU is defined as the set of contiguous BSU satisfying a pre-determined set of factors relating to the characteristics and operation of an ecosystem. Examples of these factors include land cover type, water resources and soil type. A particular feature is that the set of BSU that comprise an LCEU should be seen as operating in a relatively joint manner and independently from neighbouring LCEU.

2.48 The resulting LCEU would commonly be considered an ecosystem or biome noting that these concepts are not strictly able to be defined purely in spatial terms. Following standard approaches to statistical classification, BSU would be classified to particular LCEU on the basis of a pre-dominance of characteristics within the BSU. This is akin to classifying an enterprise to a particular industry based on the pre-dominance of a particular economic activity in that enterprise.

2.49 LCEU will vary in size depending on the situation in a given country. Also, not all countries will have all types of LCEU. For the purposes of national level ecosystem accounting it is appropriate to consider only a limited set of LCEU classes. Various studies and reports (e.g. CBD, MA, UK NEA) have used different classifications but all using terms that may be considered commonly understood (e.g. forests, wetlands, grasslands, coastal areas).

2.50 A more rigorous approach that may better suit the purposes of international comparison for ecosystem accounting has been developed based on the FAO Land Cover Classification System, version 3 (LCCS 3) (FAO, 2009). This approach uses as its starting point the Land Cover Classification presented in the SEEA Central Framework Chapter 5 (which is also based on LCCS 3) and combines these into classes that are optimised for the analysis of changes in land cover and land use. A provisional set of 15 classes is shown in Table 2.5.

2.51 At any point in time, all LCEU should be mutually exclusive, i.e. all BSU should be within only one LCEU. However, over time as changes in land cover and land use occur, some BSU will need to be re-classified to different LCEU – for example from Agriculture associations and mosaics to Urban and associated developed areas.

2.52 For smaller scale analysis, it may be relevant to undertake accounting for a single LCEU. There may also be interest in aggregation of information about specific types of LCEU, e.g. concerning all open wetlands in a country or region.

Table 2.5 Provisional Land Cover/Ecosystem Functional Unit Classes

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

2.53 It is likely that LCEU represent the closest approximation to ecosystems in spatial terms in the way that ecosystems are commonly envisaged. However, in order to more fully adapt LCEU to ecosystems types it is likely to be necessary to allow for variations in climatic conditions, geophysical conditions, and land use. In relation to land use, for some purposes it may be relevant to cross–classify LCEU by the extent to which the area is considered influenced by human activity. Thus types of LCEU (e.g. Forests) may be considered as reflecting natural, semi-natural, agricultural or other types of ecosystems.

2.54 No definitive classification of ecosystems is provided in the SEEA Experimental Ecosystem Accounting. Progressive experimentation in the development of ecosystem accounts in various countries may reveal a consistent core set of classes that can be developed into an ecosystem classification in the future.

2.3.4 Ecosystem accounting units

2.55 The delineation of an EAU is based on the purpose of analysis and should therefore take into consideration administrative boundaries, environmental management areas, large scale natural features (e.g. river basins) and other factors relevant to defining areas relevant for reporting purposes. Overall, EAU should be relatively large areas about which there is interest in understanding and managing change over time. Consequently, EAU should be fixed or largely stable spatial areas over time.

2.56 Depending on the size of the country there may be a hierarchy of EAU building from smaller reporting units to the national level. For example, starting from a local administrative unit a hierarchy of EAU may build to provincial and then national level. In all cases, a country's total area will represent a single level in a hierarchical EAU structure.

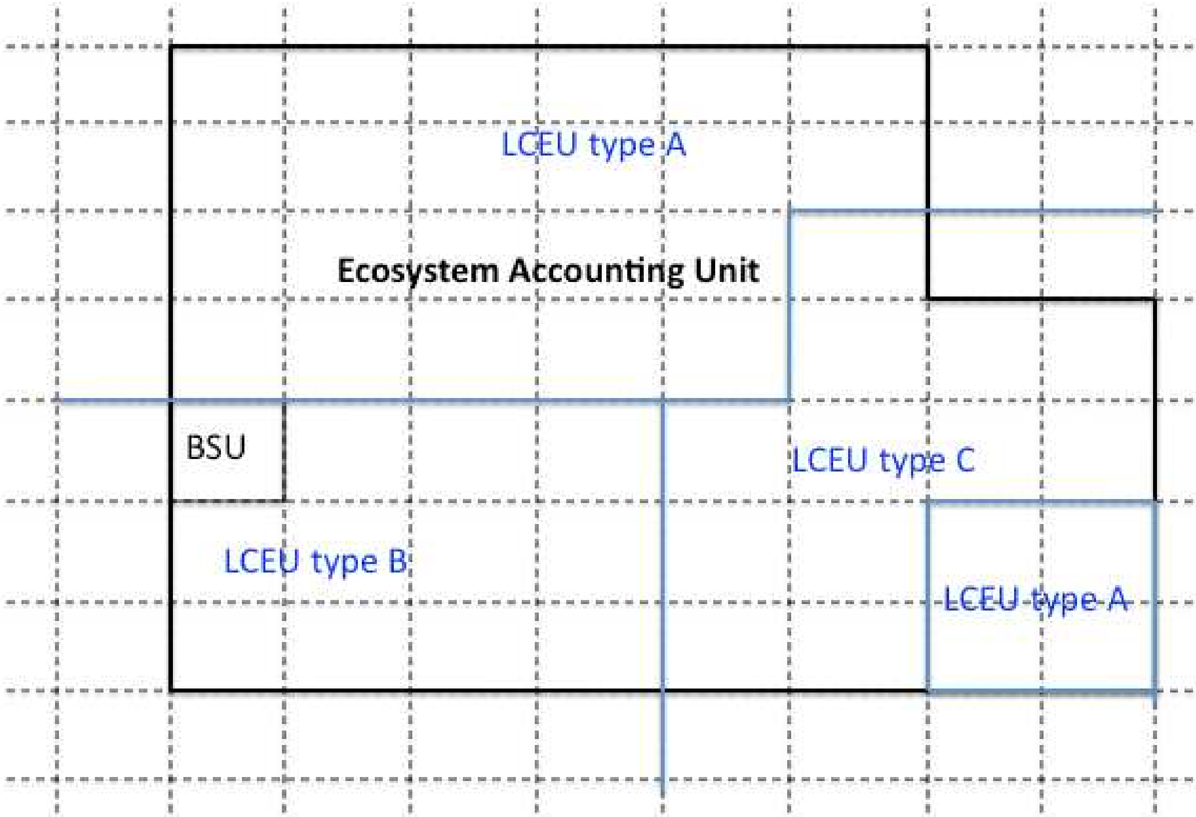
2.57 A specific concept that has been developed that may be useful in the delineation of EAU is socio-ecological systems. Areas defined as socio-ecological systems integrate ecosystem functions and dynamics as well as human activities and the range of interactions of these components.

2.58 For the purposes of national scale ecosystem accounting it is recognised that EAU are likely to contain a range of ecosystem types (reflected in different types of LCEU) and generate a range of ecosystem services.

2.59 For a single country it may be relevant to recognise different hierarchies of EAU. For example, a set of EAU may be delineated based on administrative regions, a second set may be based on catchment management areas, and a third set may be based on soil types. All EAU within each set may be aggregated to form national totals but there should not be aggregation of EAU across different sets (e.g. adding some administrative regions with some catchment areas) since this would imply the aggregation of “non-matching units”.

2.60 Figure 2.4 provides a stylised depiction of the relationships between EAU, BSU and LCEU where, in this case the BSU are defined by grid squares. Attribution of BSU to EAU and to LCEU should be based on predominance. Note that it is possible for a number of LCEU types to be present within a single EAU and for a single LCEU type to appear in various locations within an EAU.

Figure 2.4 Stylised depiction of relationships between EAU, BSU and LCEU



2.3.5 Units in relation to ecosystem services

2.61 It should be recognised that since any given spatial area may generate a number of types of ecosystem services it is likely that a single BSU will be involved in the generation of a range of ecosystem services. In this sense there is no direct analogy between the BSU and an establishment in economic statistics that undertakes a single kind of activity.

2.62 In addition, it is likely that many ecosystem services are generated over a larger spatial area than a single BSU or, at least, are measured over areas larger than a single BSU. Given this, it may be useful to map sets of BSU that are relevant to the generation of particular ecosystem services. Often these maps will reflect a contiguous set of BSU (for example, in the case of provisioning services from a forest), but this need not be the case. It is possible that some ecosystem services are generated in a single BSU (e.g. cultural services from a local fishing spot).

2.63 Although the generation of ecosystem services may take place over varying spatial areas depending on the ecosystem service, a useful measurement starting point may be to consider the ecosystem services generated within an LCEU. Particularly for provisioning and cultural services, an LCEU is likely to provide a useful spatial boundary for the measurement of ecosystem services. Maps of ecosystem service generation may be useful tools in delineating LCEU by providing an understanding of concentrations of related ecosystem services.

2.3.6 Relationship to economic classifications

2.64 The cross-classification of BSU information with economic units is central to assessment of the relationship between ecosystem services, ecosystem assets and economic activity. The application of ecosystem related information to questions of land management and ecosystem degradation requires such connections to be made.

2.65 Ideally, the linking of BSU to economic units would be undertaken in the process of attributing BSU with basic information on, for example, land use or ownership (cadastres). If this detailed linking is not possible then broader assumptions may be used for example by linking information on land cover and land use to BSU.

2.66 For certain ecosystem services it may be relevant to use economic units as a basis for collecting relevant data. This may most relevant in respect of provisioning services.

2.67 It is noted that the beneficiaries of the ecosystem services may be the land user or owner, or, it may be people living nearby (as in the case of air filtration) or populations at large (as in the case of carbon sequestration). Further, in specific cases the beneficiaries may be spatially delineated, such as in the case of people living downstream in the flood zone of an upper catchment that is managed with the aim of protecting its hydrological services.

2.3.7 Issues in the delineation of units

2.68 The delineation of units should be undertaken in concert with the development of spatial databases in Geographic Information Systems (GIS). These databases should contain information such as soil type and status, water tables, rainfall amount and pattern, temperatures, vegetation, biodiversity, slopes, altitude, etc., as well as, potentially, information on land management and use, population, and social and economic variables. This information may also be used to assess flows of ecosystem services from given spatial areas.

2.69 In presenting accounts for ecosystems at a national level, the geographic scope of the accounts should be clearly stated. Often, the scope may be limited to terrestrial areas but there may be good reasons to extend coverage to incorporate marine areas under the control of a national administration. In the context of the SEEA this is deemed to extend to the country's Exclusive Economic Zone (EEZ). Particular care should be taken in defining the treatment of coastal ecosystems that straddle terrestrial and marine areas. Additional considerations in the delineation of statistical units for coastal areas, marine environments and rivers are discussed in an annex.

2.70 The delineation of units for the atmosphere should be considered in the context of delineating BSU. It is suggested that each space above a BSU be considered a unit of atmosphere with this space constituting an "air volume". Depending on the purpose of the account any information about the quality of the air or its form (e.g. presence of greenhouse gases) may then be attributed to the terrestrial BSU below. Recognising atmospheric characteristics of BSU may be useful in, for example, the organisation of information on topics such as air pollution.

2.71 The boundaries of a country's atmosphere should align with the terrestrial and marine boundaries used in the ecosystem accounts. Thus, it would consist of all air volumes directly above that stated scope of the accounts, potentially out to the limit of the EEZ.

2.4 Ecosystem accounting tables

2.72 To provide a basis for understanding the nature of ecosystem accounting described here, this section describes some possible ecosystem accounting tables. The tables focus on the recording of information in physical terms related to flows of ecosystem services and to stocks of ecosystem assets. All of the tables are designed to give a broad sense of the potential of ecosystem accounting to organise information across a range of areas and from multiple perspectives. They are experimental in design and should serve as a starting point for compilers. The population of these tables and possible extensions to them are discussed in Chapters 3 and 4.

2.4.1 Tables for ecosystem services

2.73 Tables for ecosystem services primarily aim to organise information on the flows of ecosystem services by type of LCEU. It may also be relevant to also present information in terms of the economic units involved in generating and using the various services.

2.74 The analytical intent is to examine trade-offs between ecosystem services within a given area. In this regard it is relevant to recall that certain ecosystem services may be competing with other services while in other cases the ecosystem services are generated in tandem. Further, analysis should be undertaken in the light of various social and ecosystem contexts that may be affecting the reported area.

2.75 Table 2.1 shows a basic table for reporting information on physical flows of ecosystem services. The number of different ecosystem services reported will vary depending on the type of ecosystem and its pattern of use. It is noted that the ecosystem services shown in Table 2.1 will not be measured using the same physical units and hence totals across different ecosystem services are not shown. Further, given that there may be some uncertainty in the measurement of particular ecosystem services, for presentational purposes it may be useful to show entries in the tables in terms of up and down arrows.

2.76 Aggregation across different ecosystem services may be undertaken in different ways, all requiring some assumptions regarding the relative importance of the different services. Chapter 3 contains a description of possible extensions of the basic table shown below and approaches to aggregation. Possible measurement approaches for some of the most commonly measured ecosystem services are presented in an annex.

Table 2.1 Physical flows of ecosystem services for an EAU

	Type of LCEU								
	Ag	Urban	Forest	Wetlands	…				
Type of ecosystem services (by CICES)									
Provisioning services									
Regulating services									
Cultural services									

2.4.2 Tables for ecosystem assets

2.77 Because of the range of concepts involved in the measurement of ecosystem assets a number of tables may be constructed. Tables concerning ecosystem extent largely emerge from the asset accounts for land described in the SEEA Central Framework. Most important are measures of the area of different LCEU which may be developed along the lines explained for land cover accounts (see SEEA Central Framework Section 5.6).

2.78 Basic information concerning indicators of ecosystem condition may be compiled in basic resource accounts (e.g. for timber, water, soil, etc). Entries relating to the relevant quantities and volumes for these individual resources are described in detail in the SEEA Central Framework. The extension that is likely to be required for ecosystem accounting is the spatial disaggregation of information from asset accounts for these resources with specific recording of inter-ecosystem flows.

2.79 Relevant information from these sources together with additional indicators for specific ecosystem characteristics may be presented in a table such as Table 2.2. The data are structured by type of LCEU noting that in a given EAU there is likely to be a mix of different LCEU types.

Table 2.2 Measures of ecosystem condition and extent at end of accounting period

	Ecosystem extent	**Characteristics of ecosystem condition**				
		Vegetation	Biodiversity	Soil	Water	….
	Area	Indicators (e.g. Leaf area index, biomass index)	Indicators (e.g. species richness, relative abundance)	Indicators (e.g. soil fertility, soil carbon, soil moisture)	Indicators (e.g. river flow, water quality, fish species)	
Type of LCEU						
Forests						
Agricultural land						
Urban areas						
Inland water bodies						

2.80 Measures of ecosystem condition should cover the main aspects of each ecosystem type that affect the ongoing functioning and integrity of the ecosystem. The listed aspects of vegetation, biodiversity, soil, water and carbon are indicative only. The selection of characteristics and the development of indicators for ecosystem condition should be completed in close consultation with ecologists and other scientists.

2.81 The ambition for this table is to present indicators of ecosystem extent and condition for each LCEU type. Possible approaches to aggregation and considerations in relation to assessing change in condition are discussed in Chapter 4.

2.82 Table 2.3 presents a basic structure for information on expected ecosystem service flows. As for the measures of ecosystem services shown in Table 2.1, the entries in this table will be in different units depending on the particular service. In situations where the current use of a particular ecosystem service exceeds the ecosystem's capacity to generate that service sustainably, it will be possible to determine a total of expected flows over an ecosystem life. However, in situations where "sustainable" use is being made of the ecosystem, the estimation of total expected flows is not possible. It is therefore proposed in the table that the measurement be in terms of expected flows per year noting that this may be greater or less than an independently derived estimate of a "sustainable" flow. Measures of expected ecosystem service flows should be clearly linked to the flows of ecosystem services shown in Table 2.1.

Table 2.3 Expected ecosystem service flows at end of accounting period

	Expected ecosystem service flows per year			
	Forests	Agricultural land	Inland water bodies	…
Type of ecosystem services (by CICES)				
Provisioning services				
Regulating services				
Cultural services				

2.83 Accounting for changes in ecosystem assets is a complex task, especially in terms of defining and accounting for ecosystem degradation. The relevant issues are discussed in Chapter 4.

2.5 General measurement issues in ecosystem accounting

2.84 This section introduces a number of general measurement issues that may arise in the compilation of ecosystem accounts: (i) the integration of information across different spatial scales, (ii) benefit transfer and the scaling of data, (iii) gross and net recording, and (iv) the length of the accounting period. They are primarily practical issues but are important considerations in setting up a framework for ecosystem accounting following the general model outlined in this chapter.

2.5.1 The integration of information across different spatial scales

2.85 A primary objective of ecosystem accounting is the development of information sets for the analysis of ecosystems at a level suitable for the development of public policy. Consequently, consideration must be given to collecting and collating information pertaining to a range of ecosystems across a region or country. Following standard statistical practice, the central element in the integration of information is the delineation of statistical and reporting units. The units model for ecosystem accounting of basic spatial units (BSU), land cover / ecosystem functional units (LCEU) and ecosystem accounting units (EAU) should provide a comprehensive coverage of areas within a country.

2.86 The information used to characterise statistical and reporting units provides important data that can be used to aggregate and disaggregate across units. For example, BSU may be attributed with standard variables such as area, rainfall, and elevation, in addition to being classified to a particular land cover type. Consequently, different units of the same land cover type may be constructed, compared and differentiated through consideration of these types of variables. For example, high rainfall and low rainfall forest may be compared.

2.87 This approach is analogous to the definition of units for economic statistics. Economic units are commonly characterised by the number of people employed in addition to being classified to a particular industry. Thus, when aggregating across economic units it is possible to take into account not only the type of activity but also whether the unit is relatively large or small.

2.88 Ideally, it may be possible to produce a register of BSU containing standard information about these units. This may be possible from the use of remote sensing information, from administrative data on land management, from land based surveys of land cover and land use, or from a combination of these sources.

2.89 Where data gaps exist in terms of ecological, land use and socio-economic data, there is potential to use these “unit registers” to design sample surveys for ecosystem accounting purposes in which the samples take into account the different characteristics. In statistical terms, different groupings (or strata) of BSU could be designed and the characteristics would also form the basis for aggregations. For example, groups of BSU related to the water cycle could be constructed with information about catchments, floodplains, wetlands and rivers.

2.90 In practice however, it is likely that more understanding is needed of the operation of individual ecosystems in order to find the right set of standard variables that can be used to compare and contrast ecosystems for the purposes of higher-level analysis. Consequently, a considerable degree of caution should be used in assuming that the characteristics of one statistical unit can be easily applied in another statistical unit, even if they have the same land cover type.

2.5.2 Benefit transfer and the scaling of data

2.91 The statistical approach described above to dealing with information at different spatial scales relates strongly to common approaches used in the measurement of ecosystems referred to as benefit transfer methods. Benefit transfer methods have developed because a large amount of information on ecosystems is established for individual sites. Therefore, to develop information for other sites or over larger areas it is necessary to consider how the available information may be best used (assuming that additional data collection is not possible or cannot provide complete coverage).

2.92 Three aspects of benefit transfer are noted here. First, *value transfer* which involves using information from a specific study site and developing estimates for a target or policy site.

Second, *scaling up* which involves using information from a study site and developing information for a larger area that has similar characteristics. Third, *meta-analysis* which is a technique for assessing a large volume of information on various study sites and integrating the information to provide factors that can be used to estimate information in target areas taking into account various ecosystem characteristics.

2.93 SEEA Experimental Ecosystem Accounting recommends that a rigorous description of statistical units following standard statistical practice be undertaken before an aggregation of information to regional or national levels takes place. Using such a description of units, the application of the advancing techniques around benefit transfer may be undertaken with greater robustness and in a manner more in line with standard approaches in official statistics.

2.94 In many situations it may be necessary to attribute national or regional level information to particular statistical units. This process is generally referred to as "downscaling". Again, the effectiveness of downscaling techniques will be considerably enhanced through the development of a comprehensive set of information on different statistical units across a region or country. It is also noted that for some variables a purely technical downscaling may need to be supplemented with the use of additional models and expert judgement.

2.5.3 Gross and net recording

2.95 The terms gross and net are used in a wide range of accounting situations. In the SNA the term net is used to indicate whether an accounting aggregate has been adjusted for consumption of fixed capital (depreciation). In other situations, the term net is used simply to refer to the difference between two accounting items. The terms gross and net are also used to describe different aggregates that have related but different measurement scopes.

2.96 As far as possible, the terms gross and net are avoided in the descriptions presented in the SEEA Experimental Ecosystem Accounting. This is intended to limit the potential for confusion in the use of these terms. At the same time, the general ambition is to describe the relevant concepts in what might be considered "gross" terms such that all assumptions and relationships can be fully articulated. Further, compilers are encouraged to record accounting details in gross terms to as great an extent as possible and then explain any subsequent differencing of accounting entries.

2.5.4 Length of the accounting period

2.97 In economic accounting there are clear standards concerning the time at which transactions and other flows should be recorded and the length of the accounting period. The standard accounting period in economic accounts is one year. This length suits many analytical requirements (although often quarterly accounts are also compiled) and also aligns with the availability of data through business accounts.

2.98 While one year may suit analysis of economic trends, analysis of trends in ecosystems may require information of varying lengths of time depending on the processes being considered. Even in situations where ecosystem processes can be analysed on an annual basis, the beginning and end of the year may well differ from the year that is used for economic analysis.[9]

2.99 Although considerable variation in the cycles of ecosystem processes exists, it is suggested that ecosystem accounting retain the standard economic accounting period length of one year. Most significantly, this length of time aligns with the common analytical frameworks for economic and social data and, since much economic and social data are compiled on an annual basis, the general integration of information is best supported through the use of this time frame.

2.100 Consequently, for the purposes of ecosystem accounting, it may be necessary to convert or adjust available environmental information to a common annual basis using appropriate factors or assumptions.

2.101 Measures of ecosystem assets should relate to the opening and closing dates of the associated accounting period. If information available for the purposes of compiling accounts for ecosystem asset does not pertain directly to those dates then adjustments to the available data may be required. In making such adjustments and in undertaking analysis, an understanding of relevant seasonal and longer natural cycles will be required.

2.6 Relationship of SEEA Experimental Ecosystem Accounting to the SEEA Central Framework

2.102 The SEEA Central Framework consists of three broad areas of measurement (i) physical flows between the environment and the economy, (ii) the stocks of environmental assets and changes in these stocks; and (iii) economic activity and transactions related to the environment. The ecosystem accounting described in SEEA Experimental Ecosystem Accounting provides additional perspectives on measurement in these three areas.

2.103 First, SEEA Experimental Ecosystem Accounting extends the range of flows measured in physical and non-monetary terms. The focus in the SEEA Central Framework is on the flows of materials and energy that either enter the economy as natural inputs or return to the environment from the economy as residuals. Many of these flows are also included as part of the physical flows recorded in ecosystem accounting (e.g. flows of timber to the economy). In addition, SEEA Experimental Ecosystem Accounting includes measurement of the ecosystem services that are generated from ongoing ecosystem processes (such as the regulation of climate, air filtration and flood protection) and from human engagement with the environment (such as through recreation activity).

2.104 It is noted that the production of goods on own-account (for example, the outputs from subsistence farming and fishing, the collection of firewood and water for own-use, and the harvest of naturally occurring products such as berries) is within scope of the production boundary defined in the SNA and used in the SEEA Central Framework. Consequently, these flows are within the scope of the benefits recorded in SEEA Experimental Ecosystem Accounting.

[9] For example hydrological years may not align with calendar or financial years.

2.105 There are a number of natural inputs recorded in the SEEA Central Framework that are not recorded as part of ecosystem assets or ecosystem services. These are the inputs from mineral and energy resources, from excavated soil resources, and the inputs from renewable energy sources. In all of these cases the inputs are not considered to arise from ecosystem processes and hence, do not constitute ecosystem services. This boundary is explained in more detail in Chapter 3. It is recommended that information on these flows should be presented alongside information on ecosystem services and ecosystem assets to provide a more complete set of information for policy and analytical purposes.

2.106 Second, SEEA Experimental Ecosystem Accounting considers environmental assets from a different perspective compared to the SEEA Central Framework. Environmental assets, as defined in the Central Framework, are the naturally occurring living and non-living components of the Earth, together comprising the bio-physical environment, that may provide benefits to humanity[10] .

2.107 This broad scope encompasses two perspectives on environmental assets. The first, which is the focus of the SEEA Central Framework is of environmental assets in terms of individual resources (e.g. timber, fish, minerals, land, etc). The second perspective, which is the focus of SEEA Experimental Ecosystem Accounting, considers the bio-physical environment through the lens of ecosystems in which the various bio-physical components (including individual resources) are seen to operate together as a functional unit.

2.108 Accounting for specific elements, such as carbon, or other environmental characteristics, such as biodiversity, is covered in SEEA Experimental Ecosystem Accounting but these are specific perspectives taken within the same bio-physical environment as defined by environmental assets in the SEEA Central Framework.

2.109 While there is, in principle, no extension in the bio-physical environment, there are some particular boundary issues that warrant consideration, particularly concerning marine ecosystems and the atmosphere. The ocean and the atmosphere are excluded from the measurement scope in the SEEA Central Framework because the associated volumes of water and air are too large to be meaningful for analytical purposes. Their treatment in the context of ecosystem accounting is discussed in the context of statistical units for ecosystem accounting in Section 2.3.

2.110 An important part of the SEEA Central Framework is the definition of depletion of individual natural resources. SEEA Experimental Ecosystem Accounting incorporates measures of depletion within a broader concept of ecosystem degradation. Ecosystem degradation is a measure that covers not only the using up of resources but also the declines in the capacity of ecosystems to generate other ecosystem services (e.g. air filtration).

2.111 Third, the SEEA Central Framework outlines clearly the types of economic activity that are considered environmental and also describes a range of relevant standard economic transactions (such as taxes and subsidies) that are relevant for environmental accounting. It

[10] SEEA Central Framework, 2.17. This scope is broader than the physical asset boundary used in the SNA which is limited to those assets that have an economic value in monetary terms. Thus, in the SEEA, all land is included regardless of its value.

also shows how these flows may be organised in functional accounts – the main example being Environmental Protection Expenditure Accounts.

2.112 For the purposes of ecosystem accounts, there are no additional transactions that are theoretically in scope since the SEEA Central Framework has, in principle, a scope that covers all economic activity related to the environment including protection and restoration of ecosystems. At the same time, SEEA Experimental Ecosystem Accounting includes a discussion on the appropriate accounting treatment for emerging economic instruments related to the management of ecosystems, for example the development of markets for ecosystem services. There is no specific discussion on these types of arrangements in the SEEA Central Framework.

2.113 Finally, regarding valuation, the valuation principles of market prices is applied in SEEA Experimental Ecosystem Accounting in a manner consistent with the SEEA Central Framework and the SNA. However, since many ecosystem services are not marketed it is necessary to consider a range of approaches to the valuation of these services and to assess the consistency of these approaches with the principle of market price valuation.

Chapter 3: Accounting for ecosystem services in physical terms

3.1 Introduction

3.1 Ecosystem services have become a central concept in connecting characteristics of ecosystem assets with the benefits received from ecosystems by people through economic and other human activity. As described in Chapter 2, ecosystem services are the contributions of ecosystems to benefits used in economic and human activity.

3.2 This chapter discusses a number of measurement issues related to compiling information on ecosystem services in physical terms. The word “physical” in this context means “non-monetary” and measurement in “physical terms” encompasses ecosystem services that reflect flows of materials and flows of energy, services related to the regulation of an ecosystem, and flows related to cultural services. In Section 3.2 focus is on further articulating the measurement boundaries for ecosystem services. A classification of ecosystem services is introduced in Section 3.3 and the basic approach to compiling accounts for ecosystem services is outlined in Section 3.4. Section 3.5 introduces examples of approaches to the measurement of various ecosystem services.

3.2 Measurement boundaries and characteristics of ecosystem services

3.2.1 Types of ecosystem services

3.3 A fundamental aspect of ecosystem accounting is recognition that a single ecosystem will generate a range of ecosystem services thus contributing to the generation of a number of benefits. In some cases the ecosystem services may be produced “in tandem”, such as when forest areas are preserved and provide air filtration services and opportunities for recreation and walking. In other cases the ecosystem services may be in competition, such as when forest areas are logged thus providing the benefits of timber but losing opportunities for recreation. Ecosystem accounting enables the examination of these trade-offs.

3.4 To support evaluation of these trade-offs ecosystem services are grouped into different types. In SEEA Experimental Ecosystem Accounting, building on a number of large ecosystem service measurement projects, three broad internationally agreed categories of ecosystem services are used:

(i) Provisioning services relating to the materials that can be harvested from an ecosystem (such as the harvesting of timber from forests);

(ii) Regulating services relating to natural processes (such as the benefits from clean air that has been filtered in the environment)[11]; and

(iii) Cultural services arising from human interaction with nature (such as benefits from recreation).

[11] These services are often also referred to as regulating and maintenance services.

3.5 A Common International Classification of Ecosystem Services (CICES) is under development and provides additional detail within these broad groups. Section 3.3 presents CICES in more detail.

3.6 Commonly, ecosystem services are conceptualised in terms of the types of benefits to which they contribute. In addition to distinguishing benefits as being either SNA or non-SNA benefits (as described in Chapter 2), a complementary view is to consider the private and public nature of the benefits. In terms of the generation of ecosystem services that contribute to private and public benefits three situations can be described.

(i) First, there are ecosystem services that are generated from economic assets (including land and natural resources) that are privately and publicly owned and managed, and which contribute to the production of private benefits (e.g. in the case of agricultural production). Private benefits are equivalent to SNA benefits as defined above.

(ii) Second, there are ecosystem services that are generated from economic assets that are privately owned and managed but which contribute to the production of public benefits, i.e. the benefit accrues to other producers or society more broadly rather than exclusively to the private owner/manager of the land (e.g. absorption of carbon dioxide by a privately owned forest).

(iii) Third, there are ecosystem services that are generated from areas that are not privately owned or managed and contribute to the generation of public benefits (e.g. protected areas including national parks and some marine areas).

3.7 Together, the second and third cases comprise non-SNA benefits as described above. From an ecosystem accounting perspective, accounting for the second case is perhaps the most problematic since in this case the public benefits are likely to be produced unintentionally by a private producer. The consequence is that for a given economic asset, particularly land, it is necessary to consider both SNA and non-SNA benefits and the ecosystem services related to each of these types of benefits. This is most relevant in accounting for ecosystems in monetary terms, for example for wealth accounting, where the additional stream of benefits (in the form of public benefits) needs to be associated with private values of assets that are already included in the standard national accounts.

3.2.2 Measurement boundaries for ecosystem services

Supporting services

3.8 Chapter 2 noted that the definition of ecosystem services excludes the set of flows commonly referred to as supporting services. These include intra- and inter- ecosystem flows and the role of ecosystem characteristics that are together reflected in ecosystem processes. The exclusion of supporting services ensures that the scope of ecosystem services in accounting terms reflects only the point of interaction between humans and ecosystems. This notion of ecosystem services is often referred to as “final ecosystem services” in that they are the final outputs that are generated and used from an ecosystem.

3.9 In concept, as described at a high-level in Chapter 2, it is possible to describe a series or chain of flows linking various intra- and inter-ecosystem flows with ecosystem services and subsequently to benefits. For certain analyses, "mapping" this chain may be particularly important in order to assess the ecosystem wide implications of specific decisions, for example to understand the impact of increasing harvest of timber from a forest. In practice, the complexity of ecosystem processes means that a detailed and complete accounting for supporting services is very difficult to support. As a consequence, the approach in SEEA Experimental Ecosystem Accounting is to account for ecosystem wide effects through assessments of changes in ecosystem assets. At the same time, mapping the chains of ecosystem flows may be important in certain situations.

3.10 While supporting services should be excluded, determining the final output of an ecosystem as distinct from various supporting services may be difficult. However, in accounting terms the distinction is important. Without the distinction the measurement process may aggregate both ecosystem services and supporting services and consequently overstate the contribution of ecosystem services in the generation of benefits. Put differently, the supporting services should be seen as an input to the ecosystem services which are therefore embodied in the flow of ecosystem services to benefits. Adding together supporting services and ecosystem services therefore represents a double counting of the contribution of supporting services.

Biodiversity and ecosystem services

3.11 The relationship between ecosystem services and biodiversity is complex. On the one hand, biodiversity is a core characteristic of ecosystems and is a fundamental aspect of ecosystem processes that support the generation of all ecosystem services. In addition, people also value species diversity and/or the protection of rare species independent of the role of these species in supplying other ecosystem services.

3.12 In general, in the SEEA, biodiversity is considered a characteristic of ecosystems and hence is best accounted for as part of the assessment of ecosystem assets – in particular as part of the assessment of ecosystem condition. Falling levels of biodiversity will generally correspond to falling levels of ecosystem condition. However, there may be certain aspects of biodiversity that may be considered important final outputs and these should be recorded as appropriate. For example, ecosystem services should be recognised when iconic species, such as the giant panda, provide cultural services.

3.13 Section 4.5 presents an extended discussion on accounting for biodiversity. The material highlights the range of information that is available in relation to biodiversity and explains the ways in which this information may be organised to provide information on biodiversity directly and for the purposes of ecosystem accounting.

Abiotic services

3.14 As noted in Chapter 2, ecosystem services do not represent the complete set of flows from the environment that contribute to economic and human activity. Important examples of other environmental flows include the extraction of mineral and energy resource from underground deposits, energy from the sun for the growing of crops and as a renewable source of energy, and the movement of wind and tides which can be captured to provide sources of energy. More broadly, the environment provides the space in which economic and other human activity takes place and the provision of space may be conceptualised as an environmental flow. Collectively, these other flows from the environment are referred to as abiotic services and contribute to many SNA and non-SNA benefits.

3.15 The boundary between ecosystem services and abiotic services is defined by the scope of the processes that are relevant in their generation. It is considered that ecosystem services are generated as a result of bio-physical, physico-chemical, and other physical processes and interactions within and between ecosystems – i.e. through ecosystem processes. Abiotic services are not generated as a result of ecosystem processes.

3.16 The measurement of abiotic services is covered in Chapter 3 of the SEEA Central Framework in the discussion of natural inputs. (Natural inputs also include flows that are included as part of ecosystem services). No additional discussion on the measurement of abiotic services is presented in SEEA Experimental Ecosystem Accounting.

3.17 The importance of recognising abiotic services in ecosystem accounting lies in the organisation of information for the assessment of alternative uses of land. Most commonly there are trade-offs that can be made between land uses and in considering these trade-offs a limitation to ecosystem services would be too narrow. The consideration of both ecosystem services and abiotic services provides a more complete assessment framework. Examples of where these trade-offs may arise include cases where there may be use of agricultural land to establish mining operations, or cases where roads are extended into native vegetation.

Accounting for flows related to joint production of crops and other plants

3.18 In recognising a chain of flows between human well-being and ecosystems, the critical point in the chain for accounting is where the ecosystem service ends and the benefit begins. In some cases this point can be clearly defined but in relation to crops and other plants where there is a complex joint production involving ecosystem services and human inputs, determining the distinction between ecosystem service and benefit may not be straightforward.

3.19 The involvement by economic units in the production of crops and other plants takes place along a continuum and there are varying degrees to which the growth of these biological resources is managed. Consequently defining standard rules by which the contribution of ecosystems can be measured is difficult. To date two main approaches have emerged to define a boundary for accounting purposes. The first approach measures the ecosystem services as equivalent to the amount of the crop that is harvested, irrespective of the extent of management of the growth of the crop.

3.20 The second approach distinguishes between the extent of management of growth by defining some crops as natural and some as cultivated following the logic outlined for the SNA production boundary. Where the crop growth is not managed (e.g. timber logged in naturally regenerated forests) the ecosystem service is equal to the amount of crop that is harvested. Where the crop growth is cultivated, the ecosystem services are equated to the combination of nutrient cycling, abstraction of soil water, pollination and other ecosystem processes involved in the growth of a plant that a grower utilises in combination with other inputs (labour, produced assets, fertilisers, etc). In either situation the measured ecosystem service still represents the input "purchased" from the ecosystem by the grower and hence the ecosystem service remains the final output of the ecosystem.

3.21 For ecosystem accounting there are a range of factors to consider

(i) First, it is likely to be useful in all measurement contexts to describe the chain of flows related to cultivated and natural biological resources such that there is a full appreciation of the ecosystem linkages and to recognise that there are many points in the growth process at which human influence on the growing process may occur.

(ii) Second, as part of describing the chain of flows it is likely to be relevant to organise the information according to the type of management or harvest technique being applied. For example, there are likely to be quite different ecosystem effects from the use of small fishing boats compared to large trawlers even though the benefit extracted (fish) may be the same in both cases. Accounting for changes in management and harvest technique may be an important focus for ecosystem accounting.

(iii) Third, the purpose of the analysis may influence the choice of measurement approach. For national level assessment it may be sufficient to focus only on the harvested products whether they are cultivated or natural while for ecosystem service specific analysis a different boundary may be more relevant.

3.22 Recognising the need for measurement boundary to be drawn for accounting purposes, the proposed approach for SEEA Experimental Ecosystem Accounting is the second approach that recognises a distinction between natural and cultivated growth processes. This proposed approach provides a measurement boundary for ecosystem services that aligns with the SNA production boundary and also the boundary for the Classification of Natural Inputs as described in the SEEA Central Framework. Importantly, the principles of the approach can be applied consistently across different types of cultivated biological resource (e.g. for crops, orchards, livestock, etc).

3.23 However, it is recognised that this approach is not completely consistent with many existing approaches to measuring ecosystem services – for example MA and TEEB. In these exercises the ecosystem service boundary for crops has been equated to the crops themselves, while for livestock the ecosystem services is the same as proposed above being equal to the grass eaten. In concept, the approach used in MA, TEEB and other studies, uses principles relating to the removal of biotic resources from an ecosystem rather than consideration of the SNA production boundary.

3.24 As noted above, whatever measurement boundary that is chosen, in practice it may be difficult to articulate and measure all of the various ecosystem processes for different cultivated biological resources. Hence it may be pragmatic to apply the harvest approach for cultivated crops and other plants. This assumes that the various flows such as pollination, nutrients and water that input to the growth of the mature crop or animal are effectively proxied by recording the flows of the harvested product. Provided that the joint production function remains relatively stable (in terms of the degree of human and ecosystem involvement) then this assumption may be reasonable.

3.2.3 Other measurement issues

Defining volumes of ecosystem services

3.25 Ecosystem services are defined as the contribution to benefits and hence should be measured only when SNA or non-SNA benefits can be identified. Thus, if there are no users there can be no ecosystem service flows. Consistent with this treatment, the volume of any ecosystem service will rise as the number of users increases. For example, a walking track in a forest provides more cultural services as the number of people using the track increases. This result reflects the starting point for accounting for ecosystem services being the use of ecosystems in economic and other human activity.

3.26 As a result of this logic, in concept, there may be no ecosystem services from a given ecosystem asset during an accounting period. However, it remains relevant to assess such an ecosystem asset for two reasons. First, there may be the capacity for an ecosystem asset to provide ecosystem services in the future and hence measures of the asset and changes in the asset are relevant. Second, although an ecosystem asset may not provide ecosystem services directly, it may contribute important inter-ecosystem flows as part of the ecosystem processes that generate ecosystem services in other ecosystems. Understanding these dependencies is an important part of accounting for all ecosystem assets.

"Storage" of ecosystem services

3.27 For some ecosystem services such as those relating to the harvesting of timber or the abstraction of water, it is possible to observe the "storage" of ecosystem services for future use. This may be seen when certain natural resources available for use are not harvested during an accounting period and may increase through natural regeneration or replenishment. In accounting terms, these "unused" ecosystem services are recorded as increases in the stock of the relevant natural resources (as part of the measurement of ecosystem assets). In subsequent accounting periods these higher levels of stock are available for future use and should only be recorded as ecosystem services in the period in which they are actually harvested. In effect, part of an ecosystem asset represents an inventory of natural resources that may be increased or decreased through regeneration or extraction.

Disservices

3.28 From a societal perspective there may often be outcomes from ecosystem processes that are seen as negatives (e.g. pests and diseases). These ecosystem disservices often originate from a combination of ecosystem processes and adverse human management. In part, these disservices are included in the ecosystem accounts in an indirect manner, for example when agricultural pests lead to declines in ecosystem assets and a reduced supply of ecosystem services. However, other disservices that directly enter the production or consumption functions of households, enterprises and governments (e.g. natural pathogens having an impact on health) are not accounted for in the definition of ecosystem services outlined above.

3.29 At this stage, accounting for disservices and the relationships to ecosystem processes and benefits has not been developed. It is noted that many industries take implicit advantage of these disservices (e.g. manufacturers of pesticides and pharmaceuticals) and hence the nature of the connection between any particular disservice and overall individual and societal well-being is likely to be difficult to establish. Also, to some extent, increases and decreases in the levels of disservice may represent normal fluctuations in ecosystem processes and perhaps might best be reflected in accounting for changes in ecosystem assets. Overall, more work is required to understand and account for disservices within the ecosystem accounting framework presented here.

Scale

3.30 The scale of measurement required to assess the generation and use of ecosystem services will vary by type of ecosystem service. Some may be generated in a very small area whereas some may be generated over quite large areas. Hence the notion of services being generated "from an ecosystem" may be interpreted in different ways depending on the ecosystem service under consideration.

Spatial location of beneficiaries

3.31 The generation of ecosystem services is assumed to be able to be attributed to particular ecosystem assets whose spatial area is known. However, it is not necessarily the case that the users of the ecosystem services are located in the same spatial area. This is particularly true of regulating services and cultural services where the beneficiaries may often live in cities and large urban areas while the services are generated in ecosystems away from these areas. Although a simple assumption regarding the location of the beneficiaries cannot be made, it is important in accounting for ecosystem services that attempts are made to understand the location of beneficiaries. This information is needed to ensure that changes in the population of beneficiaries are taken into account in measuring the volume of ecosystem services. They should also be taken into account when developing estimates of ecosystem assets since measures of expected ecosystem service flows will be related to changing populations of individuals and enterprises.

3.32 For accounting purposes it may be useful to distinguish between the area within which the ecosystem services are generated and the areas in which ecosystem services are used. This may be done by recording imports and exports of ecosystem services between different areas.

3.33 The majority of provisioning services are likely to be generated and used in the same ecosystem since it is necessary for the relevant materials to be harvested *in situ*. Subsequent transactions involving the processing, transportation and sale of harvested materials are the subject of standard economic accounting and are not the focus of ecosystem accounting presented here. At the same time the linking of ecosystem accounts and standard economic accounts is facilitated through the use of the SEEA framework and hence extensions to analyse the relationship between ecosystem services and a more complete series of transactions, including international trade flows, may be developed.

Flows of ecosystem services between countries

3.34 There are two dimensions to discuss concerning flows of ecosystem services between countries. First, non-residents visiting a country are likely to use ecosystem services and, similarly, residents visiting another country are likely to use ecosystem services from the country visited. These flows of ecosystem services may be recorded as imports and exports of ecosystem services as appropriate. Of particular interest may be provisioning services related to fish caught in non-resident waters. This should be treated as an import of an ecosystem service in the accounts of the country undertaking the fishing.

3.35 Second, there are likely to be inter-ecosystem flows that cross country boundaries. Flows of water via major rivers are a particular example. As described, inter-ecosystem flows are not flows of ecosystem services however these flows should be recorded as part of a complete accounting for ecosystem assets. For accounting purposes they may be identified separately from inter-ecosystem flows within a country but the overall conceptual treatment is analogous.

3.3 Classification of ecosystem services

3.36 The classification of ecosystem services described in SEEA Experimental Ecosystem Accounting – the Common International Classification of Ecosystem Services (CICES) - is aligned with the discussion on measurement boundaries and characteristics of ecosystem services described in Section 3.2. CICES fits into the broader picture of ecosystem accounting by providing a structure to classify those flows defined as ecosystem services. It does not provide a structure to classify ecosystem assets, ecosystem processes, ecosystem characteristics, abiotic services or benefits. Figure 2.3 in Chapter 2 places all of these parts of ecosystem accounting in context.

3.37 At the broadest level three different categories of ecosystem services are distinguished in the SEEA: (i) provisioning services; (ii) regulating services; and (iii) cultural services.

(i) *Provisioning services* reflect contributions to the benefits produced by or in the ecosystem, for example a fish or a plant with pharmaceutical properties. These benefits may be provided by agricultural systems, as well as within semi-natural and natural ecosystems.

(ii) *Regulating services*[12] result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes. These services often have an important spatial aspect. For instance, the flood control service of an upper watershed forest is only relevant in the flood zone downstream of the forest.

(iii) *Cultural services* relate to the intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection. This may involve actual visits to an area, indirectly enjoying the ecosystem (e.g. through nature movies), or gaining satisfaction from the knowledge that an ecosystem containing important biodiversity or cultural monuments will be preserved.

[12] Regulating services are also commonly referred to as “regulation and maintenance services”.

3.38 These three types of ecosystem service form the highest level of the Common International Classification of Ecosystem Services (CICES). Table 3.1presents the higher levels of CICES and experience to date suggests that at this broad level the structure of CICES can be used in a range of situations. The table also provide examples of ecosystem services that are considered to be within each group without attempting to be exhaustive. Examples of related benefits are also shown in the final column. The CICES presented in the SEEA is provisional and it is anticipated that it will be developed and refined over time as accounting for ecosystem services develops further.

Table 3.1 Three levels of CICES

CICES for the SEEA Experimental Ecosystem Accounts				
Section (1-digit)	*Division(2-digit)*	*Group (3-digit)*	**Examples of ecosystem services**	**Examples of benefits**
Provisioning	***Water***	***Water***	Water taken up for the growing of crops and animals, agricultural, mining, manufacturing and household use, etc	Drinking water, water for crop production, livestock feed, thermoelectric power production, etc.
		Uncultivated terrestrial plants and animals for food	Uncultivated terrestrial plants and animals (e.g. game animal, berries and fungi in the forest) taken up for food	Food for human consumption
		Uncultivated freshwater plants and animals for food	Uncultivated freshwater plants and animals (e.g. plaice, sea bass, salmon, trout) taken up for food.	Food for human consumption
		Uncultivated marine plants, algae and animals for food	Uncultivated marine plants, algae and animals (e.g. Seaweed, crustaceans such as crabs, lobsters, crayfish) taken up for food.	Food for human consumption
		Nutrients and natural feed for cultivated biological resources	Nutrient resources for the uptake by crops; fodder for livestock; feed for aquaculture product;	Crops and vegetable products; cultivated timber and cotton; cattle for meat and diary product; aquaculture product;
		Plant and animal fibres and structures	Plant and animal fibres and structure (e.g. natural timber, straw, flax , skin, bone algae) to be harvested for manufacturing or domestic use	Logged timber, straw, flax, algae, natural guano, corals, shells, skin and bone for further processing in the manufacturing industry (e.g. fertiliser and chemicals) or final consumption
		Chemicals from plants and animals	Substances and biochemicals (e.g. rubber, enzymes, gums, oils, wax, herbal substances) from living organisms taken up for medicine use, manufacturing or domestic production	Substances and biochemicals, such as rubber, enzymes, gums, oils, wax, herbs to cosmetic and medicinal use or for further processing in the manufacturing industry
	Materials	***Genetic materials***	Genetic materials taken up for breeding programmes (e.g. for crop plants, farm animals, fisheries and aquaculture)	Genetic materials used for breeding programmes (e.g. for crop plants, farm animals, fisheries and aquaculture)
	Energy	***Biomass based energy***	Wood taken up for fuel; uncultivated energy plants, algae to be harvested for biofuel; dung, fat, oils from natural animal to be extracted for energy.	Heating, light, fuel etc.
	Other provisioning services	***Other provisioning services, n.e.c.***	Other provisioning services that are not classified elsewhere in this section, such as provisioning of exotic animals, tamed animal trained to harness	Work and pet animals
Regulating		***Bioremediation***	Chemical detoxification/breakdown of pollutants by plants, algae, micro -organisms and animal.	Reduced level of pollutant/contaminants in soil and ground water
	Remediation and regulation of biophysical environment	***Dilution, filtration and sequestration of pollutants***	Dilution of municipal wastewater in rivers, removal of organic materials and nutrients from wastewater by biogeochemical process; filtration of particulates and aerosols; sequestration of nutrients and pollutants in organic sediments, removal of odours.	Cleaner air, water and soil
		Air flow regulation	Natural or planted vegetation that serves as shelter belts, air ventilation services.	Dust storm mitigation, shelter from the wind, improvement of ventilation and heat mitigation in the urban area.
		Water flow regulation	Regulation of timing and magnitude of water runoff, flooding and aquifer recharge	Prevention of flood damage; recharge of water into surface water and ground water; reduced damage from high water.
	Flow regulation	***Mass flow regulation***	Soil and mudflows stabilization	Prevention of soil erosion, avalanche and mudflows.
		Atmospheric regulation	Capture of carbon dioxide; Climate regulation; Maintenance of urban climate (such as temperature and humidity) and regional precipitation patterns.	Reduced amount of greenhouse gas in the atmosphere; Reduced impact of climate change; Improvement of the climate condition.
		Water cycle regulation	Oxygenation of water, Retention and translocation of nutrients in water	Improvement of water quality
	Regulation of physico-chemical environment	***Pedogenesis and soil cycle regulation***	Maintenance of soil fertility and structure in the cultivated system	Improvement of soil fertility and productivity in the cultivated system
		Noise regulation	Natural buffering and screening	Reduction of noise level
		Lifecycle maintenance, habitat and gene pool protection	Pollination, seed dispersal, maintenance of habit nursery population and habitats	Improvement of productivity of crops, habitats conservation
	Regulation of biotic environment	***Pest and disease control (incl. invasive alien species)***	Control of pathogens	Reduced hazard level to crops, human health and the environment
Cultural		***Non-extractive recreation***	Landscape and seascape character and biodiversity species for hiking, bird recreation	Enjoyment for hiking, bird watching, whale watching, etc.; Increase health level; increased number of visitor in the tourism industry
	Physical or experiential use of ecosystems [environmental setting]	***Information and knowledge***	Landscape character and biodiversity species for scientific research and education	Scientific progress (e.g. such as pollen record, tree ring record, genetic patterns); Increase knowledge (e.g. subject matter for wildlife programmes and books) etc.
		Spiritual & symbolic	Landscape character and biodiversity species for cultural heritage values, sense of personal and group identity (sense of place), spiritual and religious function, etc.	Increase sense of personal and group identity, national symbol, performance of spiritual and religious functions.
	Intellectual representations of ecosystems [of environmental settings]	***Non-use***	Ecosystem capital for future generation of ecosystem services.	Availability of biodiversity and ecosystem services to future generation.

3.39 There are three important boundaries in relation to CICES.

(i) First, abiotic services are excluded. Where relevant for analysis, estimates of these flows may be appended to presentations showing ecosystem services.

(ii) Second, supporting services are excluded. There is no attempt in CICES to provide a classification that covers all of the possible intra- and inter- ecosystem flows that would need to be incorporated. It is recognised that many of the regulating services may also be considered supporting services depending on their place in the chain of ecosystem flows. However, CICES is a classification of those flows that have been defined as "final" ecosystem services and hence should be used only to classify these flows.

(iii) Third, consistent with the proposals in Section 3.2, in the case of cultivated crops and other plants, the "final" ecosystem services are not the crops or other harvested products. Rather they are flows related to nutrients, water, and various regulating services, such as pollination.

3.40 If a choice is made to use an alternative boundary for the measurement of ecosystem services related to crops and other plants, then some adaptation of the CICES would be required. It is noted that if ecosystem services are measured using flows of harvested crops, then it is necessary to exclude flows relating to the growth of these plants such as pollination, abstraction of soil water, etc. Put differently, both pollination and harvested crops should not be combined in a measure of "final" ecosystem services. This would represent a "double count" in accounting terms.

3.41 The CICES shown in Table 3.1 is provisional. It requires further development to enable a full articulation of relevant classes, description of the various levels including resolution of boundary issues, and alignment to fit within general requirements for statistical classifications. The further development of the CICES would benefit from testing and use of the provisional structure in the compilation of estimates of ecosystem services.

3.4 Accounting for ecosystem services

3.4.1 Introduction

3.42 The aim of accounting for ecosystem services is to organise information on the flows of ecosystem services by type of service, by statistical unit, and by economic units involved in generating and using the various services. In addition it may be relevant to identify the recipients of both SNA and non-SNA benefits that arise from using the contributions of ecosystem services. This section describes relevant measurement issues including statistical units, the structure of tables and possible extensions, links to the SNA and the SEEA Central Framework, and approaches to aggregation.

3.43 Following the units model outlined in Section 2.3, a useful starting point for the measurement of individual ecosystem services is likely to be at the level of LCEU. For many ecosystem services this approach will be appropriate since most ecosystem services will be generated within the spatial area defined by an LCEU.

3.44 Where an LCEU is completely contained within an EAU no attribution of observed physical flows to finer spatial levels, i.e. to BSU, is required for reporting at the EAU level. However, where either the LCEU crosses an EAU boundary, or a particular ecosystem service is generated over an area that cross LCEU and EAU boundaries, attribution of information to the BSU level will be required in order to permit aggregation to the EAU level.

3.45 The process of attributing information to BSU may require particular assumptions, scientific knowledge or other information. It is likely to be relevant to consider the discussion on integrating information across spatial scales in Section 2.5, including the discussion on benefit transfer. More generally, this is an area of ecosystem accounting in which further testing and development of methods is required.

3.4.2 Measurement units for ecosystem services

3.46 The measurement units used for recording flows of ecosystem services will vary significantly by type of ecosystem service. Provisioning services will generally be measured in units such as tonnes or cubic metres but may also be measured in units specific to the type of service. For example biomass based energy may be measured in joules.

3.47 Regulating services will also be measured in a variety of units depending on the indicator used to reflect the flow of service. For example, the service of carbon sequestration would normally be measured in terms of tonnes of carbon sequestered.

3.48 Cultural services are likely to be measured in units related to the people interacting with the ecosystem and using the ecosystem service. Possible measurement units include the number of people visiting a site or the time spent using the service. Also, since the volumes of cultural services are likely to be related to the condition of the ecosystem it may be relevant to use indicators of changes in ecosystem condition and ecosystem characteristics as indicators.

3.49 For presentational purposes it may be relevant to convert all of the measures into index form with a common reference year set equal to 100. Then focus may be placed on increases or decreases in flows of ecosystem services over time. Implicitly however, such a presentation may suggest that each ecosystem has an equal weight and thus the relative significance of each service would not be clear.

3.4.3 Possible tables for ecosystem services

3.50 The table below presents a basic table that may be used to record estimates of the physical flows of different ecosystem services. It may be best to envisage this table being constructed for a country as a whole (the highest level of EAU) which is composed of numerous LCEU of different types. Thus it is assumed in the table that the same type of LCEU in different parts of a country can be aggregated. It is also assumed that all ecosystem services are attributable to specific types of LCEU. This is likely to be appropriate for many provisioning and cultural services but may not be appropriate for some regulating services (e.g. water flow regulation).

3.51 No row is included to reflect a total flow of different ecosystem services. This is because the aggregation of estimates across different services is not straightforward and is subject to considerable caveats. The following sub-section discusses relevant approaches and concerns.

Table 3.2 Physical flows of ecosystem services for an EAU

	Type of LCEU							
	Ag	Urban	Forest	Wetlands	…			
Type of ecosystem services (by CICES)								
Provisioning services								
Regulating services								
Cultural services								

3.52 By definition the total generation of a single ecosystem service should equal to the total use of that service. However, the use of the services generated within a single EAU may not all take place within the EAU. For example, urban areas will benefit from the air filtration services provided by nearby forests. It may therefore be of interest to further disaggregate the information on the use of ecosystem services by spatial area recognising those services that are used by people within the EAU and those used by people outside the EAU.

3.53 The attribution of the generation of ecosystem services to type of economic unit (enterprises or government) will require certain assumptions regarding the nature of the ownership and management of the areas within the EAU in relation to the various ecosystem services. Table 3.3 shows a possible way of organising information on the generation and use of ecosystem services by economic units. The measurement of these flows may be of particular relevance in accounting for ecosystem degradation.

Table 3.3 Generation and use of ecosystem services for an EAU

	Generation of ecosystem services			**Use of ecosystem services**				
	Enterprises	Government	Total	Enterprises	Households	Government	Non-residents	Total
Type of ecosystem services (by CICES)								
Provisioning services								
Regulating services								
Cultural services								

3.54 Depending on the purpose of analysis it may be relevant to also include measures of abiotic services for particular spatial areas (EAU or LCEU). The joint presentation of information on ecosystem services and abiotic services may facilitate a greater understanding of the trade-offs in the management of given areas of land.

3.4.4 Approaches to aggregation of ecosystem services

3.55 In the context of ecosystem accounting, aggregation involves bringing together information about a particular spatial area to provide overall measures of flows of ecosystem services. Three different forms of aggregation can be envisaged. First, there is aggregation of the various ecosystem services within a spatial area (for example within an EAU). Second, there is aggregation of a single ecosystem service across multiple spatial areas within a country (for example, across multiple LCEU). Third, there is aggregation of all ecosystem services across multiple (potentially all) areas within a country.

3.56 Before considering methodological issues in aggregation, compilers should consider carefully the purpose of aggregation across different types of ecosystem services. Since some ecosystem services are competing and some are produced in tandem, it may be sufficient to present information on flows of different ecosystem services to allow analysis of trade-offs without undertaking aggregation.

3.57 Where aggregation of different ecosystem services is undertaken it is necessary to aggregate flows for each service that are likely to be recorded using different measurement units. Given this, aggregation requires some assumptions regarding the relative important or significance of each of the ecosystem services. This is done by establishing weights that reflect the relative importance of each service.

3.58 There are a number of possibilities to determine weights for ecosystem services. One alternative is to assume that each service has equal weight. Another alternative is to calculate a price in monetary units for each service (see Chapter 5 for discussion of this issue). A third alternative is to derive weights based on a common "currency", for example in terms of hectares or units of carbon, where different physical measures are converted into a common measurement unit.

3.59 Using a set of weights two methods of aggregation to derive overall measures may be followed depending on the type of weights being used. The first method involves the construction of a composite index. This requires converting all physical flow measures into index numbers representing the changes between two periods – generally the first period is set equal to 100. Then all numbers in a period are multiplied by the relevant weight to form an average index number value for that period. In the first or base period the average will equal 100. In effect different rates of change in the various service flows are given different levels of significance.

3.60 The second method involves the summation of observations that have been converted into a common unit of measure. An example of this is the use of prices to convert physical measures to monetary values. The monetary values of each service can then be summed to provide an aggregate measure.

3.61 Clearly, the derivation of aggregates involving a number of different ecosystem services depends heavily on the choice of weights. Without a robust rationale for the chosen set of weights, the ability to interpret the resulting aggregates will be limited. It is possible to test the robustness of the weights themselves through sensitivity analysis (i.e. testing the variation in aggregate values in response to variations in the weighting patterns). However, this should not be seen as a substitute for understanding the conceptual implications of choosing a particular type of weights. This is especially the case when considering the use of prices.

3.62 Beyond the choice of weights the other significant issue in aggregation across different ecosystem services is the extent to which the measured ecosystem services provide a complete coverage of all ecosystem services. Indeed, poor coverage may be a more significant barrier to meaningful aggregation that the selection of weights.

3.63 The aggregation of the same ecosystem service across multiple ecosystems will not generally require dealing with different measurement units. However, there are measurement challenges relating to the extent to which an ecosystem service can be considered to be of a consistent character and quality across different spatial areas. If an ecosystem service has been measured in each area and is considered to be of consistent quality then aggregation is straightforward. However, often in ecosystem services measurement it is necessary to estimate flows of ecosystem services using estimates from various sites and then to use techniques of benefit transfer (discussed in Chapter 2) to provide estimates for other areas. In these cases it is assumed that differences in quality of ecosystem services between areas are taken into account by adjusting for any variations in ecosystem characteristics.

3.64 The aggregation of ecosystem services across different services and multiple spatial areas should take into consideration the issues of weights and benefit transfers that have been described above.

3.5 Measuring ecosystem services

3.65 This section provides a general discussion on the measurement of ecosystem services in physical terms including some consideration of which ecosystem services may be the focus of measurement given that it is not possible to identify and define all ecosystem services. An annex describes potential approaches to the measurement of a range of ecosystem services (see Table 3.4 below) in physical terms in order to assist compilers in commencing work on the measurement of ecosystem services and to better explain the measurement concepts.

Table 3.4 List of selected ecosystem services described in annex

Name of ecosystem service	Description of ecosystem service	Corresponding benefit
Provisioning Services		
Services for crop production	Abstraction of soil water, nutrient uptake, pollination for the growing of crops, etc	Crops can be consumed directly or further processed.
Fodder for livestock	Rangelands provide fodder (grass, herbs, leaves from trees) for livestock	Livestock products (including animals, meat, leather, milk)
Raw materials including wood and non-timber forest products	Ecosystems, in particular forests, generate stocks of wood and non-timber forest products that may be harvested. Non-timber forest products include for instance rattan, various food products, genetic materials, ornamentals, and pharmaceutics.	Firewood, logged timber, non-timber forest products.
Fish and other aquatic and marine species from marine and inland waters	Marine and other aquatic ecosystems provide stocks of fish and other species that can be harvested.	Fish and other species can be consumed or further processed.
Water	Ecosystems filter and store water that can be used as raw material for drinking water production	Drinking water
Regulating Services		
Carbon sequestration	Ecosystem sequester and store carbon	Climate regulation
Air filtration	Trees can filter particulate matter from ambient air	Cleaner air
Flood protection	Ecosystems regulate river flows and can provide a barrier to floods	Protection of properties and lives
Cultural services		
Providing opportunities for tourism and recreation	Ecosystems present physical space and landscape features people enjoy, to watch or undertake activities in (hiking, cycling)	Recreational benefits

Provisioning services

3.66 Provisioning services should be the most amenable to measurement as many of the indicators relate to currently measured aspects of economic activity. At the same time, defining the boundary for cultivated crops and other plants may mean that a range of additional information is required in order to measure flows related to these cultivated resources.

Regulating services

3.67 Typically, regulating services involve a process regulated by the ecosystem that provides a non-SNA benefit to society and individuals in the form of lowering the risks of certain negative outcomes (such as polluted air). However, typical for this category of services is that a range of conditions and factors need to be in place before a benefit is received. Thus, the processes regulated by the ecosystem only generate a benefit - and therefore an ecosystem service - in situations where the ecosystem processes affect people. For instance, air filtration by vegetation only materialises as an ecosystem service if there is air pollution in the atmosphere that the vegetation is absorbing <u>and</u> if there are people living nearby that benefit from a lower concentration of air pollutants.

3.68 These other conditions and factors are called, for the purpose of SEEA Experimental Ecosystem Accounting, ‘enabling factors’. These enabling factors differ for the various regulating services. Note that these enabling factors are typically not an attribute of the ecosystem, and they are not reflected in measures of ecosystem capital. Nevertheless, these factors need to be understood, quantified and recorded before physical and monetary quantification of the ecosystem service can take place.

3.69 The delivery of regulating services is commonly and increasingly affected by land use choices made by economic units and society generally. At a local level the delivery of regulating services may be affected negatively by the removal of vegetation, for example. Equivalently, the delivery of regulating services may be enhanced by the planting of vegetation or the protection of existing vegetation. Thus, while the regulating services themselves are generated from ecosystem processes, the extent of their delivery can be materially affected by human activity.

Cultural services

3.70 Cultural services are more difficult to define than provisioning and regulating services since they reflect the nature of human relationships with ecosystems rather than more direct extraction of resources or use of ecosystem processes. At the same time there are some cultural services that are quite obvious, particularly tourism and recreation services, and the benefits that arise from these services are often an important part of economic activity.

3.71 For those cultural services that are not within scope of the SNA production boundary, the aim is to measure the amenity or utility that people derive from the landscape. For many people, particularly indigenous peoples, this may be strongly spiritual and cultural. In general terms, the extent of these services will be a function of human access to the ecosystem (perhaps based on the number of people interacting with the ecosystem, either directly or remotely) and the quality of the ecosystem and surrounding landscape.

Setting priorities for measurement of ecosystem services

3.72 In piloting ecosystem accounting at the national scale, it may be most feasible to initially select a limited rather than a comprehensive set of ecosystem services for inclusion in ecosystem accounting exercises. The potential feasibility to measure ecosystem services at the national scale, both in physical and in monetary terms, differs strongly between different ecosystem services. These differences occur due to differences in data availability, different methodological constructions, and different complexities related to scaling up and aggregating physical and monetary units associated with ecosystem services. In addition, there may be different policy priorities for analysing ecosystem services.

3.73 To facilitate the selection process of ecosystem services in ecosystem accounts, a list of criteria for ranking ecosystem services with regards to their potential suitability for inclusion in ecosystem accounting is presented in Table 3.5 below. The applicability of the criteria will differ between countries and the list should be seen as indicative only.

Table 3.5 Criteria for prioritization of ecosystem services for accounting purposes

	Criterion	**Brief explanation**
Environmental Concerns		
1	Sensitivity of the service to changes in the environment, including from anthropogenic stressors.	Consideration may be given to services that are sensitive to environmental change / well reflect changes in natural capital stocks.
2	Likelihood of irreversible loss of ecosystem services including by the supplying ecosystem being pushed past a significant threshold and out of its “safe operating range”.	Consideration may be given to services that are generated from ecosystems that are generally understood to be close to significant environmental thresholds.
Policy context		
3	Possibility to influence environmental and/or economic policy and decision making (decision making context)	Consideration may be given to services that can relatively easily be influenced by decision making in order to have maximum relevance for policy making.
4	Economic importance of the ecosystem service.	Consideration may be given to those services that generate the highest economic benefits.
Data and methods		
5	Availability of broadly accepted methods for analyzing ecosystem services supply in physical terms at a high aggregation level	Consideration may be given to services for which broadly accepted modelling / quantification techniques are available.
6	Availability of broadly accepted methods for analyzing ecosystem services supply at a high aggregation level in monetary terms	Consideration may be given to services for which broadly accepted valuation approaches are available.
7	Availability of data for measuring ecosystem services in physical terms	Producing national level accounts will often require scaling up estimates of ecosystem services to a national level based on underlying spatial data. Both point-based data and spatially explicit data (e.g. land cover, soils, water tables, ecosystem productivity, etc.) are required to analyse a service at the national level.
8	Availability of data for measuring ecosystem services in monetary terms	
9	Plans to generate new data on ecosystem services supply	A firm intent or high likelihood that new environmental monitoring will provide essential data.

3.74 Environmental concerns, data availability and policy contexts will differ in each country, hence the selection of ecosystem services for ecosystem accounting will differ. In general, from a methodological and data perspective, often most feasible for ecosystem accounting are the provisioning services including water supply, since the benefits arising from these ecosystem services are generally measured as part of standard economic accounts. A focus on these services is useful to understand the relative importance of the connection between economic activity and ecosystems.

3.75 As part of broadening the coverage of ecosystem services measurement two areas that may be considered for particular focus concern water and carbon.

3.76 Data on water resources is often available, in particular regarding the production volumes of drinking water and to some extent irrigation water. However, the link between ecosystem management and water provisioning is less clear, with regards to such aspects as water purification in aquatic ecosystems or in the soil, water storage in ecosystems in upper watersheds, etc. Given the economic importance of water supply and the declining water resources in many parts of the world, including this service in ecosystem accounts may be a priority in many countries. A challenge is to better understand, in particular at high aggregation levels, the infiltration, purification and storage processes involved.

3.77 Recent years have seen a strong increase in interest in the carbon related ecosystem services of carbon sequestration and the storage of carbon. There is a large amount of research on-going aimed at quantifying these services at different scales, from local processes to national stocks and flows. The development of REDD (Reduced Emissions from Deforestation and Degradation) market mechanisms means that there is also, increasingly, information available on markets related to carbon. Given the broad interest and the increasing availability of methods and data relevant for this service, this service has a high potential for inclusion in ecosystem accounts.

3.78 A challenge with regard to these ecosystem services is to account for both the storage and the sequestering of carbon. Storage and sequestering are not aligned. A high carbon stock may mean that sequestration is limited because the vegetation is close to its maximum biomass under the ecological conditions pertaining in the particular area. A low carbon stock may mean that there is scope for additional sequestration (e.g. in a recently cut forest with intact soil fertility), but this does not need to be the case (e.g. in a desert).

3.79 It should be noted however, that although scientific methods and data are relatively well developed for this service, this does not equally apply to all ecosystems, with relatively much data available for forests, and relatively few data for lakes and coastal systems. There may also be data and/or methodological constraints related to analysing carbon sequestration in degraded forests and in forest/landscape mosaics. Further discussion relating to accounting for stocks and flows of carbon is presented in Chapter 4.

Chapter 4: Accounting for ecosystem assets in physical terms

4.1 Introduction

4.1 ***Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.*** Ecosystem assets are measured from two perspectives. First, ecosystem assets are considered in terms of *ecosystem condition* and *ecosystem extent*. Second, ecosystem assets are considered in terms of *expected ecosystem service flows*. In general terms, 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.

4.2 There will not be a neat or simple relationship between these two perspectives. Rather the relationship is likely to be non-linear and variable over time. Fortunately, for the purposes of the SEEA Experimental Ecosystem Accounting, it is not necessary to build complete ecosystem models and measure every possible stock and flow. Rather, what is needed is to identify the most relevant aspects of ecosystem assets from the perspective of providing aggregated information for measuring trends and comparing ecosystem assets for policy and analytical purposes.

4.3 With this in mind, the approach outlined here involves (i) a decomposition of ecosystems into relevant characteristics, and (ii) an assessment of each characteristic in the context of the ecosystem as a whole. From this set of information, conclusions may be drawn about the overall condition of the ecosystem and its capacity to deliver ecosystem services based on expected patterns of ecosystem use. In addition, using information on flows of ecosystem services as described in Chapter 3, expected ecosystem service flows based on expected patterns of ecosystem use can also be estimated. Assessments of ecosystem degradation and ecosystem enhancement can be made using information on ecosystem condition and extent, and expected ecosystem service flows.

4.4 The challenge in applying this approach is to identify the appropriate characteristics and then to determine the relevant indicators. In particular, it is important not to lose sight of the fact that ecosystems function by all components working together and it is not necessarily a simple case of adding together an assessment of each characteristic.

4.5 This chapter outlines ways in which this indirect approach to the assessment of ecosystem assets may be carried out within an accounting structure. In Section 4.2 the main concepts used in ecosystem asset accounting are defined. In Section 4.3 the steps required to compile information on ecosystem assets are described including discussion on the aggregation of various indicators. The final two sections summarise accounting for two specific aspects of ecosystem asset accounting where measurement is more advanced – accounting for carbon (Section 4.4) and accounting for biodiversity (Section 4.5). Additional material on these topics is included in an annex.

4.2 General approaches to assessing ecosystem assets

4.6 The assessment of ecosystem assets is considered to encompass measurement of three key concepts: ecosystem condition, ecosystem extent, and expected ecosystem service flows. These concepts were introduced in Chapter 2. This section provides additional discussion of the relevant concepts in combination with approaches to measurement. There are strong relationships between all three concepts but for the purposes of exposition a distinction is made between the measurement of ecosystem condition and extent on the one hand and expected ecosystem service flows on the other.

4.2.1 Assessing ecosystem condition and extent

4.7 Assessment of ecosystem extent generally focuses on land cover although the accounting will be dependent on the definition of the spatial areas used for accounting. In this regard most focus will be on determining areas and changes in areas of various LCEU (e.g. forests, wetlands, etc).

4.8 Measures of ecosystem condition are compiled in two stages. First, a set of relevant key characteristics such as water, soil, vegetation, biodiversity, carbon, nutrient flows, etc are selected and various indicators concerning these characteristics are chosen. Generally, there will not be a single indicator for assessing a single characteristic.

4.9 The selection of characteristics and indicators should be made on scientific basis such that there is an overall assessment of the qualities of the ecosystem such as its resilience, vigour and configuration. Thus, movements in the indicators should be responsive to changes in the resilience, vigour and configuration of the ecosystem as a whole.

4.10 Where there is a strong understanding of the various processes operating within an ecosystem it may be possible to identify specific indicators (e.g. measures relating to a specific critical species) that can represent the overall condition of an ecosystem asset. Such proxy measures may be of particular use in providing indicators of change in ecosystem assets that are suitable for high-level ecosystem accounting purposes.

4.11 In the second stage of measurement, the indicators are related to a common point in time. The chosen point in time reflects a reference condition. There are a number of conceptual alternatives available to determine a reference condition. One approach from the perspective of accounting is to measure changes in condition from the beginning of the accounting period. Thus, when compiling accounts for any given accounting period, the measure of change in condition should refer to the change from the beginning of the period to the end. This reference condition is sufficient for accounting purposes but is limited in providing an assessment of the relative condition of multiple ecosystem assets since all are assumed to have the same condition at the beginning of the period.

4.12 Alternatively, a reference condition of particular importance for ecosystem accounting relates to the degree of human influence within an ecosystem. This may also be expressed as a condition reflecting an ecosystem which is relatively undisturbed or undegraded, or should reflect a situation in which the ecosystem is in relative stability. For example, long standing agricultural areas may be considered to be ecosystem assets that are relative stable in terms of significant recent human influence.

4.13 A particular benefit of using reference conditions is that ecosystems that are naturally more structurally diverse or species rich (e.g. tropical rainforests) are not necessarily assessed as having higher condition compared to ecosystems that are naturally less structurally diverse or species rich (e.g. Arctic tundra).

4.14 Where all of the relevant indicators are normalised to the same point in time (usually by setting the values of the indicators equal to 100 at that time) it is possible to make an effective comparison of changes in the ecosystem as a whole relative to the reference condition. Further, by using the same point in time for multiple ecosystem assets, it is possible to make assessments of the relative condition of different ecosystem assets. In this regard it is likely to be most relevant to select a point in time before significant patterns of recent landscape change were in evidence. Selecting more recent periods as reference conditions would effectively normalise ecosystem assets that may range from relatively natural to relatively human influenced.

4.15 While reference condition accounting leads to the recording of ecosystem condition scores between 0 and 100, these scores cannot be used to infer whether the condition of the ecosystem is good or bad. Ecosystem condition may be assessed independently of the use of an ecosystem but, *a priori*, any given level of condition is not necessarily good or bad.

4.16 In this context it is relevant to distinguish a reference condition from what may be regarded as a target condition. A target condition is one that is determined as a function of economic, environmental and social considerations and reflects an explicit or implicit preference for a particular use of an ecosystem. Ecosystem accounting does not involve the use of target conditions. The use of a reference condition therefore does not imply that all ecosystems should, ideally, have a condition score of 100. Rather a reference condition provides a comparison point that can be scientifically assessed over time.

4.17 Most focus in condition accounting is on changes in condition and extent over time rather than the actual condition score. However, while the actual ecosystem condition may not be a key indicator in some circumstances, there may be known thresholds in ecosystem condition such that, where the condition of particular characteristics falls below relevant thresholds, the whole ecosystem may be in danger of collapse. Thus at high degrees of human influence, the actual condition scores may be of particular relevance. Measures of ecosystem condition thus permit the consideration of the resilience of ecosystems.

4.18 Measures of changes in ecosystem condition and extent provide an indirect measure of intra- and inter- ecosystem flows since changes or disruptions in these ecosystem flows, for example due to changes in land use within an ecosystem, will be reflected in measures of ecosystem condition. Measures of ecosystem condition and extent should therefore take into account relationships and dependencies between ecosystem assets.

4.19 It is noted that there may be some overlap between measures of ecosystem extent and ecosystem condition in the sense that at certain scales of analysis, changes in extent may also be considered to be a part of measuring overall changes in ecosystem condition. At the same time, it is not considered that measures of changes in ecosystem extent can be used as a substitute for measuring changes in ecosystem condition.

4.2.2 Assessing expected ecosystem service flows

4.20 The second perspective on ecosystem assets focuses on assessment of the capacity of an ecosystem asset to generate an expected combination (or basket) of provisioning, regulating and cultural services from an ecosystem asset. Because the generation of some ecosystem services involves the extraction and harvest of resources, and since ecosystems can regenerate, it is necessary to form expectations on the amount of extraction and the amount of regeneration that will take place, and on the overall "sustainability" of human activity in the ecosystem.

4.21 Moreover, expected ecosystem service flows are dependent upon assumptions regarding future use patterns. In general there will be differences between current use patterns (e.g. where a fishery may be "over-fished") or alternative use patterns (e.g. fishing at a sustainable yield).

4.22 For accounting purposes a specific basket of ecosystem services based on current patterns of use must be considered. At the same time, the same framework can be used to organise information for various scenarios and alternative land uses. In this context it is also possible to develop scenarios of ecosystem asset use that "optimise" the flow of ecosystem services from a given ecosystem asset. However, the development of optimised scenarios is not the purpose of ecosystem accounting in the SEEA.

4.23 There are generally relationships between the condition of an ecosystem asset, its pattern of use, and the expected basket of ecosystem services. Thus while ecosystem condition may be assessed without considering measures of ecosystem services, the measurement of ecosystem assets in terms of their capacity to generate ecosystem services must involve assessment of ecosystem condition.

4.24 It is not necessarily the case that ecosystems with relatively lower condition will generate fewer ecosystem services. However, there is likely to be a close relationship between reductions in condition on the one hand, and the capacity of an ecosystem to generate ecosystem services sustainably on the other. At the same time, a change in condition may lead to a decrease in the capacity to supply some services, but an increase for other services.

4.25 It is through the lens of ecosystem services that it is possible to make the connection between ecosystem condition and extent, the benefits obtained, and broader measures of economic and human activity. Thus measurement of expected ecosystem service flows is important in the consideration of trade-offs between ecosystem services and, more broadly, between alternative land uses. Because of the general framework in which ecosystem services sit (see Figure 2.3) this expected flow perspective on the measurement of ecosystem assets can be combined with a broader assessment of both ecosystem services and abiotic services that may be generated from a given spatial area.

4.2.3 Assessing changes in ecosystem assets

4.26 An important accounting objective is the measurement of changes in ecosystem assets, particularly ecosystem degradation and ecosystem enhancement. These are complex concepts since ecosystem assets may change for a variety of reasons both natural and human induced and the different perspectives on the measurement of ecosystem assets open up a number of considerations.

Ecosystem degradation and ecosystem conversions

4.27 In general terms, ecosystem degradation is the decline in an ecosystem asset over an accounting period. Ecosystem degradation will be reflected in declines in ecosystem condition and/or declines in expected ecosystem service flows. Since there may not always be a linear relationship between the condition of an ecosystem and the expected flows of ecosystem services, the measurement of degradation should involve the following two conditions:

(i) That ecosystem degradation covers only the decline in expected ecosystem service flow due to economic and other human activity - thereby excluding declines due to natural influences and events (e.g. forest fires or hurricanes)[13]

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

4.28 This approach to conceptualising ecosystem degradation is particularly relevant in situations where the extent of an ecosystem asset does not change over an accounting period, or alternatively, when the composition of an EAU in terms of areas of different LCEU does not change. However, where the extent and composition of an ecosystem asset changes (e.g. due to deforestation to create agricultural land) the consequences for ecosystem degradation are less clear. These types of changes are referred to as ecosystem conversions.

4.29 From one perspective, the use of an area of land for an alternative purpose may result in a decrease or an increase in expected ecosystem services flows. If it is the former then an argument may be made to call this decrease degradation. However, since an effect of ecosystem conversions is for there to be increases in some ecosystem services and declines in others, the comparison of expected ecosystem service flows may be difficult since it involves the comparison of two different baskets of ecosystem services.

4.30 An alternative approach in cases of ecosystem conversions is to focus only on changes in ecosystem condition in the area within the ecosystem asset that has been converted. Thus, it may be considered that ecosystem degradation occurs whenever an ecosystem conversion results in a lowering of ecosystem condition relative to a reference condition. Then, irrespective of the impact of a conversion on expected ecosystem service flows, it may be relevant to record ecosystem degradation to reflect an overall decline in condition due to human activity.

4.31 A third perspective on ecosystem degradation focuses on the more general question of whether the change in the extent and condition of an ecosystem is so significant that it is not

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

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

4.32 Overall, while there is a general recognition that ecosystem degradation reflects a decline in an ecosystem asset, the precise application of this concept may vary depending on the nature of the change in the ecosystem asset and on the scale of analysis. The suggestion for accounting purposes is to endeavour to record all of the various reasons for changes in ecosystem assets and, where possible, separate changes in ecosystem extent from changes in ecosystem condition. It is noted that changes in expected ecosystem service flows are likely to reflect both changes in extent and condition but differentiating these effects may be challenging.

Ecosystem enhancement and other changes in ecosystem assets

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

4.34 Other changes in ecosystem assets should also be accounted for. Changes due to natural regeneration and normal natural loss should take into account inter-ecosystem flows (both into and out of the ecosystem) and implicitly should reflect the ongoing intra-ecosystem flows since it is these flows which underpin the regeneration process. For some purposes it may be useful to explicitly account for certain inter-ecosystem flows to highlight dependencies between ecosystems (e.g. flows of water between ecosystems). It may be the case that reductions in inter-ecosystem flows reduce the capacity to generate some ecosystem services.

Other considerations in the measurement of changes in ecosystem assets

4.35 A particular feature of ecosystem assets is that they naturally regenerate. Regeneration means that they may provide the same ecosystem services over an indefinite length of time. Consequently, it is possible over the long term for an ecosystem to have no ecosystem degradation – i.e. the expected flow of a given basket of ecosystem services is unending.

4.36 Measurement of the degree of ecosystem regeneration should take into account normal annual variation in the generation of ecosystem services, for example due to wetter or drier years. It is noted that from an accounting perspective, even if the intended management of an ecosystem is such that there are ongoing flows of a given level of ecosystem services (e.g.

through the sustainable management of fisheries), it should not be assumed that the actual flow of services is equal to the intended level of services.

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

4.38 If, over an accounting period, the increases due to natural regeneration are greater than the reductions due to human activity, then ecosystem degradation should be zero and the excess of regeneration should be shown as an addition to ecosystem assets.

4.2.4 Links to standard asset accounting

4.39 The starting point for the approach in SEEA Experimental Ecosystem Accounting is the standard asset accounting model used to account for produced assets in the SNA and as applied to the measurement of individual environmental assets in the SEEA Central Framework.

4.40 The standard asset accounting model focuses on a single asset (most commonly a produced asset) and estimates an expected flow of benefits (in terms of capital services) that accrue to the user/owner of the asset over a given period of time (the asset life). The pattern of expected flows provides the basis for valuing the asset, determining flows of income and depreciation and assessing the way in which the asset contributes to production.

4.41 This standard model provides a strong starting point for ecosystem asset accounting but there are some fundamental differences in the nature of ecosystem assets that require extensions to the standard model to be introduced. There are four key distinctions between ecosystem assets and produced assets.

4.42 First, ecosystem assets can regenerate without human involvement. Produced assets must be created (produced) new each time.

4.43 Second, a single ecosystem asset may generate varying baskets of ecosystem services over a series of accounting periods. For produced assets, even if a single produced asset may be considered to generate multiple capital services, it is assumed that it generates the same set of capital services over its life even if the user of the asset changes and the asset is used in different industries. Thus a computer continues to provide computer services whoever uses the computer.

4.44 Third, the ecosystem services from an ecosystem asset may be used by a range of different users (enterprises, households, etc). In contrast, the capital services from a produced asset are used only by the economic owner of the asset. Typically, the capital services are simply an input into a production function internal to an enterprise that ultimately leads to the production of products. While the products may be consumed by multiple users, the capital services are consumed only by the enterprise itself.

4.45 Fourth, there is not a one-to-one relationship between the capacity of an ecosystem asset to generate ecosystem services and the actual use of ecosystem services in economic and other human activity. For produced assets their capacity to generate capital services is either fully used or assumed to be at a relatively stable level of use relative to capacity. Permanently underused produced assets are assumed not to be common over a business cycle whereas for ecosystem assets such situations can easily arise.

4.46 These four distinctions require the standard asset accounting model to be adapted for the purposes of accounting for ecosystem assets. These adaptations highlight some, often implicit, assumptions that are made in standard asset accounting that should not be made in an ecosystem asset accounting context.

4.3 Compiling ecosystem asset accounts

4.3.1 Introduction

4.47 Ecosystem asset accounts are intended to organise non-monetary information regarding the extent and condition of ecosystems, and expected ecosystem service flows. The number of related concepts requires that a large amount of information be integrated and the suggestions made in this section for accounting tables are intended to provide a starting point for experimentation in compilation rather than providing definitive methodological guidance. All of these ecosystem asset tables are designed to give a broad sense of the potential of ecosystem accounting to organise information across a range of areas and from multiple perspectives.

4.48 An important observation is that these tables to do not provide rows or columns related to aggregate measures of ecosystem assets. Defining ecosystem asset aggregates is problematic due to the need to define relationships between the various characteristics. This is discussed in Section 4.3.4. As a matter of compilation practice it is recommended that focus be placed first on the description and measurement of the relevant characteristics before consideration of aggregation.

4.49 From the statistical units model outlined in Chapter 2, the ecosystem accounting unit (EAU) is the most applicable unit for the measurement of ecosystem assets since it should be relatively stable in area over time. However, for the organisation of relevant information, it is likely to be most logical to measure and organise information on the basis of LCEU since the type of characteristics of interest and types of ecosystem service flow are likely to vary most significantly by type of LCEU.

4.3.2 Accounting tables for ecosystem assets

4.50 When compiling ecosystem asset accounts at a national level, i.e. across multiple EAU and various types of LCEU, it is likely to be most useful to develop a common set of data and indicators for particular ecosystem characteristics in different types of LCEU. Further, it is likely to become apparent that there are some characteristics of ecosystems, notably soil, biomass and water, that are common and essential in all ecosystems.

4.51 Given the spatial diversity and heterogeneity of ecosystems, ecosystem asset accounts will generally need to be developed in a GIS context. Although the specific datasets will need to be determined on a country basis, there are a number of basic resource accounts that are fundamental to ecosystem accounting and will typically need to be developed in each country. These include among others: (i) land accounts; (ii) carbon accounts; (iii) water accounts; (iv) soil and nutrient accounts; (v) forest accounts; and (vi) biodiversity accounts. A number of these accounts are described in the SEEA Central Framework.

Accounts for assessing ecosystem extent

4.52 To commence the process of assessing ecosystem assets a useful starting point is the organisation of information concerning ecosystem extent. Of particular interest in this regard are land cover accounts as described in Chapter 5 of the SEEA Central Framework. For ecosystem accounting purposes the definition of the categories of land cover should align with the definition of types of LCEU which may take into account factors other than purely land cover. Nonetheless the general guidance offered in the SEEA Central Framework provides a starting point for compilers in this area.

4.53 Many countries have a variety of land cover and related statistics and this information set is becoming more developed as remote sensing technology is increasingly applied in these contexts. It is recognised that ongoing international collaboration on the development of land accounts for the purposes of ecosystem accounting will be an important part of the development of the SEEA more generally.

4.54 A potential area of extension concerns the compilation of land cover change accounts. These accounts reconcile estimates of the area of certain land cover types between the beginning and end of an accounting period. The change between land cover types can be organised to highlight particular sources of change such as deforestation, urban expansion, etc. Such accounts may be of significant use in the derivation of measures of ecosystem degradation where the cause of the ecosystem change is of particular relevance. A land cover change account builds on the information contained in a land cover change matrix (as shown in SEEA Central Framework Table 5.6.4), which indicates only the changes in land cover over time rather than considering the human and natural causes of the change.

Accounts for assessing ecosystem condition

4.55 Depending on the characteristics of interest, assessment of ecosystem condition may benefit substantially from the development of basic resource accounts containing information on opening and closing stocks and changes in stocks for individual resources such as timber resources, soil resources, water resources, etc. Following the SEEA Central Framework all of this information can be structured in asset accounts.

4.56 Table 4.1 presents a basic resource account for water. It is structured to show opening and closing stocks of water resources and the additions and reductions in water resources over an accounting period. Similarly structured accounts can be compiled for other resource types. An important extension of the asset account structure for ecosystem accounting purposes is to record inter-ecosystem flows. These entries would require the development of resource accounts that are spatially specific – i.e. relating to a particular EAU – and information at this level of detail is likely to be of particular relevance in ecosystem accounting.

Table 4.1 Physical asset account for water resources (cubic metres)

	Type of water resource						Total
	Surface water				Groundwater	Soil water	
	Artificial reservoirs	Lakes	Rivers and streams	Glaciers, snow and ice			
Opening stock of water resources	1 500	2 700	5 000		100 000	500	109 700
Additions to stock							
Returns	300		53		315		669
Precipitation	124	246	50			23 015	23 435
Inflows from other territories			17 650				17 650
Inflows from other inland water resources	1 054	339	2 487		437	0	4 317
Discoveries of water in aquifers							
Total additions to stock	1 478	585	20 240		752	23 015	46 071
Reductions in stock							
Abstraction	280	20	141		476	50	967
for hydro power generation							
for cooling water							
Evaporation & actual evapotranspiration	80	215	54			21 125	21 474
Outflows to other territores			9 430				9 430
Outflows to the sea			10 000				10 000
Outflows to other inland water resources	1 000	100	1 343		87	1 787	4 317
Total reductions in stock	1 360	335	20 968		563	22 962	46 188
Closing stock of water resources	1 618	2 950	4 272		100 189	553	109 583

4.57 Although not shown in the SEEA Central Framework, there may be particular interest in the development of basic resource accounts for other biological resources – such as significant animal and plant species. For this information, there is likely to be a link to the development of accounts for biodiversity which is discussed in more detail in Section 4.5.

4.58 Table 4.2 provides a structure for organising information on ecosystem extent and condition for various LCEU within an EAU at the beginning or end of the accounting period. The characteristics that are shown are purely illustrative and will apply to the assessment of condition in different LCEU to varying degrees. It is recognised, for example, that there may be overlaps between the characteristics of vegetation and biodiversity, but in a systems context such overlaps are inevitable and hence there must be detailed consideration of the relevant bio-physical relationships in the selection of characteristics.

Table 4.2 Measures of ecosystem condition and extent at end of accounting period

	Ecosystem extent	**Characteristics of ecosystem condition**				
		Vegetation	Biodiversity	Soil	Water	….
	Area	Indicators (e.g. Leaf area index, biomass, mean annual increment)	Indicators (e.g. species richness, relative abundance)	Indicators (e.g. soil organic matter content, soil carbon, groundwater table)	Indicators (e.g. river flow, water quality, fish species)	
Type of LCEU						
Forests						
Agricultural land						
Urban areas						
Inland water bodies						

4.59 For each characteristic there are likely to be a number of relevant indicators. For example, for water it may relate to pollutant content, number and diversity of fish species and the variability of river flows. Some indicators, for example river flows, may emerge from the basic resource accounts described above.

4.60 In some cases it may be possible to use some indicators to cover a range of characteristics. Of particular interest in this regard is the measurement of stocks and flows of carbon contained in biomass and soil which may be a powerful, broad indicator for assessing changes in ecosystem condition. Basic resource accounts for carbon follow the structure of asset accounts of the SEEA Central Framework. Section 4.4 describes the key aspects of accounting for carbon.

4.61 The selection of characteristics and associated indicators for the measurement of ecosystem condition should reflect scientifically valid measures. Consequently, to ensure the robustness of the information set it is important that the selection of characteristics and indicators be subject to a scientific accreditation process that can set measurement standards.[14] Such measurement standards are required in order to ensure the integrity of the accounting system. There are a range of relevant considerations in the establishment of scientific accreditation processes and the selection of characteristics and indicators. These are discussed in an annex.

4.62 Each of the indicators included in a table such as Table 4.2 are likely to be recorded in different measurement units. Consequently, the compilation of aggregates is not possible without the use of a common measurement unit or weighting procedure. Issues related to aggregation are considered in Section 4.3.4

Accounting for changes in ecosystem condition

4.63 Building on Table 4.2, which shows indicators of ecosystem condition at a point in time, it may be instructive to accounts may be compiled which show the changes in ecosystem condition over an accounting period. Following the broad structure of the asset accounts presented in the SEEA Central Framework, Table 4.3 shows a possible asset account for ecosystem condition for a single EAU. It is assumed that there are no changes in extent for any of the constituent LCEU. As for Table 4.2, the indicators used in Table 4.3 are likely to be in different measurement units.

4.64 Determining the estimates of the causes for the various improvements and reductions in condition may be difficult. Consequently, it may be useful to focus solely on net changes in condition over an accounting period perhaps making distinctions between relatively small, medium and large net changes. This information, for individual indicators, may be effectively presented in maps with colouring coding related to relative size of the changes.

[14] When accounting in monetary terms, the standard unit of measure is the currency of the country. The use of this measurement unit ensures a consistency and coherence through the reporting across different variables (sales, profits, wages, etc). Such standard units of measure do not exist across the various physical measures hence the requirement for an accreditation of measurement.

Table 4.3 Changes in ecosystem condition for an EAU

		Characteristics of ecosystem condition				
		Vegetation	Biodiversity	Soil	Water	Carbon
Opening condition						
Improvements in condition						
	Due to ecosystem enhancements					
	Due to natural regeneration					
Reductions in condition						
	Due to extraction/harvest					
	Due to indirect human activity					
	Due to normal natural losses					
	Due to catastrophic losses					
Closing condition						

Accounting tables for expected ecosystem service flows

4.65 The final area requiring consideration is the measurement of expected ecosystem service flows. Table 4.4 provides a table for recording estimates of expected ecosystem service flows at a point in time for a single EAU. No aggregation is presumed and additional rows are required for each ecosystem service under consideration.

Table 4.4 Expected ecosystem service flows at end of accounting period

	Expected ecosystem service flows per year by LCEU			
	Forests	Agricultural land	Inland water bodies	…
Type of ecosystem services (by CICES)				
Provisioning services				
Regulating services				
Cultural services				

4.66 Perhaps the key issue on recording entries in this table is that it is likely to be most useful to compile entries in terms of expected flows of ecosystem services per year rather than in terms of absolute quantities. Further, for presentational purposes it may be sufficient to indicate only whether the flows per year are rising or falling in trends terms (perhaps through the use of arrows or "traffic light" representations).

4.67 In making the estimates of expected flows some allowance should be made for normal year to year variation in flows of ecosystem services for example due to drier or wetter years. The range of factors taken into account in the determination of "normal" may vary from ecosystem to ecosystem and over time.

4.68 The estimates in Table 4.3 rely on measures of ecosystem services and the formation of associated expectations. In turn, estimates of expectations require an understanding of the current mix of ecosystem services and an understanding of the impacts of changes in condition and extent on the ability to provide those ecosystem services in the future in the context of the expected patterns of use and current ecosystem structure.

4.69 In addition to these general comments, the following more specific comments in relation to particular ecosystem services are relevant noting that the type of indicators required to reflect the capacity of the ecosystem to supply ecosystem services as a function of ecosystem condition and extent may differ strongly for provisioning, regulating and cultural services.

4.70 For provisioning services, indicators need to reflect both the available stock that can be harvested of the service in question, for instance the standing stock of timber in an ecosystem, and the regeneration or growth rate for these stocks (for instance the mean annual increment of timber). In turn, the regeneration or growth rate is dependent on the overall condition of the ecosystem. For instance, forests that are affected by soil degradation are likely to have a lower regeneration rate. However, establishing the specific link between regeneration and overall ecosystem condition is not straightforward, a range of different variables and complex ecosystem processes are generally involved. Since these factors differ with ecological and climatic conditions, countries will need to establish the relationship between ecosystem condition and extent, and the capacity to supply ecosystem services for the ecosystems in their countries. Such assessments will normally require the involvement of multidisciplinary expertise, for instance specific knowledge of forestry and forest ecology in the case of determining capacity to supply timber over time.

4.71 Regulating services are related to ecosystem processes, and there is no harvest or extraction involved. Often, regulating services can be linked to specific ecosystem characteristics, even though the sustained supply of services (as in the case of provisioning services) depends on the functioning of the ecosystem as a whole. For instance, air filtration involves the capture of air pollutants by vegetation, and the capacity of the ecosystem to trap air pollutants is related to its Leaf Area Index, i.e. the total surface area of leaves, expressed in m^2 per hectare. The Leaf Area Index is influenced by degradation or rehabilitation of the ecosystem (e.g. changes in species composition, or in crown cover), but is not necessarily related to the naturalness of the vegetation.

4.72 Typical for regulating services is that the relationship between ecosystem assets and ecosystem services often has a spatial aspect. For instance, the ecosystem service air filtration only arises when there are people living in the area where air quality is improved. Likewise, the service flood protection (e.g. by a coral reef or mangrove forest) only arises if there are people living nearby, or there is infrastructure in the zone at risk from flooding. An exception in this case is carbon sequestration, since the impact of one unit of carbon sequestered on the global climate is the same regardless wherever the sequestration takes place?

4.73 Regulating services will generally have a high spatial variability. For instance both marine flood risk and the mitigation of flood risk by a protective ecosystem vary as a function of local topography and distance from the sea. The spatial aspect of regulating services means that the generation of regulation services is best measured in a GIS context. In a GIS, the processes and/or components of the ecosystem that support the supply of regulating services need to be recorded, as well as the relevant features of the physical or socio-economic environment in which the service is generated. The required resolution depends on the specific ecosystem service and on data availability.

4.74 Changes in the condition and extent of the ecosystem may or may not lead to changes in the capacity to supply regulating services, depending on which specific ecosystem components or processes are affected. For instance, extinction of a rare, endemic species in a forest may affect cultural services but, unless this species was important for ecosystem functioning (e.g. a non-substitutable pollinator of specific tree species), it would not affect the air filtration (LAI) or the flood protection service provided.

4.75 Cultural services are highly varied in terms of the type of services generated and the link between the services and the ecosystem assets. Recreational services are related to the attractiveness of an area, which is a function of for instance landscape, vegetation, wildlife, visitor facilities, presence of walking trails, etc. The actual number of people that visit an area is a function of both its attractiveness and the demand for recreation (which in turn is related to for example population density, income levels, and perhaps to the availability of alternative tourism destinations). Degradation of an ecosystem, or investments in restoration of an ecosystem (reforestation, construction of walking trails, etc.) is reflected in the attractiveness, but not necessarily in the level of actual service provided (i.e. the actual number of visitors). Note also that recreation and tourism may not be necessarily related to biodiversity or ecosystem quality. Many visitors enjoy scenery or the presence of a beach rather than specific ecosystem attributes.

4.3.4 Aggregation in ecosystem asset accounting

4.76 The aggregation of indicators in the context of ecosystem asset accounting is focused on aggregate measures of ecosystem condition and expected ecosystem service flows. Measures of ecosystem extent are all described in a common unit of area, generally hectares, and hence the aggregation of extent measures is not complex.

4.77 The approaches to the aggregation of expected ecosystem service flows are analogous to the aggregation of ecosystem service flows in a single accounting period as discussed in Chapter 3. The primary difference is that different weighting patterns between ecosystem services may be relevant to account for a changing relative importance of ecosystem services over time that may be incorporated into the estimates of expected service flows, but which is not relevant in the case of a single accounting period. This difference applies even where the expected ecosystem service flows are expressed in terms of rates per year.

4.78 The approaches to the aggregation of ecosystem condition are somewhat different. Depending on the number of indicators it may be possible to apply a technique suggested for ecosystem services involving the conversion of the indicators to a common “currency”, for example in terms of hectares or units of carbon. As the number of indicators increases this approach may be less tractable.

4.79 Another approach is to normalise all indicators of ecosystem condition for a given reference condition at a particular point in time. This is the second stage in the measurement of ecosystem condition as described earlier in this chapter. While it is possible to use the beginning of the accounting period as a reference condition, for the majority of ecosystem assets, science uses a pre-industrial benchmark to set the reference condition. Relevant examples include the measures of water quality in the European Water Framework Directive and measures of threatened species in the assessment of biodiversity.

4.80 Following selection of the time of the reference condition, estimates are needed for each indicator for each characteristic at that point in time. When necessary, the values of the indicators at the reference condition may be determined through use of reference sites or through the use of models of biophysical condition. Then all observations in the reference period are set equal to 100 and current period condition score can be determined based on changes in the indicator.

4.81 In theory, provided the selection of characteristics and indicators is scientifically robust and the same reference condition is used for all indicators, an overall assessment of ecosystem condition can be made by considering the actual condition scores for the various indicators. While there is a clear logic behind the use of the reference condition approach to aggregate within and across ecosystems, the approach requires testing at this scale as it is generally applied for multiple indicators relating to particular characteristics (e.g. biodiversity) rather than across multiple characteristics.

4.82 Overall, some aggregation possibilities are available that are conceptually appropriate and aligned with the general accounting framework. However, further research and development is required in the area of aggregation of ecosystem asset related measures in physical terms. Aggregation for ecosystem accounting in monetary terms is discussed in Chapters 5 and 6.

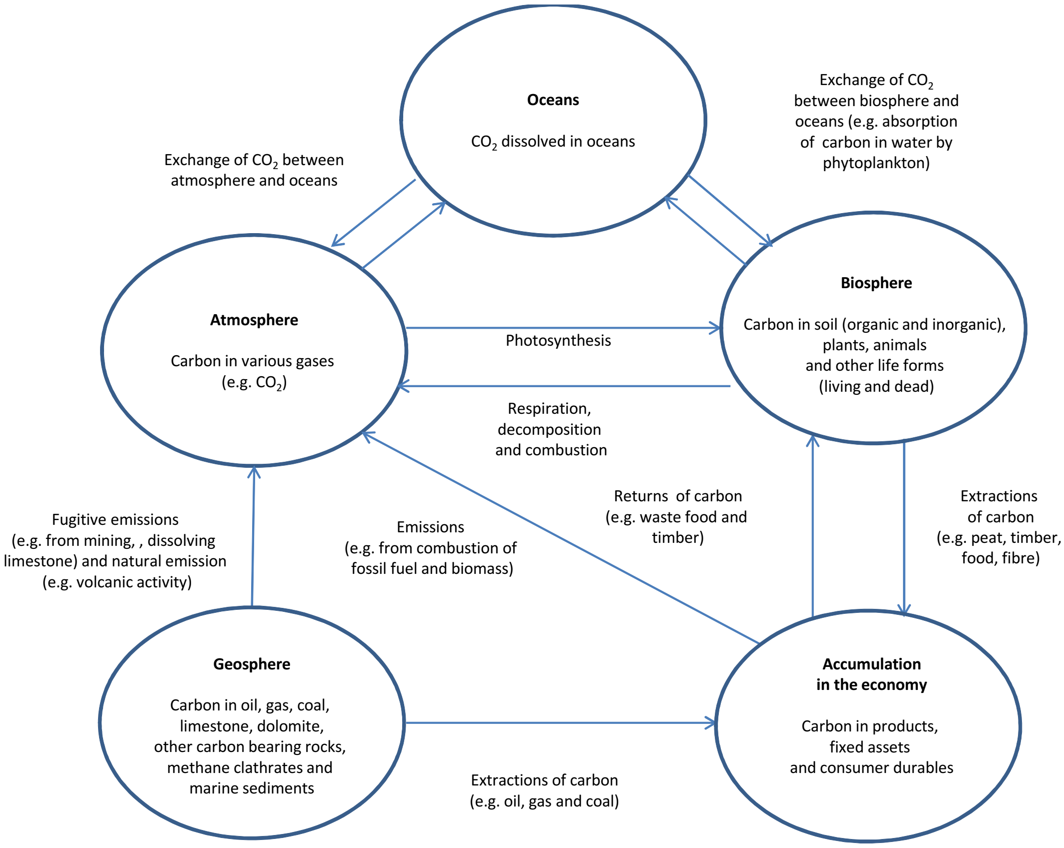
4.4 Accounting for carbon

4.4.1 Introduction

4.83 The extensive role of carbon in the environment and the economy requires a comprehensive approach to measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon from the perspectives of the geosphere, the biosphere, the atmosphere, oceans and the economy. Figure 4.4.1 below presents the main elements of the carbon cycle. It is these stocks and flows that give the underlying context for carbon accounting. Of particular relevance is that there are qualitative differences between the different stores of carbon. Carbon accounting and ecosystem accounting more generally must take these differences into account.

4.84 Applying the SEEA accounting principles of completeness and consistency and the SEEA Central Framework's approach to accounting for residual flows, carbon stock accounts record the stock changes from human activities at any point along the chain: from their origin in the geosphere and biosphere to changes in the various anthropogenic stocks (e.g. inventories of oil in storage; concrete in fixed assets; wood and plastic in consumer durables; solid waste – i.e. residuals that remain in the economy in controlled land fill sites; imports and exports) and as residuals to the environment, including emissions to the atmosphere. Carbon stock accounts can assist in informing of the implications of policy interventions at any point along the carbon cycle.

Figure 4.4.1. The main elements of the carbon cycle



4.85 The information presented has many uses for policy makers and researchers. Carbon stock accounts complement the existing flow inventories developed under the UNFCCC (UN Framework Convention for Climate Change) and the Kyoto Protocol. The carbon stock accounts presented here also align with the accounting approach of REDD (Reducing Emissions from Deforestation and Degradation).In addition, carbon stock accounts can provide consistent and comparable information for policies aimed at, for example, protecting and restoring natural ecosystems, i.e. maintaining carbon stocks in the biosphere. Combined with measures of carbon carrying capacity[15] and land use history, biosphere carbon stock accounts can be used to:

- investigate the depletion of carbon stocks due to converting natural ecosystems to other land uses;
- prioritise land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration or improved land management with their differing trade-offs against food, fibre and wood production, and;
- identify land uses that result in temporary carbon removal and storage.

[15] The mass of biocarbon able to be stored in the ecosystem under prevailing environmental conditions and disturbance regimes, but excluding human disturbance (Gupta and Rao 1994).

4.86 The information contained in carbon stock accounts can also be used more generally as part of the assessment of ecosystem assets and the measurement of ecosystem services. The following paragraphs provide an overview of the key considerations in accounting for carbon and additional detail is provided in an annex.

4.4.2 Carbon stock account

4.87 A structure for a carbon stock account is presented in Table 4.4.1. It provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and in particular the differences in the nature of particular carbon reservoirs. Opening and closing stocks of carbon are recorded with the various changes between the beginning and end of the accounting period recorded as either additions to the stock or reductions in the stock.

4.88 Carbon stocks are disaggregated to geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and soils). Geocarbon is further disaggregated into: oil; gas; and coal resources (fossil fuels) and rocks and minerals (e.g. carbonate rocks used in cement production, methane clathrates and marine sediments). Biocarbon is classified by type of ecosystem. At the highest level these are terrestrial, aquatic and marine ecosystems, and these are shown in Table 4.4.1.

4.89 The different reservoirs of carbon in the geosphere and biosphere differ in important ways, namely in the amount and stability of their carbon stocks, their capacity to be restored and the time required to do so. Different reservoirs therefore have different degrees of effect on atmospheric CO2 levels (Prentice et al. 2007). Carbon stocks in the geosphere are generally stable in the absence of human activity; however stock declines as a result of anthropogenic fossil fuel emissions are effectively irreversible.

4.90 The stability of the carbon stocks in the biosphere depends significantly on ecosystem characteristics. In natural ecosystems, biodiversity underpins the stability of carbon stocks by bestowing resilience and the capacity to adapt and self-regenerate (Secretariat of the Convention on Biological Diversity 2009). Stability confers longevity and hence the capacity for natural ecosystems to accumulate large amounts of carbon over centuries to millennia, for example in the woody stems of old trees and in soil. Semi-modified and highly modified ecosystems are generally less resilient and less stable (Thompson et al. 2009). These ecosystems therefore accumulate smaller carbon stocks, particularly if the land is used for agriculture where the plants are harvested or grazed regularly.

4.91 Structuring the carbon stock accounts to capture these qualitative differences between reservoirs is important because reservoirs with different qualities play different roles in the global carbon cycle. For given rates of fossil fuel emissions, it is the total amount of carbon and the time it is stored in the biosphere that influences the stock of carbon in the atmosphere.

Table 4.5.1 Carbon stock account

Gigagrams carbon (GgC)	Geocarbon					Biocarbon			Atmosphere	Water in Oceans	Accumulation in economy				TOTAL
	Rocks	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories *	Fixed assets	Consumer durables	Waste	
Opening stock															
Additions to stock															
Natural expansion															
Managed expansion															
Discoveries															
Upwards reappraisals															
Reclassifications															
Total additions to stock															
Reductions in stock															
Natural contraction															
Managed contraction															
Downwards reappraisals															
Reclassifications															
Total reductions in stock															
Imports and exports															
Imports															
Exports															
Closing stock															

*Excludes inventories included in biocarbon (e.g. plantation forests, orchards, livestock, etc)

4.92 A key aspect for carbon accounting is to understand the degree of human influence over particular ecosystems. In this it may be desirable to recognise varying degrees of human modification of the ecosystem and potentially introduce these aspects into a classification. Degrees of human modification may be structured to reflect, for example, natural ecosystems, semi-natural ecosystems, and agricultural ecosystems. Details on how these types of ecosystems may be defined are in the annex.

4.93 The row entries in the account follow the basic form of the asset account in the SEEA Central Framework: opening stock, additions, reductions and closing stock. Additions to and Reductions in stock have been split between managed and natural expansion. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account. Details on the types of additions and reductions described in the carbon stock accounts are included in the annex.

4.94 Various indicators can be derived directly from carbon stock accounts or in combination with other information, such as land cover, land use, population, and industry value added. The suite of indicators can provide a rich information source for policy makers, researchers and the public. For example, comparing the actual carbon stock of different ecosystems with their carbon carrying capacities can inform land use decision making where there are significant competing uses of land for food and fibre.

4.95 A key indicator that would emerge from the carbon stock account is what is commonly termed the ‘net carbon balance’ which is the stock of carbon remaining in all reservoirs, or a particular reservoir, at the end of an accounting period.

4.4.3 Links to other SEEA accounts

4.96 Carbon accounts are linked to the physical flow, environmental activity and asset accounts of the SEEA Central Framework, and in particular the energy and mineral resource and land cover accounts. They are also linked to the flows of ecosystem services presented in Chapter 3. Carbon stock accounts may also be used as one of the components in the assessment of the condition and capacity of ecosystem assets. Additional links are described in the annex.

4.97 The linking of the carbon stock account to the flow of ecosystem services, and in particular to the service of carbon sequestration, is of particular importance. In this, the total additions of stock in the biosphere shown in the stock account, would equate to the level of the flow of the carbon sequestration service. Particular attention might be given to natural and managed expansion of carbon stocks in the biosphere.

4.98 In relation to the assessment of ecosystem assets it is recalled that carbon in the biosphere is one of the fundamental components of living ecosystems. As such it must be considered in any assessment of ecosystem condition and expected ecosystem service flows. This may be done by reference to time (e.g. the time considered to be unaffected by industrial activity), some notion of carbon carrying capacity (e.g. the maximum theoretical amount of carbon that can be stored under prevailing environmental conditions and natural disturbance regimes in a particular area or ecosystem or in terms of contrasts between ecosystems (e.g. bare earth contains relatively little carbon compared to a natural forest).

4.5 Accounting for biodiversity

4.5.1 Introduction

4.99 Biodiversity or biological diversity is a fundamental component of ecosystems and underpins many ecosystem services (see Chapter 3). Human activity can drive changes in biodiversity, both directly (e.g. through the extraction of species via harvest of fish and timber) and indirectly (e.g. removal of habitat), and hence the level or quality of the ecosystems services able to be delivered. Understanding the relationships between biodiversity, ecosystems and the ecosystem services they provide, as well as quantifying the impact of human activity on biodiversity and key ecosystem services are the primary motivations for accounting for biodiversity.

4.100 In recognition of the importance of biodiversity to people there are several international agreements concerning biodiversity and the conservation of biodiversity. Perhaps the most important is the Convention on Biological Diversity (CBD)[16] which entered into force in 1993. The Convention has three main objectives: (1) the conservation of biological diversity; (2) the sustainable use of the components of biological diversity, and; (3) the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

4.101 Biodiversity accounts can be used to track progress towards policy targets such as those concerning the protection of threatened species or ecosystems (or habitats), the sustainable use of harvested species, the maintenance and improvement of ecosystem condition and capacity, and where the benefits of use of biodiversity accumulate. Such assessments can be enhanced by links to changes in land cover and land use. By making biodiversity accounts for particular spatially defined areas (EAU), the accounts on ecosystem services may be linked to the geographical extent and condition of biodiversity. If the areas (EAU) follow administrative or other boundaries for which there are economic or social data, then it is possible to highlight how human activities can cause changes in biodiversity.

4.102 At both national and sub-national scales, by linking biodiversity accounts with the land cover, land use and the environmental protection expenditure accounts of the SEEA Central Framework, the cost-effectiveness of expenditures on habitat and species conservation or returns on investment may be analysed. It is sometimes the case that the extent of land cover types, land use and other data on pressures are used as a proxy for the condition of biodiversity as the number and abundance of species changes in response to such variables[17].

4.103 This section summarises some of the key aspects of accounting for biodiversity including a description of the process of biodiversity loss and accounting for species. Additional detail and explanations are contained in an annex.

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[16] Secretariat of the Convention on Biological Diversity (2003). Convention on Biological Diversity http://www.cbd.int/convention/text/

[17] E.g. see Brooks et al (2002). Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16(4): 909-923 and; Alkemade et al, 2009.

4.5.2 Definition and description of biodiversity

4.104 Biodiversity is defined in the Convention on Biological Diversity as ‘the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and ecosystems’[18]. The scientific community has conceptualised biodiversity as a hierarchy of genes, species and ecosystems.

4.105 Species can be defined in a range of ways. They are commonly defined as a group of organisms capable of breeding and producing fertile offspring. However, this definition does not work well for some groups of organisms (e.g. bacteria). A range of definitions are available but the definition used ultimately depends of the nature of the organism of interest[19]. Species are classified according to the system of binomial nomenclature (i.e. genus and species) established by Linnaeus (1758), which continues to evolve[20].

4.106 The biodiversity accounts described below use species as the fundamental unit of observation for biodiversity. Land cover accounts, which may approximate ecosystems, are described in the SEEA Central Framework, while the extent and condition of ecosystems is covered earlier in this chapter. Accounting for genes has not yet been contemplated within the SEEA framework.

4.107 The processes contributing to biodiversity loss are many and varied and as such determining the most appropriate structures for biodiversity accounts to address this issue is difficult. However, some generic types of processes leading to changes in biodiversity at the ecosystem and species level can be identified for inclusion in the accounts.

4.108 At ecosystem level, biodiversity loss is characterised by the conversion, reduction or degradation of ecosystems (or habitats). Generally as the level of human use of ecosystems increases in extent or intensity, biodiversity loss increases.

4.109 Many species originally occurring in a particular area will decrease in abundance while at the same time some species, in particular those that benefit in disturbed habitats, increase in abundance, as a result of human interventions. That is, the species originally occurring are gradually replaced by those that are favoured by human influence, some of which may achieve large numbers (e.g. plague proportions). The extinctions of the original species are the final step in an often long process of gradual reductions in numbers. In many cases, local or national species richness (i.e. the total number of species regardless of origin) increases initially because of species introduced or favoured by humans[21]. Because of these changes ecosystems lose their regional endemic species and become more and more alike – a process described as “homogenisation”[22].

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[18] Convention on Biological Diversity, Article 2, Use of Terms.
[19] de Queiroz K., 2005. "Ernst Mayr and the modern concept of species". Proc. Natl. Acad. Sci. U.S.A. 102 (Supplement 1): 6600–7. (May 2005). doi:10.1073/pnas.0502030102
[20] See, for example, the International Commission on Zoological Nomenclature, http://iczn.org and; the International Code of Botanical Nomenclature (Vienna Code), http://ibot.sav.sk/icbn/main.htm
[21] This is the so-called “intermediate disturbance diversity peak”, Lockwood and McKinney, (2001). Biotic Homogenization. Kluwer, New York. 289p.
[22] Lockwood and McKinney, (2001). Biotic Homogenization. Kluwer, New York. 289p and Millennium Ecosystem Assessment (2005). http://www.maweb.org/en/Reports.aspx

4.5.3 Measurement of biodiversity

4.110 A wide range of techniques are used to measure biodiversity. It is not the intent here to provide a full review of these techniques but to note that biodiversity measurement is a specialist field, that different methods for assessing biodiversity provide varying levels of accuracy and precision, and that because of complexities of biodiversity measurement a focus is placed on selected indicators of biodiversity rather than accounting of all aspects of biodiversity.

4.111 Biodiversity indicators measure part of the system or capture a range of aspects of the system within single measures. Based on the recommendations of the 9th meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA9) the 7th Conference of the Parties (COP7) agreed on the list of provisional indicators for assessing progress towards the 2010 biodiversity target (COP decision VII/30, 2004)[23] that can be implemented worldwide, or at national or regional scales.

4.112 The four indicators concerning the state of biodiversity are:

(i) Trend in extent of selected ecosystems
(ii) Trend in abundance and distribution of selected species
(iii) Trend in status of threatened species
(iv) Change in genetic diversity

4.113 The first describes the remaining ecosystem types in terms of size, the second relates to the average quality of these ecosystem types (mean abundance of species characteristic of these ecosystems as compared to the reference condition), and the third shows the variability within the mean species abundance, focusing on those species that are threatened. Together these indicators reflect the degree of homogenisation, the core process of biodiversity loss as described above.

4.114 Accounts in physical terms (e.g. hectares) showing the area of different ecosystems in protected areas is a straightforward first step (i.e. using the land cover and land use accounts of the SEEA Central Framework) and these can also be linked to the environment protection expenditure (a response indicator). It is also necessary to account for the extent and condition of ecosystems outside of protected areas (i.e. the entire country), since in most countries much of the biodiversity exists outside of protected areas.

4.115 For some purposes more precise information about where, why and how the changes in ecosystem extent occurred are needed. This is of special importance if one is combine the inter and intra flows in order to combine both the measurements of changes in quality and the measurements of changes of extent in one common evaluation for policy priority purposes. To achieve this both extent and quality measures will have to refer to EAU.

4.116 The condition of biodiversity, as measured by species number and abundance can be measured directly. However, because this is costly to do for large areas, biodiversity condition is usually estimated using a range of data and methods, including modelling techniques based

[23] See http://www.cbd.int/doc/decisions/cop-07-dec-en.pdf

on information about land cover, land use, fragmentation, climate change and other pressures.[24].

4.117 At international and national levels the state of biodiversity can also be shown via composite indices. Examples of this approach for aggregate measurement of biodiversity include the Natural Capital Index[25], the GLOBIO Mean Species Abundance Index[26], the Living Planet Index[27], the Biodiversity Intactness Index[28] and the Norwegian Nature Index[29]. These composite indicators are the result of a long tradition in ecology of expressing complex changes in species abundance through indices.

4.5.4 Structuring information on species and groups of species

4.118 Species diversity can be measured by abundance and richness. Broad scale assessments of biodiversity are typically based on species richness or richness of endemic species. In this, the species occurring in particular areas are listed as present or absent to generate measures of species richness. These data are more readily available than abundance data and can be measured against the original number of species in the area. This type of assessment is often used but is more suitable for sub-national scale assessments (biodiversity "hotspots") and, which would detect regional shifts in distributions and local extinctions.

4.119 At a larger scale, these data can be insensitive to changes at the national level, and often difficult to interpret and relate to human activities. If used, indications of the species importance to region or elsewhere may be gained from other sources. For example if species detected in an area are included on the IUCN Red List of threaten species.

4.120 It is more useful if assessment of biodiversity of areas includes estimates of abundance. Abundance data are usually only available for a limited number of species. Abundance may be measured in absolute terms such as the total number of individuals of a species or a density per hectare. It can also be measured in broad classes related to absolute measures, for example very abundant, abundant, common, rare, and very rare. Abundance may also be measured in relative terms, in particular current abundance relative to the past (a benchmark or reference condition). If a species is less abundant now than in the past then it may be at risk of extinction. Different species exhibit different natural abundances: for example in mammals,

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[24] Scholes, R.J. and Briggs, R. (2005). A biodiversity intactness index. Nature, 434(3): 45-49. (3 March 2005) Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390.

[25] ten Brink, B.J.E. and T. Tekelenburg, Biodiversity: how much is left? The Natural Capital Index framework (NCI). in RIVM report 402001014. 2002: Bilthoven.

[26] Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390. Also see http://www.globio.info/home

[27] Loh, J., et al 2005. The living planet index: using species population time series to track trends in biodiversity. Philosophical Transactions Royal Society, Biological Sciences 360, 289-295, and; Loh, J.,2002. Living Planet Index 2002, World Wildlife Fund International: Gland, Switzerland.

[28] Scholes, R.J. and R. Biggs, 2005. A biodiversity intactness index. Nature. 434(7029): p. 45-49.

[29] Certain, G., O. Skarpaas, J-W. Bjerke, E. Framstad, M. Lindholm, J-E. Nilsen, A. Norderhaug, E. Oug, H-C. Pedersen, A-K. Schartau, G. I. van der Meeren, I. Aslaksen, S. Engen, P.A. Garnåsjordet, P. Kvaløy, M. Lillegård, N. G. Yoccoz, and S. Nybø. 2011. The Nature Index: A General Framework for Synthesizing Knowledge on the State of Biodiversity. PloS ONE 6 no. 4: e18930.

small rodents are naturally very abundant, while elephants other large slow breeding mammals occur in much lower abundances.

Species richness and species abundance accounts

4.121 Accounts may be prepared for individual species or groups of species. While accounts for individual species may be relatively few, some species are of particular interest, for example because they are harvested for food or have iconic values (the so-called charismatic mega-fauna), and hence accounts may be prepared for these species. Such accounts, for example for fish, are similar to those described in the SEEA Central Framework and are not described further here. Tables for species richness would be of a similar form to the table for species abundance described below.

4.122 Table 4.5.1 presents the general form of a species abundance account, in both absolute and relative terms of abundance. The account follows the general form of asset accounts in the SEEA Central Framework, with opening stock and closing stock. In this account a net change only is shown, but it would be possible to add rows showing the positive and negative changes that result from natural processes or human activity. The accounting period is one year.

4.123 The reference condition of species can refer to any time period, but ideally it should refer to an ecosystem with minimal human influence. Such a baseline can be difficult to establish but this allows the relative abundance of species to be compared between different species, and different ecosystems, within countries and between countries.

Table 4.5.1 Accounts for species abundance by Kingdom

	Animals								
	Mammals	Birds	Reptiles	Amphibians	Insects	Subtotal	Fungi	Protista	Plants
Opening population									
Closing population									
Net change									
Reference population									
Opening population as proportion of reference population									
Closing population as proportion of reference population									
Net change									

4.124 It is important that species from all Kingdoms (i.e. division of living organisms) should be included in the species abundance accounts to ensure the accounts are as representative as possible. However, in practice the species included in the accounts will need to be a representative sample from the Kingdoms as collecting data on the abundance of all species is resource intensive and some Kingdoms are better known than others (animals being the best known). The sample of species should include species that are of importance to the ecosystem being measured and priority should also be given to species that are known to be sensitive to human impacts (i.e. responsive to key drivers and pressures).

Accounts for threatened species (extinction risk)

4.125 The risk of extinction is a function of the natural population dynamics, distribution and abundance of species, environmental change and human activities directly or indirectly influencing population abundance. In this, the more widely distributed and abundant and the higher the reproductive rate of a species is, the less likely it is to become extinct. Some species are naturally rare, have limited distributions or low reproductive rates and hence are more susceptible to extinction. The IUCN Red List Categories[30] take into account these factors and others into account to determine the overall status of species.

4.126 Accounts showing the risk of extinction can be constructed using the status of species as defined by IUCN Red List categories and related criteria (Table 4.5.2). A structure for such an account and the definition of the relevant categories is described in the annex.

4.127 Threatened species accounts may be prepared for countries as a whole or for particular areas or ecosystems within countries. It should be noted that the threatened species accounts record only the presence or absence of species in a particular area.

4.5.5 Links between biodiversity accounts and other accounts

4.128 Data from biodiversity accounts becomes more useful when linked to other accounts of the SEEA Central Framework and to the ecosystem services described in Chapter 3. For the accounts in the SEEA Central Framework, links can be made to the land use account and to the environmental activity accounts. Biodiversity accounts may be prepared for countries as a whole or for particular areas or ecosystems within countries.

4.129 Socio-economic and environmental accounts can link key drivers and pressures to biodiversity loss, for example in terms of measures of energy use, carbon emissions and sinks, built up land and infrastructure, extraction of fish and timber (fisheries and forestry), agricultural expansion and intensity, climate change, fragmentation and nitrogen deposition and loads. In this context, land use, land use intensity and land cover accounts provide important information on the extent of ecosystem types and area lost by conversion. These kinds of integrated analysis will be easier to undertake if statistical units (e.g. major land cover types, forests, grasslands, etc.) can directly be linked to units and the aggregations of units in economic statistics. This requires that the basic economic units are spatially referenced.

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[30] IUCN-Species Survival Commission, 2001. Red List Categories and Criteria version 3.1. http://www.iucnredlist.org/documents/redlist_cats_crit_en.pdf

4.130 For ecosystem services, the species harvested directly for food, fibre, timber or energy, provide provisioning services. Changes in the abundance of species due to human extractive activities would be reflected in the species abundance and status. In particular, harvesting in excess of a species’ capacity to regenerate (i.e. unsustainable harvesting) would result in lower yields, reduced economic profit and a higher risk of extinction, and would be reflected in moving to higher risk categories in the species status account. Species that provide regulating ecosystem services, such as mangrove species (flood protection) and bees (pollination) can also be linked to the species and land cover accounts. For mangroves, the amount of ecosystem service would be a function of the location, extent and condition of mangroves, which could be derived from a land cover and land use account. For bees, the level of pollination service would be a function of the abundance of bees, which could be drawn from the species abundance account.

Chapter 5: Approaches to valuation for ecosystem accounting

5.1 Introduction

5.1 The valuation of ecosystem services and ecosystem assets is complex. The complexity exists because generally, ecosystem services and ecosystem assets are not traded on markets in the same way as other goods, services and assets. As a consequence, economic principles must be used to measure the prices that would have been paid for the various ecosystem services and assets. Valuation is therefore involves the estimation of "missing prices".

5.2 There are different conceptual approaches to valuation, and the valuation of ecosystem services requires detailed data on ecosystem uses and users. A question therefore is to what degree comprehensive valuation of ecosystem services for the purpose of ecosystem accounting, with an accuracy sufficient for accounting purposes, is feasible. Recognising the methodological difficulties related to ecosystem service valuation, this chapter provides a broad overview of potential approaches that may be used to explore the valuation of ecosystem services and ecosystem assets for the purpose of accounting. Specific attention is paid to the methodological complexities involved, and the issues that require further development before the monetary analysis of ecosystem services and ecosystem assets can be broadly applied in an accounting context (discussed in Chapter 6).A specific objective of the chapter is to enable compilers and analysts of ecosystem accounts to make decisions regarding valuation while being aware of the required assumptions and of the implications for interpretation.

5.3 The chapter is organised as follows. Section 5.2 outlines the general concepts of value in the context of ecosystem accounting. Section 5.3 provides a concise overview of the principles of valuation as they are applied in the SEEA and the SNA. Section 5.4 analyses approaches to pricing ecosystem services and ecosystem assets. Given that the primary motivation for valuation in the SEEA Experimental Ecosystem Accounting is - eventually - integration with the standard national accounts, this section also explores which valuation approaches are consistent with the SNA valuation principles. Finally, Section 5.5 describes a number of key issues related to the monetary valuation of ecosystem services and ecosystem assets in the context of ecosystem accounting that require further development, and provides a number of potential directions for further research.

5.2 Concepts of value

5.2.1 Ecosystem services in relation to public and private goods

5.4 Within a broad context of economic value it is relevant to consider ecosystem services in terms of their contribution to either (i) the value that accrues to individuals (private goods) and (ii) the value that accrues to society more broadly (public goods). Because of the different characteristics of private and public goods, different approaches to the estimation of relevant prices must be considered.

5.5 Provisioning services are typically private goods whereas many regulating and cultural services have a public goods character. Public goods involve the conditions of (i) nonexcludability, meaning that is not possible to deny people to benefit from the ecosystem service, and (ii) non-rivalry, meaning that one person's enjoyment of an ecosystem service does not diminish the availability of the service to others. Clean air is a typical example of a public good. Eco-tourism can be seen as a 'quasi' public good, to a degree it is non-rivalrous (assuming no over-crowding), but in principle it is excludable (e.g. by placing a fence around a particular site and charging entrance fees).

5.6 The price mechanism for the provision of public goods does not function well: consumers do not have an incentive to pay and producers do not have an incentive to supply. These market failures may reflect the nature of the production environment, for example the existence of increasing returns to scale and various externalities from production. Consequently, public intervention, most commonly through production by government units or through the definition and allocation of property rights, is needed to maintain or create an efficient allocation of such goods. Because public goods are not traded in a market, such goods require the application of non-market valuation methods. The discussion of these non-market valuation methods is the main focus of Section 5.4.

5.2.2 The motivation for valuation in ecosystem accounting

5.7 It is important to recognise that a number of motivations exist for valuation of ecosystem services and ecosystem assets. The different motivations point to different requirements in terms of coverage, methods and assumptions. Often, valuation is dismissed or utilised without a more careful consideration of the relationship between the purpose of analysis and the choice of valuation method. This section explains the key aspects that should be taken into account in determining whether to undertake valuation and how it should be done.

5.8 There are two primary motivations for undertaking valuation of ecosystem services and ecosystem assets. The first is the analysis of specific policy scenarios and the second is the integration of values related to ecosystems into accounting frameworks.

5.9 In the consideration of alternative policies it is common practice to value the various costs and benefits of different alternatives. Usually, in decisions made by governments at all levels, the assessments of costs and benefits must take into account not only the impacts on various individual enterprises and households but also on the broader community and, in the context of ecosystems, the broader environment. As is well known, these "social" aspects are not taken into accounting in the valuations provided by markets. Hence for the purposes of assessing policy choices (such as where to build a hospital, whether to install lighthouses, or whether to restore polluted wetlands) it is common practice to estimate the full social costs and benefits and hence take into account a broader range of factors than may be considered by individual economic actors. This analysis may extend to consideration of alternative tax and subsidy regimes, for example in assessing the economic implications of a chosen policy.

5.10 The integration of values of ecosystem services and ecosystem assets into accounting frameworks occurs at both the enterprise level and at the national level. At the enterprise level an increasing number of companies are undertaking exercises in the valuation of ecosystem services with the intent of better understanding the implications of their use of ecosystem services (which are usually unpriced) in relation to their standard measures of profit and loss.

5.11 At the national level, the integration of ecosystem valuations with standard national accounts may take a number of forms. First, it may relate to developing broader measures of the value of environmental assets than are obtained through the valuation of these assets based on the value of harvest and extraction. Second, it may relate to identifying the contribution in monetary terms of ecosystems to current measures of economic activity. Third, integration may relate to comparing flows of ecosystem services with economically measured flows in order to assess trade-offs when alternative land uses are being considered.

5.12 Related to the integration of ecosystems within national accounts is the desire to provide accessible measures of overall changes in ecosystem services and ecosystem assets. In this context valuation permits relatively straightforward aggregation of different stocks and flows which may be difficult when using only measures in physical terms. While valuation certainly facilitates the compilation of overall measures, it does involve a number of assumptions and measurement challenges.

5.13 For SEEA Experimental Ecosystem Accounting, the focus is on valuation that permits integration with the standard national accounts. The same considerations outlined in this chapter are likely to apply in the context of enterprise level accounting. For specific policy scenario assessment, different conclusions on the appropriateness of various valuation approaches may be reached.

5.14 Given the range of options that are available in the area of valuation it is recommended that where valuation is undertaken the purpose be clearly articulated together with a clear explanation of the underlying assumptions that have been made.

5.2.3 Objects of valuation

5.15 The two primary components of ecosystem accounting are ecosystem services and ecosystem assets. Chapters 2, 3, and 4 explain in detail the relevant concepts and the various approaches to the measurement of these two variables in physical terms. For estimates in monetary terms, the initial targets of valuation are ecosystem services. Some ecosystem services, such as the harvest of timber, contribute to benefits already in scope of the standard measures of economic activity. For the purposes of exposition, these services are referred to as market ecosystem services. Other ecosystem services contribute to non-SNA benefits (such as clean air). These services are referred to as non-market ecosystem services. As explained in Chapter 2, the focus is on the final outputs of ecosystems that contribute to benefits used in economic or other human activity. Ecosystem processes and flows within or between ecosystems are not addressed in the valuation approach outlined in this chapter.

5.16 Once estimates of different ecosystem services have been derived, a number of paths may be pursued depending on the analytical and policy questions of interest. First, it may be possible to aggregate values of all of the ecosystem services within a given spatial area (e.g. for a given EAU). Second, it may be possible to aggregate across all ecosystems in a country for a selected ecosystem service or for all ecosystem services. Third, it may be possible to aggregate over time, i.e. into the future, to determine an aggregate of all future flows of ecosystem services, and hence, following standard approaches to capital accounting, provide an estimate of the overall value of ecosystem assets. Each type of aggregation requires particular assumptions and involves distinct measurement challenges. Consequently, there may not be interest in compiling all of the potential monetary measures even though they may be conceptually possible.

5.17 A particular issue arises in the case of ecosystem assets since it may not be appropriate to apply valuation approaches developed in the context of produced assets (such as buildings and machines) to ecosystems that are complex assets, can regenerate over time and provide multiple services. A related question is whether the valuation of ecosystem degradation should be based on analysing foregone income due to the reductions in the current and future flows of ecosystem services, or if valuation of ecosystem degradation should be based on the costs of restoring the ecosystem to a previous state. This is discussed further in Chapter 6.

5.2.4 Welfare economic and exchange concepts of value

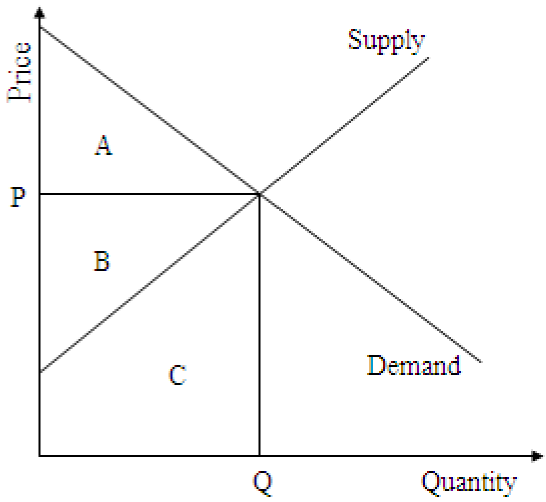
5.18 In neo-classical welfare economics, the value of a good or service is determined by the demand for and supply of that good or service in a perfectly functioning market. This is illustrated in Figure 5.1 Figure 5.1 shows a demand and a supply curve for a good traded in a market in a quantity ‘Q’ and at price ‘P’. The demand and supply curves are assumed to be linear for the purpose of this illustration, but in reality this will not normally be the case.

5.19 In Figure 5.1, area ‘A’ represents the consumer surplus, which is the gain obtained by consumers because they are able to purchase a product at a market price that is less than the highest price they would be willing to pay.[31] The producer surplus, depicted by ‘B’, is the amount that producers benefit by selling at a market price that is higher than the least that they would be willing to sell for, which is related to their production costs. The area ‘C’ can be assumed to represent the production costs, which differ between different producers. For the purpose of this chapter, the sum of areas A and B is labelled the ‘surplus’. The surplus can be seen as the net economic gain resulting from market transactions with a volume of Q at price P.

5.20 In the context of integrating values of ecosystem services within the national accounts the objective is to value the quantity of ecosystem services at the market prices that would have occurred had the services been freely traded and exchanged. This market price, equivalent to price P in Figure 5.1, reflects consumers’ marginal willingness to pay for the ecosystem service at the market equilibrium quantity of services Q. In the case of ecosystem services not traded in a market, alternative approaches to establish a price for the ecosystem, in line with the SNA accounting principles, need to be found, as further discussed in Section 5.4.

[31] It is noted that a distinction exists between individual and aggregate consumer surplus.

Figure 5.1 Consumer and producer surplus



5.21 For national accounting purposes, the focus of valuation is on the area of producer surplus plus costs of production, i.e. areas B and C. This reflects a concept of exchange value in which, while different consumers may have been willing to pay different prices for a good or service, in practice all consumers pay the same price, P. Thus the total outlays by consumers and the total revenue of the producers is equal to the area B plus C, or equivalently, is equal to P times Q. If this approach to valuation is not adopted in ecosystem accounting, the potential to account for transactions between economic units would be lost since the values of supply and use of products would be different. Analysing the monetary value of ecosystem services requires identifying and analysing the contribution of the ecosystem service to the benefits represented by this area.

5.22 Following this characterisation, the difference between the welfare economic conception of value and the national accounts conception of value is equal to consumer surplus. Much of the discussion on approaches to valuation therefore considers the extent to which consumer surplus is included in the resulting valuations. A critical aspect here is that willingness to pay measures revealed by some approaches to valuation of ecosystem services do not reflect prices at which the service would be traded on a market.

5.2.5 The 'Total Economic Value (TEV)' framework

5.23 As noted in the introduction the reason to consider concepts of value in the context of ecosystem accounting is that market prices for ecosystem services and ecosystem capital are "missing". In order to estimate these missing prices it is therefore necessary to have a clear understanding of the different elements underlying the value concept. A common framework for developing this understanding breakdowns economic value into four types: (i) direct use value; (ii) indirect use value; (iii) option value; and (iv) non-use value.

(i) Direct use value arises from the direct utilisation of ecosystems, for example through the sale or consumption of a piece of fruit.

(ii) Indirect use value stems from the indirect utilization of ecosystems, in particular through the positive externalities that ecosystems provide, for example clean air and water.

(iii) Option values relate to people's responses to uncertainty. Because people are unsure about their future demand for a service or the longer term implications of a current decision, they may be willing to pay now to retain the option of using a resource in the future (e.g. placing a value on a forest reflecting the potential to find plants for medicinal purposes) or they may be willing to pay now for insurance against possible future losses.

(iv) Non-use value is derived from attributes inherent to the ecosystem itself. Three aspects of non-use value are generally distinguished: existence value (based on utility derived from knowing that something exists), altruistic value (based on utility derived from knowing that somebody else benefits) and bequest value (based on utility from knowing that the ecosystem may be used by future generations). These different types of non-use value may be reflected, for example, in the value of iconic species such as giant panda. The different categories of non-use value are often difficult to separate from each other and from option values, both conceptually and empirically.

5.24 Aggregation of these four value types to estimate total economic value is possible if all values are expressed in monetary terms and estimated through commensurable indicators. In practice, however, few valuation studies have valued option values of ecosystem services, and there is still considerable debate on the quantification and pricing of non-use values.

5.25 It is important to recognise that both ecosystem services providing direct use value (in particular provisioning services) and services providing indirect use value (in particular regulating services) can be seen as final outputs of the ecosystem. In the context of the TEV framework, direct use values relate to ecosystem services that are an input to specific production or consumption functions. Indirect use values are generated in relation to regulating services which facilitate economic activity in particular areas (as in the case of the flood protection service of coastal dunes allowing economic activities in areas immediately inland of the dunes). Both types of services are relevant in the context of ecosystem accounting, but specific approaches need to be developed for these (and for cultural services) in order to analyse their contribution to economic activity.

5.26 Some connections may be drawn between the framework just outlined and the national accounts notion of value. Since non-use value is based purely on the utility of an individual, it can be concluded that non-use values are solely comprised of consumer surplus and hence should be considered out of scope of national accounts based measures of value. For the other components of value it is possible that all three play a role in setting prices following national accounts notions of value although exactly how these different components might be identified can only be determined on a case by case basis.

5.3 Valuation principles in the SEEA and the SNA

5.3.1 Market prices

5.27 In the SEEA, as in SNA, the values reflected in the accounts are, in principle, based on the current transaction prices or market prices for the associated goods, services, or assets that are exchanged. (2008 SNA, 3.118) Strictly, market prices are defined as amounts of money that willing purchasers pay to acquire something from willing sellers. The exchanges should be made between independent parties on the basis of commercial considerations only, sometimes called “at arm’s length”. (2008 SNA, 3.119)

5.28 Defined in this way, in a perfect market at a particular point in time, the same market price will be paid by all purchasers. In practice, market prices used in the national accounts will vary between purchasers and over time and hence they should be distinguished from a general market price that gives an indication of the “average” price for exchanges in a type of good, service or asset over a given period of time. In most cases, market prices based on the totality of transactions that actually occur over an accounting period will approximate the general “average” market prices just described.

5.29 In practice, prices are generally impacted by taxes and subsidies and as a result of the costs of distributing products to consumers (reflected in transport, wholesale and retail margins). The SNA therefore defines a number of different prices – basic prices, producer prices and purchasers’ prices –each defined by different treatments of taxes, subsidies and margins. The distinctions between these different prices should be considered in valuation exercises but they are not expanded upon here. For further details see the SEEA Central Framework Section 2.7 and the 2008 SNA Chapter 6.

5.3.2 Valuation of transactions

5.30 Following SNA, a transaction is an economic flow that is an interaction between institutional units (e.g. between corporations, households, governments) by mutual agreement or an action within an institutional unit that is analytically useful to treat like a transaction – for example household own-account production. (2008 SNA, 3.51) A large proportion of transactions are monetary transactions in which one institutional unit makes a payment (or receives a payment) stated in units of currency. Common monetary transactions include expenditure on the consumption of goods and services; payments of wages and salaries; and payments of interest, rent, taxes, and social assistance benefits.

5.31 Non-monetary transactions are transactions for which a market price is not observable or does not exist. The value of these transactions must therefore be indirectly measured or otherwise estimated. In some cases a non-monetary transaction may be clearly observed between institutional units, for example barter transactions, and for national accounting purposes, a value should be estimated to record it in the accounts. In other cases, the entire transaction must be constructed and then a value estimated for it. These constructed transactions are referred to as imputed transactions. (2008 SNA, 3.75).

5.32 Imputed transactions are recorded when there are flows that are considered analytically useful to treat as transactions. An important imputed transaction in the national accounts is the measurement of consumption of fixed capital (depreciation). This is “constructed” since the flow is one that is internal to an institutional unit and no actual monetary flows occur.

5.3.3 SNA approaches to valuing non-monetary transactions

5.33 When market prices are not observable, valuation according to market-price-equivalents provides an approximation to market prices. In such cases, market prices of the same or similar items when such prices exist will provide a good basis for applying the principle of market prices provided the items are traded currently in sufficient numbers and in similar circumstances.

5.34 In using a market-price-equivalents approach it is relevant to note two usually unstated assumptions. First, it is assumed that the price of the good or service is independent of all other goods and services, or, put differently, that the operation of the market allows prices to take into account a range of inter-related effects. Second, it is assumed that the prices being used to approximate the missing prices are themselves formed in a manner that can be considered incentive compatible. That is, the market/institutional setting is such that the revealed prices reflect the truthful responses of the market participants.

5.35 Where no sufficiently equivalent market exists and reliable surrogate prices cannot be observed, the SNA identifies a second best procedure to be used in which the value of the non-monetary transaction is equal to the sum of the costs of producing the good or service, i.e. the sum of intermediate consumption, compensation of employees, consumption of fixed capital (depreciation), other taxes (less subsidies) on production, and a net return on capital. (2008 SNA, 6.125)

5.36 The “cost of production approach” is most commonly applied in the valuation of the own account production of enterprises and households and in the valuation of the production of public goods by government units, such as the production of education and health services.[32] This approach to estimating prices effectively reflects a decomposition of the concept of a market price that is amenable to estimation, since the components are observable. In relation to Figure 5.1 this method measures area C where it is assumed that the costs of production include a normal return on capital – i.e. there is no producer surplus in the production of these outputs.

5.3.4 Valuation of assets

5.37 Assets, strictly economic assets in an SNA context, are stores of value representing a benefit or series of benefits accruing to the economic owner by holding or using the entity over a period of time. (2008 SNA, 10.8). Accounting for assets thus entails making assessments in

[32] Strictly, a distinction must be drawn between non-monetary transactions related to market output (e.g. own account production of households) and those related to non-market output (e.g. production of public goods by government units). For non-market output the costs of production are defined to exclude the net return on capital component (see 2008 SNA 6.125).

the current period of the expected future flows of benefits, for example in the form of operating surplus (profits), interest, rent and dividends.

5.38 For economic accounting purposes, the ideal source for asset prices are values observed in markets in which each asset traded is completely homogeneous, often traded in considerable volume, and has its market price listed at regular intervals.

5.39 In some cases, observed market prices may cover the values of a number of assets. For example, prices for real estate will usually include both a value for the dwelling (or buildings) on a piece of land as well as a value for the land itself (in particular its size and location). The notion of composite assets is one that is explained further in SEEA Central Framework Section 5.6 and is of relevance in the context of ecosystems which, by definition, represent a combination of bio-physical components.

5.40 When there are no observable prices an attempt should be made to estimate what the prices would be if a regular market existed and the assets were to be traded on the date to which the estimate of the stock relates. There are two main approaches that are described in the SNA to deal with this situation.

5.41 The first approach is to use the written down replacement cost which recognises that the value of an existing asset (primarily produced assets) at any given point in its life, is equal to the current acquisition price of an equivalent new asset less the accumulated consumption of fixed capital on the existing asset over its life. (2008 SNA, 13.23)

5.42 The second approach is to use the discounted value of future returns. For some assets, including many environmental assets, there are no relevant market transactions or set of acquisition prices that would permit the use of the previous approaches. Thus, no values for the asset itself, *in situ*, are available. In this situation, the discounted value of future returns approach, commonly referred to as the Net Present Value approach – or NPV – uses projections of the future returns from the use (usually extraction or harvest) of the asset. The SEEA Central Framework discusses NPV approaches at length in Chapter 5 in the context of individual environmental assets such as mineral and energy resources, timber resources and aquatic resources.

5.3.5 The decomposition of value into price, quantity and quality

5.43 The analysis of changes in value over time is an important aspect of accounting. One way of considering changes in value is to recognise that changes may arise due to changes in prices or changes in quantity. For national accounting purposes, the decomposition of value into price and quantity components is undertaken with an index number framework. This framework also provides the basis for the direct measurement of price change (for example, the Consumer Price Index). Index number theory is well established but, at the same time, there are a number of choices that can be made in undertaking any decomposition of values.

5.44 A key issue is that items being valued will generally change in quality over time. For example, a new car purchased in 1990 is likely to be quite different in quality from one purchased in 2012 even allowing for general features such as engine size and number of seats. Thus simply tracking the purchase price of a car and using a quantity of one car does not provide a good indication of the decomposition of value change. A reasonable assessment must take into account changes in price, quantity and quality.

5.45 For complex items, such as cars and computers, methods have been developed to make assessments of the changes in quality on an ongoing basis. One of these approaches is known as a hedonic approach and relies on breaking up an item into its various “characteristics”. Assessment of the change in each of the characteristics is then aggregated to form an overall assessment of whether the total value (i.e. purchase price) of an item is due to changes in quality.

5.4 Valuation of ecosystem services

5.4.1 General considerations for different ecosystem services

5.46 The appropriate valuation approach differs by type of ecosystem service. In order to design a valuation approach for a specific ecosystem service, it is necessary to understand how the services lead to the generation of benefits, and the relation between these benefits and the recording of the related economic activity in SNA. In this context it is relevant to note that generally, where a link to the SNA production boundary can be made, valuation approaches focus on the valuation of the benefit and then determine the contribution of the ecosystem service rather than valuing the ecosystem service directly.

Provisioning services

5.47 Provisioning services relate to goods extracted from or harvested in an ecosystem and generally the production of these goods is included in the SNA production boundary and hence in GDP. The usefulness in understanding the value of these services is that the contribution of these ecosystem services to GDP may be recognised.

5.48 The processes of harvest or extraction normally involve costs, and these need to be considered in the valuation of the ecosystem service. The collection of food or raw materials may take place in a fully natural ecosystem, but is more likely that harvesting and extraction occurs in an ecosystem that is modified by people. This modification may be in the form of enrichment planting of specific species in a natural environment or reflect degradation because of past overharvesting. Many ecosystems have been modified to favour the supply of specific services, as in the case of cropland or intensive pastures.

5.49 Harvesting and extraction may take place according to different management mechanisms. There may be private ownership of the ecosystem, with the land owner harvesting ecosystem services. A private owner, or a government, may also lease the land to an individual, for instance a farmer, or to a group of individuals. There may also be communal or government ownership of the ecosystem, with restricted or open-access to the resources present in the ecosystem. These institutional arrangements determine the costs of maintaining ecosystem services supply as, in the case of provisioning services, they are incurred by the user.

5.50 The monetary value of a provisioning service is influenced by the institutional arrangement involved. In the case of a private land owner harvesting timber or crops from an ecosystem, the owner is likely to have used labour and produced assets to modify the ecosystem, and to harvest the resource. The supply curve, and in particular area C in Figure 5.1, reflects the costs involved in harvesting (labour, produced assets (via depreciation costs), intermediate inputs) and the costs associated with the use or modification of the ecosystem (e.g. draining an agricultural field prone to flooding, or pruning trees in a plantation forest).

5.51 This is illustrated by the case when a land user leases the land on which he grows crops: his costs include the costs of leasing the land, with the lease price reflecting the possibility to grow crops as a function of acreage, soil fertility, hydrological properties, perhaps even the presence of local pollinators, in other words the ecosystem characteristics of the area. Hence, the annual lease price of the land reflects, to a degree, the value of the relevant ecosystem services (aligned with the scope of services discussed in Chapter 3) that are used by the land user. However, it needs to be kept in mind that the value of land may reflect several other important factors, for instance speculation on potential increase in future land value due to land development (for instance when farm land is used for residential development). In the case that an area is privately owned and used, it can be examined if the lease price observed in the market can, under the prevailing conditions of market functioning, be used as an indicator of the monetary value of the provisioning services accruing to the land owner.

5.52 In the case of the extraction or harvest of provisioning services in an ecosystem not owned or leased by the beneficiary, the beneficiary is not paying for the use of the ecosystem asset. In this case, the contribution of the ecosystem is reflected in the producer surplus, i.e. area B in Figure 5.1. An example is the collection of berries on government owned land, or fishing in waters not regulated or not requiring the purchase of a fishing license. In this case, the unit resource rent may be used as a proxy for the economic value of the ecosystem, although there are specific consideration in adopting this approach that are further analysed below. Note that one ecosystem can supply different types of provisioning services, for instance timber benefits from a forest plot may accrue to the land owner, but the collection of mushrooms and berries on the same plot may be free to the public and under an open access regime.

Regulating services

5.53 For regulating services, the overall valuation context is somewhat more difficult. Regulating services allow economic activities by means of the positive externalities they generate. For instance, an ecosystem providing flood protection services allows the safe habitation, or agricultural activities, in a zone otherwise prone to flooding. Where these services directly affect human well-being, as in the case of positive health impacts due to air filtration, they may generate in particular consumer surplus (area A in Figure 5.1), which should be excluded from valuation for ecosystem accounting purposes.

5.54 However, many regulating services may contribute to producer surplus, by allowing production to take place or avoiding damages to production. For example, flood protection services may allow agricultural production in flood plains. The costs of maintaining the ecosystem or providing the service are generally not born by the users of the service, except in the relatively rare cases where payment mechanisms for regulating services (PES) have been set up. In cases without PES, these services normally are part of the producer surplus, reflecting that as a consequence of the regulating services some producers have more favourable conditions for specific economic activities than other producers, or that they are not required to take mitigation measures (e.g. construct flood control structures).

5.55 In cases where the costs of mitigation or adaptation are higher than the producer surplus, as in the case where mechanical flood protection is very expensive, the producer is likely to cease activities when the regulating services is no longer provided, and the producer surplus presents a reasonable upper bound on the value of the ecosystem service.

5.56 For the valuation of regulating services, in the absence of markets for ecosystem services, there is a need to reveal the marginal willingness to pay for consumers for the service involved – with consumers in this case including for instance agricultural and industrial producers. Many of the valuation methods developed in the field of environmental economics include elements of the consumer surplus and are therefore less applicable in the context of ecosystem accounting. A notable exception is the replacement cost approach. This method is of particular relevance to regulating services, and is further described below.

Cultural services

5.57 For cultural services the situation differs depending on the service involved. For a number of cultural services such as spiritual & symbolic services and information & knowledge services only generate consumer surplus and cannot be meaningfully accounted for in economic terms. On the other hand, ecosystem services related to tourism and recreation are somewhat different in that they provide both a consumer surplus (which may be measured using a travel cost valuation method) and a producer surplus.

5.58 The economic activities in the recreation and tourism industries are in scope of the SNA. However, the specific contribution of the ecosystem is not generally singled out in this context. This contribution differs strongly between different parts of the industry (it may normally be smaller for a restaurant than say a canoe rental firm) – but will also vary between individual firms. For instance, a hotel located adjacent to a national park may attract tourists in particular because of the possibilities for ecotourism, which may not be the case for a hotel in a city centre.

5.59 In order to analyse the monetary value of the ecosystem services for recreation and tourism, it is therefore necessary to estimate the relative importance of recreational and experiential activities within ecosystems in determining the number of tourists who visit certain areas. The costs for managing natural parks are not normally incurred by the recreation and tourism industries. Consequently, the contribution of ecosystems in providing opportunities for recreation is reflected in (part of) the producer surplus.

5.4.2 Approaches to pricing ecosystem services

Pricing using the unit resource rent

5.60 Most commonly, the use of this approach to pricing is associated with provisioning services such as those related to outputs of the agriculture, forestry and fishing industries, in particular where there are no or limited possibilities to use land leases and prices as an indicator for the price of ecosystem services. In the case of provisioning services there is usually a measureable human input in terms of both labour and produced assets which is combined with the relevant ecosystem services to produce the benefit. The examples of ecosystem services in Chapter 3 provide an indication of the types of considerations that are needed in defining the links between benefits and ecosystem services for a range of provisioning services.

5.61 Importantly, given the use of human inputs, the price of the benefit, e.g. the price of landed fish, should not be used directly as a surrogate price for the ecosystem service. That is, some of the benefit price reflects the costs of labour and produced assets. The difference between the unit costs of labour and assets and the benefit price represents the unit resource rent.

5.62 Under this approach to valuation the unit resource rent represents an estimated price for the ecosystem service. However, a number of market conditions must be in place for estimates of unit resource rent to accurately reflect a price for the ecosystem services that takes into account the potential for degradation of the resource. These conditions include that the resource is extracted / harvested in a sustainable way and that the owner of the resource seeks to maximise their resource rent.

5.63 Often, these conditions are not met. In particular, if there is open access to the resources and no charging of access by the owner, then the marginal unit resource rent tend to zero thus implying that the price of the ecosystem service is zero. Thus depending on the access conditions in place the resource rent approach to valuing marketed ecosystem services may not be appropriate.[33].

5.64 Although the analysis of resource rent is a well established area of economics, a review of the available methods suggests that there is a general need to develop alternative approaches to analyse the value of ecosystem services in the case of open access resource management.

Replacement cost methods

5.65 The replacement cost method estimates the value of an ecosystem service based on the costs that would be associated with mitigating actions if it would be lost, as in the case of constructing a water purification plant if the water filtration service of an ecosystem supplying groundwater to an aquifer used for drinking water is impaired. This method does not involve any consumer surplus, and is based on the assumption that society would indeed chose to replace the service if it would be lost. Literature states that this method can be used, in principle, in case the alternative considered provides the same services, is the least-cost alternative, and if it can be reasonably assumed that society would chose to replace the ecosystem service if lost.

5.66 The replacement cost method may be of particular relevance in the case of the water purification service and the flood control service.

5.67 A related method is the ‘costs of treatment method’, which involves estimating the value of an ecosystem service based on the costs of repairing damages that would occur in the absence of the service. This service is of particular relevance for the erosion and sedimentation control,

[33] It is noted that there are no ecosystem services associated with the extraction of non-renewable natural resources, such as mineral and energy resources, and hence the valuation of these resources are not discussed here. See the SEEA Central Framework, Chapter 5 for details on the valuation of non-renewable resources.

and the air purification service. For instance, in the absence of erosion control, the barrier lake of a hydropower dam would receive higher sediment loads, and the costs of removing these sediments can be used as an indication of the value of the service, under the same conditions of being an adequate and least-cost treatment, and it being likely that society would chose to conduct the treatment if the damage occurs.

5.68 It is noted that these two methods differ from other "cost" methods such as avoidance costs and restoration costs. A particular feature of the replacement cost and costs of treatment methods is that they aim to estimate the price for a single ecosystem service rather than considering a basket of ecosystem services.

Payments for ecosystem services and trading schemes

5.69 There is increasing experience in establishing markets for regulating services, in particular for carbon sequestration, but to a smaller degree also for hydrological services, in particular the regulation of water flows (flood mitigation) and control of sedimentation. For carbon, there are a range of different markets operating in different parts of the world with a different degree of maturity and market turn-over. The largest market is the European Carbon Trading Scheme, but this market does not include carbon sequestration in ecosystems. Indeed, it is important to distinguish between markets that relate to the limited right to emit pollution and markets in ecosystem services themselves since the design of the market will influence the interpretation of the prices that are generated. In compliance markets, the price of carbon is strongly influenced by the regulatory setting of the market, and prices have fluctuated rapidly in response to changes in these settings.

5.70 Carbon sequestered in ecosystems is mainly traded in voluntary carbon markets. Such carbon markets are rapidly evolving. A new scheme in New Zealand permits the trading of credits from forest carbon in a compliance scheme, but so far only small quantities of forest carbon have been traded.

5.71 To date, most market transactions on forest carbon concern the flows associated with sequestering carbon rather than the service of permanent storage of carbon in ecosystems. Recently, however, a number of pilot projects in the domain of REDD (Reduced Emissions from Deforestation and forest Degradation) have been started. These projects sell carbon credits from reduced carbon emissions to the atmosphere generated by activities aiming to reduce deforestation and/or degradation, hence to maintain the storage of carbon in an ecosystem. Payments are made, in the case of REDD, for reducing emissions compared to a baseline case representing business as usual emission rates, i.e. with no REDD project in place.

5.72 The market for both the sequestration and storage of carbon in ecosystems is reflected in the way carbon services are defined for SEEA Experimental Ecosystem Accounting (see Chapter 3). In order to establish a price for carbon, a first estimate may be based on the price raised in voluntary markets. Potentially, when compliance carbon markets mature and further allow the inclusion of carbon storage and/or sequestration in ecosystems, new (generally higher) prices raised in these markets may be used to value carbon.

5.73 It may be that markets and trading schemes provide a good basis for estimating prices for certain ecosystem services. However, care is needed to understand the extent to which the institutional setting for these markets ensures that the prices conform to assumptions regarding market prices. In particular, it is important that the prices generated from the markets and trading schemes are incentive compatible. An observation in this regard is that prices from voluntary markets and prices due to regulation may not equate to measures of societal willingness to pay. Overall, in may be difficult to determine the extent to which prices from these markets contain elements of consumer surplus and hence are consistent with the SEEA concept of market price.

5.74 Estimation of ecosystem services may also be possible in the context of biodiversity. Market-conforming biodiversity mitigation mechanisms include mitigation banking of biodiversity credits, programs that channel development impact fees and offset policies. A limited number of biodiversity markets have been set up that fulfil the basic characteristics of a market: (i) the presence of buyers and sellers; (ii) a traded unit, reflecting biodiversity; (iii) a market clearing mechanism in which a price is established; and (iv) an institutional setting regulating the market and ensuring compliance. The traded unit in these markets are commonly credits related to species or to acreage of habitat conserved.

5.75 Examples of emerging biodiversity markets are (i) Conservation Auctions in Victoria, Australia; (ii) BioBanking, New South Wales, Australia; (iii) Conservation banking (US); and (iv) Wetland and Stream Mitigation Banking (US). The oldest of these schemes is the Wetland and Stream mitigation banking scheme, with total annual wetland and stream payments reported to be in the order of U$1.5 billion for 2008. These schemes allow establishing a surrogate market price for the biodiversity units traded in such markets, but in needs to be kept in mind that the prices of the units strongly depend on the local ecological and institutional setting and that it cannot easily be translated to the value of biodiversity in other places.

Other valuation methods

5.76 A range of other valuation methods for non-market ecosystem services have been developed in the environmental economics literature. They can be broadly divided into revealed preference and stated preference methods. Revealed preference methods determine the value of an ecosystem service based on observations of related goods in a market. For instance, with the hedonic pricing method, the price of environmental characteristics of goods traded in a market can be analysed. Other examples of revealed preference methods are: (i) the production function method, travel cost method, and the averting behaviour method. Stated preference methods depend on questionnaires of experiments to analyse people’s preferences. There are two main stated preference methods, contingent valuation studies and choice experiments. A short overview of these valuation approaches is presented below.

5.77 Many of these valuation methods include elements of consumer surplus. For instance, the travel cost method exclusively examines the consumer surplus accruing to visitors undertaking recreation in a specific ecosystem. Therefore, the application of these methods in an ecosystem accounting context should be undertaken with caution, and value estimates obtained through these methods should be examined in detail, and where needed adjusted prior to use in an accounting context. Given that many of the valuation studies undertaken in the environmental economics literature are preference based, and include – explicitly or implicitly – consumer surplus this means that there may be a distinct lack of data for monetary valuation of ecosystem services for the purpose of accounting. It also suggests that developing ecosystem accounting in monetary terms may require significant investment in data collection.

5.78 Production function methods estimate the contribution of ecosystem services to production processes in terms of their contribution to the value of the final product being traded on the market. The general principle, i.e. disentangling the contribution from the ecosystem versus contributions from other production factors, is analogous to the use of the resource rent as a proxy for the monetary value of provisioning services. Production function methods can also be used to value indirect use values generated by regulating services such as the storm and flood protection service, by disentangling their contribution to the generation of outputs traded in a market.

5.79 Hedonic pricing methods analyse how environmental qualities affects the price people pay for market products or assets. For example, hedonic pricing can be applied to reveal the value of local ecosystem services that contribute to the value of a property, as in the case of urban green space increasing local house prices. In this case, hedonic pricing involves decomposing sale prices of houses into implicit prices for the properties of the house (e.g. number of rooms, size of the lot, etc.), other factors, and local ecosystem services. Hedonic pricing may also be used in valuing ecosystems, for example, forests, where there are a range of possible uses, and hence ecosystem services, which each need to be priced. Hedonic pricing in this situation may also reveal option values where there are possibilities to alter the use of an ecosystem in the future. The application of a hedonic analysis requires a large amount of data to enable all of the various characteristics of the land areas, including the availability of ecosystem services, to be captured.

5.80 Averting behaviour methods are used as an indirect method to evaluate the willingness of individuals to pay for improved health or to avoid undesirable health consequences. Averting behaviour models are based on the presumption that people will change their behaviour and/or invest money to avoid an undesirable outcome resulting from ecosystem degradation. The incurred expenditures provide an indication of the monetary value of the perceived change in environmental conditions. Contrary to the replacement cost valuation method (see above), the averting behaviour method is based on individual preferences. For example, in the presence of water pollution, a household may install a filter on the primary tap in the house to remove or reduce the pollutant. It is necessary for households to be fully aware of the impacts on them resulting from environmental changes in order for this method to be applicable.

5.81 Often, ecosystem services associated with recreational sites are priced using the travel cost method. This method estimates the price of the ecosystem services based on the amounts consumers may be willing to pay based on estimated costs of visiting a recreational site. As with production function methods a challenge is to disentangle the contribution of the ecosystem to the overall recreational experience. Because this method focuses on estimating willingness to pay, albeit from a perspective of revealed prices, it incorporates measurement of some of the consumer surplus generated for visitors to ecosystems. Hence it does not provide estimates of prices that are consistent with the SEEA valuation principles.

5.82 Stated preference methods are designed to capture information on people's willingness to pay for ecosystem services but without involving actual payment. The most important approaches are the Contingent Valuation Method (CVM) and related methods (including choice experiments and conjoint analysis). Contingent valuation studies typically ask respondents to state a value they attribute to a certain ecosystem, ecosystem property or ecosystem service. Choice experiments ask respondents to compare an ecosystem, ecosystem characteristic, or ecosystem service with a marketed good or service. In conjoint analysis, survey respondents are typically given alternatives to consider (e.g. three management options with different implications for ecosystem services supply). For each of these stated preference methods, the set-up of the questionnaire is critical; respondents need to be presented a credible case for a potential payment for an ecosystem service. Econometric procedures can then be used to reveal monetary values on the basis of choices or ranks.

5.83 The main advantage of stated preference methods is that, unlike other valuation methods, they can be used to quantify the non-use values of an ecosystem in monetary terms. However, there are several points of criticism against CVM and related methods. CVM estimates are sensitive to the specific framing of the questions eliciting estimates of willingness to pay. For example, the sum of the values obtained for the individual components of an ecosystem is often much higher than the stated willingness-to-pay for the ecosystem as a whole. In addition, CVM may appear to overestimate economic values because respondents do not actually have to pay the amount they say they would be willing to pay for a service. Hence, monetary value estimates obtained with CVM and related methods need to be treated with some caution. In addition, these methods incorporate consumer surplus and are therefore not necessarily aligned with the SEEA valuation principles.

The Simulated Exchange Value Approach

5.84 A number of the valuation approaches described above can be used to derive a demand curve representing the willingness to pay for particular ecosystem services (e.g. travel cost method, averting behaviour method). Consistent with the discussion on concepts of value in Section 5.2, a possible step in the estimation of market prices is the estimation of a supply curve for the same ecosystem service. If this step could be completed then the intersection of the supply and demand curve would provide an estimated market price, from hypothetical market.

5.85 An approach has been developed that seeks to adopt this logic. The Simulated Exchange Value approach is an alternative approach to welfare based valuation which has been proposed by a team of Spanish economists in the specific context of green accounting in the forestry sector. The approach aims to measure the income that would occur in a hypothetical market where ecosystem services were bought and sold. It involves estimating a demand and a supply curve for the ecosystem service in question and then making further assumptions on the price that would be charged by a profit-maximising resource manager under alternative market scenarios. It then takes the hypothetical revenue associated to this transaction (but not the associated consumer surplus) as a measure of value of the flow of ecosystem services (see Figure 5.2).

5.86 The Simulate Exchange Value approach estimates the value of ecosystem services in terms of potential revenue and can therefore arguably represent a more consistent basis for including their value in national accounts alongside monetary transactions.

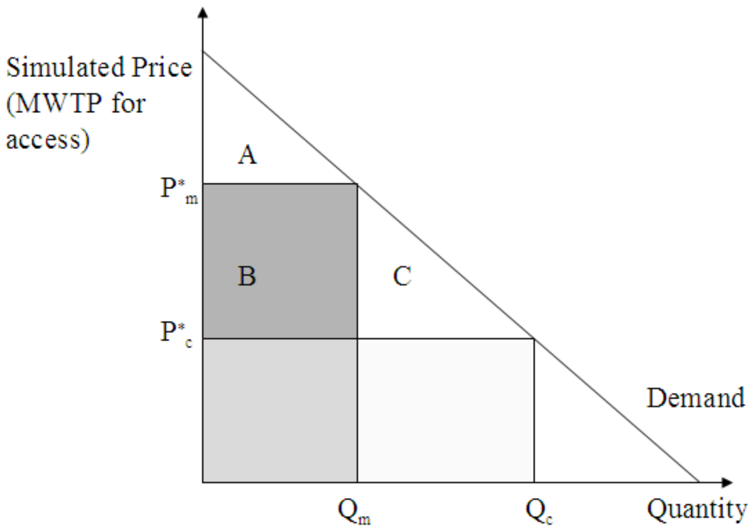


Figure 5.2 The Simulated Market Price Approach uses demand and supply curve information for the ecosystem service in question to estimate a hypothetical monopoly price (P*m) and competition price (P*c). It then estimates the associated revenue under the demand curve by multiplying these prices for the associated, hypothetical quantities. What the approach does not do is to include in these calculations consumer surplus (areas A under monopoly or A+B+C under competition in the picture).

Incorporation of cost of degradation in valuing ecosystem services

5.87 Generally, the valuation approaches described above do not take full account of the negative impacts of economic and other human activity on ecosystem assets, i.e. ecosystem degradation. Thus, either explicitly or implicitly the approaches assume the ecosystem will be used sustainably. Since this is often not the case, there is a risk that the valuation approaches will understate the "true" value of ecosystem services in terms of capturing all of the relevant missing prices.

5.88 Some approaches exist to measuring the value of degradation separately (e.g. restoration cost, value of ecosystem resilience) but more research in needed to either (i) integrate these approaches with approaches to valuing individual ecosystem services; or (ii) to develop pricing methods that do not require assumptions about how the ecosystem is used.

5.5 Key measurement issues in valuation

5.5.1 Measuring regulating services

5.89 Unlike cultural or provisioning services, the biophysical performance of the regulating services, and thereby their economic value, is influenced by the state of other ecosystems in a specific area. For example, the relation between the area covered with forest and the regulation of downstream flood levels is non-linear: a small reduction of forest cover will not reduce the service much, and in a watershed with a high forest cover initially the different plots have a low marginal value related to flood control: conversion of one or a few plots does not lead to increased flood risks downstream. However, when forest cover is further reduced, the impact of one unit of extra deforestation on flood risk will often strongly increase. This is typical for many regulating services. For ecosystem accounting, this means that prices of regulating services will normally be variable over time as a function of the state of the ecosystem.

5.90 The price of the regulating services will also vary over time as a function of economic development: the more people live in the area where the regulating service takes place, and the more economic activity they engage in, the higher the value of the regulating service. In the most extreme case, if no one is living in the area where the regulating impact of the ecosystem is felt, the value of a service may be zero. Hence, marginal value estimates for regulating services will need to be updated for every accounting cycle.

5.5.2 Aggregation

5.91 For the purposes of ecosystem accounting, the consideration of valuation must go beyond determining appropriate approaches to the estimation of prices and value for individual ecosystem service flows. In order to integrate monetary estimates of ecosystem services within broader accounting frameworks it is necessary to undertake aggregation. Aggregation itself must be considered from a number of different perspectives: (i) aggregation of the value of different ecosystem services within a single ecosystem; (ii) aggregation of the value of ecosystem services across multiple ecosystems; and (iii) aggregation of the value of expected ecosystem services flows to provide an estimate of the value of an ecosystem asset. Each of potential aggregation is considered in turn.

Aggregation within a single ecosystem

5.92 In concept the logic here is akin to the addition of values of output from an enterprise that produces a range of different outputs. Thus, for a given accounting period, it should be possible to sum the estimated value (price times quantity generated) for each ecosystem service. This may be able to be used to compare the value of ecosystem services provided by different ecosystems and also allows the relative value of different ecosystem services within an ecosystem to be compared.

5.93 While simple in concept, it must be assumed that each ecosystem service is independent or, at least, that the level of service generated takes into account that some ecosystem services are dependent on other services. In practice, it may be difficult to isolate ecosystem services in terms of their price and quantity. Aggregation of this type should ideally also take into consideration cross-ecosystem dependencies.

5.94 Aggregation within an ecosystem may be complicated through the use of different methods of pricing for different ecosystem services since the overall valuation basis may become more difficult to determine. Nonetheless, to the extent that each method used applies the same valuation basis, e.g. market prices, then the extent of this complication may be more limited.

5.95 Finally, it is observed that the meaningfulness of the resulting sum of values of different ecosystem services depends on the coverage of the measured ecosystem services. In cases where the measured ecosystem services do not provide a relatively complete coverage of the set of ecosystem services then the overall value will be of limited usefulness. In this regard, the comprehensive measurement of ecosystem service flows in physical terms is an important starting point.

Aggregation across ecosystems

5.96 Aggregation across ecosystem confronts the same issues as just outlined, and also issues of value transfer, to the extent that direct observation of each ecosystem service in each ecosystem is not possible. In general terms value transfer involves using information from a single ecosystem to estimate values in another similar ecosystem after adjusting for various characteristics such as size, proximity to population centres, etc. Value transfer is discussed further in the following sub-section.

5.97 It is to be expected that as the range of ecosystem types increases and as the number of ecosystems and ecosystem services increases, the aggregation issues will become more complex. Depending on the analytical questions under investigation this step of aggregation should be undertaken cautiously. It is noted that it may be of interest to aggregate the values of a single ecosystem service as generated from a number of different ecosystems. This is likely to still require value transfer methods but does not bring into consideration any issues of aggregation of different ecosystem services.

Aggregation to create values for ecosystem assets

5.98 For certain purposes it may be relevant to compile measures of the value, in monetary terms, of ecosystem assets. The motivations and limitations of undertaking this compilation are discussed at some length in Chapter 6. For the purposes of discussion here, the starting point in estimating aggregate values of ecosystem assets is that the expected future flows of each ecosystem service can be valued and then discounted to the current period. This derives a Net Present Value based estimate of ecosystem assets and follows the same accounting logic as applied in standard asset accounting.

5.99 The measurement of NPV based estimates of ecosystem assets raises a number of challenges. These include:

(i) The need to make assumptions as to the composition of ecosystem services flows into the future. Most likely it is only relevant in an accounting context to determine this composition based on a continuation of business as usual rather than developing a range of alternative scenarios for the use of the ecosystem. (The development of alternative scenarios for analytical purposes is possible as an extension of the SEEA Experimental Ecosystem Accounting.)

(ii) As part of developing expected estimates it is necessary to formulate an asset life – i.e. the expected period of time over which the ecosystem services are to be delivered. Given the potential for ecosystems to regenerate, implicit in determining an asset life is some view on the extent to which the delivery of the current set of ecosystem services is sustainable.

(iii) As with aggregation within ecosystems a challenge remains to understand dependencies between ecosystem services but also to extent an understanding of these dependencies into future periods.

(iv) Derivation of NPV estimates requires the selection of an appropriate discount rate. This is by no means straightforward and depending on the context may require consideration of various equity and other social issues including intergenerational equity. The SEEA Central Framework discusses discount rates and concludes that for the purpose of alignment of SEEA values with the SNA it is necessary to select marginal, private, market based discount rates in NPV calculations. This may not be considered appropriate for ecosystems as a whole whose value may be considered not properly reflected at the margin.

5.100 Given all of these considerations, careful thought should be applied before applying standard NPV approaches to the valuation of ecosystem assets. Depending on the analytical and policy requirements, aggregate measures of ecosystem assets may not be required. It is also noted that where integration of values for ecosystem assets with the values of other assets (e.g. produced assets such as buildings and machines, and non-produced assets such as land) is intended, care should be taken to ensure that the values of expected flows of ecosystem services and the expected flows of income from produced and other assets can be disentangled. This may be particularly relevant in assessing the value of land as distinct from any associated ecosystem asset.

5.101 One motivation for undertaking these valuations is to determine the change in the value of ecosystem assets and hence to derive measures of ecosystem degradation in monetary terms. Issues concerning the definition and measurement of ecosystem degradation in monetary terms are discussed at length in Chapter 6. It is noted here that measurement of the change in the value of ecosystem assets still requires consideration of all of the factors listed above and cannot be simply related to movement in the prices and quantities of ecosystem services in a given accounting period. Under this approach to ecosystem degradation it is the change in the full time series of expected ecosystem services flows that is important.

5.5.2 Benefit transfer

5.102 The discussion of valuation for ecosystem accounting is focused on the development of estimates in monetary terms for large regions or countries that may be used for the development, implementation and/or monitoring of public policy. Much work on valuation has focused on the valuation of ecosystems and ecosystem services in smaller, more targeted settings for specific ecosystems or in relation to particular events, for example the valuation of damages caused by oil spills. Consequently, much data on the value of ecosystem services is fragmented, covering only specific services over a large area, or multiple services in a more confined area, or changes in the flow of ecosystem services following a specific event. In general, great care must be taken when value estimates for ecosystem services or ecosystem assets are extrapolated to other areas.

5.103 There are two types of approaches to benefit transfer, respectively value transfers and 'meta-analysis' function transfers. A value transfer takes a single estimate of the value of an ecosystem service, or an average of several value estimates from different studies, to estimate the value of an ecosystem service in a different context. The most comprehensive way to carry out benefit transfers is to use meta-analysis, which takes all existing studies and then estimates a relationship that gives changes in the values of ecosystem services as a function of, *inter alia*, site characteristics, attributes and size of population affected, and the type of statistical method used in the analysis of existing studies. This is then transferred to the new application in a procedure referred to as meta-regression-value-transfer, which gives a range of values to the new application depending on the characteristics embedded in the meta-regression.

5.104 This approach is well suited to developing estimates for additional sites but may need to be supported with other techniques in order to provide estimates at larger scales, including at the national level.

5.105 The values provided by ecosystem services are often strongly dependent on the biophysical, economic and institutional context, which makes it difficult to assume that value estimates of specific services apply also in a different context. Furthermore, ecosystems are likely to be highly interdependent because in nature everything in connected. The value of one unit of an ecosystem is therefore likely to be contingent on the existence or proximity of other ecosystem components. In these situations, asset values are known to be interdependent rather than unique (as is the case with values revealed on regular markets). Given the likelihood of differences in quality of ecosystem services between ecosystems, a simple value transfer based on average prices is unlikely to be appropriate and meta-analysis function transfers are likely to be required.

5.106 At the same time, there is still relatively scarcity of data on the monetary value of ecosystem services, and different valuation studies may be based on different assumptions and using different methodological constructs. Hence, benefit transfer is prone to a high degree of uncertainty, in particular if done poorly.

5.5.3 Uncertainty in valuation

5.107 There are significant sources of uncertainty in ecosystem accounting. These can be grouped in four main categories: (i) uncertainty related to physical measurement of ecosystem services and ecosystem capital; (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.

(i) *Uncertainty related to physical measurement of ecosystem services and ecosystem assets* – It is clear that, given data scarcity for many ecosystem services, physical measurement of the flow of ecosystem services, in particular at aggregated levels, is prone to uncertainty. Most countries do not consistently measure flows of ecosystem services at an aggregated (national or even sub-national) scale, and services flows need to be estimated on the basis of point based observations in combination with spatial data layers and non-spatial statistics. At the same time, it is noted that information related to flows of provisioning services are generally, readily available.

(ii) *Uncertainty in the valuation of ecosystem services and ecosystem assets* – A second source of uncertainty relates to the monetary value of ecosystem services. For provisioning services, a key aspect is that attributing a resource rent to ecosystems involves a number of assumptions regarding rent generated by other factors of production. For non-market ecosystem services, it is often difficult to establish both the demand for these services and to reveal the supply of these services by ecosystems, in particular at an aggregated scale.

(iii) *Uncertainty related to the dynamics of ecosystems and changes in flows of ecosystem services* – Establishing the value of ecosystem assets requires making assumptions regarding the supply of ecosystem services over time, which in turn depends on the dynamics of the ecosystem. Changes in ecosystem assets will often be reflected in a changed capacity to supply ecosystem services. It is now recognised that ecosystem changes are often sudden, involving thresholds at which rapid and sometimes irreversible changes to a new ecosystem state occur. Predicting the threshold level at which such changes occur is complex and prone to substantial uncertainty.

(iv) *Uncertainty regarding future prices and values of ecosystem services* – Pricing benefits and costs that may accrue in the far-distant future is complex because it is extremely difficult to predict our circumstances in the future. The ecosystem implications of humanity's continuing modification of the climate and landscape are uncertain, and those implications are likely both to affect and to depend on how the future evolves. Uncertainties concerning values are even greater inasmuch as the methods of nonmarket valuation compound errors in estimation.

5.108 The best strategy to deal with the sources of uncertainty will vary per country as a function of data availability and relevant services selected for ecosystem accounting. Given the limited experience to date with analysing ecosystem services in both physical and monetary terms at the national level the approaches to limiting these uncertainties and maximise the robustness of ecosystem accounting will need to be further developed once more practical experience with ecosystem accounting has been gathered and evaluated. The experiences gathered with national level assessment of ecosystem services supply are also highly relevant in this context.[34]

[34] See for example the UK National Ecosystem Assessment (2010)

Chapter 6: Accounting for ecosystems in monetary terms

6.1 Introduction

6.1 Accounting for ecosystems in monetary terms is an important consideration in ecosystem accounting since a common objective is to bring together information on ecosystems with measures of economic activity which are usually in monetary terms. One way of bringing this information together is to create combined presentations that include measures in physical terms for ecosystem services or ecosystem assets, and standard economic measures such as value added, income, and employment. Following the descriptions in Chapter 6 of the SEEA Central Framework, these combined presentations may take a variety of forms depending on the topic or question of interest. Section 6.2 describes relevant measurement issues.

6.2 A second way of considering ecosystem accounting in monetary terms is to bring together valuations of stocks and flows of ecosystem assets into an ecosystem asset account following the standard asset account structure outlined in the SEEA Central Framework. Although seemingly straightforward, the development of an ecosystem asset account in monetary terms does require the use of some significant measurement assumptions, most prominently that it is possible to derive the value of an ecosystem as a whole as the sum of the discounted future stream of ecosystem services. Section 6.3 discusses the relevant assumptions and approaches, with a particular focus on the measurement of ecosystem degradation in monetary terms.

6.3 A third approach is to integrate the valuations of ecosystem services and ecosystem assets in monetary terms within standard national accounts frameworks and aggregates. There are a number of motivations for considering this integration generally around the notion that the standard economic measures of production, consumption, income and wealth are not designed to fully account for the non-market services that ecosystems provide to people and the economy. It is therefore usual for work in this area to start from the concepts and structures of the SNA and seek to find ways in which alternative presentations and aggregates may be formulated.

6.4 This chapter introduces possible areas of integration between ecosystem accounting and the SNA but deliberately refrains from providing recommendations. This is done for a number of reasons:

(i) First, there are strong contrary views about the meaningfulness of any integrated measures and accounts in light of the assumptions required for valuation and consequently, about the ability to use integrated measures and accounts for policy purposes.

(ii) Second, there are concerns from the official statistics community about whether the types of adjustments and extensions to the SNA that are commonly described fall within scope of the purview of official statistics.

(iii) Third, there has been no definitive conclusion to the technical discussion on integration of ecosystem accounting with the SNA and alternative presentations may be justified depending on the particular environmental situation or question of policy interest.

(iv) Fourth, there remains a range of significant measurement challenges.

6.5 Notwithstanding these concerns, SEEA Experimental Ecosystem Accounting would be incomplete without recognition of the considerable effort that has been devoted to conceptualising adjustments and extensions to the SNA. It is therefore appropriate that the key measurement issues in accounting for ecosystems in monetary terms are introduced in this chapter. This is done in Section 6.4.

6.2 Combined presentations for ecosystem accounting

6.2.1 Introduction

6.6 Combined presentations are a way of assessing changes in stocks and flows of ecosystems in the context of standard measures of economic activity without undertaking the step of valuation of ecosystem services and ecosystem assets. An example of a combined presentation is one comparing expenditures on environmental protection in monetary terms and changes in ecosystem condition in physical terms.

6.7 In combined presentations for ecosystem accounting the most significant area of interest is likely to cover linking physical measures of ecosystems with standard economic transactions that are considered related to the environment. The SEEA Central Framework Chapter 4 covers the recording of the relevant transactions by: (i) describing the compilation of Environmental Protection Expenditure Accounts (EPEA) and statistics on the Environmental Goods and Services Sector (EGSS); (ii) defining environmental taxes and environmental subsidies and similar transfers; and (iii) outlining the general treatment of payments for access to or use of natural resources and the environment.

6.8 All of the definitions and treatments for these transactions as outlined in the SEEA Central Framework apply equivalently in SEEA Experimental Ecosystem Accounting. This reflects that the treatments in the SEEA Central Framework are elaborations of the treatments of the transactions from a standard SNA perspective and there is no requirement to adopt alternative treatments of the same transactions for ecosystem accounting.

6.9 At the same time, since ecosystem accounting represents a different perspective on environmental accounting more generally, this section outlines some particular aspects of the general treatment of transactions related to the environment that are likely to be most relevant when assessing ecosystems. The particular aspects outlined are: information on environmental activity; linking ecosystems and ecosystem services to economic activity; and the treatment of payments for ecosystem services.

6.10 It is noted that the discussion of combining ecosystem accounting with standard national accounts is increasingly relevant as countries, both nationally and multi-nationally, are recognising the scarcity of some ecosystem services and are developing policy instruments to manage this scarcity. Where new property rights are established and new transactions arise, there becomes an overlap between the aim of adjusting for environmental concerns and the inclusion of these transactions in the existing framework of the SNA. Thus, for example, the treatment of payments for tradable emission permits is an important issue for the SNA as there are actual transactions, assets and liabilities that must be recorded. To the extent that ecosystem services are "internalised" in the SNA, there is need to understanding the changing measurement boundary. This is covered in sub-section 6.2.4.

6.2.2 Information on environmental activities

6.11 As defined in the SEEA Central Framework, environmental activities are either environmental protection activities or resource management activities. These are economic activities within the production boundary of the SNA that have a primary purpose of either the prevention, reduction and elimination of pollution and other forms of degradation; or preserving and maintaining the stock of natural resources. Generally, it has been expenditure on these types of activities that has been the focus of accounting, however, increasingly there is interest in measuring the production of environmental goods and services, i.e. those products produced for the purpose of environmental protection or resource management and relevant adapted goods. (For details see the SEEA Central Framework, Chapter 4).

6.12 From the perspective of ecosystem accounting there may be particular interest in combining information on ecosystem services and ecosystem assets with information on expenditure on environmental protection or resource management. If the information is organised on the same spatial scales this would facilitate the monitoring of the effect of expenditures on changes in ecosystems. For example, information may be organised by type of LCEU, combining information on expenditure to restore coastal wetlands with information on associated changes in ecosystem condition.

6.13 Conceptually, it is possible to build more complete environmental protection expenditure accounts at a spatial level. However, it is likely to be difficult to obtain sufficient information and there may be little analytical value in undertaking this work beyond describing connections between levels of expenditure and changes in ecosystems.

6.14 At the same time, at a national level, it may be useful to focus on the development of expenditure accounts for subsets of environmental protection and resource management activity that are particularly focused on the maintenance and restoration of ecosystems. The compilation of targeted statistics on the production of ecosystem related environmental goods and services, with the framework of statistics on EGSS, may also be of interest. These statistics would, for example, provide information on the share of overall value added contributed to the economy through the production of goods and services that are designed specifically for the protection or management of ecosystems.

6.2.3 Linking ecosystems and ecosystem services to economic activity

6.15 The focus of this area is on providing information on the relationship between ecosystems and standard measures of economic activity. While the focus of ecosystem accounting is often on the additional, unpriced services provided by ecosystems, there is also interest in understanding the significance of the relationship between ecosystems and standard measures of economic activity, such as GDP.

6.16 A useful approach is to spatially disaggregate measures of economic activity, perhaps using information on land use or land ownership, such that flows of ecosystem services and changes in ecosystem assets can be related directly to measures of output, employment and value added in the same spatial areas. (It is noted that the most appropriate spatial boundaries will vary for different ecosystem services and this may need to be taken into account in interpreting any detail spatial information.) Additional benefit would be gained by also integrating estimates of population at fine geographic levels.

6.17 The allocation of economic activity to small spatial areas can be conceptually difficult and may require the use of various indicators. For example, the ideal spatial allocation of transport activity is not obvious. Therefore, it may be most useful to commence with identification of measures of economic activity for those industries and activities for which a clear link can be established between an ecosystem and the location of the production – for example, agriculture, forestry, fishing, and tourism. This information may be of particular use in considering the allocation of ecosystem degradation to economic units.

6.18 Where links between economic units and particular ecosystems can be established, it is also possible to consider integrating information on a range of other transactions that may take place in relation to the economic activity. For example, payments of certain environmental taxes, payments of rent on natural resources, payments of environmental subsidies and similar transfers may be combined with standard economic indicators and indicators of ecosystem services and assets to provide a more complete picture of the relationships between a given ecosystem and the economy.

6.2.4 Treatment of payments for ecosystem services

6.19 A specific case of a link between ecosystems and economic transactions is the case of payments for ecosystem services (PES). PES have been defined as voluntary and conditional transactions over well-defined ecosystem services between at least one supplier and one user (Wunder, 2005). In the context of PES the payments relate to ecosystem services that contribute to non-SNA benefits. It is assumed that those ecosystem services that contribute to SNA benefits are already captured in current transactions.

6.20 Since PES are monetary transactions in scope of the SNA their accounting treatment should follow the SNA. To a large extent this will depend on the nature of the scheme that is in operation. Notwithstanding their general title, no payments are made to the ecosystem generating the relevant ecosystem services. Rather, payment is made to an economic unit who, in return, undertakes various remedial actions or changes patterns of use of the ecosystem (including potentially not undertaking economic activity), with the objective of maintaining or increasing the supply of ecosystem services.

6.21 Given the conceptualisation for ecosystem services that has been developed in SEEA Experimental Ecosystem Accounting it is reasonable to conclude that any payments reflect the “marketisation” of flows which might otherwise be considered outside the scope of the SNA production boundary. Thus, the situation is analogous to the treatment of the provision and consumption of services within the home. Following SNA, child care by parents at home is considered outside the production boundary, but where child care services are provided by economic units in return for money (or similar) the activity in considered inside the production boundary. In this sense PES represent an extension of the production boundary and the output of the economic unit receiving the payment should be increased. At the same time, the unit may also be required to incur current and capital expenditure and these are likely to be already recorded following SNA accounting practices.

6.22 In a combined presentation, a spatial organisation of information is relevant. For given ecosystems a combined presentation may show flows of PES together with information on the flows of ecosystem services and measures of ecosystem assets. In addition, where payments are made for the undertaking of ecosystem maintenance or restoration activity, it would be relevant to link this information with information on expenditure on these activities (see previous sub-section) and ensure consistent accounting of the relevant transactions.

6.3 Accounting for ecosystem assets in monetary terms

6.3.1 Introduction

6.23 The measurement of changes in ecosystem assets, and in particular ecosystem degradation, is an important component of environmental-economic accounting. Using the framework for asset accounts as described in Chapter 5 of the SEEA Central Framework, this section outlines the possible structure of an ecosystem asset account in monetary terms.

6.24 Underpinning the development of an asset account is the application of the standard asset accounting model as applied in the case of produced assets. In short, this application of the model requires that the values of ecosystem service flows are interpreted as analogous to income flows. Since the set of ecosystem service flows described in SEEA Experimental Ecosystem Accounting contribute to both SNA and non-SNA benefits, it implies that the production boundary, and the associated boundaries of consumption and income, are broader in SEEA Experimental Ecosystem Accounting compared to the SEEA Central Framework and the SNA. The extension of the income boundary ensures that there is alignment between the characterisation of the asset and production boundaries.

6.25 The application of the standard asset accounting model to ecosystem raises numerous concerns that must be considered before undertaking such an accounting exercise. A particular concern is the implicit assumption of weak sustainability, i.e. the potential substitutability between different assets (generally between produced and non-produced assets), that is made when stocks and flows of ecosystem and environmental assets are valued using net present value techniques. These concerns are heightened when values of ecosystem assets are integrated in extended wealth accounts (see Section 6.4) but are relevant here as well.

6.26 Following the introduction of a possible structure of an ecosystem asset account in monetary terms, most of this section is devoted to discussion of the valuation of ecosystem degradation. This has been a significant focus of work over many years and the key elements of the discussion are summarised. The discussion builds on the discussion of ecosystem degradation in physical terms in Chapter 4 and readers are encouraged to review that material before considering valuation issues. Overall, there are significant conceptual and measurement challenges involved in developing ecosystem asset accounts and this section is intended to introduce the possibility rather than recommend their compilation.

6.3.2 The structure of ecosystem asset accounts

6.27 The broader standard asset accounting model permits the development of estimates of the total value of an ecosystem asset in monetary terms. In concept, the value of an ecosystem asset may be considered to be equal to the discounted values of expected ecosystem service flows.

These discounted values provide the opening and closing estimates of ecosystem assets in monetary terms and can be presented in the form of an asset account following the structure described in the SEEA Central Framework.

6.28 The basic structure of an ecosystem asset account is shown in Table 6.1. Since the estimates are compiled in monetary terms, estimates for different ecosystem assets can, in theory, be summed to provide higher level aggregates. The information might also be presented in combination with information in physical terms.

Table 6.1 Stylised Ecosystem Asset Account Entries

	Ecosystem accounting unit
Opening stock of ecosystem assets	
Additions to stock of ecosystem assets	
Regeneration - natural (net of normal natural losses)	
Regeneration – through ecosystem enhancement	
Reclassifications	
Total additions to stock of ecosystem assets	
Reductions in stock of ecosystem assets	
Extraction and harvest	
Catastrophic losses due to natural events	
Catastrophic losses due to human action	
Reclassifications	
Total reductions in stock of ecosystem assets	
Revaluations	
Closing stock of ecosystem assets	

6.29 Ecosystem degradation is not shown explicitly in the asset account as it represents the differences between various additions and reductions in ecosystem assets. As explained in Chapter 4 there are a range of perspectives that may be taken with regard to ecosystem degradation, especially in relation to the accounting treatment for ecosystem conversions. Further discussion on the measurement of ecosystem degradation in monetary terms is presented in the following sub-section.

6.30 The value of ecosystem degradation is only part of accounting for the change in value of the ecosystem over an accounting period. A complete ecosystem asset account also requires consideration of changes in an ecosystem over an accounting period due to

- regeneration through ecosystem enhancement
- significant natural causes, e.g. floods, fires, etc
- reclassifications
- revaluations

6.31 Major restoration of ecosystems during an accounting period should be recorded separately as an addition to ecosystem assets. This may occur, for example, when major replantings of native species in deforested areas are undertaken. Such regeneration should not be considered an "offset" to reductions in ecosystem assets due to harvesting of timber resources in other forest areas.

6.32 Accounting for major restorations of ecosystems relates to a standard national accounts entry for expenditures on land improvements. These expenditures constitute a type of gross fixed capital formation and are included in the accounts valued on the basis of the costs of undertaking the improvements. In a full asset account for ecosystems, care should be taken to appropriately integrate these flows of capital formation with changes in the value of the related ecosystems.

6.3.2 Measuring ecosystem degradation in monetary terms

Valuing ecosystem degradation using expected ecosystem service flows

6.33 Since in monetary terms an aggregate value for expected ecosystem services flows is derived, the most straightforward approach to measuring ecosystem degradation is as the change in value of expected ecosystem service flows over an accounting period. However, in the case of ecosystem conversions there is a change in the basket of ecosystem services and hence the change in value of expected flows also incorporates the effects of changes in expectations. Depending on the purpose of analysis it may or may not be reasonable to incorporate these effects in measures of ecosystem degradation.

Restoration cost

6.34 If ecosystem degradation is considered to relate only to reductions in ecosystem condition it is not possible to apply standard asset accounting models to value and incorporate measures of ecosystem degradation using expected ecosystem service flows. In this case the ecosystem asset is conceptualised as a single unit and ecosystem degradation is valued in an aggregate sense rather than being considered in terms of separable ecosystem service flows. The most common approach to valuation in this situation is to determine the restoration cost – i.e. the estimated expenditure required to return the ecosystem asset to the condition that existed at the beginning of the accounting period.

6.35 There is a range of concerns about the use of a restoration cost approach. These include that the implicit price does not reflect a market price, that it is unclear whether the ecosystem should or could be restored to a previous condition, and that the use of an aggregated approach is not conducive to a full allocation of costs to relevant economic units.

6.36 At the same time the approach is a direct measure of a possible value of ecosystem degradation that can be estimated in a manner commonly used in the estimation of the value of public goods in the national accounts. Further, even if not used to value degradation, estimates of restoration cost may be of interest in their own right.

Damage-based and cost-based values of ecosystem degradation

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

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

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

Allocation of ecosystem degradation to economic units

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

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

6.4 Integration of ecosystem accounts and economic accounts in monetary terms

6.4.1 Introduction

6.42 This section introduces three areas related to the integration of ecosystem accounts with economic accounts of the SNA:

(i) The compilation of wealth accounts that compare the values of ecosystem assets with values of produced assets, financial assets (and liabilities), and other economic assets in an extended balance sheet.

(ii) The compilation of a sequence of economic accounts taking into account ecosystem services and other ecosystem flows, especially ecosystem degradation;

(iii) The derivation of aggregate measures of economic activity, such as income and saving, that are adjusted for ecosystem degradation.

6.43 The extent to which estimates of ecosystem services, ecosystem degradation and related measures can be integrated within standard economic accounts depends on the underlying approach taken to the conceptualisation of ecosystem assets and ecosystem services. Where the value of ecosystem assets is conceptualised as being directly related to expected ecosystem service flows, then there is the potential to develop integrated sequences of accounts, degradation adjusted measures and wealth accounts. Where this direct connection is not assumed such integrated accounts cannot be compiled.

6.44 This section introduces what may be possible but deliberately refrains from providing recommendations. This is done for a number of reasons:

(i) First, although there are a range of commonly articulated reasons for developing adjusted or extended accounts in monetary terms, there are strong contrary views about the meaningfulness of any alternative measures in light of the assumptions required for valuation and consequently in the ability to use adjusted measures for policy purposes.

- A particular consideration concerns the implicit assumption of weak sustainability, i.e. the potential substitutability between different assets (generally between produced and non-produced assets), that is made when stocks and flows of ecosystem and environmental assets are directly integrated with stocks and flows of economic assets in monetary terms. The relevant assumptions can also be seen from the perspective of the maximisation (or maintenance) of an extended concept of wealth.

- In contrast it is possible to consider that different assets may not be substitutable in a range of situations – this view underlies the "critical natural capital" approach. Consequently, the approaches to valuation that are commonly used to integrate values of ecosystem services into standard national accounting structures may not be appropriate.

(ii) Second, from a measurement perspective, there remain a range of significant conceptual and measurement challenges, particularly in terms of aggregation within and across ecosystems, that make it difficult to ensure a coherence between the adjustment being made (e.g. ecosystem degradation) and the existing accounting entry (e.g. GDP).

(iii) Third, there are concerns from the official statistics community about whether the types of adjustments and extensions to the SNA that are commonly described fall within scope of the purview of official statistics. While the audience for the SEEA is broader than official statisticians and SEEA Experimental Ecosystem Accounting is not an international statistical standard, the SEEA remains a document developed and managed by the international statistical system and hence its content reflects on that system.

- A particular touchstone here is the extent to which the estimates used to populate accounting frameworks are based on direct observed data or based on outputs from a modelling process. Generally, this distinction is a matter of degree since all national statistics require assumptions of various kinds to aggregate detailed observations. At issue is the robustness of the assumptions and the quality of the modelling.

(iv) Fourth, although the potential of making adjustments to the income accounts of the SNA to adjust for degradation has been discussed for over 30 years, there has been no definitive conclusion to the discussion and alternative presentations may be justified depending on the particular environmental situation or question of policy interest.

6.45 While there are a range of concerns at a technical and interpretative level, the use of estimates in monetary terms can be useful in encouraging discussion of ecosystem related information in a context that is often more familiar to policy agencies and other users. The “mainstreaming” of ecosystem accounting information through the use of estimates in monetary terms is perhaps the strongest rationale for their compilation.

6.46 Work on adjusting or extending SNA income accounts and balance sheets must be considered in the context of the concepts and measurement challenges outlined in Chapters 1-5 of this document. Three aspects in particular must be highlighted. First, adjustment requires assessment of ecosystems in physical terms. Second, adjustment or extension requires valuation techniques to be used to derive estimates in monetary terms. Third, adjustment requires aggregated measures of ecosystem services and ecosystem assets.

6.4.2 Wealth accounts

6.47 It is common for measures of well-being and progress to be considered in the context of sustaining a broad stock of assets or comprehensive wealth. Various “capital” models can be found in the literature which include economic, environmental, social, and human capital. In some cases the different types of assets may be aggregated in monetary terms or weighted together to form composite indexes.

6.48 This sub-section does not describe measurement of all of the different types of assets, rather it focuses specifically on measurement challenges in incorporating ecosystem assets within broader wealth measures.

6.49 Unlike social and human capital which are not included in the SNA asset boundary, some components of ecosystem assets are included in the SNA asset boundary and this needs to be taken into account if measures of ecosystem assets are combined with standard measures of economic assets based on the SNA. The following boundary issues should be considered:

6.50 Treatment of biological resources. Following the SEEA all natural and cultivated biological resources are considered within scope of ecosystem assets. Thus, in aggregating measures of economic and ecosystem assets, care should be taken to avoid double counting. Care may also be required in considering the scope of cultivated biological resource that are intensively managed (e.g. intensive livestock and horticulture systems) to ensure that the relevant assets are recorded once only.

6.51 Treatment of mineral and energy resources. These natural resources are defined in the SEEA Central Framework and are not considered a part of ecosystem assets as the benefits they provide are not the result of ecosystem processes. These resources will generally need to be added to ecosystem assets to obtain a broader notion of environmental assets but they may already be included as part of economic assets consistent with the scope outlined in the SNA.

6.52 Special consideration may be required of peat resources which may be used as a form of fossil fuel (and are a part of mineral and energy resources), but which also are a widely distributed type of soil. In particular, peat soils are a very significant store of carbon in many different ecosystems. Care should be taken to avoid double counting of peat soils.

6.53 Treatment of energy from renewable sources. Renewable sources of energy (such as wind and solar sources) cannot be exhausted in a manner akin to fossil energy resources and neither are they regenerated as is the case with biological resources. Thus, in an accounting sense, there is no physical stock of renewable sources of energy that can be used up or sold. Rather the value of the ongoing capture of energy from these sources is embedded in the value of the technology used to capture the energy and the associated land and water. Since these values are not dependent on ecosystem operation, no values for renewable sources of energy are included in ecosystem assets. However, the values of any energy capture technology and associated land and water are likely to be included in measures of economic assets consistent with the asset boundary of the SNA.

6.54 Treatment of water. Depending on the nature of the stock of water in a country, some deep, sub-soil water may be considered not part of ecosystem operation and hence would lie outside the asset boundary of ecosystem assets. In that case additional valuation may be required.

6.55 Treatment of marine areas. In both the SNA and the SEEA Central Framework the stock of water in marine areas is not valued. This is because the stock of water is too large to be meaningful for analytical purposes. In SEEA Experimental Ecosystem Accounting the value of marine environments is captured as part of the various ecosystem services they generate and thus the volume of water is not a measurement target per se.

6.56 Special consideration may be required in relation to the value of aquatic resources outside a country's Exclusive Economic Zone (EEZ). Following the asset boundary of the SNA and the SEEA Central Framework some of these resources may be included in the scope of economic assets in circumstances where exploitation control has been established and access rights are defined through international agreements. From the perspective of SEEA Experimental Ecosystem Accounting, no specific guidance is provided on the precise geographic scope that should be applied in the context of marine areas. Thus care should be taken to align the scope of aquatic resources captured in measures of both economic assets and ecosystem assets. In this regard the treatment of migrating and straddling fish stocks may be of particular interest.

6.57 Treatment of land. In some cases, the value of land as recorded in the SNA will provide a useful comparison point to the value of ecosystem assets for particular ecosystems. Thus for example, it would be envisaged that the value of agricultural land following the SNA would provide a value including many ecosystem services, at least from the perspective of those ecosystem services within the scope of the SNA production boundary. However, there are a number of specific boundary issues that should be considered:

(i) SNA land values will not capture the value of all ecosystem services. However, they may include some effects of, for example, protection from flooding or access to clean water, that are beyond the coverage of values related to agricultural and other production.

(ii) SNA land values will incorporate, perhaps to a significant extent, the impact of the location of the land. This locational value does not reflect a type of ecosystem service. At the same time, the location of an ecosystem is likely to play a role in the relative demand for certain ecosystem services and hence will impact on the overall value of those services. Consequently, the links between land values and values of ecosystem assets may not be able to be neatly distinguished.

(iii) Some areas of land, perhaps of high ecological significance, may not be actively traded (for example national parks) and hence may not be included in the scope of the SNA asset boundary. These areas are in scope of the SEEA Central Framework asset boundary in physical terms and, in the context of ecosystem assets, values should be included reflecting the range of non-SNA benefits provided from these areas of land.

(iv) Conceptually, urban and built up areas are a type of ecosystem. Consequently, these areas are within scope of ecosystem accounting and may be of interest for particular purposes (e.g. analysis of the role of public "green spaces" in cities). It is also noted that urban populations used significant quantities of ecosystem services, both directly and indirectly. While urban ecosystems may be of interest they may not often be considered a focus of ecosystem accounting. Hence, care should be taken to ensure that the geographic boundaries being applied in the measurement of ecosystem assets ensure appropriate coverage of economic and ecosystem assets in urban areas.

6.58 Since the measurement of ecosystem assets is undertaken starting from a spatial scale, ideally, adjustments to align the measurement boundaries between ecosystem assets and economic assets should also be undertaken spatially. This is particularly the case when considering that the value of the ecosystem does not lie in the sum of its components but rather in terms of how all of the components within a given area function. The best approach to aggregation may be to determine the spatial scope of ecosystem assets, estimate the value of economic assets in that area, and then add on the values relevant to ecosystem services that are not already captured. However, this approach may be difficult to apply in practice, especially when attempting to allocate estimates of national wealth to the institutional sector level.

6.4.3 Sequence of accounts

6.59 A sequence of accounts presents the relationships between all stocks and flows recorded in an accounting system and embodies the relationships in the accounting framework. The starting point for the SEEA sequence of accounts is the standard SNA sequence of accounts presented in the 2008 SNA. The sequence presents accounts for production, the distribution and use of income, capital and financial transactions and balance sheets. While a sequence of accounts may be developed for a country as a whole with flows to and from the rest of the world, a full sequence of accounts also records entries between all of the institutional sectors within an economy, i.e. corporations, general government, households and non-profit institutions serving households (NPISH).

6.60 Compared to the SNA, the additional feature of the sequence of accounts described in the SEEA Central Framework is the incorporation of entries for depletion in the various accounts. This addition is described in detail in Chapter 6 of the SEEA Central Framework. Overall, the sequence of accounts shows very little variation from the standard SNA sequence of accounts.

6.61 In ecosystem accounting, the structure of a sequence of accounts is more difficult to determine because of the distinctive nature of ecosystem degradation in accounting terms as discussed in the previous section and in Chapter 4. Over the past 20 years a range of alternative accounting proposals have been made.

6.62 The most significant structural choice for a sequence of accounts for ecosystem accounting is whether ecosystems are considered to constitute a separate quasi-institutional sector, alongside corporations, general government, households, and NPISH, or whether ecosystem assets are a part of the broader stock of assets used by the various institutional sectors and hence no additional, quasi-sector is needed. An annex describes in more detail the possible models regarding a sequence of accounts for ecosystem accounting.

6.4.4 Adjusted income aggregates

6.63 It has long been recognised that GDP and other income measures within the national accounts framework should not be considered measures of welfare or well-being. The 2008 SNA outlines a number qualifications to GDP in this regard, including the scope of consumption, issues of income distribution, the impact of external events (e.g. health epidemics, extreme weather), externalities of production, and various non-economic impacts on welfare, such as life satisfaction. In the context of environmental-economic accounting there is no ambition to account for all of these factors and hence any adjusted income aggregates that may be derived should not be interpreted in the very broad sense that may be envisaged.

6.64 Notwithstanding the effect of a focus only on environmental factors that affect welfare, there has been much investigation into income measures adjusted for what are generically referred to here as “environmental costs”. If these costs are limited to adjustments to income for the costs of depletion of natural resources then the SEEA Central Framework provides the appropriate accounting for derivation of depletion adjusted aggregates (see SEEA Central Framework Chapter 6).

6.65 Beyond the environmental costs of depletion, there have been ambitions to derive measures that adjust for the costs of ecosystem degradation. Often these measures are referred to as

Green GDP but this single term has been applied to many concepts and approaches and increasingly is used in a different context to refer to that part of the conventionally measured economy that is considered environmentally related. Consequently, it is strongly advised that the term Green GDP be avoided.

6.66 The measurement of ecosystem degradation in monetary terms points to one way in which an adjustment to income aggregates within the SNA may be adjusted for the costs of degradation. To retain accounting consistency the income measures themselves should be expanded to incorporate the generation and use of ecosystem services that are not captured within the standard SNA production boundary. From this broader income measure, a measure of ecosystem degradation is deducted to derive degradation adjusted aggregates. While this basic approach is possible, the underlying measurement assumptions and challenges are significant and consequently, SEEA Experimental Ecosystem Accounting does not recommend or endorse any specific approach to adjusted measures of income or any particular approach to valuation.

6.67 Beyond those challenges already noted in this chapter, and as with all of the measures and aggregates in monetary terms, adjusted income aggregates suffer from the difficulty that the values of the environmental variables cannot generally be made in a full, open market context. Consequently, the valuations are, at best, estimates of prices at partial equilibriums. Extended modelling is possible in which attempts are made to estimate what GDP (and other income measures) would be if alternative environmental constraints were in existence. So-called greened economy modelling thus derives a measure of income for an alternative view of the economy rather than deriving an alternative measure of income for the existing economy. There are no specific conceptual accounting issues in following this approach but it is an approach founded in modelling based on alternative scenarios and is thus outside the scope of the SEEA.

Annexes

Annex to chapter 3: Approaches to the measurement of selected ecosystem services

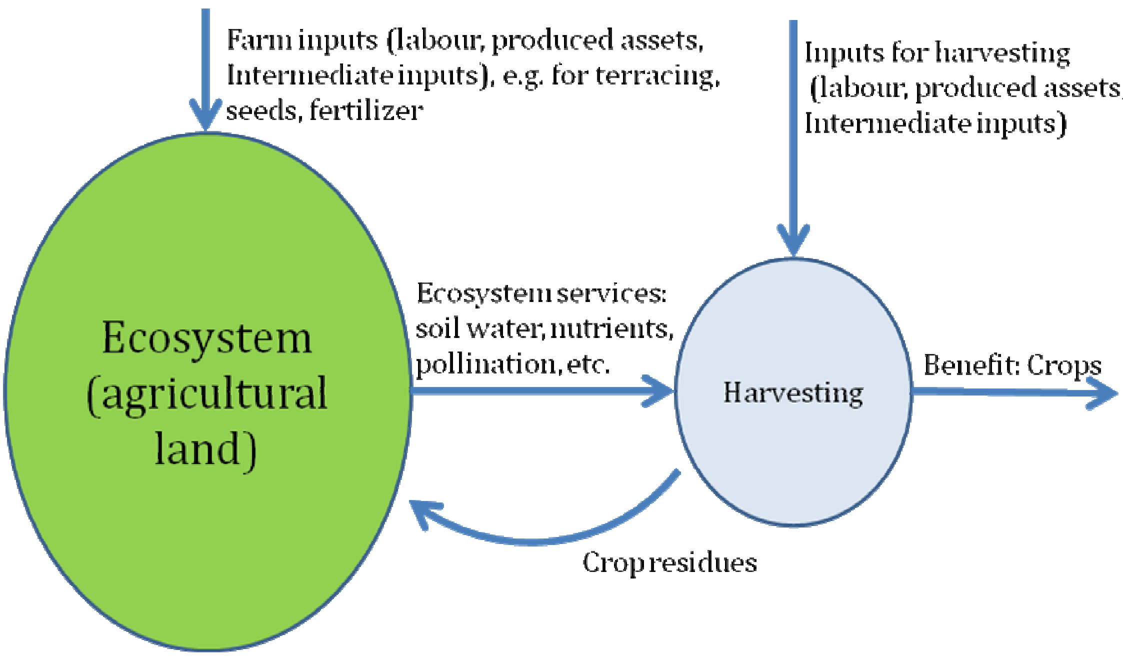
A3.1 This annex provides examples of measurement approaches for some selected ecosystem services. It is recognised that presenting the information in this de-constructed way may give the impression that ecosystem services are easily separable flows. In reality, the measurement of ecosystem services must start from a more holistic sense of an overall ecosystem and the range of different services that effectively emerge from the ecosystem as a bundle of services. However, as a matter of statistical and scientific approach, direct measurement of this bundle is not possible and hence a decomposition must be adopted.

Provisioning services

Provisioning services for crops

A3.2 Agricultural production includes the production of annual and perennial crops in cultivated land including plantations, see Figure A3.1. The ecosystem services comprise pollination, abstraction of soil water and nutrient uptake and fixation. The farmer or land manager (i) manages, on a regular basis, the overall production environment, i.e. the farm or plantation, for instance by constructing wind breaks or irrigation reservoirs, pruning, etc; and (ii) harvests crops using labour and machinery. In practice, it may not always be easy to distinguish between these different inputs at an individual farm level. Crop residues are recorded as remaining in the field, and returned to the ecosystem (a type of intra-ecosystem flow).

Figure A3.1. Crop production

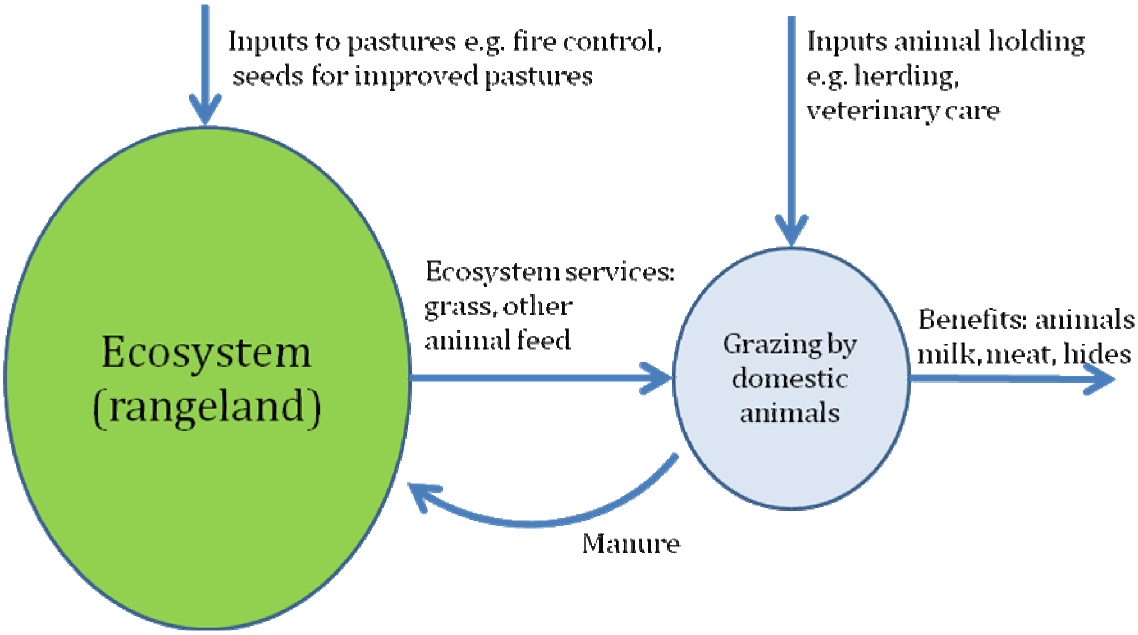


Provisioning of fodder for livestock

A3.3 In livestock grazing, the service supplied by the ecosystem relates to the amount of animal fodder grazed by livestock. This animal fodder comprises annual and perennial grasses and herbs, leaves from trees, etc. The livestock holding system may be more or less intensive, for instance free ranging cattle grazing large stretches of semi-arid rangeland, or dairy cattle grazing confined pastures. The land manager may invest in managing the overall ecosystem, for instance by sowing improved pasture varieties, or by building fences or firebreaks. Livestock holding is the activity undertaken by the land manager in the ecosystem, involving all aspects related to animal production and resulting in outputs of animals, wool, milk, meat, hides, etc.

A3.4 The ecosystem service can be measured in physical terms in terms of amount of fodder grazed by animals on an annual basis. Fodder will normally comprise different types of quality (palatability, nutrient contents, etc.). A part or all of the manure is normally returned to the field, contributing to maintaining soil fertility in the ecosystem, see Figure A3.2

Figure A3.2. **Provisioning of fodder for livestock**



Provisioning of wood and non-timber forest products

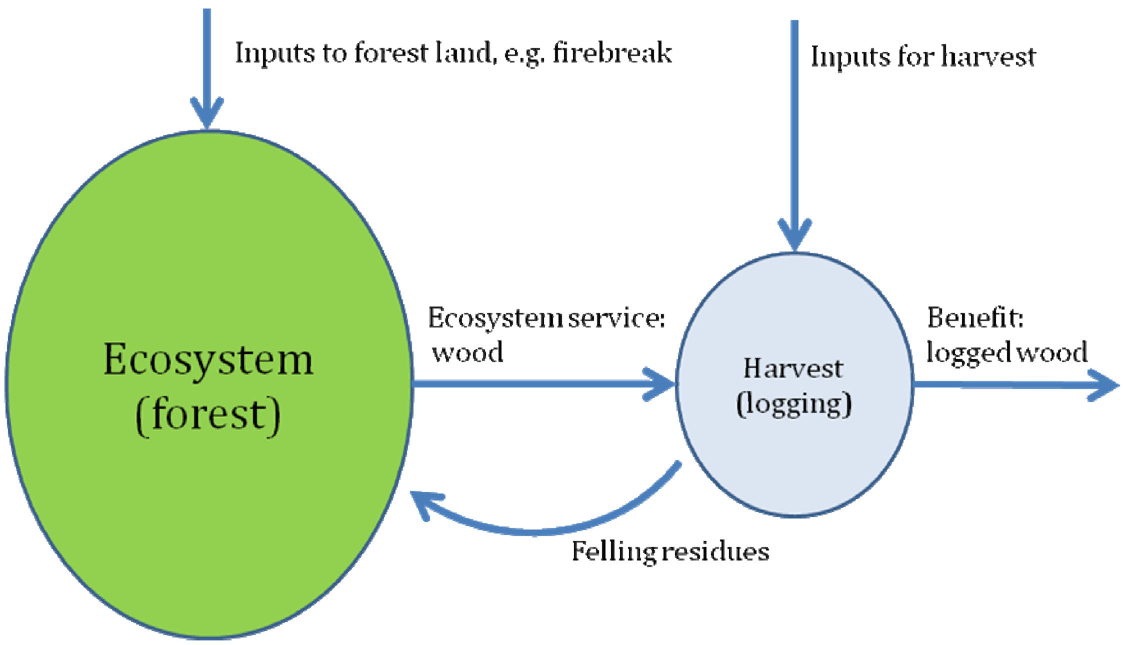
A3.5 Wood production includes the production of timber and firewood in natural, semi-natural or plantation forests. Non-timber forest products (NTFPs) include a broad range of products that can be harvested in a forest, such as fibres (e.g. rattan), fruits, mushrooms and pharmaceutical products. Plantation forests are considered cultivated biological resources and are evidenced by relatively significant levels of economic activity in the growing process including the construction of fire breaks, reforestation with specific species, the spraying of pesticides, and the thinning of branches to promote growth.

A3.6 Consistent with the application of the distinction between cultivated and natural biological resources, the flows related to wood from naturally regenerated forests and NTFP are presented in Figure A3.3 while the flows related to wood from plantations should be shown following the same logic as presented in Figure A3.1 in relation to provisioning services for crops.

A3.7 For logging, a number of inputs are required such as labour, a saw and a truck. The product resulting from the logging is logged wood, with felling residues returned to the ecosystem.

Wood can have a wide range of different qualities. Both the benefit (logged wood) and the ecosystem services (wood) can be measured in terms of kg/ecosystem/year. The difference between the two is that the ecosystem service represents wood at the moment immediately before it is felled. The benefit arises immediately after felling.

Figure A3.3 Provisioning of wood as a natural biological resource



Provisioning of fish and other aquatic and marine species

A3.8 Marine or inland waters (lakes, rivers) supply fish and other species (shrimps, shellfish, seaweed, etc.). There is generally little investment in maintaining the state of the ecosystem, even though monitoring or enforcement activities may be undertaken, and on specific occasions also restocking of specific lakes may be carried out. However, inputs are required for the harvesting of fish and other species, involving boats, nets, labour, etc.

A3.9 The ecosystem service is the fish as it is harvested (corresponding to the 'gross removal'). The benefit resulting from the activity fishing is also fish. The ecosystem service may be measured in physical terms in terms of the amount of fish caught (i.e. the gross removal from the ecosystem), accounting for differences in species. Discarded catch is usually returned to the ecosystem. Often the discarded catch consists mainly of dead specimens that do not lead to a restocking of the ecosystem.

A3.10 In the case of aquaculture, the ecosystem services are more akin to those recorded in the case of livestock. Thus the natural feed and other natural inputs are the ecosystem services representing the contribution of the ecosystem to the growth of the fish or other aquaculture products. Aquaculture operations that involve no connection to a broader ecosystem (for example fish raised in tanks) would be recorded as having no associated ecosystem services.

Provisioning of water

A3.11 Freshwater can be extracted from deep or shallow aquifers, and from surface water including lakes, rivers or man-made reservoirs. The supply of water from deep aquifers is not strongly linked to ecosystem functioning since these reservoirs tend to depend on geological water resources. The extraction of water from deep aquifers storing water that is not replenished on human time scales should therefore be interpreted as flows of abiotic services.

A3.12 For both surface water and water extracted from renewable, shallow aquifers, both the quantity and the quality of water generally depend on ecosystem functioning. Water from rivers, lakes or other reservoirs may be purified by ecosystems, in particular if it has passed through a wetland that has the capacity to break down organic pollutants, and absorb inorganic pollutants. Water pumped up from aquifers or other subsurface groundwater sources is often less polluted than surface water because of the capacity of ecosystems to breakdown or bind pollutants and filter micro-organisms harmful to human health. Often, headwaters or complete watersheds important for drinking water production are protected and managed as drinking water extraction area.

A3.13 Water supply therefore combines elements of a provisioning and a regulating service. It is a provisioning service in the sense that the extraction of water involves a flow from the ecosystem to society, however underlying the presence of the water are a number of regulating processes such as water storage (inter or intra-annual) and water purification.

A3.14 The water accounts presented in the SEEA Central Framework and in SEEA-Water detail the methods for accounting for water resources including deep aquifers. In contrast, in SEEA Experimental Ecosystem Accounts, the focus is on ecosystems’ capacity to support water extraction. The approach taken is to analyse the provisioning of water as an ecosystem service: the ecosystem service is the amount of water (before treatment) extracted from the surface water source or the shallow aquifer.

A3.15 Investments may be made in order to protect the ecosystem (generally a watershed) supplying the water (e.g. adjusted land management, monitoring of water quality, creation of retention basins) as well as for the transformation of extracted water into drinking water. The extracted, untreated water enters the production function of the drinking water company, or of the household consuming the water. The household may either consume this water directly, or filter it before consumption.

Regulating services

Sequestering of carbon and carbon storage

A3.16 Often, the services of sequestering of carbon and carbon storage are labelled by the single term “carbon sequestration”. However, they are quite different ecosystem services, albeit linked within the broader carbon cycle. Both services are important for ecosystem management and therefore for ecosystem accounting. The release of carbon stored in above ground biomass or in below ground stocks, such as peatlands, is an important source of greenhouse gas emissions worldwide. It is also the subject of much debate in the international arena, in particular with regards to the REDD (Reduced Emissions from Deforestation and

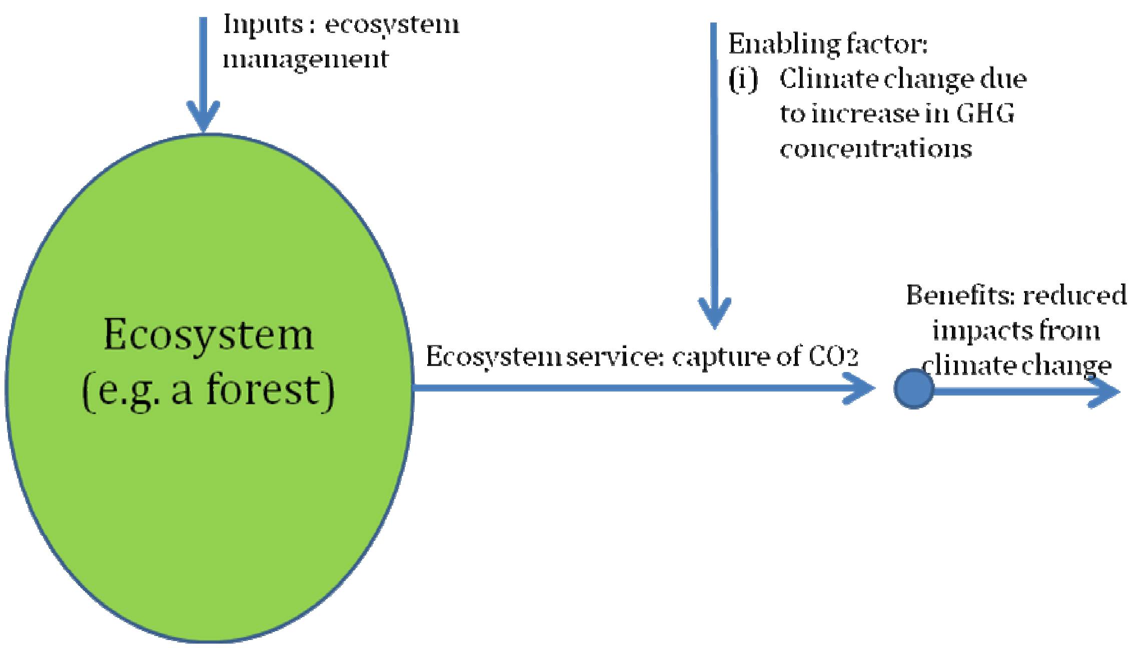
Degradation) payment mechanism. At the same time, the sequestering of carbon, i.e. the ongoing accumulation of carbon due to ecosystem processes in particular Net Ecosystem Production, is relevant since this removes carbon dioxide from the atmosphere.

A3.17 In order to capture both the stock and the flow aspect, the following conceptualisation of this ecosystem service is used for the purpose of ecosystem accounting. Analogous to other ecosystem services, the sequestering of carbon and carbon storage are service flows that can only have positive values. In both cases the flows are expressed as tons of carbon(equivalent) per year, and should be specified for spatially defined areas that can be aggregated for the purpose of national level ecosystem accounting. The service of the sequestering of carbon is equal to the net accumulation of carbon in an ecosystem due to growth of the vegetation and due to accumulation in below ground carbon reservoirs. The ecosystem service of carbon storage is the avoided flow of carbon resulting from maintaining the stock of above ground and below ground carbon sequestered in the ecosystem.

A3.18 To calculate the second part, i.e. the flow that can be attributed to maintaining carbon in storage, the avoided emissions may be calculated. Under this approach the avoided emissions only relate to the part of the stored carbon that is at clear risk of being released in the short term due to land use changes, natural processes (e.g. fire) or other factors. No service flow is recorded if stocks at risk of being released are released, but positive service flows are recorded where stocks at risk remain in storage.

A3.19 The conceptual model of the ecosystem service as a function of ecosystem state and enabling factors is presented in Figure A3.4. Figure A3.4 shows that ecosystem management will generally affect the net sequestration and/or the storage of carbon in the soil. The enabling factor for this service is the occurrence of climate change, which causes carbon sequestration and storage to provide an economic benefit resulting from avoided damages, at present and in the future.

Figure A3.4 Sequestering of carbon



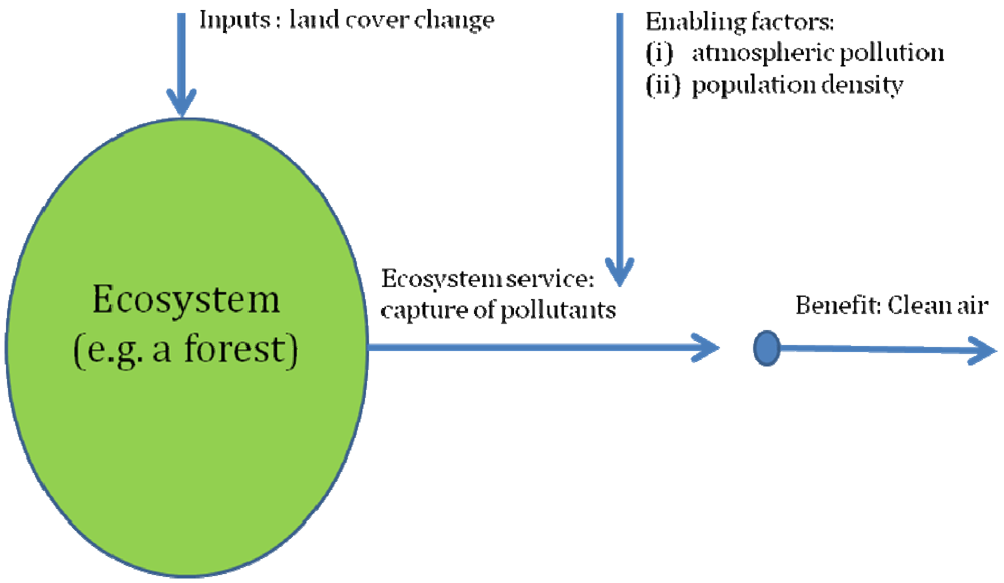
Air filtration

A3.20 Air pollution arising from particulate matter (in particular the smallest fraction of PM: PM2.5 with a diameter <2.5 µm) is a major health problem in many countries. Statistically significant relationships between PM concentration and cardiovascular and respiratory diseases, as well as lost working days due to air pollution-related illnesses have been shown in a range of studies. Air pollution removal takes place through the interception of PM by leaves (dry deposition). The amount of interception depends on the state and management of the ecosystem (for instance, on an annual basis evergreen trees capture more PM than deciduous trees). Two enabling factors are needed to turn the ecosystem process of deposition into an ecosystem service. First, there needs to be a certain pollution load (that can be measured in terms of PM concentration), and second, there needs to be an exposure of people to air pollution in the zone affected by PM deposition by the ecosystem.

A3.21 The total amount of particulate matter deposited in an ecosystem can be estimated as a function of the area, deposition velocity, time period and average ambient PM2.5 concentration, according to the formula PM↓ = A*Vd*t*C, in which PM↓ = deposition of PM2.5 (kg), A= area (m^2), Vd = deposition velocity as a function of the Leaf Area Index of the vegetation (LAI) (mm s^{-1}), t= time (s), and C = ambient PM2.5 concentration (kg/m3). The deposition velocity depends on the vegetation type, and there is an increasing number of measurements of deposition velocities as a function of vegetation type, in particular in European countries.

A3.22 A cause of uncertainty pertains to the distance at which vegetation influences air quality. The UK National Ecosystem Assessment assumed that health benefits from air filtration by forests only occur at short distances (<1 km) from the forest. Other studies state that damage assessments of particulate matter pollution need to consider that air pollution (PM) can spread over distances of several hundreds of kilometres from an emission source, which means that the effect of large forests on air quality may be noticeable at large distances from the forest edge.

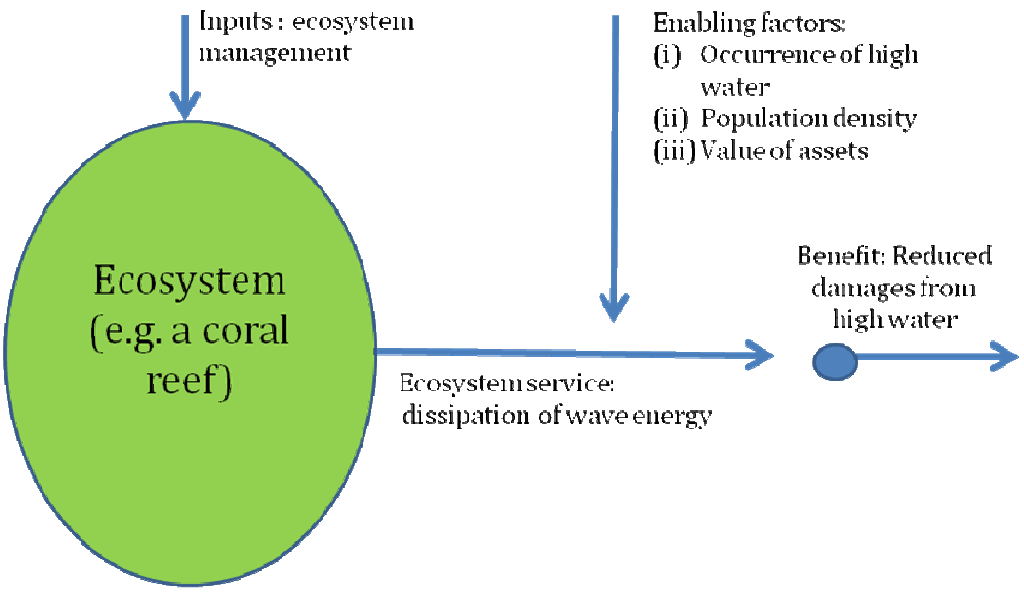
Figure A3.5 Air filtration



Flood protection

A3.23 It is clear from a range of studies that specific ecosystems can reduce the extent and intensity of floods, thus reducing the risk of damage to built environments and other ecosystems. Ecosystems such as mangroves, dunes or coral reefs, or riparian forests, are particularly relevant in this regard. This service is only relevant where there is (i) risk of high water and wave energy as a function of wind patterns and local bathymetrics; and (ii) the presence of people, economic activity and assets susceptible to loss in the exposed flood risk zone. Storm occurrence and therefore flood risk may be modelled in a probabilistic manner, on the basis of the occurrence and magnitude of storms in recent decades and on the basis of climate models accounting for climate change. In coastal areas, the ecosystem service involves the dissipation of wave energy and the prevention of inundation. In inland areas, the ecosystem service involves the channelling and dispersion of water.

Figure A3.6 Flood protection



Cultural Services

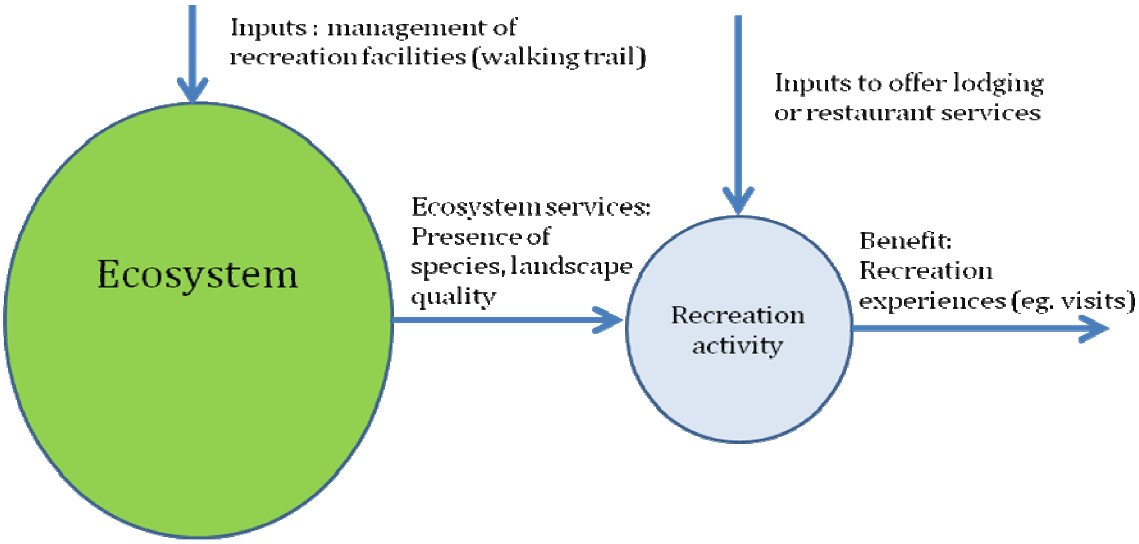
Tourism and recreation

A3.24 Ecosystems provide an opportunity for tourism and recreation. Tourism is generally interpreted as involving overnight stays, potentially visitors from abroad, and recreation is more usually associated with day trips. The service usually involves some degree of investment in the ecosystem, for instance to mark out and build walking trails, cycling paths, and camping sites. In physical terms, this ecosystem service can be measured in terms of the number of people visiting the ecosystem.

A3.25 The benefits accrue to visitors themselves, and to nearby suppliers of tourism and recreational facilities to the extent that they can attribute their operation to the ecosystem. For instance, some tourism facilities only exist because of the presence of the ecosystem, as in the case of an enterprise renting out skis or canoes. For other enterprises, the picture is mixed, and only part of their activity may be attributable to the ecosystem, as in the case of hotels or restaurants located in or near natural parks.

A3.26 Physical measurement of the ecosystem involves recording the number of visitors, in terms of visitor-days, or overnight stays, to ecosystems. Areas such as national parks that are publically accessible are most relevant for this service. As in the case of provisioning services, the use of ecosystem services in tourism involves a specific activity being undertaken, i.e. the recreation activities by people in an ecosystem.

Figure A3.7 Tourism and recreation services



Annex to Chapter 4, Section 4.4: Accounting for carbon

Introduction

A4.1 Carbon underpins practically all life on Earth with its capacity to bond to other elements particularly oxygen, hydrogen and nitrogen. Carbon is abundant in both the geosphere (in fossil fuels, rocks, methane clathrates and ocean sediments) and the biosphere (in living and dead plant and animal material in ecosystems and soils). Carbon, like water and land, is fundamental to the provision of ecosystems services, in particular the provisioning and regulating services. It is also the common thread between human energy production systems based on fossil fuels formed from ancient vegetation and the biomass fuels of today. The level of carbon in the atmosphere in the form of various gases, and in particular carbon dioxide, plays a critical role in the regulation of climate.

A4.2 The extensive role of carbon in the environment and the economy requires a comprehensive approach to measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon from the perspectives of the geosphere, the biosphere, the atmosphere, oceans and the economy. Figure 4.6.1 below presents the main elements of the carbon cycle. It is these stocks and flows that give the underlying context for carbon accounting. Of particular relevance is that there are qualitative differences between the different stores of carbon. Carbon accounting and ecosystem accounting more generally must take these differences into account. The following sub-section provides some additional detail on the carbon cycle and carbon stores.

A4.3 The accounting should also recognise different reasons for changes in the stock of carbon, for example, changes due to changes in land cover and land use, or changes due to extraction of energy resources. These various entries for stocks and changes in stocks are reflected in a carbon stock account that builds on the structure of the asset accounts for individual environmental assets described in the SEEA Central Framework, Chapter 5. The carbon stock account is presented in sub-section 4.6.3.

A4.4 Carbon stock accounts complement the existing flow inventories developed under the UNFCCC (UN Framework Convention for Climate Change) and the Kyoto Protocol. The carbon stock accounts presented here also align with the accounting approach of REDD (Reducing Emissions from Deforestation and Degradation). The classifications and data sets underpinning existing UNFCCC and Kyoto Protocol inventories are important for the construction of carbon stock accounts. For example, the IPCC (Intergovernmental Panel on Climate Change) carbon pool classification (above ground biomass, below ground biomass, dead wood, litter, soil organic matter) could be used to disaggregate biocarbon stocks for each ecosystem type. The SEEA land cover classification can be reconciled with the IPCC reporting categories for LULUCF namely: forest land, cropland, grassland, wetlands, settlements and other land for comprehensive stocks and flows accounting.

A4.5 The information presented has many uses for policy makers and researchers. In addition to policies aimed at reducing emissions by maintaining stocks of fossil fuels in the geosphere (a major focus of the UNFCCC), carbon stock accounts can provide consistent and comparable information for policies aimed at, for example, protecting and restoring natural ecosystems, i.e. maintaining carbon stocks in the biosphere. Combined with measures of carbon carrying capacity[35] and land use history, biosphere carbon stock accounts can be used to:

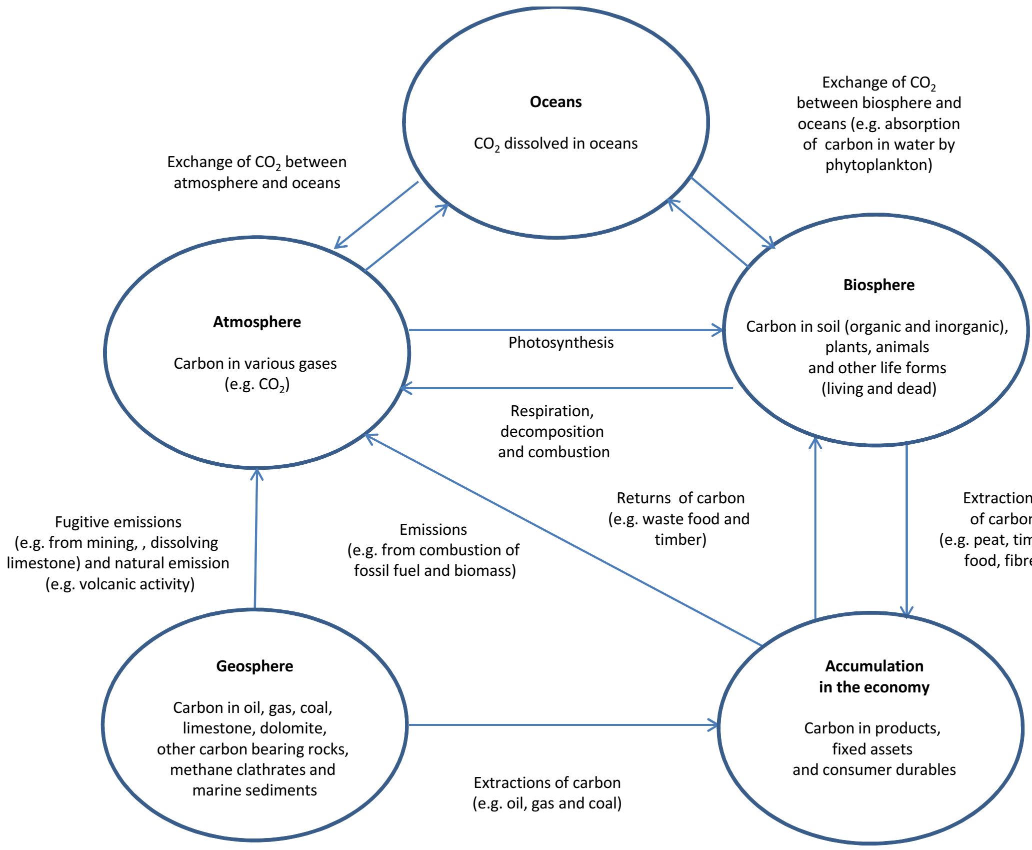
- investigate the depletion of carbon stocks due to converting natural ecosystems to other land uses;
- prioritise land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration or improved land management with their differing trade-offs against food, fibre and wood production, and;
- identify land uses that result in temporary carbon removal and storage.

A4.6 The information contained in carbon stock accounts can also be used more generally as part of the assessment of ecosystem capital and the measurement of ecosystem services. These linkages are explained in sub-section 4.6.4.

The carbon cycle

A4.7 Carbon flows between the reservoirs of carbon in the geosphere, biosphere, atmosphere and hydrosphere. This is commonly called the carbon cycle and the main elements of this are shown in Figure A4.4.1.

Figure A4.4.1. The main elements of the carbon cycle



[35] The mass of biocarbon able to be stored in the ecosystem under prevailing environmental conditions and disturbance regimes, but excluding human disturbance (Gupta and Rao 1994).

A4.8 The different reservoirs of carbon in the geosphere and biosphere differ in important ways, namely in the amount and stability of their carbon stocks, their capacity to be restored and the time required to do so. Different reservoirs therefore have different degrees of effect on atmospheric CO2 levels (Prentice et al. 2007). Carbon stocks in the geosphere are generally stable in the absence of human activity; however stock declines as a result of anthropogenic fossil fuel emissions are effectively irreversible.

A4.9 The stability of the carbon stocks in the biosphere depends significantly on ecosystem characteristics. In natural ecosystems, biodiversity underpins the stability of carbon stocks by bestowing resilience and the capacity to adapt and self-regenerate (Secretariat of the Convention on Biological Diversity 2009). Stability confers longevity and hence the capacity for natural ecosystems to accumulate large amounts of carbon over centuries to millennia, for example in the woody stems of old trees and in soil. Semi-modified and highly modified ecosystems are generally less resilient and less stable (Thompson et al. 2009). These ecosystems therefore accumulate smaller carbon stocks, particularly if the land is used for agriculture where the plants are harvested or grazed regularly.

A4.10 Structuring the carbon stock accounts to capture these qualitative differences between reservoirs is important because reservoirs with different qualities play different roles in the global carbon cycle. For given rates of fossil fuel emissions, it is the total amount of carbon and the time it is stored in the biosphere that influences the stock of carbon in the atmosphere.

Carbon stock account

A4.11 Applying the SEEA accounting principles of completeness and consistency and the SEEA Central Framework's approach to accounting for residual flows, carbon stock accounts record the stock changes from human activities at any point along the chain: from their origin in the geosphere and biosphere to changes in the various anthropogenic stocks (e.g. inventories of oil in storage; concrete in fixed assets; wood and plastic in consumer durables; solid waste – i.e. residuals that remain in the economy in controlled land fill sites; imports and exports) and as residuals to the environment, including emissions to the atmosphere. Carbon stock accounts can assist in informing of the implications of policy interventions at any point along the carbon cycle.

A4.12 The carbon stock account is presented in Table 4.5.1. It provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and in particular the differences in the nature of particular carbon reservoirs. Opening and closing stocks of carbon are recorded with the various changes between the beginning and end of the accounting period recorded as either additions to the stock or reductions in the stock.

A4.13 Carbon stocks are disaggregated to geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and soils). Geocarbon is further disaggregated into: oil; gas; and coal resources (fossil fuels) and rocks and minerals (e.g. carbonate rocks used in cement production, methane clathrates and marine sediments). For accounting purposes where the information generated from the accounts is policy focussed, the priority should be to reporting those stocks that are being impacted by human activity (e.g. fossil fuels).

A4.14 Biocarbon is classified by type of ecosystem. At the highest level these are terrestrial, aquatic and marine ecosystems, and these are shown in Table A4.4.1. This high level classification can be further broken down, but at present there is no internationally agreed classification of ecosystems. In the absence of this, compliers may chose to use the land cover classification of the SEEA Central Framework, noting that the primary purpose of this classification is not for ecosystem accounting, but for understanding production, consumption and accumulation from an economic perspective, not the ecosystem perspective. In this it should also be noted work on land cover classifications is part of the SEEA Central Framework research agenda.

Table A4.4.1 Carbon stock account

Gigagrams carbon (GgC)		Geocarbon					Biocarbon			Atmosphere	Water in Oceans	Accumulation in economy				TOTAL
		Rocks	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories *	Fixed assets	Consumer durables	Waste	
Opening stock																
Additions to stock																
	Natural expansion															
	Managed expansion															
	Discoveries															
	Upwards reappraisals															
	Reclassifications															
	Total additions to stock															
Reductions in stock																
	Natural contraction															
	Managed contraction															
	Downwards reappraisals															
	Reclassifications															
Total reductions in stock																
Imports and exports																
	Imports															
	Exports															
Closing stock																

*Excludes inventories included in biocarbon (e.g. plantation forests, orchards, livestock, etc)

A4.15 A key aspect for carbon accounting is to understand the degree of human influence over particular ecosystems. In this it may be desirable to recognise varying degrees of human modification of the ecosystem and potentially introduce these aspects into a classification. Degrees of human modification may be structured to reflect, for example:

- Natural ecosystems: which are largely the product of natural and ongoing evolutionary, ecological and biological processes. The key mechanism of 'management' in natural ecosystems is natural selection operating on populations of species which has the effect over time of optimizing system level properties and the traits of component species. System-level properties which are naturally optimized with respect to, among other things, environmental conditions include canopy density, energy use, nutrient cycling, resilience, and adaptive capacity. Natural processes dominate natural ecosystems within which human cultural and traditional uses also occur. Natural ecosystems include terrestrial and marine ecosystems.
- Semi natural ecosystems: which are human modified natural ecosystems. Natural processes, including regenerative processes, are still in operation to varying degrees. However, the system is often prevented from reaching ecological maturity or is maintained in a degraded state due to human disturbance and land use. Thus, the vegetation structure may not reflect natural optima, and the taxonomic composition may be depauperate.
- Agricultural ecosystems: which are human designed, engineered and maintained systems on agricultural lands that grow animals and crops mainly for food, wood and fibre and as feedstocks for biofuels and other materials. Plantations of trees for timber or fruit production (e.g. orchards) are included in the agricultural ecosystem. Note that these stocks in the SEEA Central framework and SNA would be included as inventories of the economy and hence must be removed from this category.
- Other ecosystems: including settlements and land with infrastructure.

A4.16 The atmosphere and ocean are the receiving environments for carbon released from primary reservoirs and accumulations in the economy. In this, the atmosphere and oceans may be viewed in a way similar to the way the rest of the world is treated in physical supply and use tables in the SEEA Central Framework, since they are not under the control of a particular owner. Oceans may be split into shallow and deep ocean reservoirs.

A4.17 Accumulations in economy are the stocks of carbon in anthropogenic products and are further disaggregated into the SNA components: Fixed assets (e.g. concrete in buildings, bitumen in roads); Inventories (e.g. petroleum products in storage, but excluding those include in agricultural ecosystems); Consumer durables (e.g. wood and plastic products); and Waste. Accounting for waste follows the SEEA Central Framework where waste products (e.g. disposed plastic and wood and paper products) stored in a controlled land fill sites are treated as part of the economy.

A4.18 Carbon stored through geosequestration (i.e. the managed injecting of gaseous CO2 into the surface of the Earth) is similarly treated as being a flow within the economy (increase in accumulations). Any subsequent release of carbon to the environment is treated as a residual flow with a reduction in accumulations in economy matched by corresponding increase in carbon in the atmosphere.

A4.19 Although not shown in the table, these ecosystem types could be disaggregated further into marine and terrestrial ecosystems. Marine ecosystems include mangroves, saltmashes and seagrass beds. Peat stocks and flows align with the biocarbon sector with peatland vegetation associated with a variety of ecosystems, including forests, grasslands, mossbeds, mangroves, saltmashes and paddies. There is potential to disaggregate Geocarbon and Biocarbon further.

A4.20 The row entries in the account follow the basic form of the asset account in the SEEA Central Framework: opening stock, additions, reductions and closing stock. Additions to and Reductions in stock have been split between managed and natural expansion. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account.

A4.21 There are six types of additions in the carbon stock account.

- Natural expansion: These additions reflect increases in the stock of carbon over an accounting period due to natural growth. This will be effectively only for biocarbon and may arise from climatic variation, ecological factors such as reduction in grazing pressure, and indirect human impacts such as the CO2 fertilisation effect (where higher atmospheric CO2 concentrations cause faster plant growth).
- Managed expansion: These additions reflect increases in the stock of carbon over an accounting period due to human-managed growth. This will be for biocarbon in ecosystems and Accumulations in economy, in inventories, consumer durables, fixed assets and waste stored in controlled land fill sites including the injection of greenhouse gases into the earth.
- Discoveries of new stock: These additions concern the arrival of new resources to a stock and commonly arise through exploration and evaluation. This applies mainly, perhaps exclusively, to geocarbon.
- Upwards reappraisals: These additions reflect changes due to the use of updated information that permits a reassessment of the physical size of the stock. The use of updated information may require the revision of estimates for previous periods to ensure a continuity of time series.
- Reclassifications: Reclassifications of carbon assets will generally occur in situations in which another environmental asset is used for a different purpose, for example increases in carbon in Semi-natural ecosystems by the establishment of a national park on an area used for agriculture would be equalized by an equivalent decrease in Agricultural ecosystems. Here, it is only the land use that has changed; that is, reclassifications may have no impact on the total physical quantity of carbon.
- Imports: A line for imports is shown to enable accounting for imports of produced goods (e.g. petroleum products). Imports are show separately from the other additions so that they are presented with exports.

A4.22 There are five types of reductions recorded in the carbon stock account:

- Natural contraction: These reductions reflect natural, including episodic, losses of stock during the course of an accounting period. They may be due to changing distribution of ecosystems (e.g. a contraction of Natural ecosystems) or biocarbon losses that might reasonably be expected to occur based on past experience. Natural contraction includes losses from episodic events including drought, some fires and floods, and pest and disease attacks. Natural contraction also includes losses due to volcanic eruptions, tidal waves and hurricanes.

- Managed contraction: These are reductions in stock due to human activities and include the removal or harvest of carbon through a process of production. This includes mining of fossil fuels and felling of timber. Extraction from ecosystems includes both those quantities that continue to flow through the economy as products (including waste products) and those quantities of stock that are immediately returned to the environment after extraction because they are unwanted, for example, discarded timber residues. Managed contraction also includes losses as a result of a war, riots and other political events; and technological accidents such as major toxic releases.

- Downwards reappraisals: These reductions reflect changes due to the use of updated information that permits a reassessment of the physical size of the stock. The reassessments may also relate to changes in the assessed quality or grade of the natural resource. The use of updated information may require the revision of estimates for previous periods to ensure a continuity of time series.

- Reclassifications: Reclassifications of carbon assets will generally occur in situations in which another environmental asset is used for a different purpose, for example decreases in carbon in Ecosystems agriculture by the establishment of a national park on an area used for agriculture would be equalized by an equivalent increase in Semi-natural ecosystems. Here it is only the land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon.

- Exports: A line for exports is shown to enable accounting for exports of produced goods (e.g. petroleum products). Exports are shown separately from the other reductions so that they are presented with imports.

- Catastrophic losses, as defined in the SNA, are not shown as a single entry but are allocated between Managed contraction and Natural contraction. Managed contraction would include fires deliberately lit to reduce the risk of uncontrolled wild fires. Also for the purposes of accounting, reductions due to human accidents, such as rupture of oil wells, would also be included under managed contraction. Catastrophic losses could, however, be separately identified in the table or a related table.

A4.23 Various indicators can be derived directly from carbon stock accounts or in combination with other information, such as land cover, land use, population, and industry value added. The suite of indicators can provide a rich information source for policy makers, researchers and the public. For example, comparing the actual carbon stock of different ecosystems with their carbon carrying capacities can inform land use decision making where there are significant competing uses of land for food and fibre.

A4.24 A key indicator that would emerge from the carbon stock account is what is commonly termed the ‘net carbon balance’ which is the stock of carbon remaining in all reservoirs, or a particular reservoir, at the end of an accounting period.

Annex to Chapter 4, Section 4.5: Accounting for biodiversity

Introduction

A4.25 A key indicator that would emerge from the carbon stock account is what is commonly termed the ‘net carbon balance’ which is the stock of carbon remaining in all reservoirs, or a particular reservoir, at the end of an accounting period.

A4.26 Biodiversity or biological diversity is a fundamental component of ecosystems and underpins many ecosystem services (see Chapter 3). Human activity can drive changes in biodiversity, both directly (e.g. through the extraction of species via harvest of fish and timber) and indirectly (e.g. removal of habitat), and hence the level or quality of the ecosystems services able to be delivered. Understanding the relationships between biodiversity, ecosystems and the ecosystem services they provide, as well as quantifying the impact of human activity on biodiversity and key ecosystem services are the primary motivations for accounting for biodiversity. In recognition of the importance of biodiversity to people there are several international agreements concerning biodiversity and the conservation of biodiversity.

A4.27 Perhaps the most important is the Convention on Biological Diversity (CBD)[36] which entered into force in 1993. The Convention has three main objectives: (1) the conservation of biological diversity; (2) the sustainable use of the components of biological diversity, and; (3) the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

A4.28 Biodiversity accounts can be used to track progress towards policy targets such as those concerning the protection of threatened species or ecosystems (or habitats), the sustainable use of harvested species, the maintenance and improvement of ecosystem condition and capacity, and where the benefits of use of biodiversity accumulate. Such assessments can be enhanced by links to changes in land cover and land use. By making biodiversity accounts for particular spatially defined areas (EAUs), the accounts on ecosystem services may be linked to the geographical extent and condition of biodiversity. If the areas (EAUs) follow administrative or other boundaries for which there are economic or social data, then it is possible to highlight how human activities can cause changes in biodiversity.

A4.29 At both national and sub-national scales, by linking biodiversity accounts with the land cover, land use and the environmental protection expenditure accounts of the SEEA Central Framework, the cost-effectiveness of expenditures on habitat and species conservation or returns on investment may be analysed. It is sometimes the case that the extent of land cover types, land use and other data on pressures are used as a proxy for the condition of biodiversity as the number and abundance of species changes in response to such variables[37].

Definition and description of biodiversity

A4.30 Biodiversity is defined in the Convention on Biological Diversity as ‘the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within

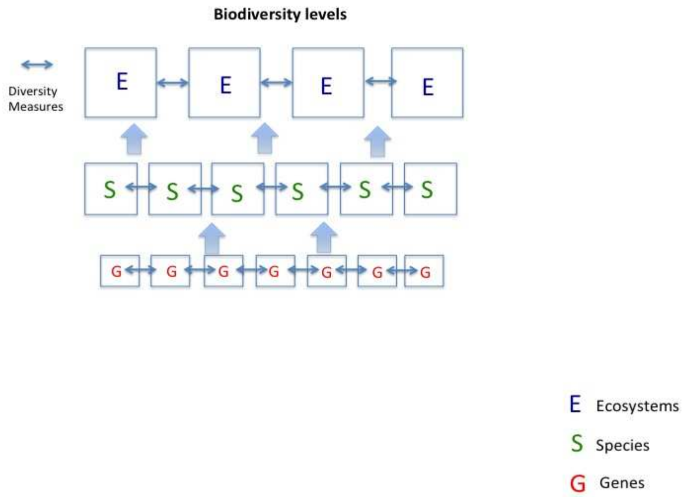
[36] Secretariat of the Convention on Biological Diversity (2003). Convention on Biological Diversity http://www.cbd.int/convention/text/

[37] E.g. see Brooks et al (2002). Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16(4): 909-923 and; Alkemade et al, 2009.

species, between species and ecosystems'[38]. The scientific community has conceptualised biodiversity as a hierarchy of genes, species and ecosystems. This is shown in Figure A4.5.1.

Please note this is a simplification.

Fig A4.5.1. The three levels of biodiversity: ecosystems, species and genes.



A4.31 Convention on Biological Diversity also defines ecosystems and two terms related to genes:

A4.32 "**Ecosystem** means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"

A4.33 **"Genetic material**" means any material of plant, animal, microbial or other origin containing functional units of heredity"

A4.34 **"Genetic resources**" means genetic material of actual or potential value"

A4.35 Species can be defined in a range of ways. They are commonly defined as a group of organisms capable of breeding and producing fertile offspring. However, this definition does not work well for some groups of organisms (e.g. bacteria). A range of definitions are available but the definition used ultimately depends of the nature of the organism of interest[39]. Species are classified according to the system of binomial nomenclature (i.e. genus and species) established by Linnaeus (1758), which continues to evolve[40].

A4.36 The biodiversity accounts described below use species as the fundamental unit of observation for biodiversity. Land cover accounts, which may approximate ecosystems, are described in the SEEA Central Framework, while the extent and condition of ecosystems is covered earlier in this chapter. Accounting for genes has not yet been contemplated within the SEEA framework.

[38] Convention on Biological Diversity, Article 2, Use of Terms.

[39] de Queiroz K., 2005. "Ernst Mayr and the modern concept of species". Proc. Natl. Acad. Sci. U.S.A. 102 (Supplement 1): 6600–7. (May 2005). doi:10.1073/pnas.0502030102

[40] See, for example, the International Commission on Zoological Nomenclature, http://iczn.org and; the International Code of Botanical Nomenclature (Vienna Code), http://ibot.sav.sk/icbn/main.htm

The process of biodiversity loss

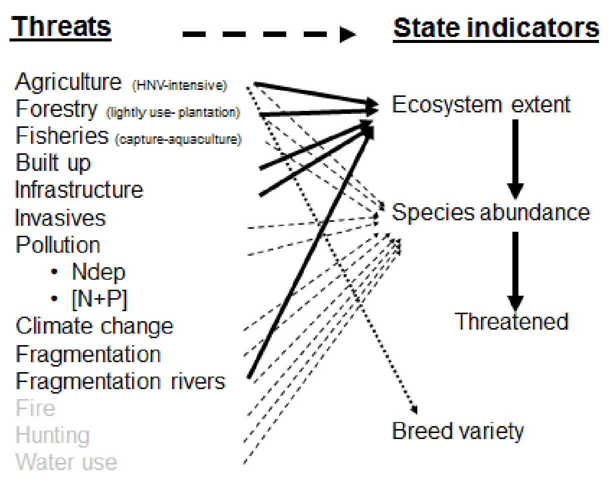
A4.37 The processes contributing to biodiversity loss are many and varied and as such determining the most appropriate structures for biodiversity accounts to address this issue is difficult. However, some generic types of processes leading to changes in biodiversity can be identified for inclusion in the accounts. These are the ecosystem and species levels.

A4.38 At ecosystem level, biodiversity loss is characterised by the conversion, reduction or degradation of ecosystems (or habitats). Generally as the level of human use of ecosystems increases in extent or intensity, biodiversity loss increases.

A4.39 Many species originally occurring in a particular area will decrease in abundance while at the same time some species, in particular those that benefit in disturbed habitats, increase in abundance, as a result of human interventions. That is, the species originally occurring are gradually replaced by those that are favoured by human influence, some of which may achieve large numbers (e.g. plague proportions). The extinctions of the original species are the final step in an often long process of gradual reductions in numbers. In many cases, local or national species richness (i.e. the total number of species regardless of origin) increases initially because of species introduced or favoured by humans[41]. Because of these changes ecosystems lose their regional endemic species and become more and more alike – a process described as "homogenisation"[42].

A4.40 Figure A4.5.2 illustrates how different types of threats may influence the ecosystem extent and also directly or indirectly the extent of ecosystems, the abundance of species, and the threat of species extinction.

Figure A4.5.2 Key drivers and state indicators of biodiversity[43]



[41] This is the so-called "intermediate disturbance diversity peak", Lockwood and McKinney, (2001). Biotic Homogenization. Kluwer, New York. 289p.

[42] Lockwood and McKinney, (2001). Biotic Homogenization. Kluwer, New York. 289p and Millenium Ecosystem Assessment (2005). http://www.maweb.org/en/Reports.aspx

[43] ten Brink, B.J.E., S. Condé, F. Schutyser (2010). Interlinkages between the European biodiversity indicators, improving their information power. Report of the working group on Interlinkages of the Streamlining European Biodiversity Indicators project (SEBI). European Environmental Agency. Copenhagen.

Measurement of biodiversity, indicators and indices

A4.41 A wide range of techniques are used to measure biodiversity. It is not the intent here to provide a full review of these techniques but to note that biodiversity measurement is a specialist field, that different methods for assessing biodiversity provide varying levels of accuracy and precision, and that because of complexities of biodiversity measurement a focus is placed on selected indicators of biodiversity rather than accounting of all aspects of biodiversity.

A4.42 Biodiversity indicators measure part of the system or capture a range of aspects of the system within single measures. The processes supporting the Convention on Biological Diversity have identified 10 criteria for selecting biodiversity indicators and also provided supporting documentation to assist with implementation[44].

A4.43 Based on the recommendations of the 9th meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA9) the 7th Conference of the Parties (COP7) agreed on the list of provisional indicators for assessing progress towards the 2010 biodiversity target (COP decision VII/30, 2004)[45] that can be implemented worldwide, or at national or regional scales. These indicators assess the threats, biodiversity state (or condition), impact (on ecosystem services) and societal responses to biodiversity loss.

A4.44 Specifically, the four indicators concerning the state of biodiversity were:

- Trend in extent of selected ecosystems
- Trend in abundance and distribution of selected species
- Trend in status of threatened species
- Change in genetic diversity

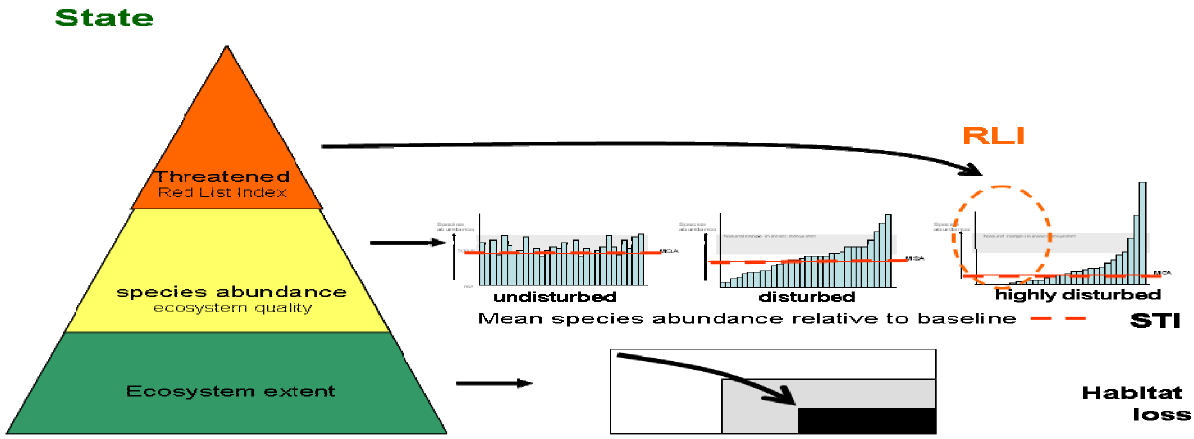
A4.45 The first describes the remaining ecosystem types in terms of size, the second relates to the average quality of these ecosystem types (mean abundance of species characteristic of these ecosystems as compared to the reference condition), and the third shows the variability within the mean species abundance, focusing on those species that are threatened. Together these indicators reflect the degree of homogenisation, the core process of biodiversity loss as described above. These indicators described above may be addressed by land cover accounts of the SEEA Central Framework, as well as the species abundance and threatened species accounts described later in the chapter.

A4.46 Figure A4.5.3 summarises the changes in ecosystem, the abundance of species and threat of extinction over time. In this it shows three points in time in terms of habitat extent (the nested squares in the lower right of the diagram). In the middle the consequences in terms change in species abundance are shown, with the red dotted lines showing a composite state index which is calculated referring to a benchmark time (or reference condition). On top, the extinction or close to extinction of some species is indicated by inclusion in the IUCN Red List.

[44] See UNEP 2003a. Monitoring and indicators: designing national-level monitoring programmes and indicators. UNEP/CBD/SBSTTA/9/10 http://www.cbd.int/doc/meetings/sbstta/sbstta-09/official/sbstta-09-10-en.pdf; and, UNEP 2003b. Report of the Expert meeting on indicators of biological diversity including indicators for rapid assessment of inland water ecosystems. UNEP/CBD/SBSTTA/9/INF/7, https://www.cbd.int/doc/meetings/ind/ahteg-sp-ind-01/other/ahteg-sp-ind-01-sbstta-09-inf-07-en.pdf

[45] See http://www.cbd.int/doc/decisions/cop-07-dec-en.pdf

Figure 4.5.3 Change in ecosystem extent, original species abundance and risk of extinction[46].



A4.47 The development of biodiversity indicators at an international level is on-going. In 2011 the CBD Ad Hoc Technical Expert Group on indicators for the strategic plan for biodiversity 2011-2020 compiled a list of about 100 candidate indicators to evaluate the progress towards the Aichi targets agreed to in Nagoya, 2010. Given the desire for a small but globally used set, SBSTTA, in its 15th meeting, requested the Executive Secretary to propose a limited number of simple, easily applicable and cost-effective indicators that can potentially be implemented by all Parties (recommendation XV/1, paragraph 10h) for global use to be discussed at the 2012 Conference of the Parties.

A4.48 At international and national levels the state of biodiversity can also be shown via composite indices. Examples of this approach for aggregate measurement of biodiversity include the Natural Capital Index[47], the GLOBIO Mean Species Abundance Index[48], the Living Planet Index[49], the Biodiversity Intactness Index[50] and the Norwegian Nature Index[51]. These composite indicators are the result of a long tradition in ecology of expressing complex changes in species abundance through indices.

[46] ten Brink, B.J.E., S. Condé, F. Schutyser (2010). Interlinkages between the European biodiversity indicators, improving their information power. Report of the working group on Interlinkages of the Streamlining European Biodiversity Indicators project (SEBI). European Environmental Agency. Copenhagen.

[47] ten Brink, B.J.E. and T. Tekelenburg, Biodiversity: how much is left? The Natural Capital Index framework (NCI). in RIVM report 402001014. 2002: Bilthoven.

[48] Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390. Also see http://www.globio.info/home

[49] Loh, J., et al 2005. The living planet index: using species population time series to track trends in biodiversity. Philosophical Transactions Royal Society, Biological Sciences 360, 289-295, and; Loh, J.,2002. Living Planet Index 2002, World Wildlife Fund International: Gland, Switzerland.

[50] Scholes, R.J. and R. Biggs, 2005. A biodiversity intactness index. Nature. 434(7029): p. 45-49.

[51] Certain, G., O. Skarpaas, J-W. Bjerke, E. Framstad, M. Lindholm, J-E. Nilsen, A. Norderhaug, E. Oug, H-C. Pedersen, A-K. Schartau, G. I. van der Meeren, I. Aslaksen, S. Engen, P.A. Garnåsjordet, P. Kvaløy, M. Lillegård, N. G. Yoccoz, and S. Nybø. 2011. The Nature Index: A General Framework for Synthesizing Knowledge on the State of Biodiversity. PloS ONE 6 no. 4: e18930.

Geographical extent of ecosystems and biodiversity

A4.49 There is a strong relationship between the extent of ecosystems, land use and biodiversity. Measures of ecosystem condition and extent are covered in more detail in earlier sections of this chapter and, to the extent that ecosystems are approximated by land cover, the SEEA Central Framework.

A4.50 Land cover is closely related to land use. Sometimes they are synonymous, for example cropland (e.g. an area covered by wheat) is used for agriculture. However, in other cases it is not, for example a forest may be used for conservation (e.g. protection of species and recreation) or forestry (i.e. to produce timber for sale).

A4.51 Land set aside for conservation is of particular relevance for biodiversity accounting. It is usually the case that land used for conservation has the express purpose of protecting biodiversity as well as providing opportunities for people to enjoy the environment and the biodiversity within it. Also implicit in this is the provision of ecosystem services from the areas set aside for conservation.

A4.52 Most countries have information on the area covered by national parks and other categories of protected areas (e.g. according to the IUCN Protected Area Categories[52]) and this has been consolidated in the World Database on Protected Areas[53]. In addition, the Ramsar Convention on Wetlands (1971)[54] currently lists just over 2,000 wetlands of international importance, covering nearly two million square kilometres.

A4.53 Accounts in physical terms (e.g. hectares) showing the area of different ecosystems in protected areas is a straightforward first step (i.e. using the land cover and land use accounts of the SEEA Central Framework) and these can also be linked to the environment protection expenditure (a response indicator). It is also necessary to account for the extent and condition of ecosystems outside of protected areas (i.e. the entire country), since in most countries much of the biodiversity exists outside of protected areas. The condition of biodiversity, as measured by species number and abundance can be measured directly. However, because this is costly to do for large areas, biodiversity condition is usually estimated using a range of data and methods, including modelling techniques based on information about land cover, land use, fragmentation, climate change and other pressures.[55].

A4.54 For some purposes more precise information about where, why and how the changes in ecosystem extent occurred are needed. This is of special importance if one is combine the

[52] For more information see, Guidelines for Applying Protected Area Management Categories, Dudley, N. Ed.(2008): http://data.iucn.org/dbtw-wpd/edocs/PAPS-016.pdf
[53] World Database on Protected Ares: http://www.wdpa.org
[54] The Ramsar Convention on Wetlands. http://www.ramsar.org/cda/en/ramsar-documents-texts-convention-on/main/ramsar/1-31-38%5E20671_4000_0__

[55] Scholes, R.J. and Briggs, R. (2005). A biodiversity intactness index. Nature, 434(3): 45-49. (3 March 2005)

Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390.

inter and intra flows in order to combine both the measurements of changes in quality and the measurements of changes of extent in one common evaluation for policy priority purposes. To achieve this both extent and quality measures will have to refer to EAU.

Structuring information on species and groups of species

A4.55 Species may be described in a number of ways. For example, species may be described in terms of their physiology (including morphology, genetic make-up), population dynamics (habitat use and reproductive biology), distribution (or range), richness (number of species), abundance and likelihood of extinction. In this, while the basic physiology of species will remain constant, the abundance of species may change across its distribution in time and space. This is particularly important for species with large distributions within countries and for species that span countries. For example, a particular species might be common in one area but rare in other.

A4.56 Species may be grouped in a number of ways according to: (1) taxonomic rank (Kingdom, Phylum, Class, Order, Family, Genus, Species); (2) the ecosystem type (e.g. terrestrial, marine, aquatic) or biome (e.g. mountains, coastal regions, marine pelagic ecosystems, etc.) in which they occur; (4) origin (e.g. native or exotic to particular areas), (5) perceived usefulness or lack of usefulness to human beings (e.g. classified as pests or weeds because they are not useful), or (6) trophic level (e.g. primary production, herbivores, omnivores and predators).

A4.57 Species diversity can be measured by abundance and richness. Broad scale assessments of biodiversity are typically based on species richness or richness of endemic species. In this, the species occurring in particular areas are listed as present or absent to generate measures of species richness. These data are more readily available than abundance data and can be measured against the original number of species in the area. This type of assessment is often used but is more suitable for sub-national scale assessments (biodiversity “hotspots”), and which would detect regional shifts in distributions and local extinctions.

A4.58 At a larger scale, these data can be insensitive to changes at the national level, and often difficult to interpret and relate to human activities. If used, indications of the species importance to region or elsewhere may be gained from other sources. For example if species detected in an area are included on the IUCN Red List of threaten species.

A4.59 It is more useful if assessment of biodiversity of areas includes estimates of abundance. Abundance data are usually only available for a limited number of species. Abundance may be measured in absolute terms such as the total number of individuals of a species or a density per hectare. It can also be measured in broad classes related to absolute measures, for example very abundant, abundant, common, rare, and very rare. Abundance may also be measured in relative terms, in particular current abundance relative to the past (a benchmark or reference condition). If a species is less abundant now than in the past then it may be at risk of extinction. Different species exhibit different natural abundances: for example in mammals, small rodents are naturally very abundant, while elephants other large slow breeding mammals occur in much lower abundances.

A4.60 As a precursor to accounts of biodiversity, information on species should be collated in databases. For structuring information on biodiversity and in order to create accounts for particular areas (i.e. Ecosystem Accounting Units), it is imperative that the data are spatially and temporally (i.e. time period) referenced.

Species richness and species abundance accounts

A4.61 Accounts may be prepared for individual species or groups of species. While accounts for individual species may be relatively few, some species are of particular interest, for example because they are harvested for food or have iconic values (the so-called charismatic mega-fauna), and hence accounts may be prepared for these species. Such accounts, for example for fish, are similar to those described in the SEEA Central Framework and are not described further here. Tables for species richness would be of a similar form to the table for species abundance described below.

A4.62 Table A4.5.1 presents the general form of a species abundance account, in both absolute and relative terms of abundance. The account follows the general form of asset accounts in the SEEA Central Framework, with opening stock and closing stock. In this account a net change only is shown, but it would be possible to add rows showing the positive and negative changes that result from natural processes or human activity. The accounting period is one year (i.e. the closing population is one year after the opening population).

A4.63 The reference condition of species can refer to any time period, but ideally it should refer to an ecosystem with minimal human influence. Such a baseline can be difficult to establish but this allows the relative abundance of species to be compared between different species, and different ecosystems, within countries and between countries.

A4.64 It is important that species from all Kingdoms (i.e. division of living organisms) should be included in the species abundance accounts to ensure the accounts are as representative as possible. However, in practice the species included in the accounts will need to be a representative sample from the Kingdoms as collecting data on the abundance of all species is resource intensive and some Kingdoms are better known than others (animals being the best know). The sample of species should include species that are of importance to the ecosystem being measured and priority should also be given to species that are known to be sensitive to human impacts (i.e. responsive to key drivers and pressures). Emerging experience suggests shows that for particular ecosystem types the monitoring of 35-40 representative species may be sufficient to gauge the state of biodiversity and, when repeated, detect changes. Surrogate measures (e.g. related to land cover or use) can also be used.

Table A4.5.1 Accounts for species abundance by Kingdom

	Animals								
	Mammals	Birds	Reptiles	Amphibians	Insects	Subtotal	Fungi	Protista	Plants
Opening population									
Closing population									
Net change									
Reference population									
Opening population as proportion of reference population									
Closing population as proportion of reference population									
Net change									

A4.65 As with all accounts understanding the quality of data is important. As data quality is a recurring issue, it may be useful to record uncertainty estimates within the tables (e.g. by showing standard errors or showing a range rather than a discrete number). Other ways of indicating data quality can be used, for example including the use of footnotes to the table. In all cases the information underpinning the account should clearly identify the data sources and methods used, and, for example, distinguish between data from monitoring systems, modelling and expert judgements.

A4.66 To aid interpretation of the tables it will probably be necessary to include other supporting information in the text or supplementary tables, on the key drivers of change (e.g. land cover and land use change accounts). Furthermore, interpretation of the species abundance accounts needs to be done with care. For example, for many species their population will be lower than in the reference condition, but in some cases they will be more abundant, which may represent a decline ecosystem quality and have a negative impact on other species as would be the case with algae blooms due to eutrophication of water ways.

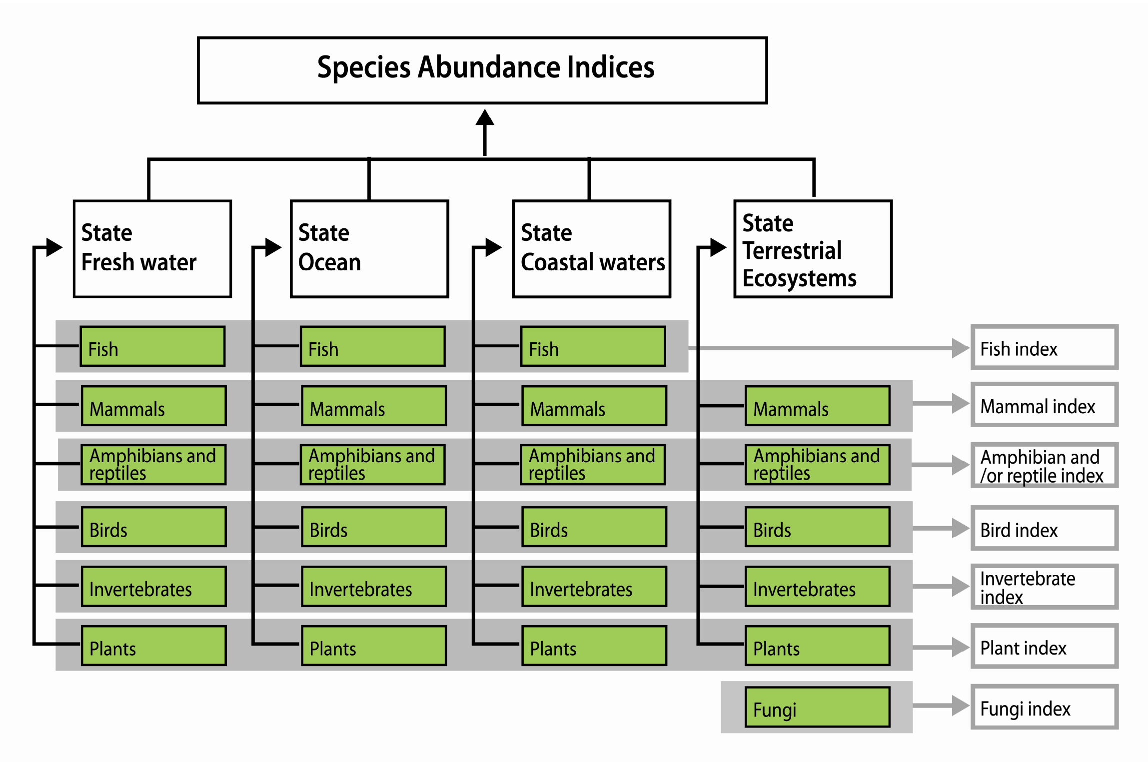
Deriving indices from species abundance biodiversity

A4.67 The index methods used for economic indicators, such as the consumer price index involving the measurement of changes in a selected basket of goods and services, may provide an approach to constructing species abundance indices from the accounts presented above. The weights used are the average consumption of the different goods and services.

A4.68 Biodiversity indices are more complicated, but usually area (extent) is one component and ensuring that each trophic level maintains equal weights implies that all parts of the ecosystem are duly represented (Certain et al. 2012).

A4.69 Changes in a total biodiversity index may be explained through a disaggregation into different thematic indices. Figure A4.5.4 shows how it might be possible to aggregate the measures of species abundance by domain (i.e. freshwater, ocean, coastal or terrestrial ecosystems) or species group (i.e. fish, mammals, etc) to derive an overall index of biodiversity or species abundance index.

Figure A4.5.4 Possible aggregation of a national nature index for mean species abundance



Accounts for threatened species (extinction risk)

A4.70 The risk of extinction is a function of the natural population dynamics, distribution and abundance of species, environmental change and human activities directly or indirectly influencing population abundance. In this, the more widely distributed and abundant and the higher the reproductive rate of a species is, the less likely it is to become extinct. Some species are naturally rare, have limited distributions or low reproductive rates and hence are more susceptible to extinction. The IUCN Red List Categories[56] take into account these factors and others into account to determine the overall status of species.

[56] IUCN-Species Survival Commission, 2001. Red List Categories and Criteria version 3.1. http://www.iucnredlist.org/documents/redlist_cats_crit_en.pdf

A4.71 Accounts showing the risk of extinction can be constructed using the status of species as defined by IUCN Red List categories and related criteria (Table 4.6.2). These categories are defined as:

- **Extinct** is when there is no reasonable doubt that the last individual of a species has died; **Extinct in the wild** is when a taxon is known to only survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range;
- **Critically endangered** is when a taxon is considered to be facing an extremely high risk of extinction in the wild;
- **Endangered** is when a taxon is considered to be facing a very high risk of extinction in the wild;
- **Vulnerable** is when a taxon is considered to be facing a high risk of extinction in the wild; **Near Threatened** is when a taxon is close to qualifying for or is likely to qualify for a threatened category in the near future;
- **Least concern** is when a taxon is widespread and abundant;
- **Data deficient** or **Not evaluated**. Data deficient is when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status (data deficient is therefore not a category of threat). Not evaluated is when a taxon has not yet been evaluated against the IUCN threat criteria.

A4.72 It should be noted that the threatened species accounts record only the presence or absence of species in a particular area.

A4.73 Threatened species accounts may be prepared for countries as a whole or for particular areas or ecosystems within countries. It should be noted that amount of effort needed to prepare account increases with the number of areas for which accounts are prepared.

A4.74 In national and sub-national accounts is important to note that the status assessments from the IUCN Red List relates to an assessment of the species in the entire world, not to the country and area in question. As such it might be that a species are assessed against different criteria at small scales.

Table A4.5.2. Accounts for threatened species

	IUCN Red List categories									
	Extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Lower risk	Near threatened	or not evaluated	Least concern	TOTAL
Opening stock										
Additions										
- from lower threat categories										
- from higher categories										
- discoveries of new species										
- rediscoveries of extinct species										
- reclassifications										
- updated assessments										
- new additions to list										
Total additions										
Reductions										
- to lower threat categories										
- to higher categories										
- reclassifications										
- local extinction										
- updated assessments										
Total reductions										
Closing stock										

Annex to Chapter 6: Possible models for a Sequence of Accounts for Ecosystem accounting

A.6.1 Following on from the brief introduction to the sequence of accounts in Section 6.4, this annex presents a summary of current thinking on possible models that may be used to incorporate entries related to ecosystem services and changes in ecosystem assets into the standard SNA sequence of accounts.

A.6.2 Table A6.1 presents simplified versions of Models A and B. The example is that a farm is a single ecosystem that provides a mix of ecosystem services (total 110) of which 80 are used by the farmer and 30 are the final consumption of households.[57] 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 noted that in the generation of ecosystem services there is no recording of "inputs" from within the ecosystem. This recording is not required for the purposes of developing a sequence of accounts focused on economic units.

Table A6.1 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 – SNA	200			200	200		200
Output – non-SNA			110	110	30		30
Total Output	200		110	310	230		230
Int. consumption – SNA	0		0	0	0		0
Int. consumption – non-SNA	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 - SNA		50		50		50	50
Ecosystem transfers – non-SNA	80	30	-110	0	-30	30	0
Disposable income	140	80	-15	205	125	80	205
Less Final consumption - SNA		200		200		200	200
Final consumption – non-SNA		30		30		30	30
Degradation adjusted net saving	**140**	**-150**	**-15**	**-25**	**125**	**-150**	**-25**

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

A.6.3 In both models, the rise in GDP only occurs in relation 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).

A.6.4 Measures of GDP may be adjusted for both consumption of fixed capital (CFC) and ecosystem degradation thus providing Degradation adjusted Net Domestic Product. At a sector level, ecosystem degradation in this model is deducted from the value added of the ecosystem quasi-sector and is not attributed to standard institutional sectors.

A.6.5 Under Model A, flows of ecosystem services are recorded in gross terms flowing from ecosystems to relevant units as either intermediate or final consumption. In aggregate the output of the economy rises by the full extent of ecosystem services, and GDP will rise to the extent that some of the ecosystem services are consumed as final consumption.

A.6.6 Under Model B, flows of ecosystem services are recorded in net terms in that “purchases” of ecosystem services for use in the production of products by the manager of the ecosystem (in this case considered to be the producer of the ecosystem services) are not shown explicitly. It would be possible to introduce extra flows into Model B to record all flows of ecosystem services in gross terms. As in Model A, GDP rises to the extent of ecosystem services consumed as final consumption.

A.6.7 In standard capital accounting practice, consumption of fixed capital, the costs associated with the use of produced assets, are deducted from the income of the user of the asset. This deduction is obvious given that there is only one economic unit that supplies the capital service and there is only one capital service for each asset. However, in ecosystem accounting the relationships between economic units and ecosystems are much more complex. Consequently, as discussed above alternative approaches to the allocation of ecosystem degradation to economic units must be considered.

A.6.8 In Model A, the full amount of ecosystem degradation is attributed to the new ecosystem quasi-sector. In effect this follows the standard capital accounting practice and assumes that the ecosystem is the sole supplier of ecosystem services and, as a producing unit, must incur the full impact of declines in the capital base. In Model B, the farmer is assumed to be the sole supplier of ecosystem services (as manager of the ecosystem) and hence all ecosystem degradation is attributed to the farmer.

A.6.9 However, neither of these assumptions provides a complete sense of the attribution of ecosystem degradation that may be anticipated. Under a full costs caused attribution it would be necessary to determine the economic units responsible for the degradation and adjust their income. Under a full costs borne approach consideration would turn to the users of the ecosystem services and hence some ecosystem degradation would be attributed to households reflecting their direct and indirect consumption of ecosystem services.

A.6.10 It is important to recognise that in both models flows of ecosystem services are recorded quite distinctly from flows of ecosystem degradation. Allowing for this difference enables a more complete and consistent recording of all ecosystem services, not only those of a particular type, i.e. provisioning, regulating or cultural.

A.6.11 Both models contain an entry named “ecosystem transfers”, which is not a standard entry in the SNA. This entry accommodates the additional consumption of ecosystem services by each sector and sums to zero across the economy. The level of the transfers is higher in Model A than in Model B, reflecting that in Model A all ecosystem services are purchased from the ecosystem quasi-sector. The inclusion of this entry means that the balancing item net lending recorded in the capital and financial accounts is consistent with the set of actual financial flows within the economy. Note that the recording of ecosystem transfers is not affected by choices for the recording of ecosystem degradation.

A.6.12 Model A appears straightforward to apply since the ecosystem is presented separably as an adjunct to standard institutional units. Unfortunately, the real depth of integration between ecosystems and economic activity means that isolating ecosystems may be difficult in practice. A particular concern is where the current balance sheet of an economic unit contains assets that are also part of an ecosystem (e.g. timber resources). Model A requires, ideally, that the value of all ecosystem assets be attributed to the new quasi-sector for ecosystems. Additionally, Model A requires a full gross measurement of ecosystem services whereas in Model B only additional, non-SNA flows need be articulated.

A.6.13 Model B reflects a more integrated view of the relationship between ecosystems and economic units. The key difference is reflected by adjustments for ecosystem degradation being made to the income of the producer rather than the imputed income of the ecosystem. Thus ecosystem degradation is attributed directly to a standard economic unit. However, this model requires the assumption that a specific institutional unit manages the ecosystem and is, therefore, responsible for the generation of ecosystem services. This assumption may be weak. It would be possible to partition the ecosystem asset across more than one institutional sector but this may not be straightforward. Estimates of ecosystem degradation also need to be partitioned if more than one institutional unit is considered to be involved.

A.6.14 An alternative model that is somewhat of a compromise between Models A and B, is to incorporate an ecosystem quasi-sector where this sector only has outputs that are non-SNA ecosystem services. Such a recording requires a partitioning of ecosystem assets, ecosystem services and ecosystem degradation. This may be accomplished by first deriving the total value of the ecosystem, and then deducting the existing values of relevant economic assets already included on the balance sheets of the standard institutional sectors. The resulting residual would be the value of the ecosystem asset attributed to the ecosystem quasi-sector. Using relationships between ecosystem service flows and economic units attribution of ecosystem degradation could then be made.

A.6.15 Overall, there is no straightforward choice to the structure of a sequence of ecosystem accounts. Neither Models A or B (or possible variants) present information on all of the relevant flows in as neat a fashion as may be desirable without the need for various allocations or assumptions. One factor to consider is the recording of ecosystem restoration expenditure. If information on this expenditure is to be integrated into the sequence of accounts it may be appropriate to keep this expenditure together (thus clearly pertaining to a specific ecosystem) rather than partitioning this expenditure across multiple ecosystem managers through a series of capital transfers.

Annex 1: Approaches to defining units for ecosystem accounting

To be developed

Annex 2: Data quality and scientific accreditation

To be developed