DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
STATISTICS DIVISION
UNITED NATIONS

System of Environmental Economic Accounting

System of Environmental-Economic Accounting—Ecosystem Accounting

Draft for the Global Consultation on the complete document

October 2020

Disclaimer:
This draft has been prepared under the guidance of the SEEA Experimental Ecosystem Accounting Technical Committee under the auspices of the UN Committee of Experts on Environmental Accounting (UNCEEA). It is part of the work on the Revision of the System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting being coordinated by the United Nations Statistics Division. The views expressed in this document do not necessarily represent the views of the United Nations.

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Abbreviations and acronyms

2008 SNA	System of National Accounts 2008
ABNJ	Areas Beyond National Jurisdiction
BIOFIN	Biodiversity Finance Initiative
BSU	Basic spatial unit
CBD	Convention on Biological Diversity
CEA	Classification for environmental activities
CICES	Common International Classification of Ecosystem Services
COED	Costs of environmental degradation
COICOP	Classification of Individual Consumption by Purpose
CPC	Central Product Classification
CV	Contingent valuation
EAA	Ecosystem accounting area
EBVs	Essential Biodiversity Variables
ECT	Ecosystem condition typology
EE-IOT	Environmentally-extended input-output tables
EESVs	Essential Ecosystem Services Variables
EEZ	Exclusive Economic Zone
EFG	IUCN GET Ecosystem Functional Groups
EGSS	Environmental goods and services sector
ESCAP	Economic and Social Commission for Asia and the Pacific
ET	Ecosystem type
FDES	Framework for the Development of Environment Statistics
GDP	Gross Domestic Product
GEO BON	Group on Earth Observations – Biodiversity Observation Network
GHG	Greenhouse gas
GVA	Gross Value Added
IAEG-SDGs	Inter-Agency and Expert Group on SDG Indicators
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification
IUCN	International Union for the Conservation of Nature
IUCN GET	IUCN Global Ecosystem Typology
LCCS	FAO Land Cover Classification System

LDN	Land degradation neutrality
LULUCF	Land use, land use change and forestry
MA	Millennium Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
NCP	Nature’s Contribution to People
NDC	Nationally Determined Contributions
NDP	Net Domestic Product
NESCS	National Ecosystem Service Classification System
NPV	Net present value
NSDI	National Spatial Data Infrastructure
NSO	National statistical office
PES	Payments for ecosystem services
PSUT	Physical supply and use tables
SBA	Service benefitting areas
SDGs	Sustainable Development Goals
SEV	Simulated Exchange Value
SOC	Soil organic carbon
SPA	Service providing areas
SUT	Supply and use table
TEEB	The Economics of Ecosystems and Biodiversity initiative
TEV	Total Economic Value
UNCCD	United Nations Convention to Combat Desertification
UNCEEA	United Nations Commission of Experts on Environmental-Economic Accounting
UNFCCC	United Nations Framework Convention on Climate Change
UNSC	United Nations Statistical Commission
UNSD	United Nations Statistics Division
WTA	Willingness to accept a payment
WTP	Willingness of individuals to pay

SECTION A: Introduction and overview

1 Introduction

1.1 What is SEEA Ecosystem Accounting?

1.1 Biodiversity loss and climate change are among the biggest challenges that humanity is facing. There is an increasing recognition that biodiversity and ecosystems represent key components towards sustaining human societies, our well wellbeing and our global economy and are central to achieving the Sustainable Development Goals and the Paris Agreement on climate change. There has been growing recognition that the degradation of nature is not purely an environmental issue and economic and human activity are having an impact on the state of the environment. A Global Biodiversity Agenda is being developed to protect biodiversity. Establishing agreed and ongoing measurement of changes in the state of the environment and the relationship to economic and other human activity is central to ensure that biodiversity and ecosystems are mainstreamed in the decision-making processes, including our economic and financial systems.

1.2 The *System of Environmental-Economic Accounting - Ecosystem Accounting* (SEEA EA) is an integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition and linking this information to measures of economic and human activity. Ecosystem accounting incorporates a wider range of benefits to people than captured in standard economic accounts and provides a structured approach to assessing the dependence and impacts of economic and human activity on the environment.

1.3 The SEEA EA complements the measurement of the relationship between the environment and the economy described in the *System of Environmental-Economic Accounting 2012—Central Framework* (SEEA Central Framework) (United Nations et al., 2014a). The SEEA EA's focus on ecosystems can be combined with the data from the SEEA Central Framework accounts on environmental pressures, individual resource stocks and environmental responses in the form of expenditures, taxes and subsidies, to provide a comprehensive picture.

1.4 The SEEA EA applies the accounting principles of the *System of National Accounts 2008* (2008 SNA) (United Nations et al., 2010), the statistical framework for the measurement of the economy. By applying national accounting principles, the SEEA framework allows for a unique integration of data to support decision making. The harmonization of environmental and economic data is intended to contribute to mainstreaming the use of environmental data on ecosystems in economic decision making and to supporting the use of economic data in environmental decision making.

1.5 The use of an accounting approach takes advantage of the inherent structure of accounts wherein both stocks and flows are part of a single recording system. In this context, the basic accounting principles are applied to the organisation of data in both physical and monetary terms to provide an integrated and coherent set of data. Further, the use of an accounting approach envisages comparable, regular and ongoing measurement.

1.6 Consistent with the general intent of the SEEA, the use of SEEA EA is primarily intended to support national level policy decision making with a focus on connecting information on multiple ecosystem types and multiple ecosystem services with macro-level economic information (e.g., measures of national income, output, value added, consumption and wealth).

1.7 At the same time, the theory and practice of ecosystem accounting is applicable at subnational scales. For example, ecosystem accounts can be used to support decision making for individual administrative areas such as provinces and urban areas, and for environmentally defined areas such as water catchments, protected areas, key biodiversity areas and coastal zones. Since the compilation of ecosystem accounts often involves the use of spatially explicit data, a richer understanding of national level information can be portrayed through the analysis of differences across locations and regions within a country. Further, the use of spatially explicit data within the ecosystem accounting framework can support the co-ordination of policy from local to national scales by establishing a common and agreed set of data and a common framing of the relationship between the environment and economic and human activity.

1.2 The statistical context for Ecosystem Accounting

1.2.1 Historical background of the SEEA

1.8 Ecosystem accounting has arisen out of work initiated by the international community of official statisticians under the direction of the United Nations Statistical Commission. Work started in the 1980s in response to the demand for internalizing natural resource depletion and degradation into macro-economic accounting and culminated with the release of the *Handbook of National Accounting: Integrated Environmental and Economic Accounting* (SEEA 1993) by the United Nations Statistics Division (United Nations, 1993). To reflect the policy demands, Agenda 21, the outcome document of the United Nations Conference Environment and Development[1] called for countries to implement the SEEA.

1.9 Based on the experimentation in countries, the SEEA 1993 was subsequently updated in 2003 through a process of expert meetings and wide consultation led by the London Group on Environmental-Economic Accounting, one of city groups established to advance methodologies and practices by the United Nations Statistical Commission. The resulting *Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003* (SEEA 2003) (United Nations et al., 2003) presented a number of different methodological approaches and a range of country examples showing varying country practices. Because of this, the SEEA 2003 was not formally adopted as an internationally agreed statistical framework However, it did provide a well-accepted and robust set of approaches for the compilation of various environmental-economic accounts.

1.10 Recognizing the critical importance of information on the environment and its relationship with the economy, the United Nations Statistical Commission established the Committee of Experts on Environmental Economic Accounting with the primary objective to mainstream environmental-economic accounting as part of official statistics. Therefore, it endorsed a second revision process which led to the development of the SEEA Central Framework. The SEEA Central Framework was adopted as "as the initial version of the international standard for environmental-economic accounts" by the Statistical Commission in March 2012.[2] It describes a standardised approach to accounting for physical flows, individual environmental assets and environmental transactions.

[1] Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992. Volume 2, Proceedings of the Conference. A/CONF.151/26/Rev.1(Vol.II). https://digitallibrary.un.org/record/168679?ln=en

[2] United Nations Statistical Commission, Report on the forty-third session, E/2012/24. https://undocs.org/E/2012/24

1.2.2 *Development of the SEEA Ecosystem Accounting*

1.11 During the development of the SEEA Central Framework, a range of highly relevant topics were identified which were new to the statistical community and required further testing and experimentation. These topics primarily concerned accounting for ecosystems and their degradation. Thus, the Statistical Commission supported the development of the *System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting* (SEEA 2012 EEA) (United Nations et al., 2014b) to complement to the SEEA Central Framework.

1.12 In March 2013, the SEEA 2012 EEA was endorsed by the Statistical Commission as an important step in the development of an integrated statistical framework for organizing biophysical information, measuring ecosystem services, tracking changes in ecosystem assets and linking this information to economic and other human activity. The Statistical Commission also encouraged the use of SEEA 2012 EEA by international and regional agencies and countries.[3] At that time, it was not adopted as an internationally agreed statistical standard but was given the label experimental because of the novelty of the conceptual framework from a statistical perspective and the lack of agreed measurement methods, including extensive testing of them.

1.13 While the ecosystem accounting framework described in SEEA 2012 EEA was novel, it reflected the integration of many well-established strands of expertise including statistics and national accounting, ecology and natural science, geography and geo-spatial measurement and environmental economics. By providing a conceptual basis on which these disciplines could exchange and share ideas, the SEEA 2012 EEA facilitated a rapid growth in the development and testing of ecosystem accounting. From a low base in 2013, by 2020 there were well over 40 examples of ecosystem accounting programs from around the world with applications in, and participation from, all sectors – public, private, academia and civil society. In support of this level of activity, in December 2017, the United Nations Statistics Division released the *Technical Recommendations in support of the SEEA EEA* (Technical Recommendations) (United Nations, 2019) which summarized the state of knowledge and practice on ecosystem accounting at that time and further supported ongoing development and testing of methods.

1.14 Given this level of interest, testing and experimentation, the Committee of Experts on Environmental Economic Accounting decided in June 2017 that a revision of the SEEA 2012 EEA was appropriate with the ambition that as many aspects of ecosystem accounting as possible should be elevated to an international statistical standard by 2021. This revision process was endorsed by the Statistical Commission at its meeting in March 2018.[4]

1.15 The revision process was carried out under the auspices of the Committee of Experts with technical leadership provided by the SEEA EEA Technical Committee. Four key revision areas were established, namely spatial units, ecosystem condition, ecosystem services and monetary valuation and accounting. Five working groups led research and discussion across these four research areas with work commencing in early 2018. Twelve primary discussion papers and numerous issue notes were drafted for review by various technical experts across the disciplines noted above. Using this content and feedback, chapters were drafted for consideration by the SEEA EEA Technical Committee and subsequently released for two rounds of global consultation that took place through 2020. Through this time there was active engagement with many expert communities, global environmental and sustainability initiatives, and the hosting of various in-person and virtual forums on ecosystem accounting.

[3] United Nations Statistical Commission, Report on the forty-fourth session, E/2013/24. https://undocs.org/E/2013/24

[4] United Nations Statistical Commission, Report on the forty-ninth session, E/2018/24. https://undocs.org/E/2018/24

This breadth of engagement has enriched the design and content of the ecosystem accounting framework and provides a basis for its ongoing implementation and refinement.[5]

1.2.3 Status of the SEEA Ecosystem Accounting

1.16 The SEEA Ecosystem Accounting – SEEA EA is the (statistical standard) for ecosystem accounting. It is expected to evolve over time to incorporate the outcomes from further research and findings from implementation. The SEEA EA is a system conceived as an integrated, internally consistent series of accounts. At the same time, its design is such that it can be implemented equally well in part or as a whole, i.e., the implementation can be flexible and modular.

1.17 Depending on the specific environmental issues faced a country may choose to implement only a selection of the accounts or compile accounts for regions within their country. For example, countries may commence implementation of accounts in physical terms and some may choose not to compile accounts in monetary terms especially at the initial stage of implementation. More generally, it is likely to be appropriate to focus initial efforts on compiling those accounts that are both of high relevance for decision making and for which data and estimation approaches are sufficiently advanced.

1.18 While there is flexibility available in the implementation of the system, much benefit will be derived from the SEEA EA's adoption as (an international statistical standard). This adoption will ensure that those countries that want to implement ecosystem accounting, will do so using a common framework and methodologies. In turn, this allows for an increased capacity to compare data from a range of countries over time. In addition, standardisation will be of particular benefit concerning environmental issues that are multinational or global in nature. In time, it is anticipated that the SEEA EA will be used to underpin international reporting in particular on topics related to biodiversity and ecosystems. The content and expectations concerning international reporting is the subject of separate multi-lateral processes, including the Biodiversity Conference of Parties and the Climate Change Conference of Parties.

1.3 The conceptual approach of the SEEA Ecosystem Accounting

1.19 The general approach to ecosystem accounting in recording stocks and flows concerning ecosystems has been described in a range of documents in varying ways. Research in the context of the SEEA (e.g., Vanoli (1995)) and in the context of extending the SNA (e.g., Council (1999)) has considered the accounting described in SEEA EA. Of particular note is work on wealth accounting being advanced by both the World Bank (2018) and the United Nations Environment Programme (2018). While most focus in this work has been on measuring natural resources, the extension to capture a wider range of benefits from the environment, including ecosystem services, is well established in the wealth accounting literature.[6]

1.20 In addition to these economic and accounting connections, the ecosystem accounting framework adapts the concepts developed on ecosystem services measurement such as the cascade model (Haines-Young & Potschin-Young, 2010) and the core ecosystem accounting model can be placed within the conceptual framing of the Inter-governmental and science

[5] The materials created and discussed through the revision process can be accessed at https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision

[6] The literature on wealth accounting is rich with more recent work including Dasgupta (2009), Arrow et al. (2012), Barbier (2013) and Fenichel & Abbott (2014).

Platform for Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015). In its spatial approach to considering ecosystems the ecosystem accounting framework builds on extensive work on the mapping and delineation of ecosystems and their services.[7] In the measurement of ecosystem condition, there are clear connections to long-standing ecological theory and measurement.[8] Overall, the underlying logic and conceptual basis for ecosystem accounting should therefore be considered to be well established.

1.21 The essence of ecosystem accounting lies in representing the biophysical environment in terms of distinct spatial areas each representing different ecosystem types. Ecosystem types include, for example, forests, wetlands, agricultural areas, urban areas, rivers and coral reefs. Each spatial area of a specific ecosystem type is, for accounting purposes, described as an ecosystem asset. Each ecosystem asset is accounted for in a manner that is broadly analogous to the treatment of produced assets in the SNA, such as dwellings, in which there is an underlying stock of capital (e.g., a house with specific characteristics (such as number of bedrooms) and of a given condition) and an associated flow of services (e.g., owner-occupied housing services and rental income).

1.22 Thus, in practice, ecosystem accounting involves recording over an accounting period (i) the stock and change in stock of each ecosystem asset including entries for ecosystem enhancement and degradation; and (ii) flows from that asset in the form of ecosystem services. The flows of ecosystem services in any accounting period will be related to the ecosystem type, its size or extent and its condition or health. While there are a wide range of conceptual and definitional issues that require explanation, the application of this framing remains applicable throughout the SEEA EA. Chapter 2 provides a more detailed overview of the ecosystem accounting framework.

1.23 The principles for recording stocks and flows, as applied in ecosystem accounting, can be used to organize data expressed in either physical or in monetary terms. For entries in monetary terms, the SEEA EA applies the concept of exchange values wherein ecosystem services and ecosystem assets are valued at the prices they are or would be exchanged if a market for the services was present. This supports comparison and integration of ecosystem accounting monetary values with those recorded in conventional economic and financial accounts, including gross domestic product, which are also based on the exchange value concept. There are a number of other approaches to monetary valuation and, more generally, there can be concerns about the applicability of monetary valuations in environmental decision making. The SEEA EA places the various approaches in context and encourages the use of data in physical terms.

1.24 The ecosystem accounting framework provides the basis for the compilation of various ecosystem accounts. Five ecosystem accounts are described: (i) ecosystem extent accounts; (ii) ecosystem condition accounts; (iii) ecosystem services flow accounts in physical terms; (iv) ecosystem services flow accounts in monetary terms; and (v) monetary ecosystem asset accounts. There is also a range of accounts and presentations related to these five accounts. All of these accounts are introduced in Chapter 2 and described in detail in relevant chapters.

1.25 The SEEA EA builds directly upon the original conceptual framework for ecosystem accounting described in SEEA 2012 EEA. In many areas, the revisions provide additional explanations and clarifications. However, there are some areas where reinterpretation or re-expression of the initial model was required, as a result of the ongoing discussions and widening of

[7] For example, (Burkhard & Maes, 2017; D. A. Keith et al., 2020; Sayre et al., 2020).

[8] See Karr, 1981; Leopold, 1949; Andreasen et al., 2001; Wheeler, 2002; Holling, 1973.

conversations with experts. This is particularly evident in the application of concepts concerning ecology and biodiversity and in the discussion on the monetary valuation of ecosystem services and assets. The main areas in which conceptual improvements have been introduced are described in Annex 1.1.

1.4 Connections to other measurement frameworks and initiatives

1.4.1 Introduction

1.26 Ecosystem accounting has a number of key features that allow it to support, complements and extends other measurement frameworks and initiatives. These key features are:

i. Ecosystem accounting encompasses accounting for ecosystem assets in terms of ecosystem extent and condition, and ecosystem services. Commonly, the measurement of ecosystem extent and condition is undertaken quite separately from the measurement of ecosystem services.

ii. Ecosystem accounting also encompasses coherent accounting in both physical terms (e.g., hectares, tons) and monetary terms using economic valuation techniques that support the derivation of exchange values. Through the coherent recording in physical and monetary terms, and coverage of stocks and flows, the ecosystem accounting framework is well suited to the derivation of a wide range of indicators from a single information base.

iii. Ecosystem accounting is designed to facilitate comparison and integration with the economic data prepared in accordance with the System of National Accounts (SNA). This leads to the adoption of certain measurement boundaries and valuation concepts which are not systematically applied in other forms of ecosystem measurement. The use of SNA-derived measurement principles and concepts facilitates the mainstreaming of ecosystem information in standard measures of income, production and wealth.

iv. Ecosystem accounting is designed to provide a broad, cross-cutting perspective on ecosystems at a country and/or comprehensive subnational level. Since many ecosystem measurements are conducted at a detailed local level, ecosystem accounting enables granular data to be utilized to produce a richly textured picture of the condition of ecosystems and the services that they supply.

v. Ecosystem accounting supports the consistent and comparable recording of data over time and thus provides information on trends in terms of key variables (e.g., condition of forests), the composition of ecosystem types (e.g., rates of change in conversion from forest to agricultural land), and relationships between changes in the stock of ecosystems and flows of ecosystem services.

1.4.2 *Connection to the SEEA Central Framework*

1.27 The SEEA Central Framework provides concepts, definitions and classifications to support integrated accounting for physical flows (natural inputs from and residual flows to the environment such as concerning water, energy, air emissions, solid waste); environmental transactions and transfers (e.g., environmental taxes, environmental subsidies and environmental protection expenditure); and individual environmental assets (e.g., mineral and energy resources, timber, fish, land, soil and water).

1.28 Connections to ecosystem accounting can be identified in a number of areas. In the context of accounting for physical flows, measures of natural inputs from the environment (for example concerning uncultivated timber) will be aligned with measures of ecosystem services, while measures of residual flows (e.g., flows of excess nitrogen) will be related to flows of ecosystem services that concern, for example, air filtration and water purification. Residual flows will also often indicate environmental pressures that can be related to changes in ecosystem condition. There are also connections that can be identified between environmental taxes and subsidies, expenditures on environmental protection and change in ecosystem condition; and between the monetary value of environmental assets such as timber and fish stocks and monetary values of ecosystem assets. The range of connections among the SEEA accounts is described in more detail in Annex 1.2.

1.4.3 Connection to the System of National Accounts

1.29 In broad terms, the connection between SEEA EA and the SNA lies in the application and adaptation of the national accounting concepts and principles for the purpose of accounting for ecosystem assets and their services. A summary of the most relevant concepts and principles is provided in Chapter 2.

1.30 The SEEA EA encompasses a broader asset boundary in physical terms than the SNA, reflecting the definition of environmental assets established in the SEEA Central Framework. In addition, the key difference between the SEEA EA and the SNA lies in the measurement of ecosystem services. In the SNA, these flows are considered outside the production boundary that establishes the set of goods and services that are the focus of measures of output, value added and GDP. The measurement of ecosystem services through ecosystem accounting can thus be seen to extend the SNA production boundary and consequently expand the measurement of output, income and GDP and associated monetary values of ecosystem assets. The SEEA EA provides an approach to valuing the contribution of ecosystems consistent with SNA concepts and principles such that the monetary values can be used to extend measures of national income and wealth. These extensions are discussed further in Chapter 2.

1.31 A longstanding ambition in environmental-economic accounting has been the derivation of adjusted measures of GDP, related measures of national income and national wealth which take into account the cost of using up environmental assets. This ambition is tackled in ecosystem accounting by measuring ecosystem degradation as reflecting the loss of future flows of ecosystem services. This complements the measure of depletion defined in the SNA and the SEEA Central Framework which focuses on the costs of using up natural resources.

1.32 The derivation of degradation-adjusted measures is one aspect of the integration of ecosystem accounting data into the SNA's sequence of institutional sector accounts and balance sheets. Chapter 11 describes how this integration can be undertaken. Two key aspects of the treatment are (i) the degradation is allocated to the economic unit who suffers the loss of ecosystem services rather than to the economic unit who causes the degradation;[9] and (ii) the additional stocks and flows are recorded by introducing a new quasi-sector labelled the "Ecosystem trustee" which holds stewardship over the ecosystem services that do not directly benefit an individual, private economic actor.

1.33 Other connections to the standard economic accounts can be developed including extended supply and use tables. In this case there is particular interest in recording the use of ecosystem services by different economic units, to better reflect the use of environmental assets as part of production and consumption patterns.

[9] Alternative presentations which apply the polluter pays principle for the allocation of degradation are described in Chapter 12.

1.4.4 *Connections to other statistical standards and guidance*

1.34 SEEA EA incorporates the findings presented in a range of other technical materials on ecosystem accounting, as developed in the period from 2013 to 2020.[10] It also incorporates findings from the large number of projects and initiatives on ecosystem accounting. These materials, projects and initiatives, which were developed by different agencies in different contexts, were important in testing the framework described in the SEEA 2012 EEA by evaluating technical and methodological options and assessing the relevance of a national accounting approach to ecosystem measurement for research, policy analysis and decision making. A range of these findings were collected and published in the Technical Recommendations.

1.35 In addition to research specifically on ecosystem accounting, there are a number of statistical standards and handbooks that are relevant to work on ecosystem accounting. These include:

- SEEA methodological documents - SEEA Agriculture, Forestry and Fisheries (FAO & UNSD, 2020); SEEA-Energy (United Nations, 2018); and SEEA-Water (United Nations, 2012) - which provide guidance on accounting for stocks and flows for these themes
- Framework for the Development of Environment Statistics (FDES) (United Nations, 2017) – which provides guidance on the collection of environmental statistics including a number of themes related to ecosystem accounting
- Measuring the Sustainability of Tourism (MST) (UNWTO, 2018) – which provides guidance on linking ecosystem accounting to measures of tourism activity
- Ocean Accounts[11] – which provides a broad framework to connect relevant elements of the SNA, SEEA Central Framework and SEEA Ecosystem Accounting to harmonize priority data on the ocean covering economic, ecological, governance and social aspects
- Accounting for biodiversity (UNEP-WCMC, 2016) – which provides guidance on how standard measures of species diversity can support ecosystem accounting
- Measuring Capital – OECD Manual (OECD, 2009) – which provides detailed guidance on the theory and practice of measuring stocks of produced capital

1.4.5 *Relationship to other global environmental measurement initiatives*

1.36 SEEA EA incorporates a wide range of ecological and biophysical data, with its broad coverage of all types of ecosystems, including data on their extent and condition and flows of ecosystem services which commonly require data from biophysical models such as hydrological models. Given its intention to support comparable measurement in these areas over time and across countries, ecosystem accounting provides a robust framework that can be connected to measurement and reporting activity for a number of global environmental and sustainability initiatives. In many cases, the data currently collected through these initiatives may provide source data for the compilation of ecosystem accounts.

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[10] These include Cropper & Khanna, 2014; Maes et al., 2013; UN Environment (UNEP), 2014; Weber, 2014.

[11] See "Technical Guidance on Ocean Accounting for Sustainable Development" submitted as background document to the United Nations Statistical Commission, fifty-first session, 3-6 March 2020. Available at: https://unstats.un.org/unsd/statcom/51st-session/documents/BG-item-3h-TG_Ocean%20accounting_ESCAP-E.pdf

1.37 These latter initiatives include:

- Monitoring of the Sustainable Development Goals (SDGs), in particular progress towards Goals 14 and 15;
- The Post-2020 Global Biodiversity Agenda of the Convention on Biological Diversity (CBD) and its monitoring framework;
- The measurement of land degradation under the United Nations Convention to Combat Desertification (UNCCD);
- The regional and global assessments of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES);
- The development of wealth accounting encompassing measures of the value of natural capital (World Bank, UNEP);
- International Union for the Conservation of Nature (IUCN) knowledge products including the Red List of Species; Red List of Ecosystems, World Database on Protected Areas (UNEP-WCMC and IUCN) and Key Biodiversity Areas; and
- The measurement of greenhouse gas emissions and removals by the Land Use, Land Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and associated Nationally Determined Contributions (NDC).

1.38 The relevant measurement and reporting frameworks across these initiatives are not currently aligned, although all have the common broad ambition to ensure that the environmental stocks and flows are a standard feature of decision making. There is consequently an opportunity for the statistical community to further enhance wider collaboration and engagement.

1.39 As well, given the range of measurement and reporting work underway, there is considerable potential for compilers of ecosystem accounts to consider how these data may be used or adapted for the purpose of compiling ecosystem accounts in their country. This rationale extends also at country level where data used in, for example, state of environment reports or environmental impact assessments, might be relevant and important sources of information.

1.5 Measurement, implementation and application

1.5.1 Introduction

1.40 The implementation of SEEA Ecosystem Accounting can be approached in a flexible and modular way. Progressive and staged development of the range and detail of the ecosystem accounts is likely an appropriate strategy in the early phases of implementation. The following discussion provides a summary of different roles in implementation and alternative compilation pathways that might be adopted. In addition, it is noted that the implementation of ecosystem accounting will require the establishment of networks of users comprising policymakers, decision makers, local communities and other stakeholders.

1.41 Ecosystem accounts are most informative when not conducted as one-off, irregular or short term studies of specific areas or environmental themes. Generally, the data generated from such studies do not support ongoing, long-term measurement of trends and hence the design and monitoring of policy responses. Aligned with the expectations associated with the preparation of common socio-economic data, including national accounts, employment, population census, it is expected that, over time, long time series of ecosystem accounting data can be established. This will provide the opportunity to strengthen and improve institutional arrangements and measurement approaches over time and will contribute to the compilation of enduring data sets. In turn, these data sets can underpin further research and analysis, which, ideally, would generate a virtuous circle of strengthened information supply.

1.5.2 The role of national statistical offices

1.42 National statistical offices (NSOs) have traditionally focused on producing official statistics independently, in relative isolation from other data producers. However, the role of NSOs has begun to change over the past several years, as new technologies have allowed for unparalleled levels of data collection from a variety of new sources, and as official statistics have become one source of information among many. Increasingly, this has prompted NSOs to undertake the role of data stewards. As data stewards, NSOs have shifted from being solely a producer of statistics, to also becoming a service provider, whereby the NSO facilitates a collaborative approach to data and statistics across different data and statistics communities and provides oversight and governance.

1.43 Arguably, no other domain epitomizes the role of NSOs as data stewards more than the ecosystem accounting. The implementation of the SEEA EA is often led by the official statistics community and NSOs, but given the highly cross-cutting and spatial nature of ecosystem accounting, implementation necessitates a highly collaborative approach. Implementation almost involves the active participation of representatives of many different agencies and disciplines, including geography, ecology, economics and statistics. A key objective is to work towards the appropriate institutionalization of the processes (including data sharing), roles and responsibilities for the compilation of ecosystem accounts.

1.44 In addition, as data stewards, NSOs provide oversight and better governance through giving an independent and expert opinion of data produced within government and across society to ensure trust and quality. Given the wide interest in ecosystem accounting by multiple stakeholder groups (e.g., academia, government, private sector, etc), the role of NSOs in promoting high-quality ecosystem accounts is especially important. National statistical offices are especially well-positioned to provide oversight and governance given their experience in providing standard measurement and data quality frameworks. Moreover, the voice of NSOs can be an authoritative one by virtue of their independence and particularly unique role within government.

1.45 The SEEA Implementation Guide[12] provides general advice on how to establish programmes of work for the implementation of the SEEA and various tools have been developed to guide compilers on the relevant steps. In addition, the Guidance on Biophysical Modelling for Ecosystem Accounting (UNSD, n.d., forthcoming) provides advice specific to implementation of ecosystem accounts and biophysical modelling. Ecosystem accounts compilers are also encouraged to learn from the experiences in other countries and regions.[13]

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[12] Paper for the Ninth Meeting of the United Nations Committee of Experts on Environmental-Economic Accounting New York, 25-27 June 2014. https://unstats.un.org/unsd/envaccounting/ceea/meetings/ninth_meeting/UNCEEA-9-6d.pdf

[13] Many examples can be found in the SEEA Knowledge Base at: https://seea.un.org/content/knowledge-base

1.5.3 *Ecosystem accounting compilation approaches*

1.46 Compilation of the ecosystem accounts can follow several alternative approaches located along a spectrum. At one end are "spatially-explicit" approaches which entail detailed and comprehensive spatial measurement of ecosystem services and rigorous delineation of ecosystem assets. At the other end are "minimum spatial" approaches which seek to provide a broad overview of trends in key ecosystem types and services. The content of the accounts compiled using either of these extremes will be conceptually aligned but there will be differences in the level of detail shown in the accounts (e.g., concerning the number of ecosystem types) and, in the minimum spatial approach, there will be limited capacity to disseminate outputs as maps showing the location and configuration of ecosystem assets and the services they supply.

1.47 In practice, the compilation of ecosystem accounts will lie between these two extremes, with the degree of spatial detail utilized being dependent on (a) the type of research question being investigated and (b) the availability of source data and the budgetary resources for compilation. In general terms increasing the level of spatial detail has the potential to increase the level of robustness of the accounts, and perhaps open up a wider range of applications, but it will also increase the level of complexity in compilation. In practice, it is likely that a mix of spatial detail will be applied depending on the specific account, the variable being considered and the environmental context of a country.

1.48 A common starting point for ecosystem accounting will be the compilation of ecosystem extent accounts which provide a statistical frame for the accounts. Where national level data are not available, global data sets could provide a suitable starting point. Beyond the extent account, depending on the data available and issues of particular interest, efforts may turn to the compilation of ecosystem condition accounts for different ecosystem types and to the quantification of ecosystem services flows. Monetary valuation, which commonly relies on the organisation of a wide array of data in physical terms, could be undertaken as a final part of a compilation process.

1.5.4 *Uses and applications of ecosystem accounting*

1.49 In support of ongoing reporting requirements and discussion of emerging issues, the accounts provide information that is:

- comprehensive, i.e., it encompasses a wide range of ecosystem types, services and assets; maps and tables; and physical and monetary indicators;
- structured, i.e., it follows the SEEA internationally agreed framework encompassing agreed accounting rules aligned with those of the SNA;
- consistent, i.e., it presents data that are consistent over time and with respect to concepts and classifications;
- coherent, i.e., it integrates a broad range of data sets in order to provide information on ecosystem services and assets; and
- spatially referenced, i.e., it links data to the scale of ecosystems and allows the integration of data across different accounts.

1.50 Given these features, ecosystem accounts provide a range of information in support of economic and environmental policy and decision-making. These applications include highlighting the ecosystems and ecosystem services of particular concern to policymakers; supporting assessments of biodiversity and indicating specific areas or facets of biodiversity under particular threat; monitoring the effectiveness of various policies; providing detailed spatial information on ecosystem services supply; and supporting economic and financial decision-making.

1.51 Further, in applying a set of coherent data the accounts can, in turn, support implementation of a wide variety of specific approaches including cost-benefit analysis, risk assessments, system-based modelling, scenario analysis and forecasting and trade-off analysis. Thus, ecosystem accounting can be used in conjunction with other methods and tools for application in policy and decision making.

1.52 Ideally, accounts should be updated on a regular basis (e.g., annually) considering source data availability and user needs, so as to ensure that a structured, comprehensive and up-to-date database is available to respond to policy demands for specific information, for example, an environmental cost-benefit analysis of a proposed policy. Although assessment of specific policies or investments will likely require information additional to that presented in the ecosystem accounts; the data from the accounts should be able to describe relevant structures and trends, and in many cases, to support the modelling of a wide range of environmental and economic impacts. Further, where different assessments are based on a common underlying data set it allows improved comparison of policy alternatives.

1.6 Structure of the SEEA EA

1.53 <<To be drafted following finalisation of accounting treatments. Include also paragraph/s on the research agenda.>>

Annex 1.1: Main conceptual changes from the SEEA 2012 EEA

<< To be developed after the Global Consultation and prior to the finalization of the publication for the final submission to the UN Statistical Commission. >>

Annex 1.2: Linking the SEEA EA and the SEEA Central Framework

Introduction

A1.1 The SEEA EA is designed to complement the SEEA Central Framework to provide a more complete picture of the relationship between the environment and the economy using the same accounting principles. The complementarity can be considered in two ways – first with respect to the definition of environmental assets and second with respect to the coverage of data within a basic pressure-state-impact-response (PSIR) framework.

A1.2 With regard to environmental assets, the SEEA Central Framework provides a definition of environmental assets that encompasses the measurement of both individual environmental assets (such as land, soil, water and timber) and ecosystem assets. The associated asset boundary is broader that that provided for in the SNA by establishing a physical boundary and not requiring flows of benefits to accrue to owners of environmental assets. This extension is applied in both the SEEA EA and the SEEA Central Framework.

A1.3 Within this broader asset boundary, the focus of accounting in the SEEA Central Framework is on the individual components that make up the environment, such as minerals, timber, water, land and soil. This focus comprises those types of individual resources used in economic activity. The focus of accounting for environmental assets in the SEEA EA is on ecosystems and, in many senses, how individual components function together. Consequently, there are often strong connections between accounting for individual environmental assets, as described in the SEEA Central Framework, and measures of ecosystem assets and ecosystem services.

A1.4 A common framing for measurement and analysis of the connection between the environment and the economy is the PSIR framework. The focus of the SEEA EA is on the state and impact components of this framework. Thus, measures of the changing mix of ecosystem types, the changes in condition of ecosystem assets and the changes in ecosystem services provide a more complete picture of environmental state and the impacts of economic and human activity than provided by the accounts of the SEEA Central Framework.

A1.5 The SEEA Central Framework on the other hand provides a rich framework for considering the pressures of economic activity, in particular through its measurement of physical flows (e.g., concerning water use, energy use, air emissions, solid waste). It also supports the organization of data on the response to environmental issues through accounts concerning environmental taxes and subsidies, environmental protection expenditure and the activities of the environmental goods and services sector (EGSS).

A1.6 While there is the possibility to identify common points of measurement, a general difference lies in the fact that the general focus of accounting in the SEEA Central Framework is at the national level whereas in ecosystem accounting there is commonly a focus at sub-national levels and often measurement using detailed spatial data and models. Thus, the integration of data from the SEEA Central Framework, for example on residual flows, may require attribution of flows to locations within a country, to establish clearly the link between the residual flows and a change in ecosystem condition. A broad, national-level, comparison of residual flows and condition at a national level is likely to miss important variations across locations within a country.

A1.7 In the area of monetary valuation, both the SEEA EA and the SEEA Central Framework apply the exchange value concept and use the net present value approach for the valuation of environmental assets. The primary difference between estimates of the monetary value of environmental assets therefore concern the range of flows that are within scope of the valuation. For the SEEA Central Framework this is limited to those flows within scope of the SNA, primarily concerning extraction/harvest of natural resources, while for ecosystem accounting the scope extends to capture all relevant ecosystem services. This extension to include a broad range of ecosystem services leads to an expanded conception of wealth in the SEEA EA since the underlying environmental assets are recognised to provide a much wider set of benefits than is traditionally recognised.

A1.8 The following sections provide additional details on these connections. It is fundamental to recognise that neither the SEEA Central Framework nor the SEEA EA provide a complete set of information for analysing the environmental-economic relationship but that when combined a rich data set can be envisaged.

Recording environmental assets and related stocks

A1.9 As noted above, the SEEA Central Framework has a focus on individual assets, i.e., without considering the broader context or system in which those assets, commonly natural resources, are located. For example, the SEEA Central Framework has a focus on timber resources, whereas SEEA EA has a focus on the forest which does not only supply timber biomass but also a range of other ecosystem services. The same comparison can be drawn between fish resources and marine ecosystems.

A1.10 From the perspective of recording physical changes in the stock of ecosystem assets there should be a coherence with related recordings of changes in individual environmental assets. That is, for the same accounting period and in the same location, the changes in stock and changes in ecosystem assets should convey the same change, recognising that the metrics for recording change will be different. However, in the measurement of benefits and the related valuation of assets, there will be a different scope in the SEEA EA.

A1.11 As a result of the coherence in the measurement of physical stocks, there are important advantages for ecosystem accounting in compilation since it becomes possible to use the range of materials and documentation that has been developed related to the measurement of water resources, including *SEEA-Water* (United Nations, 2012); and for agriculture, forests and timber, fisheries (SEEA for Agriculture, Forestry and Fisheries (FAO & UNSD, 2020)). While these materials have generally not been developed for ecosystem accounting purposes, they will support the development of relevant estimates and accounts, especially in relation to methods and data sources.

A1.12 In addition, SEEA EA describes two areas, accounting for carbon and accounting for species populations, to which the individual environmental asset accounting described in the SEEA Central Framework is applied. The emerging range of materials in these two areas of measurement can also be used to support the measurement of ecosystem assets and ecosystem services and should be coherent with the individual environmental asset accounts of the SEEA Central Framework.

A1.13 The SEEA Central Framework also defines the depletion of natural resources and introduces the concept of ecosystem degradation. The distinction between these concepts lies primarily in the scope of the measurement and mirrors the distinction between a focus on individual environmental assets and ecosystems as a whole. Thus depletion is defined in relation to using up the stock of resources relative to the rates of regeneration. Degradation is defined in relation to changes in condition and future flows of ecosystem services.

A1.14 Since depletion is measured with respect to an individual resource with a single benefit stream there is a direct connection that can be made between changes in the stock and changes in future benefit streams. With degradation, this relationship is more complex since a bundle of ecosystem services will generally be supplied and the relationships to changes in condition will be variable. Nonetheless, for a given ecosystem asset, there should be a reasonably close relationship between measures of depletion and measurement of degradation as they pertain to provisioning services such as timber or fish biomass.

Environmental flows

A1.15 The SEEA Central Framework describes accounting for environmental flows, such as of water, energy, GHG emissions and solid waste. These flows are recorded in physical terms. Three types of flows are defined – natural inputs, products and residuals.

A1.16 "Natural inputs are all physical inputs that are moved from their location in the environment as part of economic production processes or are directly used in production" (SEEA Central Framework, para. 3.45). In general terms this definition will encompass the set of provisioning services that contribute to the production of agricultural, forestry, fisheries and similar outputs. However, a number of differences in scope must be noted:

- Natural inputs include inputs of mineral and energy resources and soil resources (excavated), and inputs energy from renewable sources (e.g., solar, wind). These are excluded from the scope of ecosystem services but may be recorded as abiotic flows in the SEEA EA framework.
- Natural inputs include inputs of timber, aquatic (e.g., fish) and other biological resources only in cases where the production process is uncultivated, i.e., natural. In SEEA EA, provisioning services arise in both cultivated and uncultivated contexts.
- Natural inputs include inputs of nutrients, carbon, nitrogen and other elements. These flows are not commonly recorded in an ecosystem accounting context but may be relevant in the measurement of some regulating and maintenance services, for example in the context of recording inputs of ecosystem services to the growth of cultivated biological resources.
- Natural resource residuals are defined in the SEEA Central Framework represent those flows of natural resources that are extracted or harvested but where some quantity is immediately returned to the environment. Examples include discarded catch in fishing and felling residues in forestry. In SEEA EA, flows of provisioning services are recorded in gross terms before natural resources residuals are recorded thus the recording is aligned with the gross recording of natural inputs used in the SEEA Central Framework.

A1.17 Physical flows of products take place within the economy and are not recorded within the SEEA EA. Nonetheless, in concept flows of final ecosystem services that contribute to SNA benefits should be able to be linked to physical flows of products, for example, biomass provisioning services can be linked to flows of food and other products to which they are inputs. This may be of particular interest in developing "footprints" and understanding the extent to which ecosystem services are embodied in traded goods and services.

A1.18 "Residuals are flows of solid, liquid and gaseous materials, and energy that are discarded, discharged or emitted by establishments and households through processes of production, consumption or accumulation." (SEEA Central Framework, para. 3.73) These physical flows are generally not recorded directly in the ecosystem accounts. Rather, these flows reflect either measures of environmental pressures that may be used as proxy measures in the assessment of ecosystem condition; or measures related to the flow of ecosystem services provided by ecosystem assets that receive, store or process the relevant residual (e.g., particulate matter (PM2.5) absorbed by trees will be a component in the measurement of air filtration services).

A1.19 While there is not a direct alignment in the recording of residual flows between SEEA EA and the SEEA Central Framework, the quantities of residual substances that are not broken down or absorbed will be of particular interest with respect to the measurement of environmental pressures, as they are related to changes in ecosystem condition. Indeed, since flows of residuals are likely to affect the capacity of ecosystem assets to supply ecosystem services, the potential to quantify this type of feedback loop is an important aspect in considering the linkages between ecosystem accounting and the accounts of the SEEA Central Framework. Information on residuals flows will also be relevant in the assessment and valuation of ecosystem disservices and externalities. This is discussed further Chapter 12.

A1.20 In terms of accounting structures, the basic structure of the ecosystem services supply and use table is derived from the design of physical supply and use tables (PSUT) in the SEEA Central Framework. There are three principle alterations. First, unlike the PSUT, which contains just one column representing the environment, the ecosystem services flow account contains multiple columns, each representing a different ecosystem type.

A1.21 Second, the PSUT covers three types of flows: natural inputs, products and residuals. While in general concept ecosystem services align to natural inputs as defined in the Central Framework, the coverage of natural inputs is limited to provisioning services (as discussed above), and further flows of regulating and maintenance services and cultural services are not included in the SEEA Central Framework.

A1.22 Third, the SEEA Central Framework does not consider the ways in which different stocks and flows assets may be connected spatially (i.e., it incorporates an individual-resource perspective) and it describes accounting at national scale rather than allowing for the location of ecosystems and their services to be reflected in the accounts. In contrast, the ecosystem services flow account has the capacity to record intermediate services reflecting the dependencies between ecosystem assets and there is the potential to directly present the results in the form of maps.

Environmental transactions

A1.23 Chapter 4 of the SEEA Central Framework focuses on the recording required in relation to environmental transactions including environmental activity accounts, environmental taxes, subsidies and other payments related to the environment. Information on environmental activities, particularly those related to the restoration of ecosystems, may be of particular relevance in both the compilation of ecosystem accounts and in providing a more comprehensive picture of responses, for example to changes in ecosystem condition. Indeed, measures of expenditure on, for example, ecosystem restoration, may be compared to changes in ecosystem condition and changes in flows of ecosystem services to provide an assessment of the effectiveness of any expenditure.

2 Principles of ecosystem accounting

2.1 Introduction

2.1 This chapter provides a summary of the ecosystem accounting framework, its core conceptual components, the main accounts and relevant national accounting principles. The intention is to demonstrate the nature of the connections between the different accounts as well as the approach to the integration of the ecological and economic approaches to considering the relationship between the environment and the economy.

2.2 Overview of the ecosystem accounting framework

2.2.1 An accounting approach

2.2 In general terms, the essence of an accounting approach lies in recording data on relevant stocks and flows in a systematic way. In corporate accounting, the focus of accounting are business units and in national accounting the focus is on the range of different economic units (businesses, households, governments) located in a geographical area, usually a country. Accounting can also be undertaken for an individual asset such as a house.

2.3 Ecosystems are the focus of ecosystem accounting. Ecosystem accounting thus aims to record data in a systematic fashion on the stocks and flows of selected ecosystems. While ecosystems are the starting focus, the accounting approach applied in the SEEA also encompasses documenting the relationships among ecosystems, people and economic units. In doing so, it provides a basis for analyzing the role that ecosystems play in supporting economic and human activity and understanding the impact that economic and human activity has on ecosystems.

2.4 A feature of ecosystems is that they can be attributed to specific locations. Indeed, the measurement of ecosystems is most commonly undertaken with an understanding of where different ecosystems are located, how they are arranged in relation to other ecosystems and how they are changing over time. Ecosystem accounting therefore places considerable focus on recording data on the stocks and flows at sub-national and finer spatial scales. While location is also relevant in national accounting, for example an economic territory is needed to define the accounts for a country, in ecosystem accounting the application of spatial measurement is at the heart of the measurement approach.

2.5 The approach described in the SEEA EA has two particular features. First, it describes accounting concepts and structures in both physical and monetary terms. Second, it applies the accounting principles and related measurement boundaries from the national accounts described in the System of National Accounts 2008 (2008 SNA) (United Nations et al., 2010). This facilitates integration of data from ecosystem accounts with the data from the conventional economic accounts, for example measures of gross domestic product (GDP).

2.2.2 Measurement perspectives on ecosystems

2.6 Following the Convention on Biological Diversity (CBD) an ***ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment***

interacting as a functional unit.[14] Ecosystems change as a result of natural processes (e.g., succession and natural disturbances, such as a storm) and because of human actions, involving deliberate management or disturbance, such as the extraction of natural resources, pollution or restoration and conservation activity.

2.7 While this provides a clear focal point for accounting, the functional ecological unit that is an ecosystem can be viewed in a number of different ways that are all relevant in different measurement contexts and for different purposes. The statistical framework of the SEEA EA integrates these various perspectives. Five distinct perspectives are relevant:

- Spatial frame perspective: Here the concept of an ecosystem is used to establish the number of occurrences of ecosystems within a defined territory that can be classified in mutually exclusive ways. In doing so, a comprehensive measurement base is formed.
- Ecological perspective: Here the concept of an ecosystem is the focus for the measurement of its ecological integrity, health and condition and serves to underpin concepts such as ecosystem resilience and the assessment of ecological thresholds.
- Societal benefit perspective: Here ecosystems are seen as a source of benefits for people, the economy and society potentially in terms of a relational connection or in a more economic sense of supplying services and benefits.
- Future value perspective: Here ecosystems are seen as units that provide services and benefits into the future depending on their ecological status and social demands. Issues of ecosystem degradation and enhancement are considered in this perspective.
- Institutional ownership perspective: Here there is a consideration of how ecosystems might be considered in relation to existing economic and legal entities. Issues of stewardship and allocation of degradation costs are considered here.

2.8 Each of these perspectives will have different measurement considerations but they are fundamentally interconnected since they all of the same underlying focus for measurement, i.e., the ecosystem.

2.9 Under each of these perspectives, different labels are applied to refer to the ecosystem that is the focus of measurement. The labels are commonly interpreted as referring to specific understandings or interpretations of the ecosystem. Given the intent of integration, and to avoid the confusion of having different labels for different perspectives within the ecosystem accounting framework, in the SEEA EA the label ecosystem asset is applied. The label ecosystem asset is thus used to refer to the individual statistical units that comprise the set of ecosystems that determine the scope of the accounts; the ecological functional units that are the focus of biophysical measurement and assessment; the supply or producing units that deliver ecosystem services and associated benefits; the assets which are stores of future value and the entities that have status in their own right or may be linked to existing legal, social and institutional units.

2.10 A unique feature of ecosystem accounting is its use of the same statistical unit across all accounts, building on the measurement base established through the spatial frame perspective. This may represent a measurement compromise for any single perspective, but it has the significant advantage of facilitating the co-ordination and integration of data in a manner that supports informed discussion across the perspectives.

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[14] See Convention on Biological Diversity, article 2, entitled “Use of terms” https://www.cbd.int/convention/articles/?a=cbd-02

2.11 Since it is the spatial frame perspective that links the components of the accounting framework, the definition of ecosystem assets speaks directly to this origin. Thus, ***ecosystem assets are contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions.*** It should be considered a statistical interpretation of the scientific concept of an ecosystem described in the CBD definition. The definition is thus not bound by the focus of measurement and should not be regarded as being linked specifically to an ecological, economic or institutional interpretation of ecosystems. Finally, defined in this way, ecosystem assets remain nested within the broader concept of environmental assets as defined within the SEEA Central Framework which is tied primarily to the components of the biophysical environment and not to considerations such as ecological status, benefit flows, or ownership.

2.2.3 The logic of the ecosystem accounting framework

2.12 The central logic of the ecosystem accounting framework builds from the definition of an ecosystem asset. A set of ecosystem accounts will encompass those ecosystem assets within a defined ecosystem accounting area. The ***ecosystem accounting area (EAA) is the geographical territory for which an ecosystem account is compiled***. An EAA may be defined by, for example, the boundary of a country, a sub-national administrative area, a water catchment or a protected area. Within the EAA, the ecosystem assets will reflect different ecosystem types each with their own structure, function and composition and with associated ecological processes.

2.13 Information on the ecosystem types will be reflected in measures of ecosystem extent and ecosystem condition. ***Ecosystem extent is the size of an ecosystem asset in terms of spatial area. Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics.***

2.14 Depending on the ecosystem type, its extent and condition, and on their location and patterns of use by economic units (including households, businesses and governments), ecosystem assets supply a bundle of ecosystem services. ***Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity***.

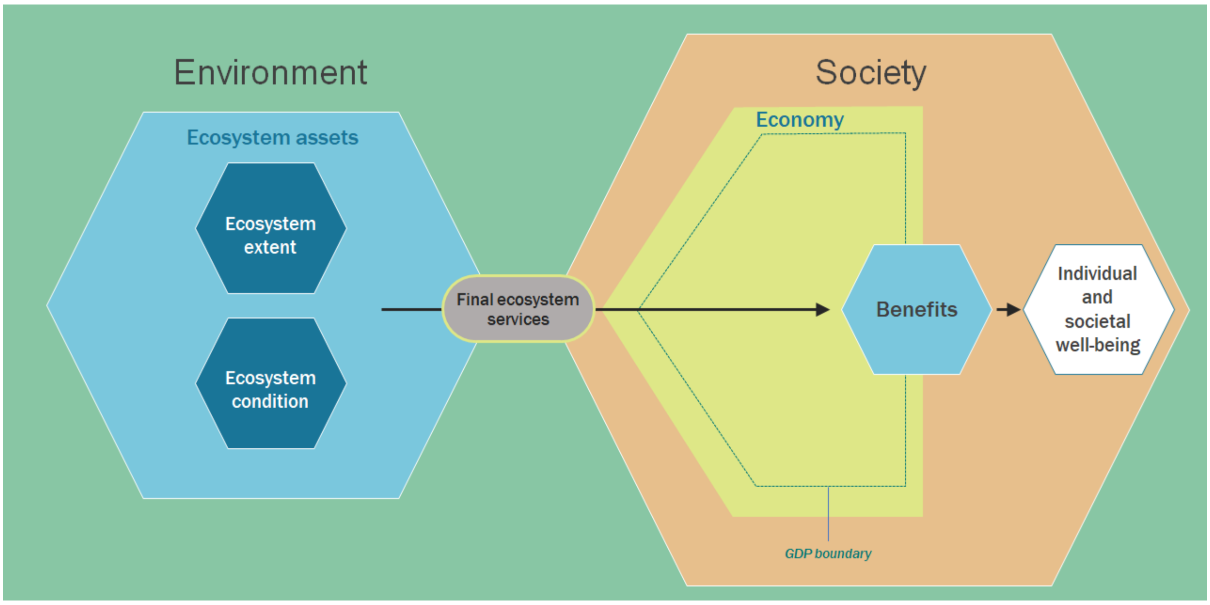
2.15 ***Benefits are the goods and services that are ultimately used and enjoyed by people and society***. The benefits to which ecosystem services contribute may be captured in current measures of production (e.g., food, water, energy, recreation) or may be outside such measures (e.g., benefits arising from air filtration services, and flood control services).

2.16 In an accounting context, flows of ecosystem services are revealed in the sense of being observable interactions between economic units, people and ecosystems. Many of these interactions will not be related to exchanges in monetary terms, but nonetheless, some of the value of these exchanges can be represented in monetary terms.

2.17 In connecting the stock and flows elements of the framework, the SEEA EA uses the concept of ecosystem capacity reflecting, in broad terms, the capacity of an ecosystem asset to provide services into the future. Measures of ecosystem capacity with respect to ecological limits are therefore relevant. In accounting terms, an ecosystem's capacity will underpin a store of future value.

2.18 The relationships among these key components of ecosystem accounting are shown in Figure 2.1.

Figure 2.1: The general ecosystem accounting framework



2.2.4 Ecological considerations concerning the ecosystem accounting framework

2.19 In line with the definition of environmental assets in the SEEA Central Framework, the SEEA EA has a broad coverage of ecosystem types to ensure all areas, including urban areas, of a country or other accounting area are considered. Often ecosystems are perceived as more or less "natural" systems which are subject to only limited human influence. However, a wider interpretation is necessary based on the understanding that human activity is embedded within and influences ecosystems across the world. Different degrees of human influence can be observed. For instance, in a natural forest ecosystem processes exert the dominant effect on 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, for example, in ponds where there is intensive aquaculture, ecosystem processes are heavily influenced by human management. Finally, ecosystems close to, and within, areas of human settlement may be significantly affected by human activity and disturbances such as pollution.

2.20 Assessment of ecosystems should therefore consider the key characteristics of the ongoing operation and location of ecosystems. Key characteristics of the operation of an ecosystem are (a) its structure (e.g., the food web within the ecosystem); (b) its composition, including living components (e.g., flora, fauna and micro-organisms) and non-living components (e.g., mineral soil, air, sunshine and water); (c) its processes (e.g., photosynthesis, decomposition); and (d) its functions (e.g., recycling of nutrients and primary productivity). Key characteristics of an ecosystem's location are (a) its extent (i.e., its size, usually in area); (b) its configuration (i.e., the way in which the various components are arranged and organized within the ecosystem); (c) the landscape forms (e.g., mountain regions and coastal areas) within which the ecosystem is situated; and (d) climate and associated seasonal patterns.

2.21 Understanding biodiversity is integral to assessment of the structure, function and composition of ecosystems. Following the CBD, ***biodiversity is 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 of ecosystems.[15] The SEEA EA tends to focus on data concerning ecosystem diversity and between species diversity (commonly referred to as species diversity). The effects of levels of, and changes in, within species diversity (commonly referred to as genetic diversity) will be implicit but not separately identified at the other levels of biodiversity.

2.22 The processes contributing to changes in biodiversity are many and varied. Nonetheless, some generic types of processes leading to such changes at the ecosystem and species level can be identified. At the ecosystem level, biodiversity loss is characterized by the conversion, reduction or degradation of ecosystems (or habitats). Generally, as the level of human use of ecosystems increases or intensifies above critical thresholds, biodiversity loss increases and there is a reduced capacity to maintain ecosystem function. The corollary is that increases in biodiversity, for example through habitat restoration or natural succession, are shown to lead to improvements in the capacity to maintain ecosystem function, increases in the resilience of ecosystems and increases in the range of available and potential ecosystem services.

2.23 Commonly, biodiversity loss is characterized by a decrease in abundance of many endemic species existing in a particular area, while at the same time, some species, in particular those that benefit from disturbed habitats, increase in abundance. The extinction of the endemic species is often the final step in a long process of gradual reductions in abundance. In many cases, local or national species richness (i.e., the total number of species regardless of origin or abundance) increases initially because of the introduction or favouring of exotic species by humans.[16] However, because of these changes, ecosystems lose their regional endemic species and become more and more alike—a process described as "homogenization".[17]

2.24 Ecosystems can be identified at different spatial scales, for instance, a small pond may be considered an ecosystem, as may a tundra stretching over millions of hectares. In addition, ecosystems are interconnected, and are commonly nested and overlapping. They are subject to processes that operate over varying time scales; consequently, the scale of analysis will depend on whether there is a focus on the internal interactions within ecosystems or more broadly on ecosystem types.

2.25 It is widely recognized that ecosystems are subject to complex dynamics. The propensity of ecosystems to withstand pressures to change, or to return to their initial condition following natural or human impact, is called ecosystem resilience. The resilience of an ecosystem is not a fixed, given property, and may change over time, for example, owing to ecosystem degradation (e.g., through timber removal from a forest) or ecosystem enhancement (e.g., through management of wetlands). Other aspects of the complex dynamics of ecosystems are reflected in the presence of thresholds, tipping points and irreversibilities which are breached when ecosystem processes break down. These complex dynamics and the associated non-linear relationships that are evident over multiple and intersecting time frames between the different ecosystem characteristics make the behaviour of ecosystems as a function of human and natural impacts difficult to predict, although there have been significant improvements in the understanding of those dynamics.

[15] See Convention on Biological Diversity, article 2, entitled "Use of terms" https://www.cbd.int/convention/articles/?a=cbd-02
[16] This is the so-called intermediate disturbance diversity peak (see Lockwood & Mckinney (2001)).
[17] See Lockwood & Mckinney, 2001; and Millennium Ecosystem Assessment, 2005.

2.2.5 *Economic considerations concerning the ecosystem accounting framework*

2.26 Ecosystem assets supply ecosystem services, either from a single ecosystem asset or by multiple ecosystem assets operating collectively. In this framing, ecosystem assets may be characterized as producing units. For accounting purposes, it is assumed that it is possible to attribute the supply of each ecosystem service to a single ecosystem type (e.g., timber provisioning services from a forest) or, where the supply of services involves more than one ecosystem type (e.g., flood control services across a catchment), to estimate the contribution of each associated ecosystem type to the total supply.

2.27 Ecosystem services encompass a wide range of services and may be categorized into provisioning services (i.e., those related to the supply of food, fibre, fuel and water); regulating services (i.e., those related to activities of filtration, purification, regulation and maintenance of air, water, soil, habitat and climate); and cultural services (i.e., the experiential and non-material services related to the perceived or realized qualities of ecosystems whose existence and functioning enables a range of cultural benefits to be derived by individuals). A reference list of ecosystem services for ecosystem accounting purposes is described in Chapter 6.

2.28 In many instances, the receipt of benefits by economic units involves a joint production process involving inputs from the ecosystem (i.e., ecosystem services) and human inputs including combinations of labour, produced assets, intermediate inputs (e.g., fuel, fertilizer) and individual's time. Thus, for example, the ecosystem contribution to the growth of wild fish (which is reflected as being supplied by an ecosystem (e.g., lake) and used by an economic unit (e.g., a fisherman) must be distinguished from the benefits which, in this example, are the fish sold by the fisherman to other economic units. Further, ecosystem accounting allows recognition that the combination of inputs will vary. Thus, for example, where fish are sourced from aquaculture facilities the ecosystem input will be significantly lower.

2.29 The main focus of ecosystem accounting is on the supply of final ecosystem services to economic units, including businesses and households. These are recorded as transactions between ecosystem assets (the suppliers) and economic units (the users). For a supply of final ecosystem services to be recorded, there must be a corresponding use.

2.30 The ecosystem accounting framework also supports the recording of flows of intermediate services, which are flows of services between ecosystem assets. Recording these flows supports an understanding of the dependencies among ecosystem assets, for example, within a water catchment.

2.31 The definition of ecosystem services and the approach to their recording is designed to support integration of ecosystem accounting data with data on the production of goods and services that is currently recorded in the standard national accounts. In effect, ecosystem accounting recognizes a set of flows that are not recorded within the current production boundary of the SNA. The approach taken provides the opportunity to compile broader measures of output, income and consumption.

2.32 Recognizing ecosystems as stores of value concerning future flows of ecosystem services, invokes three points for discussion. First, it allows making the connection between the extent and condition of ecosystem assets and the potential for these ecosystem assets to supply services and associated benefits into the future and for future generations, a concept referred to as ecosystem capacity. Ecosystem capacity is discussed in greater detail in Chapter 6.

2.33 Second, recognizing a store of value highlights the importance of investment in, and management of ecosystem assets to underpin the future supply of ecosystem services. There may be a wide range of motivations for undertaking investment in ecosystem assets and there are a range of ways in which accounts can present data to show the connection between ecosystem assets and those economic units who are responsible for this investment.

2.34 Third, recognizing a store of value opens a discussion on the scope of value that should be considered in relation to ecosystems. There is a range of perspectives on the value of ecosystems that must be considered. Ecosystem accounting accommodates a perspective founded on accounting and economic principles wherein the value of an ecosystem is embodied in the expected future flows of services. While this perspective is useful in some contexts, it does not and cannot provide a complete perspective on the value of ecosystems. Section 2.4 on the framing of values for ecosystem accounting discusses this topic at more length.

2.35 In monetary valuation, the SEEA EA uses the exchange value concept from the SNA. A key feature of this valuation concept is that the accounting entries are estimated on the basis of the current set of institutional arrangements including relevant laws and market structures. While this establishes a baseline monetary value that can be compared to the national accounts, it will also mean that in many cases the reported monetary value is lower than it might be under alternative institutional arrangements. For policy and analytical purposes there will therefore commonly be a need to complement the accounting values will those estimated using alternative institutional arrangements or encompassing other aspects of value, such as consumer surplus, which are not included in the accounts. The gap between these two valuations may be of high policy interest. An introduction to complementary valuations is provided in Chapter 12.

2.3 The set of ecosystem accounts

2.3.1 Ecosystem accounts

2.36 The SEEA EA consists of a system of integrated *ecosystem accounts*. These constitute the heart of the ecosystem accounting system. The SEEA EA also describes *related accounts*, which provide for complementary presentations, connections to the SNA and SEEA Central Framework and specific accounting information for policy relevant themes. These various accounts are summarized in this section.

2.37 There are five ecosystem accounts as listed in Table 2.1. These five accounts constitute an accounting system where the accounts are strongly interconnected and provide a comprehensive and coherent view of ecosystems. There is no single, all-encompassing ecosystem account and, while designed as a system of integrated accounts, each account has merit and information content in its own right.

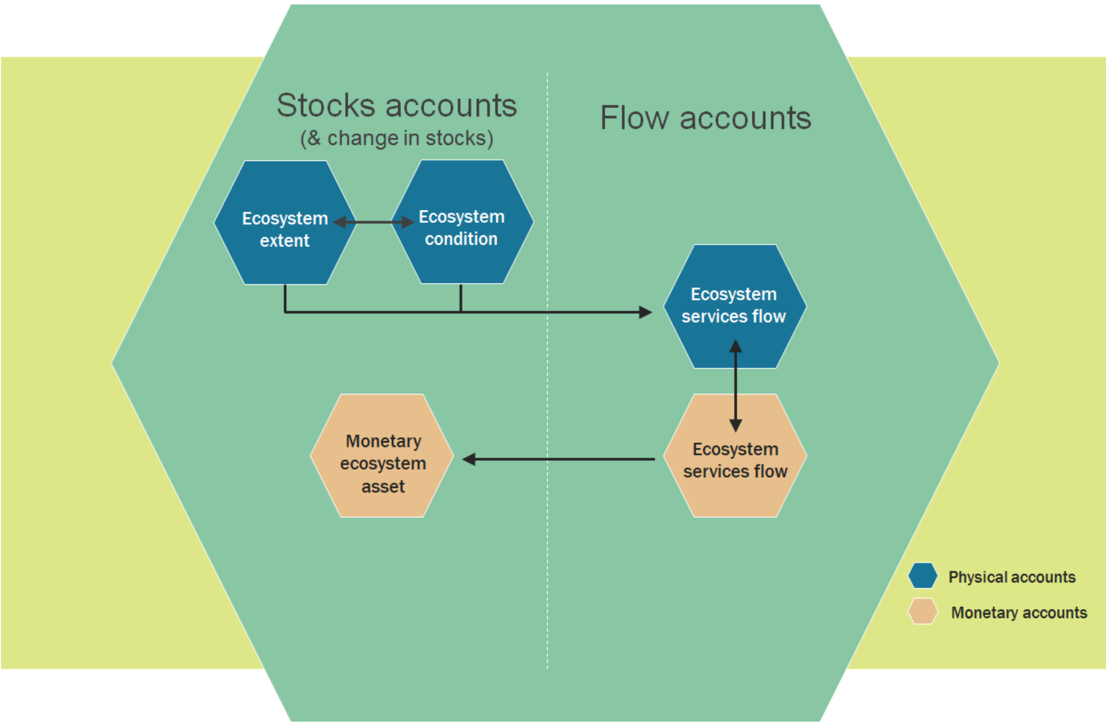
Table 2.1: The ecosystem accounts

1	Ecosystem extent account – physical terms
2	Ecosystem condition account – physical terms
3	Ecosystem services flow account– physical terms
4	Ecosystem services flow account – monetary terms
5	Monetary ecosystem asset account – monetary terms

2.38 The logic underpinning the connections between the various ecosystem accounts is articulated in Figure 2.2. In terms of compilation, there will be particular connections between (i) the ecosystem extent and ecosystem condition accounts each focusing on the description of ecosystem characteristics; (ii) the ecosystem extent and condition accounts and the ecosystem services flow account in physical terms since the characteristics of an ecosystem will influence its capacity to supply ecosystem services; (iii) the ecosystem services flow accounts in physical and monetary terms with both presenting data on ecosystem services; and (iv) the ecosystem services flow account in monetary terms and the ecosystem monetary asset account, for which compilation of the latter will require estimation of future flows of the former.

2.39 While these close connections can be identified, there remain general connections among all of the accounts such that, for example, measures of the extent and condition of an ecosystem asset are connected with measures of future ecosystem services flows that underpin the monetary valuation of ecosystem assets and changes in condition will relate directly to measurement of ecosystem enhancement and degradation as recorded in the ecosystem monetary asset account. Supporting the coherence of various ecological and economic data is a core feature of ecosystem accounting.

Figure 2.2: Connections between the ecosystem accounts



2.40 **Ecosystem extent accounts** organize data on the extent or area of different ecosystem types. Data from extent accounts can support the derivation of indicators of deforestation, desertification, urbanization and other forms of land use driven change and thus provide a common basis for discussion among stakeholders of the changing composition of ecosystem types within a country Compilation of these accounts is also relevant in determining the appropriate set of ecosystem types that will underpin the structure of other accounts. Chapter 3 describes how ecosystem assets are delineated, including the classification of the various ecosystem types. Ecosystem extent accounts are discussed in Chapter 4.

2.41 **Ecosystem condition accounts**. A central feature of ecosystem accounting is its organization of biophysical information on the condition of different ecosystem types. The ecosystem condition account organizes the relevant data on selected ecosystem characteristics and the distance to a reference condition to provide insight into the ecological integrity of ecosystems. The structure of the ecosystem condition account is described in Chapter 5.

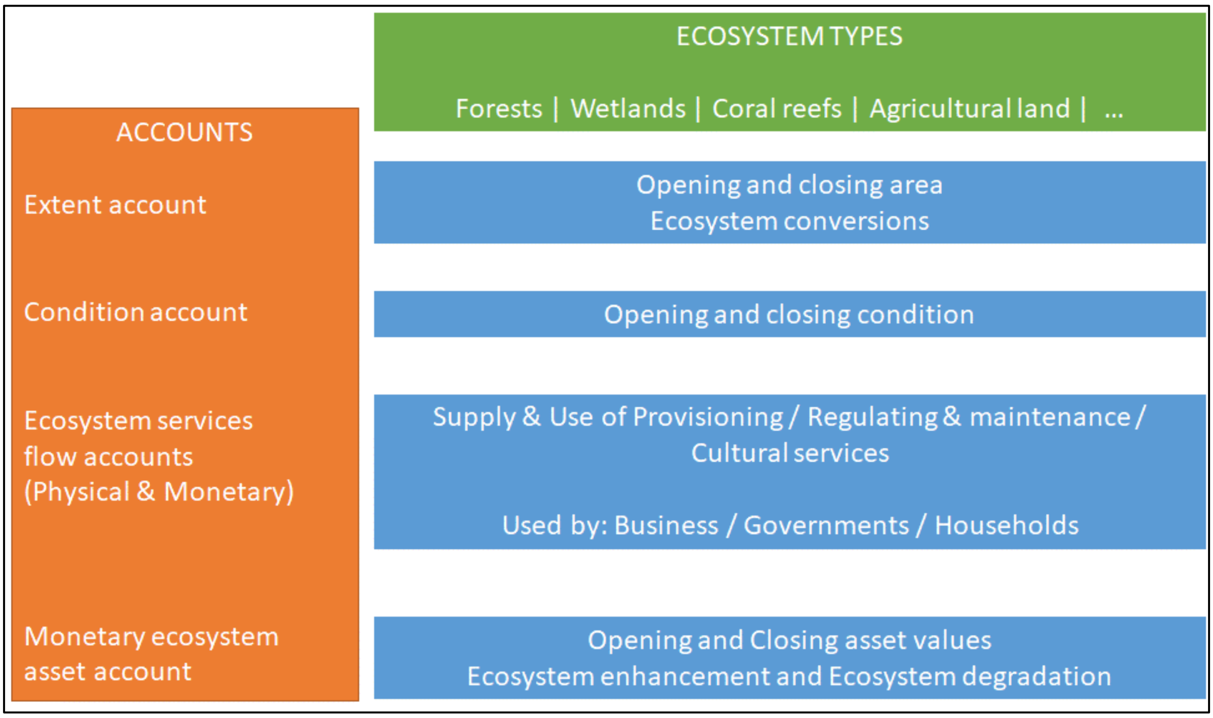
2.42 **Ecosystem services flow accounts – physical terms.** The supply of final ecosystem services by ecosystem assets and the use of those services by economic units, including households, enterprises and government, constitute one of the central features of ecosystem accounting. The supply and use table records the flows of final ecosystem services supplied by ecosystem assets and used by economic units during an accounting period, and also allows for the recording of intermediate service flows between ecosystem assets. Chapter 6 describes ecosystem services concepts and the reference list of ecosystem services. Chapter 7 discusses the ecosystem services flow account in physical terms.

2.43 **Ecosystem services flow accounts – monetary terms.** Commonly, estimates of ecosystem services in monetary terms are based on estimating prices for individual ecosystem services and multiplying through by the physical quantities recorded in the ecosystem services flow account in physical terms. Conceptual and measurement issues on the pricing and monetary valuation of ecosystem services is discussed in Chapters 8 and 9.

2.44 **Ecosystem monetary asset accounts**. Asset accounts are designed to record information on stocks and changes in stocks (additions and reductions) of assets. The ecosystem monetary asset account records this information in monetary terms for ecosystem assets based on the monetary valuation of ecosystem services and applying the net present value approach to obtain opening and closing values in monetary terms for ecosystem assets at the beginning and end of each accounting period. The measurement of changes in asset values due to, for example, ecosystem enhancement, ecosystem degradation and ecosystem conversion are also included in this account. These issues are described in Chapter 10.

2.45 To demonstrate the links between these accounts in a stylised way, Figure 2.3 shows how information on selected ecosystem types (e.g., forests, agricultural land, wetlands, marine ecosystems and urban areas) may be considered in each of the ecosystem accounts. Ultimately, the essence of ecosystem accounting lies in telling a comprehensive story about each ecosystem type in a manner that is coherent with other ecosystem types and that is able to be connected to measures of economic and human activity.

Figure 2.3: Stylised integration of ecosystem accounts for selected ecosystem types



Source: own elaboration.

2.3.2 Related accounts

2.46 The ecosystem accounts provide an integrated and relatively comprehensive view of ecosystems in both physical and monetary terms. Nonetheless, for both compilation and analytical purposes, there are number of additional, related accounts that may be appropriate for monitoring and analysis in different circumstances. Related accounts are grouped broadly into four types: (i) extended economic accounts; (ii) combined presentations; (iii) complementary monetary accounts; (iv) thematic accounts; and (v) individual stock and flow accounts.

2.47 **Extended economic accounts** emerge from the application of national accounting principles. This allows data from the ecosystem accounts to extend the standard economic accounts of the SNA that encompass the measurement of economic production; and institutional sector accounts which record the generation of income, capital formation and wealth. Thus, extended supply and use tables, extended balance sheets and extended sequence of institutional sector accounts can all be compiled, including associated aggregate measures of income and wealth adjusted for the enhancement and degradation of ecosystem assets. These accounts are described in Chapter 11.

2.48 **Complementary valuations**. In serving as the basis for the integration of ecosystem data with the accounts of the SNA, the ecosystem accounting framework incorporates a range of measurement choices, particularly as regards the scope of ecosystem services, the use of the exchange value concept for monetary valuation and the attribution of degradation to the economic unit who suffers from the loss of ecosystem condition. It is possible to design complementary valuations and monetary accounts by using different valuation concepts and assumptions (e.g., concerning institutional arrangements) to support different policy and analytical purposes, or. Possible complementary valuations and monetary accounts are discussed in Chapter 12.

2.49 **Thematic accounts** are accounts, that organise data on themes of specific policy relevance. Examples of relevant themes include biodiversity, climate change, oceans and urban areas. In all of these cases, some data can be obtained from the ecosystem accounts but relevant data can also be sourced from SEEA Central Framework and SNA accounts, for example concerning greenhouse gas emissions and resource management expenditure. For biodiversity and climate change additional accounts are also relevant, namely species accounts and carbon accounts. The principles and design of thematic accounts are described introduced in chapter 13.

2.50 **Combined presentations and indicators** are a means of collating and tabulating data on a selected set of variables from the ecosystem accounts and elsewhere to allow users to quickly see relationships of analytical significance. Often within a standard accounts structure there are only a relatively limited set of key measures and these presentations provide a means to highlight relevant data, particularly for the derivation of indicators. Indicators can be design and selected in many ways and accounting frameworks provide a strong base for their derivation and coherence. These topics are discussed in Chapter 14.

2.4 Framing of values in ecosystem accounting

2.4.1 Introduction

2.51 The SEEA EA's integration of both physical and monetary data allows it to provide data that is relevant in supporting assessments based on a number of different value perspectives. Nonetheless, it is recognized that the concepts and methods of ecosystem accounting cannot encompass all value perspectives concerning ecosystems and hence the data from ecosystem accounts should not be considered to provide a holistic, complete or "true" value of nature; or reflect all of the multiple value perspectives on ecosystems.

2.52 The concepts and methods applied in SEEA EA reflect specific, well defined, objectives in considering the values related to ecosystems and ecosystem services. The primary objective is considering ecosystems and ecosystem services in the context of economic measures of production, consumption and accumulation. This framing will thus primarily inform economic policy and decision making. While this objective is commonly interpreted as implying the need for valuation in monetary terms, the SEEA EA aims to demonstrate how physical data, for example on ecosystem extent and condition, can also be integrated in economic policy and decision making. Beyond this primary objective, data from the accounts will be relevant in a range of other contexts such as sustainability and environmental reporting and spatial planning, particularly where in concerns the integration of environmental and economic considerations.

2.53 This section does not aim to provide a definitive summary of the literature or to establish a SEEA EA values perspective. Rather, this section places the value perspective of ecosystem accounting in a broader values context to support an understanding of the different ways in which ecosystems can be valued and hence support appropriate interpretation and application of ecosystem accounting data.

2.4.2 Summary of multiple value perspectives about nature

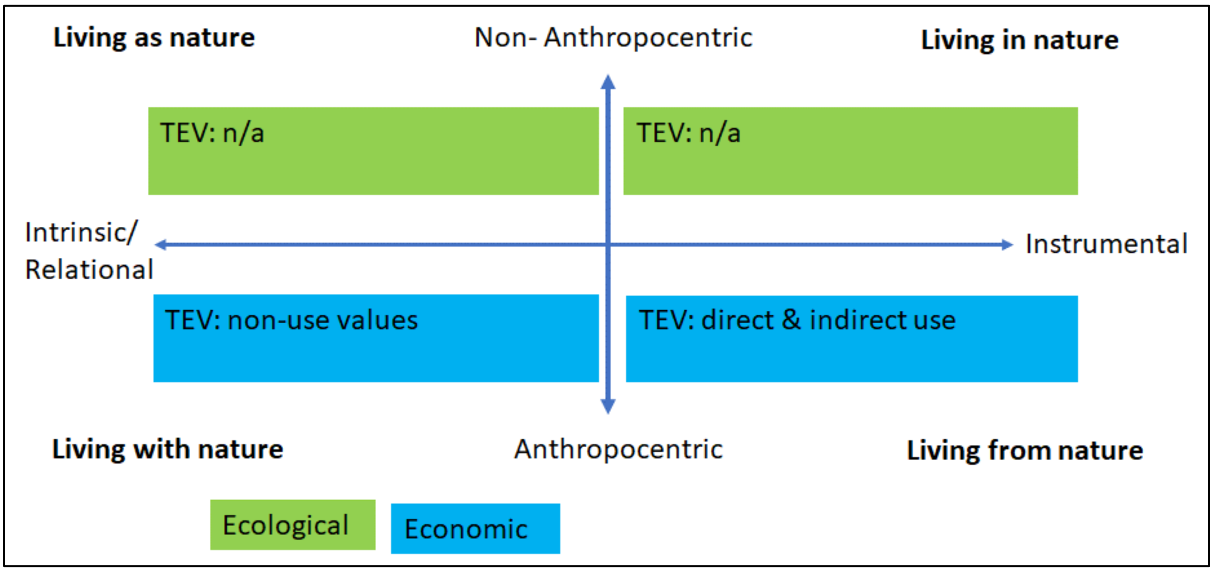
2.54 Section 2.2 described five measurement perspectives with respect to ecosystems. In a similar way there are multiple perspectives on the value of ecosystems recognizing that each one retains a focus on the same, extant, ecosystem. The purpose of value frameworks is to place the various perspectives in a common context and hence allow different analysts and decision makers to see how their views may align or differ from others.

2.55 Two particular continuums are commonly used to reflect value perspectives: (i) the continuum from anthropocentric to non-anthropocentric values; and (ii) the continuum from instrumental to intrinsic and relational values. Using this framing a number of different value frameworks can be placed in context. These are shown in Figure 2.4 and reflect and integration of contributions from Turner et al. (2003), the Total Economic Value (TEV) framework (e.g., Pearce (1992); TEEB (2010)), the IPBES values framework (Díaz et al., 2015; Pascual et al., 2017) and the life framework of values (O'Connor & Kenter, 2019; O'Neill et al., 2008).

2.56 To support the discussion here the following definitions from Pascual et al. (2017) are noted:

- *Anthropocentric values* are those that are centred on human beings
- *Instrumental value* is the value attributed to something as a means to achieve a particular end.
- *Intrinsic value* refers to inherent value, that is the value that something has independent of any human experience or evaluation. Such a value is viewed as an inherent property of the entity (e.g., an organism) and not ascribed or generated by external valuing agents (such as human beings).
- *Relational values* are values relative to the meaningfulness of relationships, including the relationships between individuals or societies and other animals and aspects of the life world, as well as those among individuals articulated by formal and informal institutions.

Figure 2.4: A combination of value frameworks



Note: TEV – Total Economic Value framework.

Source: own elaboration.

2.57 Although presented along continuums, these values are not in some manner additive; i.e., it should not be concluded that by recognizing all types of value an aggregate value of nature could be obtained. Rather, it is more appropriate to consider that, for a given ecosystem, each value perspective will provide a different value – i.e., there are multiple, potentially incommensurate, values to be compared and contrasted in decision making.

2.58 A challenge in applying any values framework, especially in a measurement context, is that there is no clear demarcation between values. Value concepts are overlapping, as well as nested. Definition of policy objectives, specific decision choices ex ante and change contexts ex post help identify which values are involved and determine their scope and boundaries. While this somewhat open and potentially fluid framing is necessary for recognizing all value perspectives, a consequence may be the challenges implied for implementation of multiple value perspectives in a wider institutional context.

2.59 In this respect a standardized, albeit incomplete, statistical framing of the value of ecosystems may be able to play an important role in recognizing at least some of their value as a regular component of decision making. Indeed, an advantage of standardization of ecosystem accounting value concepts is that there is an agreed measurement definition which is stable over time, and so can be used as a common baseline for operational policy design that extends over several policy cycles.

2.4.3 Linking the ecosystem accounts and multiple value perspectives

2.60 In broad terms, the commonly understood focus of the SEEA EA is on values of anthropocentric origin – i.e., values that are cantered on human beings. Further, measurement focus is commonly on instrumental or use values, in part because these interactions are most readily quantified and also because, from a monetary valuation perspective, these values are most readily reflected in monetary terms. From a policy perspective, the focus on anthropocentric, instrumental values may also be considered of high relevance since it is in this quadrant that the sources of pressure on ecosystems are most evident. Thus, a more sustainable approach to living “from” nature may be considered to be well correlated with satisfying other value perspectives.

2.61 Ecosystem accounting data in monetary terms is valued using the concept of exchange values wherein ecosystem services and ecosystem assets are valued at the prices they are or would be exchanged on a market. Thus, measures of consumer surplus are excluded. This approach to monetary valuation is chosen to support integration with the monetary values recorded in the SNA. The use of SNA-derived measurement principles and concepts facilitates the mainstreaming of ecosystem information in standard measures of income, production and wealth and to supporting the use of economic data in environmental decision making. Chapter 8 describes the exchange value concept in more detail and Annex 12.1 explains the relationship between exchange values and other economic valuation concepts and approaches.

2.62 The monetary values in ecosystem accounting are limited in scope to the range of ecosystem services that are included in a given ecosystem account. Aside from a focus on instrumental values, the use of exchange values reflecting an ecosystem contribution does not provide a broader monetary value of direct and indirect benefits received from using and enjoying ecosystem services. In this respect, monetary data from the ecosystem accounts, in line with the valuation basis used in the SNA, do not provide a comprehensive monetary value of well-being. Complementary approaches to monetary valuation are discussed in Chapter 12.

2.63 It is common for the discussion of values and valuation in accounting to assume a singular focus on economic values expressed in monetary terms. However, it is evident from consideration of the wider literature that since ecosystem accounting encompasses data in both physical and monetary terms, which is also locally spatially explicit, there is the potential for ecosystem accounting data to support discussion of a wider range of value perspectives. This includes supporting discussion of perspectives on the economic value of nature that are not based on framing the environment as a supplier of benefits for human use.

2.64 Specifically, it is noted that physical data on ecosystem extent and condition will support discussion of a number of aspects of the intrinsic and non-anthropocentric perspectives on the value of nature. Further, data on flows of ecosystem services in physical terms will support discussion of instrumental values and some aspects of relational values. Finally, data from related accounts such as species accounts, carbon stock accounts and water resources accounts will also support these discussions.

2.65 Lastly, the assessment of multiple values often requires consideration of local contexts and a wider variety of users. Generally, ecosystem accounts are described for relatively large areas with multiple ecosystem types and for broad categories of users, e.g., households, businesses and governments. However, in principle the compilation of accounts can be undertaken at smaller scales (with finer resolution for local administrative areas) and/or for particular social groups. For example, measurement may focus on the use of specific ecosystem services which may be elaborated in greater detail concerning contributions to municipal provision of utilities, or uses of ecosystem services by households of different income levels. The potential to undertake such measurement will necessarily be subject to the availability of data.

2.66 Overall, the data from a set of ecosystem accounts in physical and monetary terms will be relevant in supporting assessments based on a number of different value perspectives.

2.5 General national accounting principles

2.5.1 Introduction

2.67 Recording entries in the ecosystem accounts follows the general principles of national accounting as described in the 2008 SNA, Chapter 3. A summary of some of the aspects of most relevance to the SEEA EA is provided in the SEEA Central Framework Chapter 2. These aspects concern: double and quadruple entry accounting, the time of recording, units of measurement, and valuation rules and principles.

2.68 This section describes the accounting principles that require particular consideration in the context of ecosystem accounting. The discussion of valuation principles is not described here but Chapters 8 and 9 provide more detail on the range of non-market valuation considerations that arise in ecosystem accounting.

2.5.2 Length of the accounting period

2.69 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 of time satisfies many analytical requirements, although often, quarterly accounts are also compiled.

2.70 While one year may be suited to analysis of economic trends, analysis of trends in ecosystems may require information for 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 beginning and end of year that is used for economic analysis.[18]

2.71 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 the general integration of information is thus best supported through the use of this time frame.

2.72 Consequently, for the purposes of ecosystem accounting, it may be necessary to convert or adjust available environmental information so as to align it to a common annual basis using appropriate factors or assumptions (for example, by applying interpolation or extrapolation techniques), while recognizing that data may be collected irregularly over time intervals longer than one year.

2.5.3 Time of recording

2.73 The general national accounting requirement is that transactions and other flows must be recorded as occurring at the same point in time in the various accounts for both units involved. In respect of ecosystem services, this implies that the supply of ecosystem services must be recorded in the same accounting period as the use of those services. It is noted that the timing of the transaction may be different from when an ultimate benefit is received. For example, the benefits of carbon sequestration will occur well after the sequestration itself takes place. In this regard it is relevant to recall that the focus of ecosystem accounting is recording the supply and use of ecosystem services rather than the well-being or outcomes that eventuate.

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

2.5.4 Units of measurement

2.75 In the measurement of stocks, the entries will relate to a unit of measure at a point in time, e.g., total area, total volume. In the measurement of flows, the entries will relate to a unit of measure per unit of time, e.g., cubic metres per year. The unit of time that is appropriate will depend on the selected length of the accounting period.

2.76 For accounts compiled in monetary terms, all entries in the accounts must be measured in terms of money, i.e., currency units.

2.77 For accounts compiled in physical terms, the units of measurement will vary and will depend on the account and the relevant variable. In ecosystem extent accounts a common unit of area, such as hectares, is recommended to allow for the relative size and composition of ecosystem types within an ecosystem accounting area to be assessed. Using a common unit of area also ensures that accounting balances and aggregations can be applied for this account.

[18] For example, hydrologic years may not align with calendar or financial years (see Unesco. & Organization. (1992)).

2.78 In ecosystem condition accounts, each characteristic and associated variable is likely to involve use of different measurement units. This implies that there is no natural aggregation across characteristics without the use of appropriate weighting or aggregation approaches.

2.79 In ecosystem services supply and use accounts in physical terms, it will be the case that different ecosystem services are recorded in different measurement units. Given the structure of supply and use accounts it is possible to aggregate across columns for a single service to provide an estimate of total supply or total use of that service. However, it is not possible to aggregate across different ecosystem services, i.e., over rows, to provide total supply or use of ecosystem services for an ecosystem type or type of economic unit.

2.80 In measuring supply and use, it is fundamental that the same measurement unit be applied for both supply and use of a single ecosystem service in physical terms. Thus, if the supply of a service is measured in tonnes per year, then the use of that service must also be measured in tonnes per year. This allows balancing of supply and use and related reconciliation.

2.5.5 Gross and net recording

2.81 The terms "gross" and "net" are used in a number of accounting situations. In the SNA, the term "net" is used in some situations to indicate whether an accounting aggregate has been adjusted for consumption of fixed capital (depreciation). In other situations, the term is used simply to refer to the difference between two accounting items, e.g., net lending which is the difference between a sector's transactions in financial assets and the incurrence of liabilities.

2.82 In the measurement of ecosystem services, the term "net" is often used to indicate that the estimates do not incorporate any double-counting which may arise owing to overlaps between areas, overlaps in the use of different methods, or overlaps due to the failure to record clearly the differences between products in the SNA production boundary, final ecosystem services and underlying ecosystem processes.

2.83 In ecosystem accounting, the recording of ecosystem services is undertaken such that all flows between ecosystem assets and economic units are explicitly identified, i.e., the recording is in gross terms. Thus, for example, final ecosystem services are recorded as the output of ecosystem assets and inputs to economic units. A subsequent output of SNA products may be recorded for the economic unit and hence the net position for that unit will be the difference between the output of the SNA product and the input of the final ecosystem service. No double counting is implied in this treatment and it applies to accounting in both physical and monetary terms. These recording principles are elaborated in Chapter 7.

2.84 In the monetary valuation of ecosystem services, it is common to express the relevant values being in "net" terms when the costs of supplying the ecosystem service are deducted. Deducting these costs, as appropriate for the valuation technique being applied, is required to ensure that the monetary valuation is focused on the contribution of the ecosystem. Further discussion on these issues of valuation are in Chapter 9.

2.5.6 Scale of application

2.85 The ecosystem accounting framework and associated accounts have been designed with the intent of being applied at national (or large sub-national) scale, i.e., in the context of multiple ecosystem assets (i.e., across the variety of ecosystem types within an ecosystem accounting area) and for multiple ecosystem services. This is analogous to the general application of the national accounts, which covers the activities of all industries resident within an economic territory.

2.86 It is recognized, however, that the application of the ecosystem accounting framework may also have a more tailored focus. For example, the framework may be applied for measurement of:

- A single ecosystem asset or ecosystem type (e.g., a forest or forests) and/or a single ecosystem service (e.g., water regulation). For individual provisioning services, there may be a direct connection to natural resource accounting, as described in Chapter V of the SEEA Central Framework.
- A single ecosystem asset or ecosystem type and multiple ecosystem services. Accounting at this scale may be of interest in the management of specific ecosystems or ecosystem types (e.g., wetlands)
- Multiple ecosystem types and single ecosystem services. Accounting of this type may be of interest for monitoring and understanding the dynamics of the supply of a specific service across a broad spatial area (e.g., water regulation, carbon sequestration)
- Areas of land within a country that have common land-use or land management arrangements in place (e.g., national parks, protected areas)

2.87 The logic of the ecosystem accounting framework described above can be applied in all of these "reduced" or tailored cases, since the accounting principles themselves are scale independent. Moreover, to the extent that individual projects focus on these more tailored accounts, it should be possible to integrate the findings within a broader project covering multiple ecosystem assets and services. The potential for integration is heavily dependent on the adoption of consistent measurement boundaries and classifications, which would then become a prime motivation for application of a common ecosystem accounting framework.

2.5.7 Data quality and scientific accreditation

2.88 The concept of data quality for official statistics is a broad-ranging one, encompassing factors of relevance, timeliness, accuracy, coherence, interpretability, accessibility and the quality of the institutional environment in which the data are compiled. The development of frameworks, such as the ecosystem accounting framework presented here, is designed to assist in the advancement of quality, particularly in the areas of relevance, coherence and interpretability.

2.89 Commonly, data quality is associated with accuracy but this in fact is only one aspect that needs to be considered. Given the measurement challenges faced in advancing ecosystem accounting, it is important that all factors contributing to data quality be brought forward for consideration.

2.90 In ecosystem accounting, it is likely that a reasonable proportion of the information used will be drawn from disparate data sources, possibly developed primarily to provide information for administrative purposes rather than information for statistical purposes. Administrative data sets are often produced and analysed with a focus on smaller or borderline cases rather than on those cases that may be the most statistically significant. Some ecological data are similarly treated. For example, data on the quality of water may be collected for areas where there is a known pollution problem rather than to provide broad coverage and a representative sample of water quality. Care must therefore be taken to ensure that, as far as possible, the data used is representative of the various local contexts.

2.91 It is also likely that information for ecosystem accounting will be drawn from various independent studies in the biophysical sciences and economics literature. This being the case, appropriate review and validation of the data will be required, for example considering the measurement concepts and scopes that have been applied, to ensure that it is suitable for the purposes of ecosystem accounting and that coherence across the accounts can be obtained.

2.92 Compilers are encouraged to work at national and international levels to develop relevant accreditation processes for scientific and other information relevant for ecosystem accounting. In this context, it is noted that general statistical quality frameworks, such as the United Nations National Data Quality Assurance Framework, are applicable to biophysical data as well as socioeconomic data. These frameworks are tools designed to assure that data are collected and compiled according to international standards and are subject to appropriate quality assessment procedures.

2.6 Introduction to stylised example

2.93 <<To be developed after the Global Consultation and prior to the finalization of the publication for the final submission to the UN Statistical Commission. It is intended to incorporate in the final SEEA EA a single, coherent stylised example to illustrate the entries in the various accounts and to show the linkages between the accounts.>>

SECTION B: Accounting for ecosystem extent and condition

3 Spatial units for ecosystem accounting

3.1 Introduction

3.1 A key feature of ecosystem accounting is its ability to integrate spatially referenced data about ecosystems, i.e., data about the location, size and condition of ecosystems within a given area and how these are changing over time. Recording these stocks and changes in stocks in a coherent and mutually exclusive manner, supports the derivation of indicators (for example, the rate of change in forest areas relative to the rate of change in agricultural areas).

3.2 For accounting purposes, different ecosystems are treated as spatial units. The delineation of ecosystems into spatial units requires careful consideration of various ecosystem characteristics across the various ecological realms, including terrestrial, freshwater and marine ecosystems. The present chapter outlines the approach used in the SEEA EA to define, classify and delineate spatial units. Section 3.2 describes the different types of spatial units used in ecosystem accounting while Sections 3.3 and 3.4 present the general principles and considerations for the delineation and classification of spatial units for ecosystem accounting purposes.

3.3 The availability of spatial data to describe ecosystems and their economic uses and associated beneficiaries is an important consideration in the compilation of ecosystem accounts. The spatial and thematic detail of these data, as well as their geospatial comparability and integration into a shared spatial data infrastructure, influences the richness of ecosystem accounts that can be compiled. This issue is discussed in section 3.5.

3.4 Data on the size and changes in size of ecosystems are recorded in ecosystem extent accounts, and their location and configuration can be presented in maps. Understanding the size and location of ecosystems supports the measurement of ecosystem condition and the measurement and valuation of many ecosystem services, the flows of which will vary from ecosystem to ecosystem. These matters are discussed in later chapters.

3.2 Types of spatial units

3.2.1 Ecosystem assets

3.5 The primary spatial units for ecosystem accounting are labelled ecosystem assets. Ecosystem assets (EAs) are contiguous spaces of a specific ecosystem type (ET) characterized by a distinct set of biotic and abiotic components and their interactions. The definition of ecosystem assets is a statistical representation of the general definition of ecosystems from the CBD.[19]

3.6 Ecosystem assets play a key role in ecosystem accounting. They are the statistical units for ecosystem accounting, i.e., the ecological entities about which information is sought and about which statistics are ultimately compiled. This includes information concerning their extent, condition, the ecosystem services they provide and their monetary value. Each ecosystem asset is classified to an ***ecosystem type (ET) which reflects a distinct set of abiotic and biotic components and their interactions***. Components include, for example, the animals,

[19] See CBD definition of ecosystems in Chapter 2, para. 2.6.

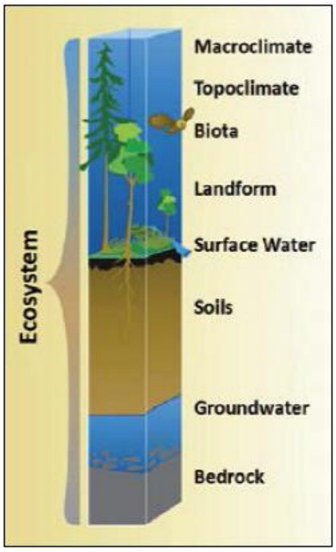
plants, fungi, water, soil, minerals present in ecosystems. Annex 3.1 provides an introduction to a range of ecological concepts and terms.

3.7 The statistical outputs from ecosystem accounting are most commonly presented either in tabular form where data on ecosystem assets are grouped according to their ecosystem type; or in the form of maps where individual ecosystem assets can be identified and the configuration and location of different ecosystem types can be displayed.

3.8 Ecosystem assets are encompassed by the definition of environmental assets in the SEEA Central Framework, where environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity (SEEA Central Framework, 2.17). As for environmental assets, ecosystem assets are considered assets on the basis of their biophysical existence and are not dependent on establishing flows of benefits or ownership as is required for economic assets in the SNA.[20]

3.9 Conceptually, ecosystem assets are envisaged as three-dimensional spaces (see Figure 3.1 and Figure 3.2). While most ecosystems in the ecological realms – i.e., terrestrial, freshwater, subterranean and marine ecosystems - are all located close to the Earth's surface, they all have three dimensional characteristics. For example, for terrestrial systems, the biotic components usually extend from the soil life and plant roots below the surface to the vegetation growing above the surface. The abiotic components are those components that directly interact with these living components: the soil, the surface and soil water, and also the air from the atmosphere.

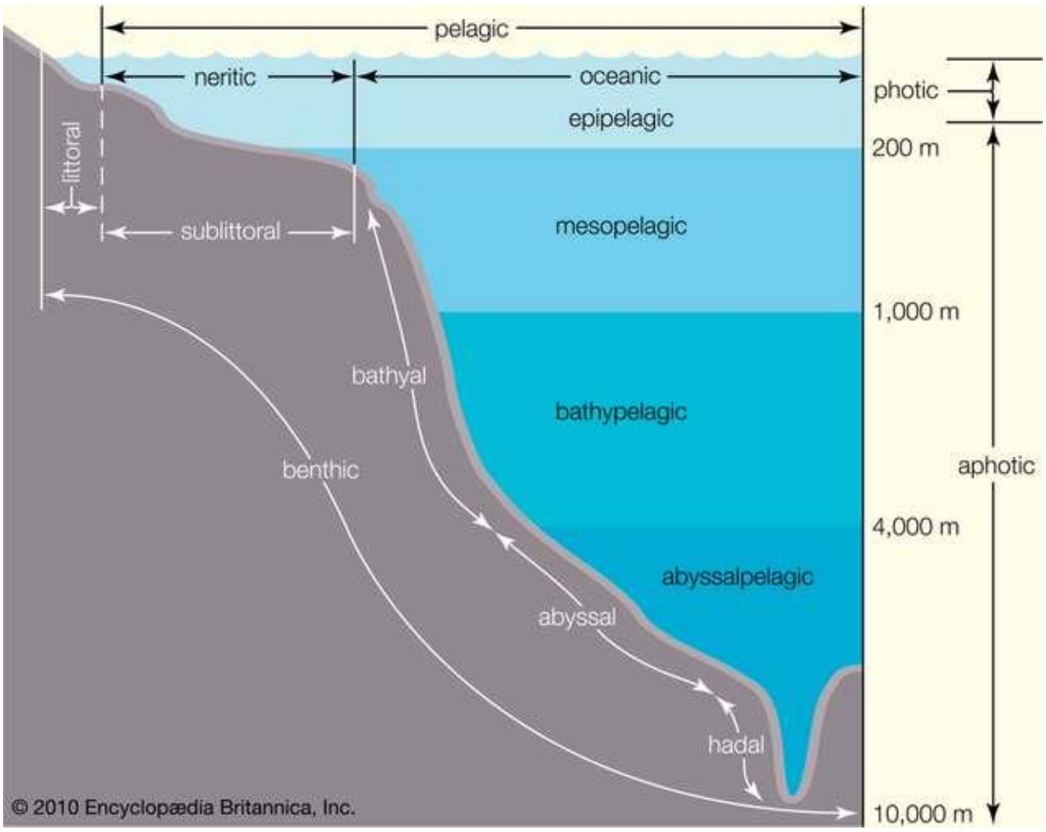
Figure 3.1: Vertical structure of a terrestrial ecosystem (indicative figure only)



Source: Bailey et al. (1996).

[20] As discussed in Chapter 11, establishing the economic ownership of ecosystem assets and attributing benefits is required for the integration of ecosystem accounting data with economic accounts.

Figure 3.2: Vertical structure of marine ecosystems (indicative figure only)



Source: Kingsford (2018).

3.10 Marine ecosystems. Marine ecosystems are not concentrated near one surface (i.e., the air-land/water interface) but extend throughout the water column and the underlying sediment (see Figure 3.2). In concept, ecosystem assets for marine ecosystems could be delineated based on both area and depth, i.e., taking account of ecological differences within the water column.

3.11 The conceptual approach for marine ecosystems in the SEEA EA is:

- For marine ecosystems within the continental shelf,[21] delineate ecosystem assets based on the areas of different ecosystem types associated with the sea bed – e.g., seagrass meadows, subtidal sandy bottoms and coral reefs.
- For marine ecosystems beyond the continental shelf, adopt vertically stratified spatial units, i.e., the ecosystem assets are delineated with respect to both location and depth within the water column. Here the sea floor is distinguished from the overlying water column.

3.12 For marine ecosystems beyond the continental shelf, it may be difficult to delineate ecosystem assets in a vertically stratified manner. Consequently, delineation based on surface area is likely the most practical measurement pathway for accounting purposes.

[21] The continental shelf is that part of the continental margin which is between the shoreline and the shelf break or, where there is no noticeable slope, between the shoreline and the point where the depth of the superadjacent water is approximately between 100 and 200 metres.

3.13 Atmospheric boundary. Several important ecological processes are based on the interaction with the atmosphere, including respiration, nitrogen fixation, and those associated with the impact of air pollution on vegetation and fauna such as air filtration. To establish a clear boundary for accounting, the atmosphere directly above and within an ecosystem is considered part of the ecosystem asset as one of the abiotic components within the spatial unit.

3.14 The interaction between the Earth's surface and its ecology, and the atmosphere is limited to the atmospheric boundary layer. For accounting purposes, this forms the natural upper boundary of ecosystem assets. The atmospheric boundary layer is defined as the bottom layer of the troposphere that is in contact with the surface of the earth (American Meteorological Society, 2020). Parts of the atmosphere above this layer are not considered ecosystem assets, but may be considered as a separate environmental asset, the atmosphere, when relevant for the organization and treatment of certain environmental data, for example, data on air quality.

3.15 Subsoil boundary. The subsoil that is directly involved with ecosystem processes is considered part of the ecosystem asset. This holds for terrestrial (soil), freshwater and marine ecosystems (sediments). These ecosystem processes include water flows between soil layers and aquifers, bioturbation, carbon cycling, the cycling of nutrients, other diagenetic processes etc. The precise sub-soil boundary layer for an ecosystem asset will be dependent on the structure of the soil, sediment and bedrock.

3.16 Aquifers. All aquifers, both confined and unconfined, will contain some biotic components and are treated as ecosystems. Confined aquifers should be treated as distinct ecosystem assets from the ecosystem assets located above them. Unconfined aquifers may be treated distinctly or integrated with the surface ecosystem asset depending on the context.

3.17 Subterranean ecosystems. There are a variety of subterranean ecosystems including caves and underground streams. These ecosystems satisfy the general conceptual definition of ecosystem assets having a distinct set of biotic and abiotic components.

3.18 Subsoil abiotic resources. Resources located in the deeper substrate within the lithosphere, such as natural gas, oil and coal, and mineral ores, that are in no direct interaction the surrounding ecosystems, are not considered ecosystem assets, but are included in the broader definition of environmental assets.

3.2.2 Applying the conceptual boundary for ecosystem assets

3.19 Although ecosystem assets are conceptually three-dimensional (3D), they have a two-dimensional (2D) footprint. This footprint is defined by the intersection of the 3D bounding envelope of the ecosystem asset with earth's surface. The sides of this envelope are assumed to be vertical, such that the resulting footprints of adjacent ecosystem assets do not overlap. In practice therefore, for accounting purposes, ecosystem assets are represented in two dimensions by their area.

3.20 For those ecosystem assets that are located below surface level terrestrial and freshwater ecosystems such as subterranean ecosystems and aquifers, it is also possible to define their footprint in 2D terms. However, since these areas will co-exist with the areas of other ecosystem assets closer to the Earth's surface, their extent should be accounted for separately depending on analytical requirements.

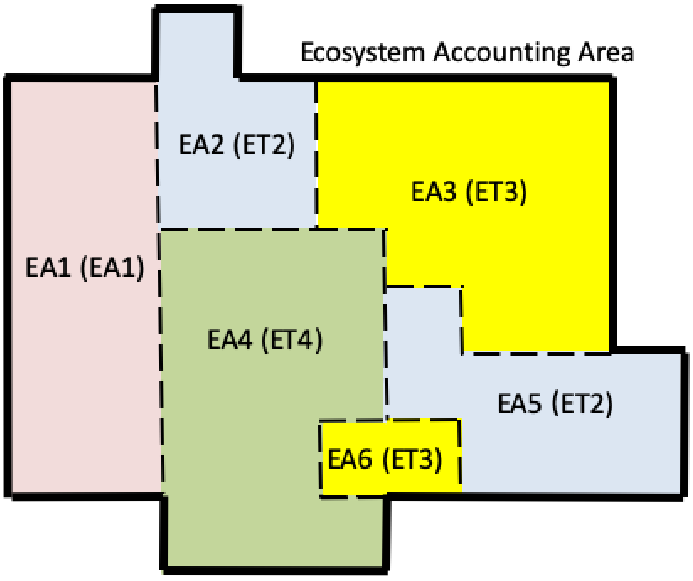
3.2.3 Ecosystem accounting areas

3.21 The second type of spatial unit for ecosystem accounts are ecosystem accounting areas. The ***ecosystem accounting area (EAA) is the geographical territory for which an ecosystem account is compiled.*** The EAA therefore determines which ecosystem assets are included in an ecosystem account.

3.22 An EAA is a two-dimensional construct providing an accounting boundary around a set of ecosystem assets represented by their two-dimensional footprints, such that the sum of the areas of the ecosystem assets is equal to the total area delineated by the EAA.

3.23 The relationships between the spatial units are presented in mapped form in Figure 3.3 where the combination of different ecosystem assets of various ecosystem types within an EAA is shown for a stylised context. The same relationships can also be presented in tabular form where, at a given point in time, the sum of the areas of different ET will be equal to the total EAA. This is shown in Table 3.1, which provides the basic entry point to accounting for ecosystem extent which is discussed in Chapter 4.

Figure 3.3: Relationships between spatial units in ecosystem accounting



Note: Ecosystem assets (EA) represent individual, contiguous ecosystems.

Source: adapted from SEEA 2012 EEA, figure 2.4 (United Nations et al., 2014b).

Table 3.1: Tabular presentation of spatial units

Spatial unit	**Size***
Ecosystem type #1 (EA1)	12
Ecosystem type #2 (EA2 & EA5)	13
Ecosystem type #3 (EA3 & EA6)	15
Ecosystem type #4 (EA4)	14
Ecosystem Accounting Area (EAA)	**54**

Note: * Any measurement unit for area may be used, including for example hectares and square kilometres

3.24 Common forms of EAA are:

i. National jurisdictions / groups of countries (e.g., countries of the European Union);

ii. Subnational administrative areas (e.g., state, province);

iii. Environmentally defined areas within a country (e.g., water catchments, ecoregions) or across countries (e.g., regions defined by river systems such as the Amazon, the Mekong and the Nile);

iv. Other areas of policy or analytical interest such as protected areas; areas owned by specific industries or sectors, e.g., government-owned land; or areas outside national jurisdiction, e.g., open oceans and high seas.[22]

3.25 Consistent with the scope in the SEEA Central Framework, the scope of national jurisdictions for ecosystem accounting should include all relevant ecological realms, i.e., terrestrial, freshwater and marine ecosystems, to the boundary of the Exclusive Economic Zone (EEZ). In practice, the initial scope may be more limited, for example covering only terrestrial and freshwater ecosystems; but it is important to aim to extend the coverage to incorporate all ecosystems under national jurisdiction.

3.26 Generally, the measurement objective of the SEEA EA is to provide information about the changes in ecosystem-related stocks and flows in relatively large and diverse areas encompassing different ecosystem types, as suggested by the examples of EAA above. Conceptually, it is possible to compile ecosystem accounts for an individual ecosystem asset such as a single forest, wetland or agricultural area but this is not the focus of the SEEA EA.

3.27 Usually, an EAA will reflect contiguous areas but this is not a requirement for accounting purposes. For example, accounts may be developed for all protected areas within a country or for a specific ecosystem type (e.g., for all natural grasslands in a country).

3.28 Within an EAA, multiple ecosystem assets will be grouped into different ecosystem types, e.g., forests, wetlands and agricultural land. The resulting accounting structures will generally be such that measures of ecosystem extent, ecosystem condition and ecosystem services will be presented for aggregations of ecosystem assets, i.e., by ecosystem types. For example, for a given EAA, an ecosystem extent account would show the changing total area of each ecosystem type (e.g., forest, wetland or agricultural land) but not the changing area of each individual ecosystem asset. The same underlying data may be mapped to show the configuration and distribution of individual ecosystem assets within an EAA. Approaches to accounting for ecosystem extent are discussed in Chapter 4.

3.29 Since an EAA is a two-dimensional construct, the area of subterranean ecosystems cannot easily be incorporated alongside those ecosystem assets closer to the earth's surface. Therefore, for the purposes of accounting for ecosystem extent and aligning the area of the EAA and ecosystem assets, the area of subterranean ecosystems should be excluded.

3.30 Complementary accounts for marine ecosystems beyond the continental shelf that encompass the full range of relevant ecosystem assets, including those associated with pelagic ocean waters and deep-sea floors can be compiled. Similarly, complementary accounts for subterranean ecosystems can be compiled for ecosystem extent. Where data can be compiled on the condition of these ecosystem types and the supply and use of ecosystem services, this information can be incorporated alongside similar data for other ecosystem types, at least in tabular form.

[22] These areas may be the focus of regional or international accounting work.

3.3 Delineating ecosystem assets

3.3.1 General principles

3.31 In concept, an ecosystem asset is differentiated from neighbouring ecosystem assets by the extent to which the interactions between biotic and abiotic components within the ecosystem asset are stronger than the interactions with components outside of the ecosystem asset. The differences will be reflected in variations in function, structure and composition. Hence, ecosystem assets should be delineated based on various ecosystem characteristics such as physical structure and type (including vegetation structure and type), species composition, ecological processes, climate, hydrology, soil characteristics, topography and depth.

3.32 It is expected that there will be a general persistence of the characteristics of an ecosystem asset over time while allowing for a reasonable degree of natural variation. For example, the loss of vegetation as a result of disturbances such as fire and flood, will not necessarily imply a change in the ecosystem type. It is also expected that in the delineation of an ecosystem asset the condition of that asset will be relatively homogenous following the approach to the measurement of ecosystem condition described in Chapter 5.

3.33 In delineating ecosystem assets for the purpose of ecosystem accounting, the following principles should apply.

i. *Ecosystem assets should represent ecosystems.* The spatial units should align with the definition of ecosystems following the CBD in which there is consideration of organisms, their environmental setting and ecosystem processes. It is accepted that the delineations cannot be perfect representations of the complex ecological reality.

ii. *Ecosystem assets should be capable of being mapped.* Ecosystem accounting is commonly implemented using a spatially-based approach, in which case it is necessary that ecosystem assets can be mapped and identified in a specific location.

iii. *Ecosystem assets should be geographically and conceptually exhaustive, and comprehensive across ecological realms.* The 'exhaustive' criterion is understood as reflecting comprehensiveness, both spatially and conceptually, including built environments. The set of ecosystem assets should allow for an EAA to be fully tessellated, i.e., filled.

iv. *Ecosystem assets should be mutually exclusive, both conceptually and geographically.* Thus, EAs should not overlap, either conceptually or geographically, and any area on the land or the sea floor, or any horizontal depth layer in the ocean, should be occupied by one and only one ecosystem type. As long as the ecosystem assets are mutually exclusive, there can be no "double-counting" of the same space.

3.34 The occurrence and extent of ecosystem assets delineated using these principles can change over time. Indeed, the expectation is that over time, through the use of consistent principles and classifications, different boundaries would be delineated to reflect the changing sizes and configuration of ecosystem assets (e.g., due to deforestation). Recording these changes, labelled in SEEA EA as ecosystem conversions, is the focus of accounting for ecosystem extent described in Chapter 4.

3.35 Where the boundary of an EAA, e.g., a country's national border, passes through a delineated ecosystem asset, only the area of the ecosystem asset inside the EAA boundary should be included in the account. While this effectively partitions the ecosystem asset, it ensures that the area of all ecosystem assets is equal to the total EAA area.

3.36 An EAA will contain a range of ecosystem types. In broad terms, a gradient exists from pristine natural areas to intensively managed ecosystems, including production plantation forests;

croplands and meadows, and built environments. While natural and semi-natural areas are mainly governed by natural ecological processes, the intensively managed areas will primarily be defined by land use maintained by human activity. However, since all of these types of areas may be within an EAA, all of these ecosystem types should be accounted for.

3.3.2 Principles for the delineation of small ecosystems and features

3.37 The composition of ecosystem types within an EAA will rarely be reflected in neat boundaries between easily identified areas of, for example, forests, wetlands and agricultural areas. In reality there will be a mixture of different features and ecosystem types throughout an EAA. In this context, two specific factors will influence the delineation in practice. The first factor concerns the number of different ecosystem types for which delineation is undertaken (the thematic resolution). Thus, the greater the number of ecosystem types to be delineated the more challenging the task but, at the same time, the greater the richness of the picture that will be able to be drawn and the more homogenous the units.

3.38 The second factor concerns the spatial scale at which delineation is undertaken. Thus, where delineation is undertaken at a large scale, for example for 5km grid cells, it will be less likely that specific ecosystem types, such as small wetlands, will be identified at all. On the other hand, where delineation is undertaken at very fine scales, for example for 30m grid cells, many distinct ecosystem types may be identified.

3.39 In practice a balance must be found between the scale at which delineation is undertaken (and the related rules by which ecosystem types are identified) and the number of ecosystem types to be delineated. This balance will depend on data availability and analytical requirements. The general principle is that for a given ecosystem account a single spatial scale of analysis should be selected (e.g., 100m grid cells) and consequently an ecosystem asset will not be further delineated unless it is sufficiently large in area such that it is identified at that scale.

3.40 This section considers two particular cases in which specific guidance is appropriate: linear features and complex mosaics.

3.41 **Linear features:** In all EAA there are a variety of linear features. Typical examples are streams and rivers, hedgerows and road verges. If the scale of delineation is sufficiently small, these ecosystem types may be readily identified, but commonly they will be missed. For ecosystem accounting purposes, it is relevant to make a distinction between ‘narrow’ linear features, whose width is small enough to be treated as zero in accounting for the total area of an EAA (which must be equal to the sum of areas of individual ecosystem assets), and ‘wide’ linear features, whose width is large enough such that the associated area should be recognized.

3.42 The following treatments are adopted in the SEEA EA using the distinction between narrow and wide linear features and considering rivers and streams separately from other linear features.

i. For rivers and streams, width will change downstream along a river system, such that there will be a transition from ‘narrow’ upstream headwater reaches, to ‘wide’ downstream trunk rivers. The area of sufficiently wide rivers and streams should be separately recorded. The treatment of this transition in the accounts will depend on the nature of the source data involved (e.g., between raster data, types of vector data).

ii. For other linear features that are ecologically linked to surrounding landscape, such as ditches or hedgerows in a pasture landscape, it is recommended that they should not be separately identified and any associated area should be attributed to the ecosystem type of the surrounding ecosystem.

iii. For any linear features that are not ecologically linked to the surrounding landscape, such as forest access roads, the choice is to treat them like streams and rivers if sufficiently wide (i.e., as a separate ecosystem type with an associated area), or to include them with the surrounding ecosystem types (i.e., without an associated area). This choice should be guided by the added value that a separate ecosystem type would have for the account or its applications.

3.43 It is noted that where a linear feature is attributed to the surrounding ecosystem, the condition of that ecosystem should take the presence of the linear feature into account. Thus, changes in the extent of linear features, e.g., increases in the kilometres of hedgerows, should be reflected in changes in the measure of condition. Incorporating linear features may have positive or negative effects on a measure of condition depending on the context.

3.44 While this treatment allows for the integration of linear features into a standard 2D extent account, there may be interest in a separate recording of linear features in terms of their length. A complementary set of one-dimensional extent accounts for such a purpose is described in Chapter 4.

3.45 **Complex mosaics**: Some spatial areas are characterised by a complex mix of different features, including linear features. Examples include urban areas and agricultural areas with small farm holdings. Where ecosystem accounting is undertaken for relatively large regions, it is recommended that the complex mix be seen as reflecting characteristics within a broader ecosystem type where changes in the characteristics (e.g., changes in the share of urban green spaces) may be accounted for as a change in the condition of the ecosystem asset.

3.46 Where it is considered important to account specifically for complex mosaics, including urban areas, it will likely be appropriate to apply specific classifications of ecosystem types (e.g., to identify urban parks) and then apply the general principles for the delineation of ecosystem assets within those mosaics. A discussion on the broader issues of accounting for alternative themes, such as accounting for urban areas, is presented in Chapter 13 on thematic accounting.

3.4 Classifying ecosystem assets

3.4.1 General principles

3.47 Ecosystem assets are classified into ecosystem types. Given the variety of ecosystem types and contexts around the world, there are many examples of ecosystem related classifications. For SEEA purposes, any ecosystem classification to be used for ecosystem accounting should ideally satisfy the definition of ecosystem assets and the principles for delineating ecosystem assets listed in section 3.3.1.

3.48 Depending on the data available, compilation of accounts at national or sub-national level may involve the use of a large number of ecosystem types to ensure that accounts are suitable for the context. For the purpose of reporting and comparison among countries, a smaller number of higher-level classes is appropriate to facilitate use of the ecosystem data by a wide range of users.

3.49 It is recommended that existing national ecosystem classification schemes be used for ecosystem accounting wherever possible. Generally, such classification schemes will provide detailed descriptions and classes that incorporate specific local ecological knowledge. Cross-referencing of units to the SEEA EA reference classification, the International Union for the

Conservation of Nature (IUCN) Global Ecosystem Typology (GET), will enable national level accounts to be scaled up and compared between countries (see 3.54).

3.50 Where a national classification of ecosystems is not available, the International Union for the Conservation of Nature (IUCN) Global Ecosystem Typology (GET) (described in section 3.4.2) may be used to develop one by scaling down to locally-derived and locally-relevant ecosystem types.

3.51 For the purposes of international reporting and comparison, the SEEA Ecosystem type reference classification should be applied, reflecting the IUCN GET Ecosystem Functional Groups (EFG).

3.4.2 SEEA Ecosystem Type reference classification

3.52 The SEEA Ecosystem Type reference classification reflects the IUCN GET which was developed to support implementation of the Red List of Ecosystems. The IUCN GET is a global typological framework that applies an ecosystem process-based approach to ecosystem classification for all ecosystems around the world. In this approach, ecological assembly theory is used to identify key properties that distinguish functionally related ecosystems, and to synthesize traditionally disparate classification approaches across terrestrial, freshwater, subterranean and marine ecological realms. Using a focus on functionally related ecosystems at the higher levels of the classification allows similar but locally-different ecosystem types to be grouped in an ecologically meaningful way. This is particularly important for international comparison purposes where the variety of ecosystem types is very large.

3.53 The IUCN GET has a structure consisting of six levels. The three upper levels (levels 1-3) differentiate the functional properties of ecosystems, while IUCN GET Levels 4-6 correspond to finer levels of detail on ecosystem types that will be relevant in national and sub-national contexts. It would be expected that existing national ecosystem type classes would be described at a level of detail corresponding conceptually to IUCN GET level 5 or 6. A full description of the IUCN GET and its approach to classification is provided in (D. A. Keith et al., 2020).

3.54 The SEEA Ecosystem Type reference classification is equivalent to IUCN GET Levels 1-3. The focus on these levels allows (i) national variations in the description of local ecosystem types to be developed recognising the importance of locally-relevant classes; and (ii) ecologically meaningful groupings of locally-relevant ecosystem types to be formed for the purposes of integrating national-level data from different sources (e.g., agriculture, environment, forestry, and marine data) and for international comparison.

3.55 The top level defines four realms: marine (M); freshwaters and saline wetlands (F); terrestrial (T); and subterranean (S). A realm is a major component of the biosphere that differs fundamentally in ecosystem organization and function. The top level also provides for the classification of atmospheric units to the atmospheric realm at a future date which would provide complete coverage of the biosphere. As noted in section 3.2.1, that part of the atmosphere above the atmospheric boundary layer is not included in the scope of ecosystem assets.

3.56 The second level of the classification broadly follows the modern functional biome concept in which a biome is “a biotic community finding its expression at large geographic scales, shaped by climatic factors and characterized by physiognomy and functional aspects, rather than by species or life-form composition.” (Mucina, 2019). The IUCN GET defines 24 biomes: four exclusively in the marine realm; three exclusively in the freshwater realm; seven exclusively in the terrestrial realm; four exclusively in the subterranean realm; and six that are located in transitional areas between different realms. These transitional areas represent interfaces between various combinations of the marine, freshwater, subterranean and terrestrial realms.

3.57 Levels 1 and 2 of the SEEA Ecosystem Type reference classification are shown in Table 3.2. Many of the ecosystem types described at Level 2 are familiar as naturally occurring biomes, including tropical forests, deserts, freshwater lakes and others. Four biomes are defined by anthropogenic processes,[23] where human activity is pivotal to ecosystem assembly and maintenance of ecosystem components and processes.

3.58 The third level of the classification describes ecosystem functional groups (EFG) which are functionally distinctive groups of ecosystems within a biome and are defined in a manner consistent with the CBD definition of ecosystems which underpins the SEEA EA concept of ecosystem assets. Ecosystem types within the same EFG share common ecological drivers which promote convergence of the biotic traits that characterize the group. There are 98 EFGs in the IUCN GET though it would be highly unlikely for a country to have ecosystem assets representative of all EFG. More commonly, less than 40 EFG would be present in a single EAA. A full listing of EFG classes is provided in Annex 3.2.

3.59 For the compilation of ecosystem accounts at national or sub-national level it is expected that the delineation of ecosystem assets would occur at fine levels of detail using national classifications. The compilation of ecosystem accounts may occur at this same level of classification. For the presentation of ecosystem accounting outputs, either in tabular or map format, it may be appropriate to combine fine level classes. For example, presentation may occur at the equivalent of the EFG level. It is expected that for the purposes of international comparison, the reporting of data at the EFG level (level 3) would be appropriate.

3.60 Specific mention is made of the Anthropogenic Biomes T7 (Intensive land use), which includes croplands, pastures, plantations and urban areas, F3 (Artificial wetlands), M4 (Anthropogenic marine ecosystems), S2 (Anthropogenic subterranean voids), MT3 (Anthropogenic shorelines) and SF2 (Anthropogenic subterranean freshwaters), and their composite EFGs. For a range of ecosystem accounting purposes, there will be interest in accounting at a finer level of detail than the EFGs that are within these biomes. For example, urban ecosystems (T7.4) are often structurally complex and highly heterogeneous; and annual croplands (T7.1) consist of fields of varying crop types and fallow land. To delineate and report on spatial units within the above mentioned anthropogenic biomes and their corresponding EFGs, it is recommended that national land use classes be used, or as needed, the classes of the SEEA Central Framework Land Use Classification (at the 3-digit level). Depending on analytical requirements, the heterogeneity within these land use classes may be described by means of condition variables (e.g., the percentage cover of trees, grass and water within urban parks).

[23] Also referred to as “anthromes” - see Ellis (2011) and Ellis et al. (2010).

Table 3.2: SEEA Ecosystem Type Reference Classification based on the IUCN Global Ecosystem Typology

Realms	Biomes
Terrestrial	T1 Tropical–subtropical forests
	T2 Temperate–boreal forests & woodlands
	T3 Shrublands & shrubby woodlands
	T4 Savannas and grasslands
	T5 Deserts and semi-deserts
	T6 Polar-alpine
	T7 Intensive land-use systems
Freshwater	F1 Rivers and streams
	F2 Lakes
	F3 Artificial fresh waters
Marine	M1 Marine shelfs
	M2 Pelagic ocean waters
	M3 Deep sea floors
	M4 Anthropogenic marine systems
Transitional	TF1 Palustrine wetlands
	FM1 Semi-confined transitional waters
	MT1 Shoreline systems
	MT2 Supralittoral coastal systems
	MT3 Anthropogenic shorelines
	MFT1 Brackish tidal systems

Source: (D. A. Keith et al., 2020).

3.61 The use of the IUCN GET as the reference classification of ecosystem types reflects the need for a globally applicable classification of ecosystem types covering all realms. There are a range of existing global classifications of ecosystem types, habitats, land cover and land use; and also regional or realm specific classifications of ecosystem types that may be used in other contexts. Examples of these classifications include World Terrestrial Ecosystems for terrestrial areas (Sayre et al., 2020); EUNIS and MAES classes; FAO Global Agro-Ecological Zones; SEEA Land cover and land use classifications; MODIS classes; and global reporting classes such as concerning IPCC and RAMSAR. To support the integration of data and the compilation of accounts correspondences among these classifications will be developed building on, for example, Bordt & Saner (2019).

3.5 Considerations in the delineation of spatial units

3.5.1 Delineation of ecosystem assets in practice

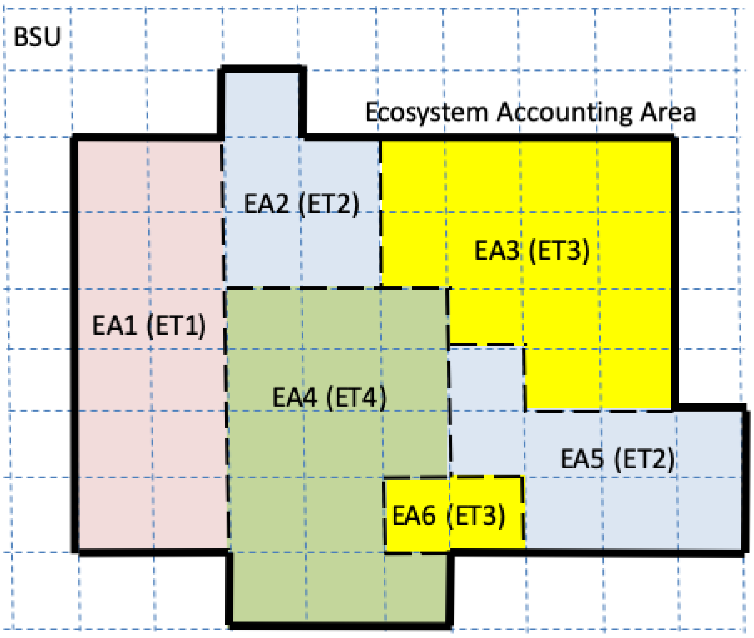
3.62 The distinction between ecosystem assets of different types is ecological. This reflects an understanding of the differing composition, structure and function of the various biotic and abiotic components and their interactions. In principle then, delineating the boundaries between ecosystem assets is statistically observable and can be undertaken through comprehensive and regular assessments by ecologists on the ground, including assessments of changes over time.

3.63 In practice, the high resource costs involved in ground assessments mean that the delineation of ecosystem assets will involve the mapping of different types of ecosystem assets within an EAA using remote sensing data analysed by applying geographic information systems (GIS) platforms and techniques. This work is specialised but there is extensive practical and theoretical understanding of the use of GIS to support the delineation of ecosystem assets for ecosystem accounting purposes. It is noted also that the use of GIS platforms and techniques will be relevant in many areas of ecosystem accounting. Accompanying technical guidance on the use of GIS techniques and tools for ecosystem accounting is being developed (UNSD, n.d. forthcoming).

3.64 While the use of GIS is standard, it will be necessary to involve ecological expertise to assure that the boundaries drawn between ecosystem assets are appropriate in ecological terms with regard to the ecosystem type classification that is adopted and that the changes through time are meaningful. In addition, where ground assessments are carried out this information should be integrated appropriately to provide the most accurate measures.

3.65 To operationalise the delineation of EA within GIS systems, it can be appropriate to use a basic spatial unit (BSU). A BSU is a geometrical construct representing a small spatial area. The purpose of BSUs is to provide a fine-level data framework within which data about a range of characteristics can be incorporated. An example of a BSU is a grid cell, but other BSU shapes, for example reflecting polygons, may be used. Figure 3.4 shows how a grid based BSU can be overlaid on an EAA to assist in delineating the ecosystem assets included in the earlier example (shown in Figure 3.3).

Figure 3.4: Applying a grid based BSU to delineate EA



Source: adapted from SEEA 2012 EEA, figure 2.4 (United Nations et al., 2014b).

3.66 To apply a BSU technique, each BSU is attributed with data on relevant characteristics that are relevant in distinguishing between ecosystem assets of different types. One way of considering this is that over the entire EAA each characteristic is mapped at the BSU level to establish a data layer for that characteristic.

3.67 As noted, different ecosystem types will be distinguished through combinations of a number of characteristics. At a basic level it is necessary to combine data on land cover, climate (e.g., temperature regime, precipitation regime, potential evapotranspiration) and landforms (e.g., soil type, lithography, geomorphology). From this starting point, a range of other characteristics may be added, for example concerning water, carbon, nutrients, etc.

3.68 This approach has been applied in a number of contexts. An example is the map of terrestrial World Terrestrial Ecosystems (WTEs) (Sayre et al., 2020), which was derived from the objective development and integration of global temperature domains, global moisture domains, global landforms, and 2015 global vegetation and land use data.

3.69 The extent to which it is possible to combine multiple data sets to delineate ecosystem assets will depend on data availability. Where available, existing maps that delineate ecosystem assets may be used. As a second option, ecosystem asset maps may be generated using national level information on land cover, climate, landforms and other characteristics as relevant following the descriptions above. Where national level data on basic characteristics are not available, global datasets may be used. As a final option, it may be necessary to use data on the single characteristic of land cover to provide an initial delineation of ecosystem assets.

3.70 For those biomes that are subject to direct human management (particularly Biome T7: Intensive land-use, including croplands and plantations), it will be appropriate to incorporate data on land/ecosystem use in addition to land cover in the delineation of ecosystem assets as these data provide an indicator of differing ecological composition, structure and function.

3.71 While the focus of the description here is on the use of spatial approaches to delineating ecosystem assets, data on the extent of ecosystem assets, or at least the extent of specific ecosystem types, may be collected via other means, for example, using surveys of land holders. For certain ecosystem types, for example forests, the collection of data in this way will provide input to the accounts. However, data in this form will not support the derivation of maps since the precise location and boundaries of the ecosystem assets will not be recorded. Consequently, alignment with data on other ecosystem types may also be challenging and the risks of double counting or missing areas of ecosystems is increased. It is recommended that a high priority be placed on establishing an agreed delineation of ecosystem types within a country. However, non-spatial data may be valuable to support data quality assurance and estimation of ecosystem condition and ecosystem services.

3.5.2 The use of data on the characteristics of land

3.72 In ecosystem accounting there is commonly an interest in accounting for terrestrial ecosystems and hence the use of data associated with the various characteristics of land is of immediate interest. As described above, while land cover and land use data are not sufficient to delineate ecosystem assets, they provide much relevant information.

3.73 Both land cover and land use data should be organised following the concepts and definitions outlined in the SEEA Central Framework. Land cover refers to the observed physical and biological cover of the Earth’s surface and includes natural vegetation and abiotic (non-living) surfaces. At its most basic level, it comprises all of the individual features that cover the area within a country. For the purposes of land cover statistics, the relevant country area includes only land and inland waters.

3.74 There are several international land cover classifications that may be used, providing well documented and tested metadata. The standard classification of land cover in the SEEA Central Framework is based on the FAO Land Cover Classification System (LCCS).[24]

3.75 Land use reflects both (a) the activities undertaken and (b) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions. In effect, “use” of an area implies the existence of some human intervention or management. Land in use therefore includes areas, for example, protected areas, as they are under the active management of institutional units of a country for the primary purpose of conserving biodiversity and other environmental values (SEEA Central Framework, para. 5.246).

3.76 Land management is the process of managing the use and development of land resources. The degree that areas of land and water are managed by humans may differ from intensively managed (e.g., build up areas, cropland) to not managed (e.g., polar regions, oceans). The degree of land management can have positive or negative effects on ecosystems and monitoring changes in the degree of management may be of interest in monitoring the links between changes in ecosystem assets, their condition and land management policies and decisions. Of particular interest in the analysis of ecosystems may be data on the extent and changes in extent of protected areas.

3.77 Land ownership, encompassing ownership across all ecological realms, is a key characteristic that provides a direct link between ecosystems, their management and economic statistics. Economic assets, including land, can be assigned and classified to institutional units (i.e., corporations, non-profit organizations, government, households) based on ownership. Not all ecosystems are owned, namely some remote natural areas or the oceans (e.g., the high seas beyond the EEZ) and hence various accounting conventions are established. Also, in many countries there are communally owned areas – for example areas used for the rearing of livestock. Relevant conventions for the allocation of ownership are discussed in Chapter 11 in the context of integrating ecosystem accounts with the SNA sequence of accounts. Data on land ownership for terrestrial ecosystems is available in many countries in the form of cadastres. Cadastres are registers of areas defined administratively and delineated on the basis of ownership.

3.78 The data on each of these characteristics – cover, use, management and ownership – can be overlaid (where spatial data are available) or presented in conjunction with data on the extent of ecosystem assets and associated measures of condition and ecosystem services. Thus, for example, data from cadastres showing the sector of ownership or the nature of the tenure can be linked to data on ecosystem assets, and hence provide a basis for monitoring the effects of land management policies within a given region, e.g., a water catchment.

3.5.3 Organising data about socio-economic and other characteristics

3.79 Beyond land related data, the delineation of ecosystem assets will generally require the use of various data concerning ecological characteristics. The organisation of these data to undertake delineation creates the opportunity to establish a richer data base of spatial information. This would include data on land management and ownership described above and also data on, for example, the stocks and flows of water and carbon; the presence of particular species (either endemic or invasive); measures of soil and water quality;

[24] For the FAO Land Cover Classification System (LCCS) see http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1036361/

temperature, slope and elevation; pollution and other residual flows; the production of agricultural, forestry and fisheries outputs; and indicators of recreational activities and cultural sites.

3.80 A strong motivation for organising these additional data emerges from ecosystem accounting since while data on only certain characteristics are required for the delineation of ecosystem assets, there are many other characteristics that will be relevant for accounting for ecosystem condition and estimating flows of ecosystem services. Further, analysis of data on ecosystem extent, condition and services may be enriched by integration of spatially detailed socio-economic data, for example population data.

3.81 Particular note is made concerning measurement of ecosystem services where both the supply and the use of ecosystem services must be recorded. In some cases, e.g., biomass provisioning services, the location of the supply and the use of the services is the same and occurs in a single ecosystem asset. In other cases, e.g., air filtration services, the supply of the service may take place in a different location from the use; and in other cases, e.g., flood mitigation services, the supply of the service emerges from a combination of ecosystem assets. Spatial attribution of the supply and use of ecosystem services is therefore an important task to ensure appropriate recognition of the role of different ecosystems and the mix of different users. These issues are discussed further in Chapter 7.

3.82 Spatial data concerning additional characteristics should be attributed to ecosystem assets to support coherence in accounting terms. Operationally, this attribution may be applied using a BSU based structure to align and integrate spatial data on different characteristics which will most commonly be available with varying spatial coverage, scales and projections. Since the extent and configuration of ecosystem assets will change over time, the nature of the attribution of data will also change. Thus, use of an agreed BSU structure, or “master layer” will likely provide considerable computational advantages.

3.83 Ideally, it is envisaged that a country would establish a National Spatial Data Infrastructure (NSDI) to underpin the collation and organisation of spatial data, which in turn could provide a coherent “one-map” for a country, including its marine ecosystems, across many characteristics. Countries are therefore encouraged to use the implementation of ecosystem accounting as an opportunity to integrate spatial data and techniques.

Annex 3.1: Ecological concepts underpinning spatial units for ecosystem accounting

Key ecological concepts

A3.1 In ecology, a range of related but different characteristics of areas are used, each reflecting different ecological concepts. This section summarizes the key concepts of relevance in the context of ecosystem accounting.

Ecosystems

A3.2 The central concept of interest for ecosystem accounting and classification is that of the ecosystem itself. The most important element of this definition is the final clause "interacting as a functional unit", which means that the abiotic environment (climate, lithology, hydrology, etc.) is not relevant on its own, but in relation to biota (if only in a one-directional way), from an ecosystem functioning point of view. Ecosystem function refers to the processes related to the fluxes of resources like energy and water, photosynthesis and decomposition, that make up the interactions between the ecosystem components (Agren & Andersson, 2011).

A3.3 (D. A. Keith et al., 2020), building upon assembly theory (i.e., the selection of ecological communities through environmental filtering of available trait/species pool; Keddy (1992)), distinguish five groups of processes that govern ecosystem functioning.

- **Resources** (Energy, nutrients, water, carbon, oxygen etc.). One of more of these will often be limited, inducing an ecosystem functional response such as competition.
- **Ambient environmental conditions** (Temperature, salinity, geomorphology etc.). These factors regulate the availability of, and access to resources, as well as ecological processes (temperature controls biochemical reaction kinetics, geomorphology controls soil moisture conditions, etc.).
- **Disturbance regimes** (fire, floods, mass movements etc.). These factors episodically destroy existing ecosystem structures and/or introduce or release new resources and niches.
- **Biotic interactions** (competition, predation, ecosystem engineering etc.). These are largely endogenous processes that shape ecosystem structure and function, but they include organisms that act as mobile links connecting different ecosystems and regulating transfers of matter and energy between them.
- **Human activity** Anthropogenic processes are a special kind of biotic interaction that influence structure and function of ecosystems either directly (e.g., land cover change, movement of biota) or indirectly (e.g., the harvest of biomass and other forms of resource use, climate change)

A3.4 Together, these processes and conditions give rise to a variety of ecosystem traits, such as productivity, diversity, trophic structure, physiognomy, life forms and phenology. The assembly processes and ecosystem traits both influence stocks of assets and flows of services by shaping ecosystem structure and function. The same processes that determine the 'identity' of an ecosystem also determine their integrity. Accordingly, variables that describe these processes and characterize the state of an ecosystem with respect to them will also be in the focus of ecosystem condition accounts (Chapter 5).

Habitat and biotope

A3.5 The concept of habitat is closely related, but not identical to ecosystems. It is defined as "a location (area) in which a particular organism is able to conduct activities which contribute to survival and/ or reproduction" (Stamps, 2008). It thus is organism-specific, focuses on both biotic and abiotic factors, and has a geographical component. Thus, habitats are provided by ecosystems for individual species. For example, a closed cover of Larix trees may define a taiga forest ecosystem which provides a habitat for woodpeckers.

A3.6 The term biotope is often used interchangeably with habitat, but is often assigned to the community concept, and habitat to the species concept. Thus, a species has a certain habitat, but the group of species that share an ecosystem with that species in a geographic region, share a biotope (Dimitrakopoulos & Troumbis, 2019). A biotope is a topographic unit, and can be considered to be equivalent with Ecosystem Asset.

Biome

A3.7 A biome is *"…a biotic community finding its expression at large geographic scales, shaped by climatic factors, and perhaps better characterized by physiognomy and functional aspects [of vegetation], rather than by species or life-form composition. Biomes are frequently used as tools to provide large-scale (regional to global)* backgrounds *in a range of ecological and biogeographical studies."* (Mucina, 2019). Biomes are the largest geographical biotic communities that are convenient to recognize. Most of them broadly correspond with climatic regions (zonobiomes), although other environmental controls are sometimes important, e.g., soils (pedobiomes) or topography (orobiomes).

A3.8 There is no single authoritative list of biomes. While some biomes are recognized by all authors (e.g., tropical rainforest, taiga) many different biomes are proposed for less well-defined ecosystems, especially those on ecotones, such as savannas and woodland. For SEEA purposes, the IUCN GET list of biomes is used as a reference.

Ecoregions

A3.9 An ecoregion is "A geographic group of landscape mosaics", "resulting from large-scale predictable patterns of solar radiation and moisture, which in turn, affect the kinds of local ecosystems and animals and plants found there (Bailey, 2009, 2014). Individual ecosystems (i.e., ecosystem assets) within an ecoregion may have a strong functional relationship with each other, e.g., where upstream ecosystems regulate water and nutrient resources for downstream ecosystems, or they may be functionally unconnected, e.g., when two ecosystem assets of the same ecosystem type, but in adjacent subcatchments, simply reflect the same abiotic conditions as soil, climate and topography. Ecoregions are often used within a mapping context, and are described with a hierarchical structure. Terrestrial ecoregions are often grouped into higher order biogeographic regions, where the different biogeographic regions (e.g., Nearctic for North America, Indomalaya for India and SE Asia, etc.) reflect global differences in species distributions due to geographic separation and evolutionary history. On a smaller scale, ecoregions may be spatially contiguous units of a single biome, or subdivisions thereof, e.g., "West Siberian Taiga" and "East Siberian Taiga" (Olson et al., 2001).

Ecotones

A3.10 Ecotones are places where ecosystems grade into each other along a gradient in one or more resources or environmental controls. A typical example is the transition from forest to grassland on a gradient of moisture availability. The precise location of ecosystem types, and hence the ecotones between them is ultimately subjective. Where these gradients are very gentle, ecotones can occupy quite extensive areas. The translation of gradients and ecotones on ecosystem classification will depend on the nature and 'sharpness' of the transition, and the scale of application.

Realms

A3.11 A realm is a major component of the biosphere that differs fundamentally in ecosystem organization and function.

Key drivers and characteristics of ecosystems

A3.12 In each of the three primary environmental realms - terrestrial, freshwater, and marine - ecosystems are commonly understood as occupying space and comprising an abiotic complex, a biotic complex, and interactions between the two. This section describes the key drivers and characteristics of terrestrial, freshwater and marine ecosystems. These characteristics are linked to ecosystem structure and functioning and play a key role in classifying ecosystems within each realm, as well as in measuring their condition.

Terrestrial ecosystems

A3.13 For terrestrial ecosystems, key drivers are climate, topography, lithology and human activities. Key characteristics of the abiotic complex are soil and moisture regime. Key characteristics of the biotic complex include vegetation, and animals, often linked to human activity:

A3.14 Drivers:

- **Climate**, pragmatically defined as the statistics of weather, is an important driver of many ecosystems, because of its strong links to resources (e.g., water, energy) and constraints (e.g., droughts). From an ecological point of view the most relevant climatic parameters are:
    - **Temperature**: mean annual temperature; seasonality; temperature of the coldest month; accumulated growing degree-days.
    - **Precipitation**: total annual precipitation; seasonality.
    - **Potential evapotranspiration**: annual total; seasonality.
- **Topography and geomorphology**, affects climate (on the global or local scale) and moisture conditions (on the regional and local scale), and nutrient redistribution Examples include:
    - **Hillslopes vs plains**: hillslopes have improved drainage condition compared to plains.
    - **Gentle vs steep slopes**: Steeper slopes will have shallow soils, faster drainage and possible more disturbance due to mass movements.
    - **Low vs high topography**: Adiabatic expansion of rising air causes cooler and wetter (micro) climate on high plains and mountains.
    - **Profile and planform convexity**: topographic controls on hillslope hydrology promote relative dry conditions on convex divergent hillslopes, and relatively wet conditions on concave hollows and the convergent channel network.
- **Lithology** determines the parent material for soil formation, and as such controls vegetation primarily through a number of resource processes, especially nutrient availability, through mineral composition and weathering products.
- **Human impact** on ecosystems can be either direct (e.g., land cover change, movement of biota) or indirect (e.g., resource use, climate change).

A3.15 Characteristics:

- **Soil**, controls vegetation primarily through a number of resource processes, and is formed partially by the local current and past ecosystem processes:

    - **Lithology** affects nutrient availability, through mineral composition and weathering products.
    - **Soil chemical properties** such as Cation Exchange Capacity (CEC) determine the capacity of the soil to retain nutrients
    - **Soil physical properties**, such as its water retention characteristics, control moisture availability during dry spells.
    - **Soil organic matter**, is an important biota-controlled soil characteristics that contributes to these chemical and physical properties
- **Vegetation**, as a proxy for all biota. The terms vegetation and ecosystems are often used interchangeably (e.g., Tropical Rainforest), but vegetation is rather a biotic element of an ecosystem and exists in a physical environment context which defines it. For many ecosystems, and for terrestrial ecosystems in particular, vegetation is an important element of the classification and labelling process. Vegetation is generally characterized by species assemblages which have a strong spatial expression and whose occurrences are therefore recognizable on the landscape. Vegetation can also be characterized by a set of more generic plant functional traits (e.g., Pérez-Harguindeguy et al. (2013)).
    - **Growth form**, e.g., trees, shrubs, grass etc. and the corresponding **canopy architecture**.
    - **Raunkiær life-form**, e.g., Phanerophytes (woody, buds >25 cm above the ground), geophytes (buds in dry ground), hydrophytes (buds below water) etc. and **Life history**, e.g., annuals vs perennials.
    - **Leaf type and phenology**, e.g., broadleaved, needle-leaved, deciduous, evergreen.
    - **Adaptations** to oxygen stress (phreatophytes), moisture stress (xerophytes) or salt stress (halophytes).
- **Animals** play a vital role in ecosystem function as detritivores, herbivores and predators. They may be sometimes difficult to detect due to their behaviour and mobility.
- **Time** drives the succession of ecosystems, which naturally progress from pioneer stage to a climax vegetation, provided that stable environmental conditions pertain.

Freshwater ecosystems and wetlands

A3.16 Fresh water ecosystems are characterized by the presence of permanent or ephemeral surface waters whose surface extents vary spatially over time, and whose vegetation consists of largely aquatic species. The main distinction is between flowing water systems (rivers and streams) on one side of the spectrum and low- or non-flowing systems (lakes, ponds, and wetlands) on the other side.

A3.17 Abiotic drivers of **Rivers** and **streams** include

- **Geomorphology**. By definition, rivers and streams are geomorphological features.

- Stream order, i.e., the position from source (lowest order) to outlet (highest order), as a proxy for and classification of, drainage area.
    - **Fluvial zone** (erosional; transfer; depositional).
    - **Sediment size** (bedrock; boulders; gravel; sand; clay) and mobility (bedload, suspended).
    - **Channel pattern**[25] (Straight; meandering; wandering; braided; anastomosing).
    - **Bedform** (Planar; ripples; pool-riffle; bars).
- **Hydrology** (ephemeral; intermittent; perennial; interrupted).
- **Chemistry** (e.g., Na/Ca vs total salt).

A3.18 The biotic characteristics include:

- fish; macroinvertebrates; vegetation

A3.19 Note that many of these attributes are correlated with each other, and vary reasonably predictive along a downstream gradient.

A3.20 Abiotic drivers of **Lakes and pools** include:

- **Origin**: e.g., tectonic, volcanic, glacial, karstic, fluvial, artificial.
- **Stratification**: e.g., meromictic (never mixes), monomictic (mixes once a year), dimictic (twice a year) and polymictic (often mixed).
- **Trophic status**: oligotrophic (nutrient-poor) vs eutrophic (nutrient-rich).
- **Salinity**: freshwater lakes vs salt lakes.
- **Permanency**: e.g., episodic vs seasonal vs permanent lakes.

A3.21 While biotic characteristics are generally similar as for rivers and streams

A3.22 **Wetlands** can be broadly defined as ecosystems that arise when inundation by water produces soils dominated by anaerobic processes, which, in turn, forces the biota, particularly rooted plants, to adapt to flooding (Keddy, 2010).

A3.23 Some key abiotic drivers are:

- **Morphology**: terrain-conforming vs self-emergent
- **Hydrological system**: permanence/seasonality of water levels (water availability), minerotrophic (groundwater, surface) vs ombrotrophic (precipitation)
- **Trophic status**: oligotrophic (nutrient-poor) vs eutrophic (nutrient-rich).
- **Landscape position**: along streams(riverine), lakes (lacustrine), estuarine or disconnected/upstream (palustrine)

A3.24 Their key biotic feature is:

- **Dominant vegetation type**: Bryophytes and graminoids (bog and fen or peatland), graminoids, shrubs, forbs or emergent plants (marsh) or trees, shrubs and forbs (swamp), submerged of floating aquatic plants (shallow water)

[25] Note that channel pattern is strongly controlled by bank strength, which itself is partly controlled by vegetation. On longer time scales channel pattern can thus be regarded as an ecosystem characteristic, rather than a driver

Marine ecosystems

A3.25 Marine ecosystems consist of all salt-water ecosystems that are directly connected to the world's oceans. The key abiotic drivers of marine ecosystems are:

- **Horizontal zonation**: e.g., intertidal zone, continental shelf, continental margin, abyssal plain.
- **Vertical layering**: water column (pelagic zone) vs sea bottom (benthic zone); photic zone.
- **Climate**: tropical, temperate, polar waters.
- **Water quality:** e.g., nutrients and transparency
- **Currents:** esp. upwelling zones.
- **Bottom characteristics**: e.g., rocky, sand, mud, biogenic.

A3.26 The key biotic characteristics are:

- **Pelagic biota**: e.g., algae; invertebrates; fish; mammals.
- **Benthic biota**: e.g., plants; invertebrates; coral.

Annex 3.2: IUCN Global Ecosystem Typology

A3.27 Upper three levels of the IUCN Global Ecosystem Typology (D. A. Keith et al., 2020). Realms listed are Terrestrial (T), Freshwater and saline wetlands (F), Marine (M), Subterranean (S), and transitions between these.

Realm	Biome	Ecosystem Functional Group
Terrestrial	T1 Tropical–subtropical forests	T1.1 Tropical-subtropical lowland rainforests
		T1.2 Tropical-subtropical dry forests and scrubs
		T1.3 Tropical-subtropical montane rainforests
		T1.4 Tropical heath forests
	T2 Temperate–boreal forests & woodlands	T2.1 Boreal and temperate montane forests and woodlands
		T2.2 Deciduous temperate forests
		T2.3 Oceanic cool temperate rainforests
		T2.4 Warm temperate laurophyll forests
		T2.5 Temperate pyric humid forests
		T2.6 Temperate pyric sclerophyll forests and woodlands
	T3 Shrublands & shrubby woodlands	T3.1 Seasonally dry tropical shrublands
		T3.2 Seasonally dry temperate heaths and shrublands
		T3.3 Cool temperate heathlands
		T3.4 Rocky pavements, lava flows and screes
	T4 Savannas and grasslands	T4.1 Trophic savannas
		T4.2 Pyric tussock savannas
		T4.3 Hummock savannas
		T4.4 Temperate woodlands
		T4.5 Temperate subhumid grasslands
	T5 Deserts and semi-deserts	T5.1 Semi-desert steppes
		T5.2 Thorny deserts and semi-deserts
		T5.3 Sclerophyll deserts and semi-deserts
		T5.4 Cool deserts and semi-deserts
		T5.5 Hyper-arid deserts
	T6 Polar-alpine (cryogenic)	T6.1 Ice sheets, glaciers and perennial snowfields
		T6.2 Polar-alpine rocky outcrops
		T6.3 Polar tundra and deserts
		T6.4 Temperate alpine grasslands and shrublands
		T6.5 Tropical alpine grasslands and shrublands
	T7 Intensive land-use	T7.1 Annual croplands
		T7.2 Sown pastures and fields
		T7.3 Plantations
		T7.4 Urban and industrial ecosystems
		T7.5 Derived semi-natural pastures and old fields
Freshwater	F1 Rivers and streams	F1.1 Permanent upland streams
		F1.2 Permanent lowland rivers
		F1.3 Freeze-thaw rivers and streams
		F1.4 Seasonal upland stream
		F1.5 Seasonal lowland rivers
		F1.6 Arid episodic arid rivers
		F1.7 Large lowland rivers
	F2 Lakes	F2.1 Large permanent freshwater lakes
		F2.2 Small permanent freshwater lakes
		F2.3 Seasonal freshwater lakes
		F2.4 Freeze-thaw freshwater lakes

		F2.5 Ephemeral freshwater lakes F2.6 Permanent salt and soda lakes F2.7 Ephemeral salt lakes F2.8 Artesian springs and oases F2.9 Geothermal pools and wetlands F2.10 Subglacial lakes
	F3 Artificial fresh waters	F3.1 Large reservoirs F3.2 Constructed lacustrine wetlands F3.3 Rice paddies F3.4 Freshwater aquafarms F3.5 Canals, ditches and drains
Freshwater-Terrestrial	TF1 Palustrine wetlands	TF1.1 Tropical flooded forests and peat forests TF1.2 Subtropical-temperate forested wetlands TF1.3 Permanent marshes TF1.4 Seasonal floodplain marshes TF1.5 Episodic arid floodplains TF1.6 Boreal, temperate and montane peat bogs TF1.7 Boreal and temperate fens
Freshwater-Marine	FM1 Semi-confined transitional waters	FM1.1 Deepwater coastal inlets FM1.2 Permanently open riverine estuaries and bays FM1.3 Intermittently closed and open lakes and lagoons
Marine	M1 Marine shelfs	M1.1 Seagrass meadows M1.2 Kelp forests M1.3 Photic coral reefs M1.4 Shellfish beds and reefs M1.5 Photo-limited marine animal forests M1.6 Subtidal rocky reefs M1.7 Subtidal sand beds M1.8 Subtidal mud plains M1.9 Upwelling zones
	M2 Pelagic ocean waters	M2.1 Epipelagic ocean waters M2.2 Mesopelagic ocean waters M2.3 Bathypelagic ocean waters M2.4 Abyssopelagic ocean waters M2.5 Sea ice
	M3 Deep sea floors	M3.1 Continental and island slopes M3.2 Submarine canyons M3.3 Abyssal plains M3.4 Seamounts, ridges and plateaus M3.5 Deepwater biogenic beds M3.6 Hadal trenches and troughs M3.7 Chemosynthetically-based ecosystems
	M4 Anthropogenic marine systems	M4.1 Submerged artificial structures M4.2 Marine aquafarms
Marine-Terrestrial	MT1 Shoreline systems	MT 1.1 Rocky shorelines MT 1.2 Muddy shorelines MT 1.3 Sandy shorelines MT 1.4 Boulder and cobble shorelines
	MT2 Supralittoral coastal systems	MT 2.1 Coastal shrublands and grasslands
	MT3 Anthropogenic shorelines	MT 3.1 Artificial shorelines
Marine-Freshwater-Terrestrial	MFT1 Brackish tidal	MFT1.1 Coastal river deltas MFT1.2 Intertidal forests and shrublands MFT1.3 Coastal saltmarshes and reedbeds
Subterranean	S1 Subterranean lithic	S1.1 Aerobic caves S1.2 Endolithic systems

	S2 Anthropogenic subterranean voids	S2.1 Anthropogenic subterranean voids
Subterranean-Freshwater	SF1 Subterranean freshwaters	SF1.1 Underground streams and pools SF1.2 Groundwater ecosystems
	SF2 Anthropogenic subterranean freshwaters	SF2.1 Water pipes and subterranean canals SF2.2 Flooded mines and other voids
Subterranean-Marine	SM1 Subterranean tidal	SM1.1 Anchialine caves SM1.2 Anchialine pools SM1.1 Sea caves

Source: (D. A. Keith et al., 2020).

4 Accounting for ecosystem extent

4.1 Purpose in accounting for ecosystem extent

4.1 A common starting point for ecosystem accounting is the organization of information on the extent of different ecosystem types within a country or other ecosystem accounting area (EAA), and how that extent is changing over time. This information is summarised in an ecosystem extent account.

4.2 Accounting for ecosystem extent is relevant for four reasons. First, an ecosystem extent account provides a common basis for discussion among stakeholders of the composition (mix/combination) of, and changes in, ecosystem types within a country. Thus, an extent account supports the derivation of coherent indicators of deforestation, desertification, agricultural conversion, urbanization and other forms of ecosystem change; they support the measurement of ecosystem diversity and the derivation of indicators of changes in biodiversity; and when information underpinning an extent account is mapped, it can support an understanding of the locations and configuration of ecosystem types within an EAA and how this is changing over time (e.g., with respect to fragmentation of the landscape, or the proximity of agricultural areas to natural ecosystems).

4.3 Second, given a core intent of ecosystem accounting is to mainstream ecological data in economic planning and decision making, the organisation of data on ecosystem extent provides a straightforward but meaningful entry point to the discussion of ecosystems for those less familiar with ecological concepts and data. In particular, extent accounts provide a common framing through which other data about ecosystems can be presented. For example, maps on ecosystem condition and ecosystem service flows can be tabulated by ecosystem type to communicate a summary and integrated perspective.

4.4 Third, the structure of the ecosystem extent account, as set out below, demonstrates in an accessible and readily interpreted way, the capability of accounting to provide a time series narrative, in this case through the estimation of opening and closing balances for an accounting period. Showing a time series of change is particularly important to reveal the degree to which the extent and composition of ecosystem types has changed, and the nature of conversions between ecosystem types.

4.5 Fourth, the spatial data most commonly used to compile an ecosystem extent account provides an underlying infrastructure for the measurement of ecosystem condition and for the measurement and modelling of many ecosystem services. In both cases the relevant indicators of condition and services will commonly vary by ecosystem type and will depend on the location and configuration (spatial arrangement) of ecosystem types within an EAA.

4.2 Ecosystem extent accounts

4.2.1 Scope of extent accounts

4.6 Following the principles described in Chapter 3, an ecosystem extent account is compiled for the total area of an EAA. Thus, an ecosystem extent account records the areas and changes in areas, of all of the ecosystem assets within an EAA, classified by ecosystem type, i.e., the areas of all ecosystem assets of the same ecosystem type are aggregated. Since input data are commonly spatial data available in the form of maps, mapped outputs can be produced where all of the ecosystem assets of the same ecosystem type would be coded equivalently. Further, in this case, extent accounts are tabulated outputs from the mapped input data.

4.7 In concept, at the national level, the EAA extends to cover all terrestrial, freshwater and marine ecosystems with a boundary set by the country's border with other countries and its exclusive economic zone (EEZ).[26]

4.8 Compilers may choose to use an EAA of smaller geographical scope – for example using a focus on the terrestrial or marine realm or a focus on a sub-national region. Also, it is possible to compile accounts covering areas outside national jurisdiction, for example for oceans areas including the high seas. These may be compiled as part of regional or international accounting efforts. Complementary extent accounts for subterranean ecosystems, aquifers and linear features may also be compiled. Potential structures for these accounts are described in section 4.2.4.

4.2.2 Structure of extent accounts and accounting entries

4.9 The structure of an ecosystem extent account is shown in Table 4.1. The structure of the rows reflects the general logic of asset accounts as described in the SEEA Central Framework, with an opening extent, closing extent, and additions and reductions in extent. Entries are in terms of area using measurement units appropriate for the scale of analysis, e.g., hectares, square kilometres.

4.10 The column headings correspond to the classes of the selected ecosystem type classification. In Table 4.1, these classes are examples of ecosystem types at the EFG (level 3) of the SEEA ET reference classification based on the IUCN Global Ecosystem Typology (GET), as described in Chapter 3 and outlined in Annex 3.2.

4.11 At national or sub-national level, it will be most appropriate to compile accounts using an existing ecosystem type classification and to make a correspondence to the SEEA Ecosystem Type reference classification for the purpose of international comparison.

4.12 From an accounting perspective, there is no specific limit on the number of ecosystem types that are included or the level of detail that is included. The choice made should be dependent on relevance of different ecosystem types and data availability. The overall constraint is that the sum of the areas of all different ecosystem types must be equal to the total area of the EAA.

[26] Sub-surface ecosystems, such as subterranean ecosystems and aquifers are excluded from the primary extent account as their area cannot be added with the area of other realms without double counting

Table 4.1: Ecosystem extent account (units of area)

	Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		
Realm	Terrestrial												Freshwater			Marine			
Biome	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
Selected Ecosystem Functional Group (EFG)	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	⋮	Temperate pyric sclerophyll forests and woodlands	⋮	⋮	⋮	Derivied semi-natural pastures and old fields	Permanent upland streams	⋮	Intermittently closed and open lakes and lagoons	Seagrass meadows	⋮	Coastal saltmarshes and reedbeds	
	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	**TOTAL**
Opening extent																			
Additions to extent																			
Expansions																			
Managed expansion																			
Natural expansion																			
Reductions in extent																			
Managed regression																			
Natural regression																			
Net change in extent																			
Closing extent																			

4.13 The accounting entries encompass opening and closing extent, additions to extent and reductions in extent. The following treatments should be applied noting that, depending on data availability, it may not be possible to complete all accounting entries that distinguish the different types of additions and reductions. In this case, it is sufficient to record the opening and closing extents and the net change in different ecosystem types. This level of detail can still provide important information on trends in ecosystem extent.

4.14 Relevant accounting entries are:

- Opening and closing extent represent the total area of ecosystem assets for a given ecosystem type at the beginning and end of an accounting period, generally one year.
- Additions to extent represent increases in the area of an ecosystem type. Where possible, additions to extent should be separated into managed expansion and unmanaged expansion.
    - Managed expansion represents an increase in the area of an ecosystem type due to direct human activity. Examples include the conversion of forests into agricultural land or land reclamation work in coastal areas. Human activity may also create new areas of more natural ecosystem types, for example by the reforestation of agricultural areas.
    - Unmanaged expansion represents an increase in area of an ecosystem type resulting from natural processes, including seeding, sprouting, suckering or layering. Unmanaged expansion can be influenced by human activity, for example, the expansion of deserts due to the effects of climate change.
- Reductions to extent represent decreases in the area of an ecosystem type. Where possible reductions in extent should be separated into managed regression and natural regression.
    - Managed regression represents a decrease in the area of an ecosystem type due to direct human activity. Examples exclude deforestation and increases in urban areas.
    - Unmanaged regression represents a decrease in area of an ecosystem type associated with natural processes. Unmanaged regression can be influenced by human activity for example the loss of coral reefs due to the effects of climate change.

4.15 All additions and reductions in extent are considered ecosystem conversions and imply a change in the ecosystem type. It is not sufficient that there is a change in the condition of an ecosystem since this does not necessarily involve a change in ecosystem type. In particular, it is noted that the effects of extreme events, for example due to bushfire or hurricane, where there may be considerable loss of vegetation, soil or other ecosystem components, need not imply a change of ecosystem type. Indeed, most commonly these events will be followed by a period of regeneration and patterns of disturbance should be expected. Section 4.2.3 provides further discussion of ecosystem conversions.

4.16 The availability of updated input data or changed methods may permit a reassessment of the size of the area of different ecosystem types, for example, from new or re-interpreted satellite imagery. Where such changed data and methods are used it will likely require the revision of previous estimates to ensure a continuity of time series. Time series may also be revised when updated classifications are applied. No distinct entry for revisions is recorded in the accounts, rather the individual entries for opening and closing extent and additions and reductions are altered. For analytical and dissemination purposes, it may be appropriate to show the size of the revisions by differencing estimates from historical and revised accounts.

4.17 Generally, additions to one ecosystem type will be matched by an entry for reduction in another ecosystem type, for example an increase in agricultural land may be matched by a reduction in forest land. If there is an addition or reduction in the total area of the EAA a matching entry is not recorded.

4.18 Changes in total area of an EAA due to political factors (e.g., changes following a realignment of borders) should be recorded as upward or downward reappraisals for the relevant ecosystem types. These changes do not require revisions to past accounts although it may be of analytical interest to compile historical information pertaining to ecosystem assets within the changed boundaries.

4.19 The area of an EAA for a national jurisdiction including marine, terrestrial and freshwater realms is unlikely to change significantly from the opening to the closing stock. Hence, the total area recorded in the right-hand column of Table 4.1 will generally be the same for the opening and closing extent and hence the total additions will equal the total reductions.

4.20 However, changes at the edges of the realms and associated transition areas, particularly between the marine and terrestrial realms are likely to occur, for example through coastal erosion and aggradation and sea level rise, or through land reclamation work. The associated changes in ecosystem type will need to be accounted for.

4.21 For the ecosystem extent account presented in Table 4.1, there is no requirement that the areas recorded for each ecosystem type are contiguous. That is, the total area of, for example, Trophic savannas (T4.1), is likely to be spread out across an EAA in distinct ecosystem assets. The locations of the ecosystem types will be apparent when extent data are presented in maps.

4.2.3 Recording ecosystem conversions

4.22 The ecosystem extent account records changes in ecosystem type. These changes are collectively referred to as ecosystem conversions. ***Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services.***

4.23 Ecosystem conversions are of particular interest in understanding trends in ecosystem condition, biodiversity and flows of ecosystem services. Identification of ecosystem conversions relies on determining the time at which the opening extent is recorded, the length of the accounting period and identification of the differences between ecosystem type. These issues are discussed in this section.

4.24 Generally, the length of the accounting period is one year and this will be an appropriate reporting period to record managed expansions and regressions. Time frames for unmanaged expansions and regressions may, however, vary considerably. When there are extreme events and it is expected that the ecosystem will recover from the effects, it is appropriate to record no change in ecosystem type, i.e., the change may be considered to be part of normal patterns of disturbance. In this case, changes in patterns of disturbance (e.g., more frequent bushfires) are likely to be better represented as changes in condition.

4.25 Where changes are gradual and longer term, for example changes in coral reefs due to ocean acidification, it is also appropriate to record annual changes as changes in the condition of the ecosystem asset. However, it is possible, at some point in time, that the ecosystem is considered to have changed sufficiently in terms of its ecological structure, composition and function to be considered a different ecosystem type. This change of ecosystem type for a given ecosystem should be recorded in the accounting period in which the change took place.

4.26 Even though determining the precise time at which an ecosystem conversion takes place may be a matter of ecological uncertainty, by adopting an annual reporting approach, there will be a clear structure in place that ensures consideration of changes on a regular basis and provides a full range of options in terms of time of recording. This highlights the relevance of considering measures of ecosystem condition in understanding changes in ecosystem extent.

4.27 Due to data and resource limitations, it may not be possible to compile annual extent accounts. This outcome should not be interpreted as meaning that changes in ecosystem extent over time are necessarily slow or are insignificant on an annual basis. While this may be the case in some instances the significance of recording changes in the composition and configuration of ecosystem types in a timely fashion cannot be underestimated. It is noted as well that the increasing availability of remote sensing and similar data sets is reducing the barriers to regular compilation. These data may also support the use of benchmarking and interpolation techniques to provide up-to-date information to support policy and analysis.

4.28 A common, and broader, ambition of ecosystem extent accounting is to record differences in the composition of ecosystem types compared to a natural condition. This requires estimation over long periods of time, often dating back to points in time associated with the industrial revolution and increases in human effects on the landscape. Conceptually, the compilation of extent accounts to compare two, or more, points in time that are considerably apart is straightforward. For instance, using the same structure as shown in Table 4.1, the opening extent could be estimated for 1750 (or a similar time point) and the closing extent estimated for 2015. Other points in time might also be chosen to provide additional time point for comparison, or a series of accounting periods might be defined from 1750 to 2015 such that the progressive changes in the composition of ecosystem types is recorded. Overall, the ecosystem extent accounting approach does not limit the potential to record changes over long periods of time.

4.29 The structure of Table 4.1 allows for recording changes that are managed and unmanaged. Depending on the availability of data and policy interest, an extension to the ecosystem extent account may be developed to classify ecosystem conversions by the reasons for change. Examples of reasons include urban expansion, intensification of agriculture and afforestation.[27]

4.3 Complementary presentations of ecosystem extent data

4.3.1 Mapping ecosystem extent

4.30 Significant analytical benefits are likely to arise from presenting maps of ecosystem extent which show the configuration of ecosystem assets by different ecosystem types across an EAA. Analysis of a time series of extent maps will also enable analysis of the location of changes in ecosystem types. Mapping ecosystem extent can also reveal patterns of changing fragmentation of ecosystem assets which will not be evident when data are presented in tabular form.

4.31 Spatially detailed data on the area of ecosystem assets can also be used to derive a range of supporting indicators, some of which may be relevant in assessing the condition of ecosystems, in particular concerning characteristics related to fragmentation and connectivity of ecosystems. Example of such indicators include measures of the number occurrences of an ecosystem type (number of patches); average patch size; and edge length.

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[27] Proposals for classifying conversions are described in Weber (2011).

4.3.2 Ecosystem type change matrix

4.32 Using spatially detailed data, additional detail on the nature of ecosystem conversions may be obtained by comparing maps from two periods to compile an ecosystem type change matrix. The ecosystem type change matrix set out in Table 4.2 shows the area of different ecosystem types at the beginning of the accounting period (opening extent); the increases and decreases in this area according to the ecosystem type it was converted from (in the case of increases) or the ecosystem type it was converted to (in the case of decreases) and, finally, the area covered by different ecosystem types at the end of the accounting period (closing extent). As described above, the dates for the opening and closing extent could be recent or historical.

Table 4.2: ET change matrix (units of area)

				Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology) Closing Extent																		
Realm				Terrestrial												Freshwater			Marine			
	Biome			T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
		Selected Ecosystem Functional Group (EFG)		Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derivied semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	
				T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	**Opening**
Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology) Opening Extent — **Terrestrial**	**T1 Tropical-subtropical forests**	Tropical-subtropical lowland rainforests	T1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Tropical-subtropical dry forests and scrubs	T1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Tropical-subtropical montane rainforests	T1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Tropical heath forests	T1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	T2 Temperate-boreal forests and woodlands	Boreal and temperate high montane forests and woodlands	T2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Deciduous temperate forests	T2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		...	...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Temperate pyric sclerophyll forests and woodlands	T2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	...	...	...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		...	...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	T7	...	...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Derivied semi-natural pastures and old fields	T7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Freshwater	**F1**	Permanent upland streams	F1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	...	...	...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	FM1	Intermittently closed and open lakes and lagoons	FM1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Marine	**M1**	Seagrass meadows	M1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	...	...	...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	MFT1	Coastal saltmarshes and reedbeds	MFT1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
			Closing	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

4.3.3 Extent accounts for linear features and sub-surface ecosystems

4.33 Conceptually, most ecosystem assets have a two-dimensional (2D) footprint geometry, allowing their extent to be measured by their area. However, for some ecosystem assets this approach is less appropriate because their length far exceeds their width, such that their footprint geometry is effectively one-dimensional (1D). Typical examples are streams and smaller rivers, hedgerows and road verges. These are collectively referred to as linear features.

4.34 An extent account for linear features can be compiled by recording the length of each individual linear feature (each being an ecosystem asset). Each linear feature can also be assigned to an ecosystem type allowing aggregation by type of linear feature. This follows the same logic as for a 2D extent account (as described above) but uses length units instead of area units. The resulting 1D extent account can complement a 2D extent account, noting that the total 1D length cannot be aggregated with total 2D area due to the different dimensionality.

4.35 An example of a presentation showing this distinction is presented in Table 4.3 where (larger) rivers are shown having both area and length while smaller rivers and streams are recorded as having only length. The fact that narrow linear features have an assumed area of zero, does not disqualify them from being ecosystem assets with an associated condition or the potential to supply ecosystem services.

Table 4.3: Presentation of closing balances including both 1D and 2D ecosystem types

Ecosystem Type		**Extent**	
		Area (km2)	**Length (km)**
2D	Forest	345	
	Lakes	50	
1D	Rivers	5	50
	Streams		200
	Total	400	250

4.36 Complementary extent accounts can also be compiled for sub-surface ecosystem assets including subterranean ecosystem and aquifers. Following the classification of ecosystem types, accounts could be compiled showing the number of occurrences, the area or footprint of these ecosystems and, potentially, the volume of the ecosystems. As appropriate, these indicators of ecosystem extent may be complemented by data on ecosystem condition and ecosystem services.

4.3.4 Linking extent accounts and economic data

4.37 Across all SEEA accounts there is a general ambition to link environmental data to measures of economic activity. In the context of the ecosystem extent accounts a primary means by which this can be undertaken is by linking data on ecosystem extent by ecosystem type with data on the economic owners or managers of the underlying ecosystem assets. Data on economic owners or managers may be classified by institutional sector or by type of activity depending on the data available and the purpose of analysis. Such tables can provide information, for example, on the mix of ecosystem types that are managed by government as distinct from the household sector, or on the ecosystem types managed by the agricultural industry. An example of a table showing this cross-classification of ecosystem assets is provided in Table 4.4. It shows ecosystem types (in this case IUCN EFG classes) in the columns and types of economic units in rows for a single point in time, for example the opening of the accounting period. The classes of economic units shown here reflects a production or management perspective and thus industrial classes are prominent. An alternative set of classes reflecting economic ownership by institutional sector (e.g., non-financial corporations, financial corporations, general government, households) may also be developed. Extent data classified by economic use and ownership should be maintained as distinct data layers and cross-tabulated or mapped when required.

Table 4.4: Ecosystem extent by type of economic unit (units of area)

		Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		
	Realm	Terrestrial											Freshwater			Marine				
	Biome	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
	Selected Ecosystem Functional Group (EFG)	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	…	Temperate pyric sclerophyll forests and woodlands	…	…	…	Derivied semi-natural pastures and old fields	Permanent upland streams	…	Intermittently closed and open lakes and lagoons	Seagrass meadows	…	Coastal saltmarshes and reedbeds	**TOTAL**
		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	…	T2.6	…	…	…	T7.5	F1.1	…	FM1.3	M1.1	…	MFT1.3	
Closing extent by economic unit																				
Agriculture, forestry and fishin	ISIC A																			
Agriculture																				
Forestry																				
Fishing																				
Mining and quarrying	ISIC B																			
Manufacturing	ISIC C																			
Electricity, gas, steam and air conditioning supply	ISIC D																			
waste management and remediation activities	ISIC E																			
Services																				
Other industries																				
Government																				
Households																				
TOTAL																				

4.38 Information linking ecosystem extent to economic units can be of particular importance in the design and implementation of policy since the outcomes with respect to specific ecosystem types are likely to be highly influence by the characteristics of the owning or managing economic units. It is likely that this type of analysis is of most relevance for terrestrial ecosystems but in certain contexts, for example in relation to marine spatial planning, the types of ownership and access rights will also be of relevance.

4.39 The structural information on the links between ecosystem assets and economic units such as presented in Table 4.4 also provides the basis for creating links between economic units and data from other ecosystem accounts, in particular ecosystem services flow accounts.

5 Accounting for ecosystem condition

5.1 Introduction

5.1.1 The measurement focus in accounting for ecosystem condition

5.1 A central feature of ecosystem accounting is its organization of biophysical information on the condition of different ecosystem assets and ecosystem types within an ecosystem accounting area (EAA). Ecosystem condition accounts provide a structured approach to recording and aggregating data describing the characteristics of ecosystem assets and how they have changed.

5.2 ***Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics***. Condition is assessed with respect to ecosystem structure, function and composition which, in turn, underpin the ecological integrity of the ecosystem, and support its capacity to supply ecosystem services. Measures of ecosystem condition may reflect multiple values and may be undertaken across a range of temporal and spatial scales.

5.3 Measurement of ecosystem condition is of significant interest in supporting environmental policy and decision making, which is often focused on protecting, maintaining and restoring ecosystem condition. Comprehensive and comparable measures of ecosystem condition are therefore of direct relevance.

5.4 Ecosystem condition accounts complement environmental monitoring systems by using data from different monitoring systems, for example concerning biodiversity, water quality and soil properties. The intention of the ecosystem condition account is therefore to build upon and synthesise, rather than replace, existing monitoring systems. Further, as described in more detail in section 5.6, ecosystem condition accounts provide a means to mainstream a wide range of ecological concepts and data into economic and development planning processes, while the regular production of ecosystem condition accounts may in turn help to systematise and strengthen existing monitoring systems.

5.5 Although the recording of asset condition is not a standard output within economic accounts, measurement of, and assumptions regarding, asset condition are inherent in accounting for assets. For example, in estimating rates of deterioration in the measurement of depreciation of produced assets, generally, it is assumed that the condition of an asset is embodied in its current market price. Since ecosystem assets do not usually have a market price, explicit recording of ecosystem condition in physical terms is an important aspect of completing the accounting picture.

5.6 A primary benefit of compiling ecosystem condition accounts stems from using an approach to compiling data on different aspects of ecosystem condition that supports alignment with other data on ecosystems, for example concerning ecosystem extent and ecosystem services flows. This structured approach – based on a common understanding of the size, composition, function, location and types of ecosystem assets – offers insight into changes that is more comprehensive than that provided by individual data sets.

5.1.2 Ecological concepts underpinning the measurement of ecosystem condition

5.7 The concept of ecosystem condition used in the SEEA EA is based on long-standing ecological knowledge and is related to several other terms that are used in the scientific literature or in legislation that aims to assess and protect ecosystems (D. A. Keith et al., 2020). Although these terms may look different, the underlying concepts are overlapping, with historical differences reflecting the fact that they have been developed and used by different researcher communities for different ecosystem types.

5.8 Ecosystem condition is often defined by measuring the similarity (or the distance) of a current ecosystem to a reference state, such as minimally impacted by people or a historical state (Costanza, 1992; Palmer & Febria, 2012). Ecosystem condition can be described by combinations physical, chemical and biological indicators, an approach commonly used by water managers to assess the state of wetlands, rivers and lakes, and subsequently adapted to marine and terrestrial ecosystems. Naturalness and intactness or the opposite term hemeroby are sometimes also used to describe the distance of an ecosystem from an (undisturbed) reference. It must be recognised that humans have modified or replaced natural ecosystems over large parts of the globe and hence the measurement of ecosystem condition also needs to be suitable for semi-natural and anthropogenic ecosystems.

5.9 In ecology, the description of ecosystem condition is strongly rooted in the concept of ecosystem integrity, which implies an unimpaired condition of being complete or undivided (Karr, 1993). Ecosystem integrity is defined as the ecosystem's capacity to maintain it characteristic composition, structure, functioning and self-organisation over time within a natural range of variability (Pimentel & Edwards, 2000). Ecosystems with high integrity or condition are typically more resilient – able to recover from disturbances or to adapt to environmental changes (Holling, 1973).

5.10 Not all ecosystems, regardless of their condition, are equally resilient. Coastal zones or estuaries for instance are often exposed to a highly dynamic environment and they have evolved to be able to absorb or recover from disturbances. In contrast, fragile ecosystems that often exist under extreme resource limitations in terms of water, nutrients or temperature, for example sphagnum bogs or alpine herb fields can be in a good condition but have a low level of resilience as they may quickly collapse into a degraded state even under light pressure.

5.11 Biodiversity (the diversity within and between species and of ecosystems) is integral in measuring ecosystem condition, contributing to the composition, structure and function of ecosystems. For example, commonly used biodiversity metrics such as species abundance, species richness or species-based indices are often used measure aspects of ecosystem condition, in particular composition (Rendon et al., 2019). Functional diversity of species support to ecosystem function (Cadotte et al., 2011), while fine scale diversity of ecological communities contributes to biodiversity within an ecosystem.

5.12 Ecosystem condition and ecosystem services are linked, but the relationship varies between different services, and often is not linear. For many services, ecosystems in better condition can support a greater quantity and quality of the relevant ecosystem services (see Smith et al. (2017) for a meta-analysis), providing an argument for sustainable ecosystem management. The relationship between ecosystem condition and service provision is central to the concept of ecosystem capacity (see chapter 6).

5.13 These related concepts provide a strong scientific and statistical foundation for the SEEA EA to define ecosystem condition and to propose practical methods for implementation of ecosystem condition accounts. The variables and indicators used to describe ecosystem condition, ecosystem health, and ecosystem integrity are largely the same. A key aspect of these concepts is that they encompass consideration of both ecosystem conservation and the sustainable use of ecosystem services by humans.

5.1.3 General approach to compiling ecosystem condition accounts

5.14 In ecosystem accounting, the condition of an ecosystem asset is interpreted as the ensemble of multiple relevant ecosystem characteristics, which are measured by sets of variables and indicators that in turn are used to compile the accounts. Variables and indicators are selected in relation to the context and purpose of assessment, and different considerations will be relevant across natural and anthropogenic ecosystems. Individual indicators can be aggregated to composite indices that provide a synthesis of the integrity, health or naturalness of an ecosystem asset.

5.15 Ecosystem condition accounts record data on the state and functioning of ecosystem assets within an EAA using a combination of relevant variables and indicators. The selected variables and indicators reflect changes over time in the key characteristics of each ecosystem asset. Ecosystem condition accounts are compiled in biophysical terms and the accounting structure provides the basis for organizing the data, aggregating across ecosystem assets of the same ecosystem type, and measuring change over time between the opening and closing points of accounting periods.

5.16 A three-stage approach is described in the SEEA EA to account for ecosystem condition as described through sections 5.2, 5.3 and 5.4. Outputs at each stage are relevant for policy and decision making. It is intended that these three stages in the compilation of ecosystem condition accounts are used in an integrated way. The move from one stage to another requires a progressive building of data and the use of additional assumptions.[28]

5.17 Outputs from stages one and two comprise the ecosystem condition accounts, and correspond to the presentation of data on condition variables and condition indicators. Overall measures of ecosystem condition for multiple ecosystem types and multiple indicators can be undertaken in the (optional) third stage through the derivation of composite indices and applying appropriate aggregation approaches.

5.18 The precise structure of ecosystem condition accounts will depend on the selected characteristics, data availability, uses of the accounts and policy applications. Ecosystem condition accounts are commonly compiled by ecosystem type because each type has distinct characteristics. For example, the characteristics of forests may include tree density and age, while for rivers, characteristics concerning water quality will be relevant. However, some characteristics may be common across a number of ecosystem types, for example species richness or functional diversity will be relevant across all ecosystems, and other characteristics will be relevant to a combination of ecosystem types within a landscape,[29] for example the diversity among different ecosystem types.

5.19 The approach to accounting for ecosystem condition is spatially explicit and builds, conceptually, from the level of ecosystem assets. Aggregate measures, for example for an ecosystem type within an EAA, will therefore reflect a measure of the average condition of the constituent ecosystem assets. This will be appropriate for a range of policy and analytical contexts. However, particularly with respect to aggregate measures of biodiversity, it will be necessary to incorporate data about characteristics that are not attributable to individual ecosystem assets. For example, information on the total number of species across an EAA (a measure of gamma diversity), should be incorporated in an aggregate measure of biodiversity

[28] The approach described to accounting for ecosystem condition reflects the body of research summarised in Keith H. et al (2020).

[29] A landscape or seascape (including those involving freshwater) is defined for accounting purposes as a group of contiguous, interconnected ecosystem assets representing a range of different ecosystem types. The term landscape is commonly applied to cover this concept irrespective of the ecological realms that are the focus of measurement.

for an EAA. These issues are described further later in this chapter and also in Chapter 13 in the context of accounting for biodiversity.

5.2 Defining and selecting characteristics and variables of ecosystem condition

5.2.1 Introduction

5.20 The first stage in measuring ecosystem condition involves setting the measurement focus and defining and selecting ecosystem characteristics and associated variables. This stage is important in underpinning the compilation of the second stage with ecosystem condition indicators and the third stage of deriving aggregate measures of condition across multiple ecosystem types.

5.21 The primary spatial units are ecosystem assets and these are expected to be delineated such that they are reasonably homogeneous in terms of their main characteristics (see Chapter 3), a feature that will flow on to their condition too. Ideally, and subject to data availability, it is recommended that the condition variables are recorded for each ecosystem asset to ensure full reliability and transparency of the ecosystem condition accounts. Where data are available, measures of ecosystem condition may be mapped to highlight variation in condition across ecosystem assets.

5.22 Conceptually, it is possible to compile accounting tables for an individual ecosystem asset, such as a single forest, wetland or farming area. Nevertheless, the measurement objective of the SEEA EA is to provide information about the changes in ecosystem-related stocks and flows in relatively large and diverse areas, so there is no expectation that all individual assets should be represented in a tabular form in the accounts.

5.23 The accounts shown here include entries for opening and closing condition, i.e., pertaining to observations on the state of the ecosystem at the beginning and end of an accounting period. If required, accounts can incorporate entries to show a more complete time series although in this case alternative configurations for the account tables will likely be required. Ecosystem condition accounts should also present important pieces of additional information (e.g., concerning measurement units and reference levels) that clearly document the flow of information from raw data to high level indices.

5.24 Further, for clarity of presentation, the accounts shown here include entries only for a single ecosystem type. Extensions of the accounting structure to include additional ecosystem types, (or the compilation of separate accounts for each ecosystem type) should follow the same broad structure for each ecosystem type, accepting the need to record different variables and indicators.

5.2.2 Ecosystem condition characteristics

5.25 ***Ecosystem characteristics are the system properties of the ecosystem and its major abiotic and biotic components (water, soil, topography, vegetation, biomass, habitat and species) with examples of characteristics including vegetation type, water quality and soil type.*** The term ecosystem characteristics is intended to encompass all of the perspectives taken to describe the long term, 'typical behaviour' of an ecosystem. Characteristics include the attributes of an ecosystem asset (incl. components, structure, processes, and functionality), recurrent interactions among ecosystem assets, as well as recurrent interactions between ecosystem assets and human society. Ecosystem characteristics may be stable in nature, such as soil type or topography, or dynamic and changing as a result of both natural processes and human activity, such as water quality and species abundance.

5.26 ***Ecosystem condition characteristics are those ecosystem characteristics that are relevant for the assessment of ecosystem condition.*** Ecosystems have many characteristics, and there is no way to integrate all of them into condition accounts. Appropriate selection of the relevant characteristics is discussed together with the selection of ecosystem variables in section 5.2.4. Generally, the focus in assessing condition will be on characteristics that can show a directional change over consecutive accounting periods in a scientifically sound way. However, data on stable characteristics should still also be collected. They are of direct relevance in the delineation of ecosystem assets and the modelling of flows of ecosystem services. Generically, these types of data are referred to as ancillary data and encompass data that are used in the compilation of accounts but may not be directly reported in ecosystem accounts. Beyond stable ecosystem characteristics, ancillary data includes data on population and demographics, emissions of pollutants, types of natural resource management and expenditure on ecosystem restoration (Czúcz et al., 2020).

5.2.3 Ecosystem condition typology

5.27 ***The SEEA ecosystem condition typology (ECT) is a hierarchical typology for organizing data on ecosystem condition characteristics.*** By describing a meaningful ordering and coverage of characteristics, it can be used as a template for variable and indicator selection and provide a structure for aggregation. The ECT also establishes a common language to support increased comparability among different ecosystem condition studies.

5.28 Ecosystems and their characteristics are highly complex, and hence the ECT provides a balance that meets the requirements for statistical purposes and is ecologically meaningful in terms of ecosystem structure, function and composition. Since different ecosystem types have different characteristics, which in turn should be described by different variables and indicators, the ECT is designed to be universal, i.e., it is expected to be relevant for all major ecosystem types, while also supporting the incorporation of ecosystem-specific metrics at lower levels. Section 5.5.2 provides an indicative set of ecosystem condition variables for major ecosystem types structured according to the ECT. More detail about each ECT class, and their relationships to other relevant classification systems is given by Czúcz et al. (2020).

5.29 The SEEA ECT has six classes as listed in Table 5.1. This classification can be applied for ecosystem characteristics, as well as for ecosystem condition variables and indicators, for which it is used to create a reporting and aggregation structure. The classification derives a set of ecosystem condition groups and classes with the common aim of being exhaustive and mutually exclusive (each metric can only be assigned to one class). It must be recognized that composition, structure, and particularly function are extremely broad concepts, interpreted in different ways by the different researcher communities. To avoid ambiguities, and to ensure the *mutual exclusivity* of the classes, the following interpretations for each class should be applied.

5.30 The class **physical state characteristics** (A1) includes the physical descriptors of the abiotic components of the ecosystem (soil, water, air). Physical stocks (e.g., water table level, impervious surfaces) that may be subjected to degradation due to human pressures are relevant choices, as they are sensitive to change, and relevant for policy interpretation.

5.31 The class **chemical state characteristics** (A2) includes descriptors of the chemical composition of the abiotic ecosystem components. This typically involves a focus on the accumulated stocks of pollutants or nutrients in soil, water, or air. Similar to *physical state characteristics*, indicators should describe the state ("stocks" of pollutants) rather than the flows (emission of pollutants), i.e., the stock variables should be sensitive to the changes in the flows.

Table 5.1: The SEEA Ecosystem Condition Typology (SEEA ECT)

SEEA ECT groups and classes
Group A: Abiotic ecosystem characteristics
Class A1. Physical state characteristics: physical descriptors of the abiotic components of the ecosystem (e.g., soil structure, water availability)
Class A2. Chemical state characteristics: chemical composition of abiotic ecosystem compartments (e.g., soil nutrient levels, water quality, air pollutant concentrations)
Group B: Biotic ecosystem characteristics
Class B1. Compositional state characteristics: composition / diversity of ecological communities at a given location and time (e.g., presence / abundance of key species, diversity of relevant species groups)
Class B2. Structural state characteristics: aggregate properties (e.g., mass, density) of the whole ecosystem or its main biotic components (e.g., total biomass, canopy coverage, annual maximum NDVI)
Class B3. Functional state characteristics: summary statistics (e.g., frequency, intensity) of the biological, chemical, and physical interactions between the main ecosystem compartments (e.g., primary productivity, community age, disturbance frequency)
Group C: Landscape level characteristics
Class C1. Landscape and seascape characteristics: metrics describing mosaics of ecosystem types at coarse (landscape, seascape) spatial scales (e.g., landscape diversity, connectivity, fragmentation)

5.32 The class **compositional state characteristics** (B1) includes a broad range of 'typical' biodiversity characteristics which describe the composition of ecological communities from a biotic perspective. This includes characteristics such as the presence / abundance of a species or taxonomic group, or the diversity of specific groups at a given location and time. From a location-based perspective (required by spatial consistency), the distribution of a species also reflects species composition (local presence). Compositional characteristics can thus concern the presence / absence or abundance individual species, taxonomic groups (birds, butterflies, provenance of a species), or non-taxonomic guilds (e.g., soil invertebrates, macro-zoobenthos). Characteristics that concern specific functional groups (e.g., pollinators, nitrogen fixers, predators, decomposers, etc.) should be considered as *functional state characteristics*. Abundance characteristics of very large guilds (e.g., trees, phytoplankton) comprising entire ecosystem compartments should be considered as *structural state characteristics* (biomass, vegetation).[30]

5.33 The class **structural state characteristics** (B2) includes characteristics primarily focused at the vegetation and biomass of ecosystems that describe the local amount of living and dead plant matter (vegetation, biomass). This class includes all characteristics concerning vegetation density and cover, either related to the whole ecosystem, or just specific compartments (e.g., canopy layer, belowground biomass, litter). For marine and freshwater ecosystems this class can include phytoplankton abundance, or plant biomass (e.g., seagrasses). There is some

[30] Note that in using biodiversity characteristic to describe the composition of an ecosystem asset, it should not be inferred that this is sufficient information to describe completely the composition of a species which will require additional information concerning the links between the species and wider spatial scales.

overlap between *compositional* and *structural* state characteristics, particularly for foundation-species-based ecosystems such as mangroves, or where species groups and vegetation compartments coincide (trees on savanna, lichens on mountain rocks). Where overlap occurs, such cases should be registered in this class (structural).

5.34 The class functional state characteristics (B3) includes characteristics about relevant ecosystem processes (e.g., frequency, intensity) which are not already covered by other indicators. Also, characteristics that concern specific functional groups (e.g., pollinators, nitrogen fixers, predators, decomposers, etc.) should be included here. Ecosystem functions is a hugely diverse umbrella concept, which is used in different ways by the various research communities (Pettorelli et al., 2018). Many of the characteristics that can be seen as 'ecosystem functions' can also be seen as a compositional (e.g., species abundances), structural (e.g., plant biomass), or abiotic state descriptors (e.g., surface albedo) It is good practice to avoid placing functional characteristics into this class if they can be readily included in another class.

5.35 The class **landscape and seascape characteristics** (C1) includes characteristics of ecosystem assets that are quantifiable at larger (landscape, seascape) spatial scale but that have an influence on the local condition of ecosystems. Examples include metrics that quantify how an ecosystem asset is connected to other ecosystem assets of the same type. Metrics of connectivity / fragmentation measure important landscape and seascape characteristics from the perspective of a specific ecosystem type (or group of ecosystem types), for example the fragmentation of a river system by dams. Landscape and seascape connectivity can be interpreted and measured very differently in terrestrial, freshwater, and marine biomes. Furthermore, in the case of ecosystem types which themselves are 'mosaics' of relevant subtypes (e.g., a cropland with nested semi-natural vegetation fragments), the abundance or the spatial pattern (connectivity) of these subtypes can also be hosted under this class.

5.36 Chapters 3 and 4 highlighted the important distinction between ecosystem types whose ecosystem processes are primarily naturally driven and those ecosystem types that are more directly influenced by human activity and management. This distinction is also important in the measurement of ecosystem condition. The ECT will apply to all ecosystem types but it is noted that there is likely more similarity in the characteristics selected for natural and semi-natural ecosystem types compared to those selected for anthropogenic ecosystem types.

5.2.4 Ecosystem condition variables and their selection

5.37 ***Ecosystem condition variables are quantitative metrics describing individual characteristics of an ecosystem asset.*** A single characteristic can have several associated variables, which may be complementary or overlapping. Variables differ from characteristics (even if the same descriptor is applied to them) as they have a clear and unambiguous definition (measurement instructions, formulae, etc.) and well-defined measurement units that indicate the quantity or quality they measure. Examples of variables are the number of bird species, tree coverage (%) and turbidity (nephelometric turbidity unit, NTU).

5.38 Generally, selection of variables should prioritise those that reflect a role in ecosystem processes, and hence contribute to whole-ecosystem functioning, and their risk of change (Mace, 2019). Environmental variables should reflect stocks rather than the connected flows, which are often more obvious and observed as pressures or degradation processes. Examples of variables as stocks that are appropriate as measured variables include the thickness of the soil layer, concentration of pollutants, or abundance of invasive species. These may be considered as renewable or degradable stocks. Variables selected to reflect ecological processes can include the presence, abundance, or diversity of species with specific biological attributes that reflect interactions within the ecosystem. Functional classifications of species based on sets of traits, described in terms of their response to environmental factors, provide useful metrics of biodiversity and the relationship with ecosystem integrity (Cernansky, 2017; Lavorel et al., 1997). Examples of functional variables include fruit-eating species that disperse seeds, nectar-eating species that pollinate, decomposer organisms, and canopy emergent species that provide habitat for epiphytes.

5.39 Variables used to measure ecosystem condition are those that are likely to change because of human interventions. However, many ecological processes and their responses to human or environmental impacts are complex, and hence response functions of variables may be non-linear. For example, plant growth increases with temperature until the temperatures are too high. These can be reflected in curvilinear, bimodal or multimodal functions. The form of these responses can be quantified and interpreted based on understanding of the ecological processes.

5.40 Selection criteria should be used to guide the selection of variables. Variables that are superior with respect to the selection criteria, for example that are more sensitive to change, should be preferred for inclusion within an ecosystem condition account. The criteria listed in Table 5.2 provide a basis for selection. The first 10 criteria are decisive as to whether a specific variable (and/or the underlying characteristic) is eligible for inclusion in the ecosystem condition accounts. The last two criteria ensure that the set of variables represents the state of the ecosystem in a meaningful way.

5.41 Altogether, condition accounts should cover as much relevant ecological information as possible, but parsimoniously, using as few variables as possible. It is not expected that the measurement of condition would require the inclusion of a vast number of characteristics and variables. From an ecosystem accounting perspective, the aim is to provide a broad indication of the change in condition rather than to fully map the functions of every ecosystem asset.

5.42 The most appropriate breadth and detail of variables selected to characterize ecosystem condition is difficult to standardize given the range of ecosystem types and differences across countries. The ECT, together with their criteria for selection, supports adoption of a pragmatic and structured approach that can be applied in all circumstances and can encompass measurement at a range of scales. Ideally, the compilation of ecosystem condition accounts should ensure that for each ecosystem type, at least one variable is selected for each of the six ECT classes. This rule of thumb aims to ensure a minimum level of comprehensiveness in the full set of condition variables.

5.43 Based on evaluation of examples of existing ecosystem condition accounts, a set of around six to ten indicators for a given ecosystem type generally should provide sufficient information to assess the overall condition of an ecosystem asset, provided they are well selected. In practice, it is important to incorporate knowledge of local ecosystems. The selection of variables and metrics should be based on existing ecological knowledge and monitoring systems, with ecologists directly involved in the selection process.

Table 5.2: Selection criteria for ecosystem characteristics and their metrics (variables and indicators)[31]

Criterion	Short description
Conceptual criteria	
Intrinsic relevance	characteristics and metrics should reflect the existing scientific understanding of ecosystem integrity, supported by the ecological literature.
Instrumental relevance	characteristics and metrics should be related to the availability of ecosystem services (characteristics that exert the strongest influence on the highest priority services should be favoured)
Sensitivity to human influence	characteristics and metrics should be responsive to known socio-ecological leverage points (key pressures, management options)
Framework conformity	characteristics and metrics should be differentiated from other components of the SEEA ecosystem accounting framework
Feasibility criteria	
Scientific reliability	metrics need to give a scientifically valid representation of the characteristics they address
Spatio-temporal reference	metrics need to cover the studied spatial and temporal extents with the required resolution
Cost effectiveness	metrics need to be achievable in terms of the resources and time available
Directional meaning	metrics need to have a potential for a consensual interpretation, i.e., it should be clear if a change is favourable or unfavourable with respect to ecological integrity
Optimization criteria	
Simplicity	metrics should be as simple as possible
Compatibility	the same characteristics should be measured with the same (compatible) metrics in the different ecosystem types and/or different ecosystem accounting areas (countries)
Ensemble criteria (for the whole set of variables and indicators)	
Comprehensiveness	the final set of metrics, as a whole, should cover all of the relevant characteristics of the ecosystem, providing a complementary set of measures
Parsimony	the final set of ecosystem condition metrics should be free of redundant (correlated) variables

5.2.5 Ecosystem condition variable account

5.44 The ecosystem condition variable account is shown in Table 5.3 where opening and closing entries are recorded for selected variables for an ecosystem type. The variables are grouped based on the ECT.

5.45 The initial focus on variables provides a structured system for recording data on ecosystem condition. In particular, the use of standard classes of ecosystem types allows clear

[31] A detailed discussion of selection criteria is presented in Czúcz et al. (n.d.).

connections to be drawn to measures of ecosystem extent and flows of ecosystem services that are organised using the same classes.

5.46 Particular emphasis should be placed on definition and documentation of the variables and metrics included in the account since it is common for a single descriptor to be used for related but different variables. The documentation should contain enough information for scientific reproducibility, they should be unambiguously linked to the short names used in the variable and indicator accounts and they should be able to be communicated effectively to users of the accounts.

5.47 Data in ecosystem condition variable accounts can provide useful information about the state of an ecosystem and its change over time. For example, measurement of soil pH is a variable that is sensitive to change due to human land management and monitoring this change, irrespective of a reference level, is useful to report in a condition account to demonstrate changes in soil properties due to human impacts or changing environmental factors.

5.48 The recording of variables in this account reflects an explicitly neutral approach since each entry is not compared to a baseline and there is no implied judgement of relative importance, for example interpreting an entry in the account as being high, medium or low. Since there is no information incorporated in the account to interpret the data, the use of the data in this account should focus on monitoring and reporting change in variables over time. Thus, the information will support the preparation of indicators that describe changes in ecosystem condition.

5.49 In an EAA, for each ecosystem type there are usually a large number of ecosystem assets. Each asset can have different values for the variables describing condition. This spatial variation is caused by spatially explicit patterns of pressures on ecosystems, ecosystem management, or characteristics that shape ecosystems such as slope and elevation. To take the spatial explicit character of ecosystem condition into account, the values recorded in an ecosystem condition variable account should be calculated as the area weighted arithmetic mean of ecosystem assets belonging to the particular ecosystem type within the EAA. Other statistical moments (e.g., variance, median, minimum, maximum values, or the number or area of ecosystem assets with a value above a certain threshold) can also be recorded if considered useful. Area weighted averaging results in a condition account that describes the average condition of an ecosystem type within an EAA. It follows that if the condition of one or more assets changes between accounting periods, the average condition of the ecosystem type will also change.

5.50 Care should be taken when variables are added directly to the condition account at the ET or EAA level since they do not necessarily capture the average condition of an ecosystem type derived from the variation over the ecosystem assets. An example is the total number of species observed in an ecosystem type within an EAA (also known as gamma diversity). While species richness of an EAA is an important variable in understanding the state of biodiversity, it might be less appropriate to quantify the ecosystem condition of a specific ecosystem type. Thus, where species richness is used as ecosystem condition variable, it is more appropriate to measure local species richness of different ecosystem assets and report the average species richness in the compilation of a condition account.

5.51 In practice, many data are available at aggregated level for EAA, for instance data based on the range or distribution of species or globally used indices such a Living Planet Index or the Ocean Health Index. These data may appear to lend themselves to being directly included in an ecosystem condition account as they don't need area weighted averaging from individual ecosystem assets. However, since they are likely compiled using a different approach and at a different spatial scale than variables that are based on measurements pertaining to individual assets, ideally they should not be included in the condition account, in particular if the origin of the data is unknown. Data that report biodiversity at a spatial scale of the EAA such as beta and gamma diversity are preferably reported in species or biodiversity accounts.

Table 5.3: Ecosystem condition variable account

SEEA Ecosystem Condition Typology Class	Variables		Ecosystem type		
	Descriptor	Measurement unit	Opening value	Closing value	Change
Physical state	Variable 1	ml/g	0.4	0.25	0.15
	Variable 2	% area	10	30	20
Chemical state	Variable 3	g/g	0.05	0.04	0.01
Compositional state	Variable 4	no. species	85	80	5
	Variable 5	presence	1	0	1
Structural state	Variable 6	t/ha	110	65	45
Functional state	Variable 7	t/ha/yr	15	10	5
Landscape/waterscape characteristics	Variable 8	% area	50	20	30

5.3 Ecosystem condition indicators

5.3.1 Deriving ecosystem condition indicators from variables

5.52 ***Ecosystem condition indicators are rescaled versions of ecosystem condition variables***. They are derived when condition variables are set against reference levels determined with respect to ecological integrity. Two steps are involved. First, data values for each variable are transformed to a common dimensionless scale, with the two endpoints (or a range along) the scale representing a top value (1 or 100%) and a bottom value (0 or 0%) for that variable.

5.53 Second, the transformed data are converted to ecosystem indicators. The simplest conversion uses two reference levels to reflect a high or low condition score. In this case, the indicator is calculated by a linear transformation shown in the formula below. It is important to note that while in some cases the top values for a variable will also reflect a high condition score, the opposite is also possible, i.e., bottom values for a variable will reflect a high condition score.

$$I = (V - V_L) / (V_H - V_L)$$

where I is the value of the indicator, V is the value of the variable, V_H is the high condition score and V_L is the low condition score.

5.54 Other types of rescaling functions can be used but may not be appropriate for all metrics, such as those including both positive and negative numbers, and hence should be clearly documented and justified. Values of variables should be transformed such that the upper reference level is higher than the lower one to ensure that the direction of the scale for indicators is consistent. For example, the high reference level of a pollutant may equate to a variable value of 0 since this represents a high level of condition. This way of rescaling ensures that higher indicator values are always associated with a higher condition, even if the scale of the original variable was the opposite. Rarely, there might be cases when the value of the variable is out of the range of the two reference levels, for example above the high reference level. In these cases, it is recommended that the values of the indicator be truncated at 0 (0%) or 1 (100%) (Paracchini et al., 2011).

5.55 Applying a reference level, converts that variable from being a measure of trends in ecosystem characteristics to an assessment of ecosystem condition in relation to a reference. Such normalization adds value in the interpretation of trends and is also required by any later aggregation steps, which need commensurate metrics measured on the same scale using common units (Nardo et al., 2005).

5.56 A set of indicators for a condition account can include some common or global indicators in addition to indicators specific to an ecosystem type. Examples of indicators are presented in Section 5.5.1.

5.3.2 Reference levels

5.57 ***A reference level is the value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable.*** The difference between the value of a variable and its reference level represents the distance from the reference condition. Following the steps outlined above, the value of the reference level is used to re-scale a variable to derive an individual condition indicator. Reference levels are defined in a structured and consistent manner across different variables within an ecosystem type, and for the same variable across different ecosystem types. This ensures that the derived indicators are compatible and comparable, and that their aggregation is ecologically meaningful.

5.58 Reference levels are usually set with high and low levels reflecting the limits or endpoints of the range of a condition variable that can be used in re-scaling. For example, the high level may refer to a natural state and the low level may refer to a degraded state where ecosystem processes are below a threshold for maintaining function (such as ecosystem collapse; (D. A. Keith et al., 2013)). One of the reference levels can often be replaced by the natural zero value of the variable, for example zero abundance (local extinction) for a species, or the lack of a specific pollutant. Reference levels applied to the same variables are likely to differ for different ecosystem types. For example, using the normalized difference vegetation index (NDVI) to measure the variable of biomass quantity will require different reference levels for forest, savannah and grassland ecosystems.

5.59 Different reference levels can be set depending on the purpose of an individual indicator. As a result, different indicators may be derived from the same variable within the same ecosystem. For the measurement of ecosystem condition in the SEEA EA, the purpose is to measure ecological integrity and for this purpose the reference level should be established in relation to a common reference condition as described below.

5.60 Individual reference levels can be assigned using different types of information, including absolute values of the measurement, data from sites in a reference condition, models of ecosystem dynamics or species populations, expert assessment, and maximum potential quality for the ecosystem type.

5.3.3 Reference condition

5.61 ***A reference condition is the condition against which past, present and future ecosystem condition is compared to in order to measure relative change over time.*** It represents the condition of an ecosystem that is used for setting the high level (or one endpoint) of reference levels of the variables that reflect high ecological integrity. The reference condition corresponds to a state where all condition indicators have a value of 1 (100%). The best way to ensure the consistency of reference levels for different variables describing the same ecosystem asset is to start from a single reference condition. Using the concept of reference condition, the condition of an ecosystem asset is measured in terms of the distance of its current condition to its reference condition.

5.62 For ecosystem accounting purposes, the reference condition is based on the principle of maintaining ecological integrity, stability and resilience (over ecological timeframes).[32] In many ecosystem types, it refers best to the natural state of intact native/natural ecosystems, in terms of ecosystem characteristics at their natural condition allowing for dynamic ranges. The metrics of condition represent the distance from natural irrespective of the characteristic, ecosystem type, or potential desired outcome from a human perspective. The reference condition of an ecosystem corresponds to the condition where the structure, composition and function are dominated by natural ecological and evolutionary processes including food chains, species populations, nutrient and hydrological cycles, self-regeneration and involving dynamic equilibria in response to natural disturbance regimes. An ecosystem at a natural reference condition exhibits an absence of major human modification. An ecosystem at its reference condition attains maximum ecological integrity (Gibbons et al., 2008; Mackey et al., 2015; Palmer & Febria, 2012).

5.63 Using the natural state as the reference condition allows recognition of the characteristics of the natural state and change from the natural state to be reflected in ecosystem accounts. The natural state may not be related to supply of ecosystem services and may not be the target of current legislation, policy or ecosystem management objectives. However, measuring condition relative to the natural state provides an important means of understanding the degree of ecosystem change that has taken place, as well as supporting the assessment of many environmental policies and associated objectives concerning conservation values.

5.64 Using the natural state as the reference condition is preferred and recommended. However, in many cases, it may not be possible to define a reference condition as 'natural' in absolute terms, since the environment may have changed due to both human and natural processes. In cases where a natural state does not represent a meaningful reference for condition accounts, particularly for anthropogenic ecosystems such as agricultural and urban ecosystems, alternative reference conditions, still characterised by integrity, stability and resilience, can be established and considered as anthropogenically-derived reference conditions.

5.65 Based on a common principle for defining reference conditions, a range of methodological options may be used in practice for establishing reference conditions given the differences in ecosystem types, disturbance regimes and data availability. Annex 5.1 summarises the possible approaches. Reference conditions, and their associated reference levels, can be difficult to determine appropriately and explicitly, and describing the rationale for their selection and their links to the purpose of the accounts is important.

5.66 In setting reference conditions, since both the timespan and extent of human influence has varied in different parts of the world, assigning a date in time as the reference condition is problematic. For example, variation has occurred in the time of human settlement, development of agriculture, hunting, domestication of livestock, use of fire to influence

[32] Many related meanings have been assigned to reference condition for different purposes related to varying levels of human disturbance, where each refer to specific types of assessments. It is preferable that the range of specific meanings and methods should be described by their specific terms, for example, minimally disturbed condition, historic condition, least disturbed condition, best attainable condition (Stoddard et al., 2006). These specific meanings of condition incorporate implicit differences in assumptions and methods of assessment, and hence differences in classification and interpretation in the comparison of condition indices. Hence, they should not be confused with the term reserved for reference condition related to ecological integrity (Stoddard et al., 2006).

vegetation structure and composition, major land clearing and intensive production. More generally, using inconsistent reference conditions across ecosystem types will prevent meaningful comparisons, and individual years may be subject to considerable variability and inconsistency due to ecosystem dynamics.

5.67 Developing reference conditions to assess changes in ecosystem condition is important to support international conventions. The selection of a reference condition should be applied as consistently as possible across the different realms (terrestrial, freshwater, subterranean and marine), biomes and ecosystem functional groups. Globally agreed reference conditions are useful to support global comparisons, for instance to evaluate individual country commitments towards ecosystem maintenance and restoration (see (H. Keith et al., n.d.) for examples). However, some of these reference conditions may incorporate aspects concerning policy targets and hence may not fully reflect the conceptual basis for a reference condition for ecosystem accounting.

5.3.4 Ecosystem condition indicator account

5.68 The ecosystem condition indicator account (Table 5.4) builds directly on the ecosystem condition variable account (Table 5.3) by relating each variable to a reference level. The variable is rescaled (transformed) to a uniform dimensionless scale [0, 1] using the reference level. The data in the indicator account allows descriptions of trends in condition to be interpreted relative to an agreed reference level based on ecological integrity. This allows for statements concerning whether, for a given variable, ecosystem condition can be considered high (close to the reference level) or low (distant from the reference level). The indicator account can be used to monitor and report change in values over time.

5.69 Among the set of ecosystem accounts, the ecosystem condition indicator account is a key output. In a structured way it organises key ecological data in a manner that allows comprehensive reporting on the ecological integrity of the ecosystems within an ecosystem accounting area across a range of ecosystem characteristics. Regular reporting of an ecosystem condition indicator account is intended to support an extensive, and ecologically informed, discussion of both the effectiveness of strategies aimed at improving ecosystem condition and the changing capacity of ecosystems to supply ecosystem services.

5.70 Further, the data from the ecosystem condition indicator account will underpin the derivation of composite indices of ecosystem condition. Such indices may be of considerable power in conveying general messages around changes in ecosystem condition. A number of different aggregations of indicators from a single ecosystem condition indicator account are possible following different approaches to aggregation. These approaches and relevant assumptions are discussed in section 5.4. Irrespective of the approach to aggregation that is applied, it remains appropriate to compile an ecosystem condition indicator account such that the summary messages in the composite indices can be appropriately interpreted and understood.

Table 5.4: Ecosystem condition indicator account

SEEA Ecosystem Condition Typology Class	Indicators	Ecosystem type					
		Variable values		Reference level values		Indicator values (rescaled)	
	Descriptor	Opening value	Closing value	Upper level (eg natural)	Lower level (eg collapse)	Opening value	Closing value
Physical state	Indicator 1	0.4	0.25	0.7	0.1	0.5	0.25
	Indicator 2	10	30	0	100	0.9	0.7
Chemical state	Indicator 3	0.05	0.04	0.08	0	0.625	0.5
Compositional state	Indicator 4	85	80	90	0	0.94	0.89
	Indicator 5	1	0	1	0	1	0
Structural state	Indicator 6	110	65	200	20	0.5	0.25
Functional state	Indicator 7	15	10	15	0	1	0.66
Landscape/waterscape characteristics	Indicator 8	50	20	100	0	0.5	0.2

5.4 Aggregate measures of ecosystem condition

5.4.1 Ecosystem condition indices

5.71 Where there is interest is reporting on ecosystem condition at higher levels of aggregation than presented in the ecosystem condition indicator account, the derivation of aggregate ecosystem condition indices is possible. The aggregation of ecosystem condition indicators aims to generate summarized information from a large number of data points. A hierarchical approach to aggregation reflects the structure of the typology of the indicator classification, with first aggregated sub-indices from the indicators, and then an aggregated index from the sub-indices. Hierarchical aggregation schemes should also contain a description about how missing indicators or sub-indices are handled. The hierarchical structure means that indices should be scalable across spatial resolutions.

5.72 ***Ecosystem condition indices and sub-indices are composite indicators that are aggregated from the combination of individual ecosystem condition indicators recorded in the ecosystem condition indicator account.*** The aggregation process is underpinned by using compatible reference levels through a common reference condition. Thus, component indicators are scaled according to their reference levels, normalised to a common scale and direction of change, and combined to form a composite index. The use of a typology for indicators and an appropriate aggregation scheme allow derivation of various sub-indices and overall condition indices. General guidance on the derivation of these measures can be found in, for example, (Andreasen et al., 2001; Buckland et al., 2005; Burgass et al., 2017; OECD, 2008; Van Strien et al., 2012).

5.73 The structure of ecosystem condition accounting described in this chapter allows for aggregation in several ways. For example, aggregation is possible across indicators within the same ECT class, across classes of characteristics in the ecosystem condition typology, or across ecosystem types. Sub-indices derived through aggregation can relate to specific typology classes (e.g., structural state of forests) or ecosystem types (e.g., an ecosystem condition index for forests).

5.74 An example is creation of an overall ecosystem condition index where the aggregation can take the form of a condition index applied to each ecosystem type, weighted by area of the ecosystem type within the ecosystem accounting area, then summed for all ecosystem types in the area to derive an overall ecosystem condition index (Brink, 2007; Czúcz et al., 2012). This makes it possible to express the average condition of the ecosystem assets.

5.75 Aggregation requires expert opinion in selecting groups of indicators and mathematical methods for the aggregation based on an ecological understanding of the ecosystems, and a clearly defined purpose for the resultant index. Data for individual variables or indicators should be preserved in a disaggregated form and as high a resolution as possible within the information system. Consequently, aggregation is the last step in the analysis, and it should be possible to scale up and down and across at different resolutions depending on the purpose and form of analysis.

5.76 Aggregation has both thematic and spatial aspects. The basic thematic units are the ecosystem condition indicators, which are dimensionless and have a common scale. The indicators can be combined according to the ECT classes and groups. Within each ecosystem type there is a different list of relevant indicators, but the typology classes and groups are the same for all ecosystem types. Accordingly, the relevant levels of thematic resolution are the indicators, sub-indices (condition of typology classes or groups within an ecosystem type); indices (condition of an ecosystem type in an ecosystem accounting area), and overall indices (overall condition of multiple ecosystem types in an ecosystem accounting area).

5.77 Thematic aggregation assumes that different indicators can compensate for each other, depending on the structure of the index. Consider two forest condition indicators: the number of forest bird species and the amount of dead wood. Increasing values of both indicators are associated with increasing condition. Both indicators can, however, have different directions of change. Assume forest birds are declining but dead wood is increasing. Thematic aggregation might lead to the conclusion that the forest condition remains stable.

5.78 Spatial aggregation involves aggregation across ecosystem types. Care is required in aggregation as some ecosystem types are fundamentally different and so aggregation across them may not always be meaningful. Aggregation across ecosystem types from different realms (e.g., marine and terrestrial) or with different reference conditions (natural vs. anthropogenic) is not recommended. Aggregation should be confined to ecosystem types that have the same reference condition so that the increases and decreases in condition of each group can be identified.

5.79 The common temporal units for aggregation in accounting are years. However, temporal aggregation can be done at different scales depending on the purpose and other information to which it is related, for example financial year for economic data, or growing seasons for plants.

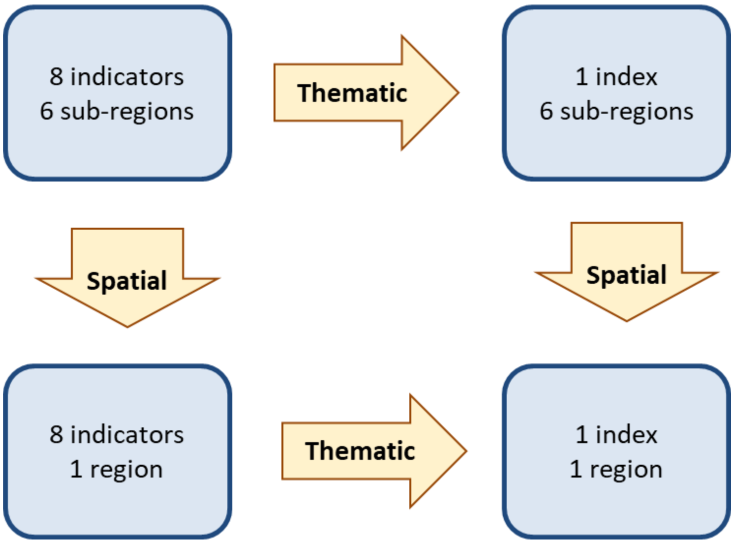
5.80 Biotic ecosystem characteristics, and their associated variables and indicators, have metrics at a range of scales from local to global. Assessment of biodiversity across these scales is imperfectly nested, and hence cannot always be upscaled or aggregated simply. Several biodiversity indicators only emerge at broad (national, continental) spatial scales and cannot be produced as “sums” of smaller parts (e.g., the beta diversity of large areas).

5.81 The approaches to spatial aggregation described here involved aggregation of variables that are meaningful at the level of individual ecosystem assets. The resulting aggregate indicators are therefore average measures of condition reflecting the condition of the constituent ecosystem assets. For some purposes, in particular for aggregate measures of biodiversity, it will be appropriate to also incorporate data on variables at a range of scales as described in the previous paragraph. Relevant considerations are discussed in section 5.5.4 and Chapter 13.

5.4.2 *Potential aggregation functions and weights*

5.82 Aggregation functions and weights are used in various forms in each type of aggregation operation. Ideally, aggregation operations should be commutative, i.e., subsequent operations should lead to the same result irrespective of the order in which these operations were performed (Figure 5.1).

Figure 5.1: Aggregation commutativity: subsequent aggregation operations result in the same aggregated values, no matter the order of the operations.



5.83 In principle there are several choices for aggregation functions for each type of aggregation operation that can be distinguished, depending on the purpose of the index being developed/applied. The range of types of functions used to calculate central tendency include arithmetic mean, geometric mean, minimum and maximum operators, quantiles and median. The arithmetic mean is the most commonly used function, but the geometric mean and harmonic mean have more sensitivity to low values and to skewed distributions. Hence, the geometric mean is often used in environmental science for describing statistics associated with variables that tend to vary in space or vary by several orders of magnitude. Minimum or maximum operator or threshold detection approaches are often used to recognize the importance of the lowest values or poorest condition of an indicator, or alternatively the highest values or best condition of an indicator. The one out - all out approach, where the condition index is based on the lowest value indicator, is a special case of using the minimum function as the central tendency.

5.84 The selection of a weighting system depends on the relative importance of each indicator to an assessed overall condition of the ecosystem. The approach to weighting should have a scientific rationale and incorporate the input from ecologists with expertise in the specific ecosystem types. For spatial aggregation area-weighted sums and means are a typically good choice. Equal weighting assumes equal importance, and while this is the most common approach for thematic aggregation, equal importance may not necessarily be true across all indicators. Non-equal weighting may be appropriate if there is an imbalance in availability of indicators (e.g., some characteristics are represented with more indicators then others), or when the different characteristics, measured by their respective indicators, play relatively different roles from an ecological perspective. Relationships between characteristics may be non-linear and different thresholds may apply.

5.85 The selection of methods for the aggregation of condition metrics derived for individual spatial units should consider the landscape context and derivation of representative mean and range in condition. In some cases of aggregation, a combination of approaches of functions and weightings are appropriate for different indicators associated with threshold effects or differing relative importance. Methods for weighting and normalizing scores can be complex and influence the outputs, so documentation and explanation of the assumptions is important and the applicability of aggregated indices across characteristics or ecosystem types should be tested.[33]

5.86 Many of the options for aggregation are widely used in established environmental indicator frameworks. For example, the Human Development Index applies arithmetic means for sub-indices, followed by a geometric mean for the overall index. A 'precautionary' one out - all out approach (where a single declining indicator means a decline in condition whereas improvement is based on an ensemble of increasing indicators) is used in the assessment of the conservation status linked to the European Union Habitats and Birds Directives and the IUCN Red Lists of species and ecosystems. Nevertheless, neither the purpose nor the data types of these aggregation framework match those of the SEEA EA condition accounts. Further scientific studies should explore the advantages and disadvantages of particular aggregation strategies (i.e., combinations of aggregation functions and weighting schemes for the various aggregation dimensions) including consideration of dealing with uncertainties in measurement.

5.4.3 Presentation of ecosystem condition indices

5.87 As described above, as required, it is possible to aggregate ecosystem condition indicators to form sub-indices according to the ECT classes both within ecosystem types and across different ecosystem types. Aggregation of indicators requires scaling/normalisation of indicator values against a single reference condition for the ecosystem type, so that different variables and classes of characteristics can be compared. Aggregated sub-indices and indices have the same range and direction as the indicators, for example [0 – 1]. An aggregated sub-index is derived for each class in the ecosystem condition typology that provides a composite measure from the combination of indicators that describe the same class in the typology for a given ecosystem type. An ecosystem condition index is derived from a second aggregation step using the sub-indices for each ecosystem type ('mean values' approach) (Table 5.5).

5.88 An alternative method for presenting data of the aggregate indices is recording the areas of each ecosystem type that is covered by various ranges of ecosystem condition relative to the reference condition. For example, an account for the ecosystem type of forests could show the total area of forest divided into low, medium or high condition. Area values can be reported in absolute terms (e.g., ha) or in relative terms (as a percentage of the total area). Different threshold scores can be used based on different methodologies to define the number of intervals and their range ('discretised ranges' approach) (Table 5.6). The 'mean values' and the 'discretised ranges' approaches have both been used in existing condition accounts (Maes et al., 2020).

[33] Examples of the evaluation of indices include Andreasen et al., 2001; Buckland et al., 2005; Fulton et al., 2005; Rowland et al., 2020.

Table 5.5: Ecosystem condition indices reported using rescaled indicator values ('mean values' approach)

SEEA Ecosystem Condition Typology Class	Indicators	Ecosystem type			Ecosystem type	
		Indicator value			Index value	
	Descriptor	Opening value	Closing value	Indicator weight	Opening value	Closing value
Physical state	Indicator 1	0.5	0.25	0.05	0.025	0.013
	Indicator 2	0.9	0.7	0.05	0.045	0.035
	Sub-index				*0.07*	*0.048*
Chemical state	Indicator 3	0.625	0.5	0.1	0.063	0.05
Compositional state	Indicator 4	0.94	0.89	0.067	0.063	0.062
	Indicator 5	1	0	0.033	0.303	0
	Sub-index				*0.366*	*0.062*
Structural state	Indicator 6	0.5	0.25	0.12	0.06	0.03
Functional state	Indicator 7	1	0.66	0.08	0.08	0.053
Landscape and seascape characteristics	Indicator 8	0.5	0.2	0.5	0.25	0.1
Ecosystem condition index	Index			1.0	0.889	0.343

Table 5.6: Ecosystem condition indices reported using discretised ranges (i.e., area (%) in each range of condition)

SEEA Ecosystem Condition Typology Class	Indicators		Ecosystem type					
	Descriptor	Indicator weight	Opening value			Closing value		
			High	Medium	Low	High	Medium	Low
Physical state	Indicator 1	0.05	10	80	10	5	45	50
	Indicator 2	0.05	70	25	5	60	20	20
	Sub-index		*40*	*52.5*	*7.5*	*32.5*	*32.5*	*35*
Chemical state	Indicator 3	0.1	30	40	30	20	50	30
Compositional state	Indicator 4	0.067	80	15	5	80	10	10
	Indicator 5	0.033	100	0	0	0	0	100
	Sub-index		*86.6*	*10.1*	*3.4*	*53.6*	*6.7*	*6.7*
Structural state	Indicator 6	0.12	30	30	40	10	20	70
Functional state	Indicator 7	0.08	100	0	0	50	30	20
Landscape and seascape characteristics	Indicator 8	0.5	30	30	40	20	20	60
Ecosystem condition index	*Index*	1.0	42.2	28.9	28.9	25.8	23.7	50.5

5.5 Considerations in the measurement of ecosystem condition

5.5.1 Introduction

5.89 The description of the three-stage approach to accounting for ecosystem condition provides an appropriate structure for measurement. Nonetheless, there are a range of different considerations and issues that will affect measurement in practice. This section discusses these issues.

5.5.2 Variables and indicators for selected ecosystem types

5.90 Following the approach described above, the measurement of ecosystem condition requires the selection of variables covering relevant ecosystem characteristics for different ecosystem types. The general principles and criteria for the selection of variables have been outlined in section 5.2 and by Czúcz et al. (n.d.). In this section, a short summary is provided of considerations in variable selections for a number of key ecosystem types. As noted above, in practice, it is important that ecologists and related specialists with knowledge of the ecosystem types concerned are involved in the process of variable selection, as well as in the determination of reference conditions and levels.

5.91 As examples, an indicative selection of variables is presented in Table 5.7. For selected biomes (following IUCN Global Ecosystem Typology) and according to the classes of the ECT, the table shows possible variables. In no way is this table intended to provide definitive measurement guidance for the selection of variables. In the first instance it is expected that local context will be considered in the selection of variables, i.e., that the measurement of ecosystem condition will be grounded in specific ecological knowledge and expertise. Of particular relevance in this regard will be knowledge of the underlying ecosystem functional groups and more detailed sub-types and their composition within a country or region.

5.92 Second, the descriptors in the table refer to a mix of variables and data sources. These examples are given as an indication of the potential for measurement. However, in practice, the selection of variables and indicators will require careful consideration to ensure their appropriate interpretation, for example concerning directionality. Additional guidance on the selection of variables and the collection of data will be developed.

Table 5.7: Indicative ecosystem characteristics for selected ecosystem types[34]

IUCN Global Ecosystem Typology: Selected Biomes	Physical state	Chemical state	Compositional state	Structural state	Functional state	Landscape/waterscape characteristics
T1 Tropical-subtropical forests	Soil water availability in the driest quarter Topographic wetness index	Soil organic carbon Leaf and litter nitrogen concentration	Tree species richness Density of epiphytes	Tree cover density; Dominant tree height Number of canopy layers deadwood; forest age	Dry matter productivity Presence of specific fruit-eating species for seed dispersal	Forest area density; landscape diversity; forest connectivity Ratio of edge distance to interior area of forest patches
T2 Temperate-boreal forests & woodlands	Litter depth Water infiltration rate	Soil organic carbon Air pollutant concentration	Tree species richness Presence of top predator species	Tree cover density; deadwood; forest age	Dry matter productivity Density of trees with hollows	Forest area density; landscape diversity; forest connectivity Age class distribution
T3 Shrublands & shrubby woodlands	% Burnt area; soil layer thickness (degree of erosion)	Soil organic carbon Soil phosphorus concentration	Bird species richness	Tree cover density; an NDVI-based (biomass?) index	Dry matter productivity Proportion of re-sprouting species after fire	landscape diversity; shrubland/forest connectivity
T4 Savannas and grasslands	% bare ground	Soil organic carbon Soil pH	Bird species richness; Butterfly species richness Proportion of cover by exotic species	The presence/ density of trees/ small woody features	Dry matter productivity Abundance of termite mounds	landscape diversity; grassland connectivity; the presence/ density of trees/ small woody features
T5 Deserts and semi-deserts	Water availability (index) Degree of surface crusting	(Soil organic carbon) soil pH	Reptile abundance	an NDVI-based index	Density of viable seeds per gram soil	Spatial distribution of waterholes
T6 Polar-alpine	% bare ground Snow depth	Pollutant deposition	Lichen abundance	an NDVI-based index Lichen cover on rocks	Extent of sea ice	Altitudinal gradient of habitat types Connectivity of routes for migratory species
T7 Intensive land-use systems	Water infiltration rate Soil bulk density	Soil organic carbon phosphorous concentration Nitrogen concentration	Bird species richness	% organic farming Number of cropping cycles per year	Soil nutrient availability Soil respiration rate	The presence/ density of seminatural vegetation fragments (or just ...of trees/ small woody features); Landscape diversity (mosaic)

[34] This table is indicative only and is not intended to provide definitive measurement guidance for the selection of variables in any given context

IUCN Global Ecosystem Typology: Selected Biomes	**Physical state**	**Chemical state**	**Compositional state**	**Structural state**	**Functional state**	**Landscape/waterscape characteristics**
T7.4 Urban and infrastructure lands	Imperviousness	NO_2 concentration	Bird species richness	% urban green space	Leaf Area Index	Maximum distance of houses to open green space
TF1 Palustrine wetlands	Wetness (index)	Nitrogen concentration Phosphorous concentration	Bird species richness	NDVI (or an NDVI-based index)?	Rate of water flow	landscape diversity; wetland/water connectivity
F1 Rivers and streams	River flow (relative to ecological base flow); water regime (permanence)	Nitrogen concentration Phosphorous concentration Sediment load	Macro-invertebrate species richness	Vegetated river banks	Permanence of water flow	Share of river flow controlled by dams or barriers / Presence of anadromous fish; river system fragmentation
F2 Lakes	Water clarity; water regime (permanence)	Nitrogen concentration Phosphorous concentration Sediment load	Fish species richness	Steepness of water temperature depth profile	Rate of water flow	Connectedness of riparian vegetation within the catchment
F3 Artificial fresh waters	Water clarity	Nitrogen concentration Phosphorous concentration	Occurrence of algal blooms	Steepness of water temperature depth profile	Habitat requirements for fish breeding	Proportion of catchment vegetated
M1 Marine shelves	Water depth	Chlorophyll a % anoxic area		Trophic composition number; ratio fishing mortality and fishing at MSY		
M2 Pelagic ocean waters		Chlorophyll a; % anoxic area		Trophic composition number; ratio fishing mortality and fishing at MSY		
M3 Deep sea floors	Light intensity	Oxygen concentration	Invertebrate species richness	Habitat diversity	Sea floor sediment density	

5.5.3 *The use of data on environmental pressures*

5.93 The measurement of environmental pressures is often considered as an indirect approach for measuring ecosystem condition (e.g., European Commission (2016), p.31). If there are little data available on state, then pressures can be considered a useful surrogate, as long as the relationship between the two is well understood and justified (Bland et al., 2018). This can be considered a compromise, since conflating pressures with state variables can compromise the credibility and salience of the resulting accounting tables. At the same time, in some cases there may be little difference between a state and a pressure indicator and, in other cases, where there is a considerable lag between evidence of a pressure and a resultant change in state, a measure of pressure may provide relevant information.

5.94 Indeed, accounting tables should not be blind to the policy issues highlighted by the most relevant pressures. In the case of most pressures (e.g., erosion, pollution, invasive species) there is an underlying variable, that reflects the ecosystem response to that pressure. This underlying variable can be considered an environmental stock (e.g., the thickness of soil layer, the concentration(s) of substances, or the abundance of species) that is gradually affected by the pressure. Typically, such stocks can meet all the selection criteria, so they can be quite appropriate for condition accounting rather than the connected flows (e.g., degradation / depletion rates, fluxes, flows, or other indicators of flow intensity).

5.95 Using these environmental stocks as condition indicators comes with multiple further advantages: they can be used to formulate very clear and pertinent policy messages on ecosystem degradation (concerning a change in these environmental stocks); and the degree of policy attention highlights those environmental stocks that are perceived as the most valuable or most endangered. Identifying environmental stocks in a condition account is particularly relevant when ecosystem extent is measured using remote sensing. Remote sensing will detect a stock loss due to a change in ecosystem type, e.g., clearing vegetation, but may not detect a stock loss due to a decline in condition (e.g., loss of understory or weed invasion).

5.96 A further important type of pressure is over harvesting, which can frequently be linked to environmental stocks (e.g., timber stocks for forests or fish stocks for marine ecosystems). In this case, the associated ecosystem types can have a specific target ecosystem service (typically a provisioning service) and traditional ecosystem management aims at the maximizing the flows of that service (de Groot et al., 2010). The intensity of these management activities has been shown to exert strong influences on the supply of a broad range of services, well beyond the original target ecosystem service (Santos-Martín et al., 2019).[35]

5.97 Where the pressure relates to expansion of agricultural activity, the effects may be captured by changes in ecosystem extent, depending on the intensity of the agricultural practices. The focus of condition measurement should be on the change in the state of the relevant ecosystem type but measures of pressures such as livestock per hectare or rates of fertilizer and pesticide use may provide useful supporting data.

5.98 Some pressure indicators should probably not be used in the ecosystem condition accounts. This includes pressures (or drivers) which provide more indirect measures of change in ecosystem state (e.g., climate change, human demographic changes). These changes should be considered external to the studied ecosystems. Habitat loss is a measure of direct pressure which should be addressed through measures of ecosystem extent rather than ecosystem

[35] Examples of the evaluation of indices include Andreasen et al., 2001; Buckland et al., 2005; Fulton et al., 2005; Rowland et al., 2020.

condition.[36] Note that some effects of habitat loss, such as fragmentation, may be picked up in selected condition indicators.

5.99 Indicators of protection status (e.g., the location, area, or representativeness of protected areas) are also frequently proposed as proxy measures for condition if no other information is available (e.g., Maes et al., 2016). Protection could be thought of as a rough proxy for reduced pressures, especially for reduced overexploitation (i.e., indicating lower management intensities). However, indicators describing policy interventions performed in response to management or conservation objectives are not considered appropriate as condition indicators. There is no inherent relationship between protection status and other indicators of ecosystem condition, for example, an ecosystem could be protected and nevertheless be in poor condition. In order to avoid confusion and double counting, the use of indicators describing policy response categories should be avoided. Among other issues, including such indicators would compromise the potential to use the accounts to assess the effects of policy responses (e.g., the effect on condition of establishing a new protected area).

5.5.4 The role of biodiversity in ecosystem condition accounts

5.100 Following the CBD definitions, biodiversity is the variety of life within species (genetic diversity), between species, and between ecosystems (CBD article 2) and ecosystems are shaped by the interactions among species, and between species and the non-living environment (CBD article 2). As a consequence, there is overlap in how biodiversity and ecosystems are measured.

5.101 Biodiversity is integral to the maintenance of ecosystem integrity that is the reference from which condition of ecosystem assets is assessed. Thus, in the SEEA ECT (Table 5.1) the overlap in measurement is mainly evident in the biotic ecosystem characteristics. Variables that describe species composition, ecosystem structure and ecosystem processes are also used to characterize biodiversity and are therefore considered as essential biodiversity variables.

5.102 Besides overlap, there is also a difference between measuring biodiversity and ecosystem condition. Ecosystem condition accounts consider physical and chemical quality of the ecosystem along with biotic health, and often focus on species-related metrics to account for biodiversity. Variables that describe between-ecosystem diversity are generally less appropriate and rarely used to measure the condition of a single ecosystem asset or ecosystem type. The relevant biodiversity metrics for assessing an individual ecosystem asset's condition include characteristics of composition, structure, function and landscape characteristics where these can be attributed to the condition of an individual ecosystem asset.

5.103 Before selecting species-based metrics to assess the condition of ecosystems, it is important to realize that there are different spatial and temporal dynamics between individual species and ecosystems. Therefore, not all species or species-based biodiversity indicators are suitable to assess condition at all scales. For instance, to measure the long-term condition of a single ecosystem, monitoring non-mobile species that are sensitive to pollution such as lichens may be more appropriate than taking observations of an occasional visitor that only uses the ecosystem to take a rest during their seasonal migration. However, observations of

[36] On the other hand, if a habitat change is internal to a specific ecosystem type (e.g. soil sealing in the case of urban ecosystems, loss of large trees within a forest), then it may be included in the condition account (preferably with an indicator describing the underlying environmental stock; e.g. the share of impervious surfaces for soil sealing, number of large trees).

the migrating species may be important in understanding the importance of that ecosystem to species conservation at a broader scale.

5.104 Consequently, some individual biodiversity metrics, such as the diversity of ecosystem types within an EAA, should not be attributed to individual ecosystem assets and should instead be considered emergent properties. As a result, these metrics will not be incorporated in aggregate measures of ecosystem condition based on the condition of individual ecosystem assets. The emergent properties can be incorporated in aggregate measures of biodiversity, for example at ecosystem type and EAA scale using aggregation approaches that appropriately consider the process related and pattern related issues. A technical note summarising the relevant spatial aggregation issues and methodological approaches provides appropriate guidance.[37] In addition, Chapter 13, on thematic accounting, provides an introduction to the use of accounting more generally in organising data to support discussion of biodiversity, including the design of species accounts.

5.5.5 Accounting for ecosystem conversions

5.105 Ecosystem conversions occur when part or all of an ecosystem asset changes from one ecosystem type to another between the beginning and end of an accounting period. Examples of ecosystem conversions include clearing a natural forest for use by grazing animals; converting a natural grassland to cropland; urban sprawl into agricultural land; draining a wetland and ploughing for agriculture; creation of a new hydropower reservoir; natural encroachment following permafrost melt; or the potential future flooding of coastal areas due to sea level rise. Chapter 4 discusses the identification and recording of ecosystem conversions, which should take place in the ecosystem extent account.

5.106 Concerning the measurement of condition, four practical measurement challenges emerge in the context of ecosystem conversions.

i. In some cases, thresholds for the condition indicators are required to identify the conversion from one ecosystem type to another. These thresholds will depend on how the ecosystem type is classified and delineated and the specific indicators applied. For example, in a conversion of a forest to a woodland, the threshold canopy cover needs to be determined at which the ecosystem is no longer classified as a forest. Hence, rules or thresholds are required to determine changes in ecosystem type resulting in reclassification.

ii. Rules are often required to specify a time period over which the change must remain in order to be re-classified, to distinguish permanent change from temporal variability.

iii. Selection of the set of condition indicators used to describe the ecosystem types is important such that a change in the level of one or more indicators can identify a conversion to another ecosystem type. For example, the indicator of canopy cover is a poor indicator for detecting the difference between a natural forest and a plantation but a good indicator of the difference between a forest and a grassland.

iv. The spatial scale of assessment of condition indicators is important, that is the level of aggregation of spatial units for reporting within the accounting area. Metrics for condition indicators that may be used to assess conversions likely occur at different scales, from point sources to emergent landscape scales.

[37] Technical note on spatial aggregation of biodiversity-focused metrics for ecosystem condition accounts is being finalized and will be published as a revision background paper at: https://seea.un.org/content/accounting-biodiversity.

5.107 These measurement challenges are confronted in the first instance in the compilation of the ecosystem extent accounts described in Chapter 4. In these accounts, the change in the area of ecosystem types between the opening and closing of the accounting period is recorded in gross terms, i.e., both the additions and reductions in the area of ecosystem types are recorded. The characteristics and criteria for the delineation of ecosystems types will underpin the recording of conversions. Maintaining a time series of ecosystem extent accounts will support understanding the relative extent of different ecosystem types and support analysis of conversions from the set of ecosystem types present in a natural condition.

5.108 From an ecosystem condition measurement perspective, it is noted that, ecosystem condition is measured with respect to the ecosystem type present at the end of the accounting period using the relevant characteristics and indicators. Where ecosystem conversions occur, this implies that for a given location, the relevant set of characteristics and indicators, and the associated reference levels, will be different from those used at the beginning of the period. Significant care should therefore be taken in interpreting the change in condition over time for that location and, as a general approach it is recommended that either the converted areas be excluded from the analysis of change or handled as a distinct type of area in any aggregations.

5.109 At the same time, often there is strong interest in understanding ecosystem conversions involving the change from natural to anthropogenic ecosystem types. To support analysis of these changes beyond measures of changes in extent, it may be appropriate to provide complementary measures of changes in ecosystem condition for all ecosystem types (i.e., both the natural and anthropogenic ecosystems) relative to a natural reference condition. This analysis will be most relevant where changes have occurred relatively recently, e.g., over the past 200 years.

5.5.6 Relationship between ecosystem condition, ecosystem capacity and ecosystem degradation

5.110 In the ecosystem accounting framework, there is the intention to record data on both the stocks of ecosystem assets and flows of ecosystem services. The general concept is that the extent and condition of ecosystem assets will have an influence on the flows of ecosystem services both in the current period and in future periods. Also, in some cases the supply and use of ecosystem services will impact on ecosystem condition. The connection between these stocks and flows is encapsulated in the concept of ecosystem capacity. Measurement of ecosystem capacity is related to, but different from the measurement of ecosystem condition. Section 6.5 provides a longer discussion of ecosystem capacity in the context of ecosystem accounting.

5.111 Measures of ecosystem condition will be more general and integrative than measures of the capacity to supply specific ecosystem services. That is, characteristics of ecosystem condition, and their associated measured variables and indicators, should include more than those relevant to providing final ecosystem services used by humans.

5.112 Ecosystem degradation is defined as the decrease in the value of an ecosystem asset over an accounting period that is associated with a decline in the condition of an ecosystem asset (see section 10.2). Since the value of an ecosystem asset will be related to future flows of ecosystem services, there are connections among the concepts of ecosystem condition, ecosystem capacity and ecosystem degradation. However, they are not the same concept and it need not be the case that declines in condition necessarily imply ecosystem degradation. Annex 10.1 provides a discussion on the links between measures of ecosystem condition and ecosystem degradation and other changes in the value of ecosystem assets.

5.6 Applications of ecosystem condition accounts

5.113 Ecosystem condition accounts can be applied at regional, national and international scales for a wide range of applications. Data for different components of condition accounts, such as ecosystem variables, indicators, reference levels, reference conditions and ecosystem condition indices, are used for different applications. Ensuring consistency in terms, definitions and metrics between the information system provided by the ecosystem accounts and any policies that refer to them will help to ensure effective application.

5.114 Condition accounts are used to synthesize information about changes over time in the state of ecosystem assets. This information can be used to inform policy and decision-making across a range of sectors that impact on or depend on ecosystems and natural resources, including land-use planning, environmental impact assessment, agricultural planning and authorization processes, and programmes for ecosystem rehabilitation or restoration. Overall measures (such as an ecosystem condition index) can be used to inform strategic planning at the national level. Where accounts are compiled with spatially explicit detail, and include information on particular characteristics of ecosystem assets, the accounts can also be used to inform landscape-level planning.

5.115 The use of variables, indicators, or ancillary information to assess the capacity of ecosystems to supply ecosystem services is an important application for the purpose of informing policy on the future availability of ecosystem service flows from ecosystem assets. As described in Chapter 10, information on future ecosystem service flows may be used for estimating a monetary value of ecosystem assets. Further, condition accounts can be used to analyse the impact that activities associated with supplying ecosystem services (e.g., timber harvesting) are having on ecosystem condition.

5.116 Several examples demonstrate the range of applications of ecosystem condition accounts in providing information. Quantification of indicators and reference levels can be used to operationalize the definition of ecosystem degradation and enhancement. Further, indicators of ecosystem condition could be combined with information on ecological thresholds (e.g., concerning points of change in ecosystem type) to assess the risk of change, or alternatively, to assess the degree of resilience within ecosystems under conditions of change. This could allow condition accounts to inform the identification of threatened ecosystems (e.g., (D. A. Keith et al., 2013), Red List of Ecosystems).

5.117 Some cases of assessment of ecosystem condition or capacity to supply ecosystem services will depend on complex interrelationships of multiple indicators for determining threshold levels to define sustainability. The ability to connect the critical levels of ecosystem service capacity back to the ecosystem condition variables that have the highest influence on specific ecosystem services would be a valuable exercise to explore. This would allow information in the ecosystem accounts to be applied to quantifying the ‘critical natural capital’ described in economics (Ayres et al., 2001) or the ‘planetary boundaries’ concept in ecology (Rockström et al., 2009).

5.118 The development of ecosystem condition accounts has the potential to make many key policy commitments measurable, and thus more likely to be implemented, at the national and international level. The measurement may then, in turn, support the design and development of policy and associated targets. International policies where the information from ecosystem condition accounts can be applied include measures of land degradation to support the goal of land degradation neutrality (LDN) under the UN Convention on Combatting

Desertification,[38] the Sustainable Development Goals,[39] and the Post-2020 Global Biodiversity Framework.[40] Further, in the UNFCCC Paris Agreement,[41] the inclusion of the concept that ecosystem integrity must be promoted while accounting for national emissions reductions demonstrates significant progress in adopting a holistic approach to environmental issues. This concept is developed further in a report describing specific mitigation actions (Dooley et al., 2018).

5.119 A difference between scientific and policy aims in the development and use of condition indicators is that scientists aim to understand the complexity of ecosystems and encapsulate this reality, whereas policy-makers often need headline indicators of the ecosystem that can be evaluated readily with indicators representing economic, social, political and other realities. Accounting thus needs to support both the overview and the detail. Hence, individual variables, indicators and ecosystem condition indices all have a role in applying ecosystem condition accounts in decision making.

[38] See https://www.unccd.int/actions/achieving-land-degradation-neutrality

[39] See https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[40] See https://www.cbd.int/conferences/post2020

[41] See https://cop23.unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

Annex 5.1: Options for establishing reference conditions for natural and anthropogenic ecosystems

Reference condition based on:	Strengths	Weaknesses	Examples of reference conditions
1. Stable or resilient ecological state maintaining ecosystem integrity	● Can be assessed by long-term monitoring. ● Can be defined by a level of tolerable change or risk.	● May not exist in some places and be difficult to define. ● Direct measurement difficult to encompass temporal variability. ● Reference might change due to global change or as scientific understanding improves.	● Optimal or equilibrium state, typically approximated by primary, pristine or natural state
2. Sites with ecosystems with minimal human disturbance	● Ecosystem variables can be measured on least disturbed reference sites and can deliver reference levels for variables and indicators. ● Statistical approaches based on current data collections of ecosystem variables can be used to screen reference sites based on knowledge about pressures.	● Most, if not all, ecosystems are under some form of human pressure (in particular climate change). ● For some ecosystems it is no longer possible to find reference sites and difficult to distinguish shifting baselines. ● Can fail to recognise spatial and temporal variation, in particular in cases where only few reference sites remain that are not evenly distributed (e.g., old growth forests, wilderness, undisturbed marine habitats)	● Undisturbed, minimally or least disturbed state/condition ● Many examples for surface water ecosystems (reference condition is defined in the EU Water Framework Directive)
3. Modelled reference conditions	● Can be modelled globally and can incorporate climate change / emissions scenarios.	● Modelling usually does not involve all of the selected condition variables, and often differ from measured variables. ● Requires assumptions to establish reference levels for condition variables, e.g., scientific debate on the role of megafauna and early humans on potential natural vegetation ● Unclear how to assess semi-natural systems with often high levels of species diversity	● Potential natural vegetation (Hickler et al., 2012) ● Maximum ecological potential (possibly based on expert judgement) ● Theoretical stable state of an ecosystem ● Best attainable state.
4. Statistical approaches	● Simple, pragmatic approach, familiar for accountants. ● Methods can be applied consistently across variables, e.g., normalizing with the maximum values of available data.	● Reference levels are arbitrary, with no real meaning for policy or science. ● Simple approaches can create hidden artefacts (e.g., the condition of a 'homogeneously' degraded ecosystem can appear much better than the condition of another for which a few good sites still exist). ● Relies on data for the range in values at the current state, which can create spatial inconsistencies and a strongly shifting baseline. The simplicity of the method can create a false sense of consistency. ● Difficult to scale conditions at levels outside the range of the available data. Variables moving out of their established range (e.g., improving beyond the previous upper reference level) can cause serious complications.	● Stochastic frontier analysis
5. Historical reference condition (Setting a baseline period against which past, present or future	● A common baseline for climate and biodiversity science and policy. Shows the magnitude of loss of biodiversity. ● Can be partly reconstructed based on species lists (paleo-ecology), or paleo-climate indicators.	● Data on ecosystem characteristics are usually not available (in particular for marine ecosystems). ● Data available are not representative. ● Degree of human impacts varied in time across continents.	● Pre-industrial state (1750) (e.g., Red List of Ecosystems) ● 1500 (Biodiversity Intactness Index for modelling)

condition can be evaluated)			● Pre-intensive land use (where the date may vary in different countries) ● Earliest date that data are available.
6. Contemporary reference condition (Setting a baseline year against which past, present or future condition can be evaluated)	● Simple, pragmatic approach, familiar for accountants. ● Data are more likely to be available ● Can be used to assess the condition of novel ecosystems or ecosystems heavily modified by humans (also natural ecosystems) ● Can be based on current data of ecological characteristics and maximum values or statistical approaches such as percentiles.	● The choice of year may be considered arbitrary ● Reliance on contemporary data in evaluating changes can result in a shifting baseline. ● Appropriate dates differ for different indicators and ecosystem types. ● Different starting dates in different regions creates inconsistencies. ● Condition of variables about a single point in time can be highly variable (inconsistencies between the variables). ● Difficult for scaling conditions at levels which are higher than the reference, e.g., when variables move out of their established range. ● Open to policy influence and are often changed. ● Contemporary baselines diverge greatly from pre-industrial era baseline conditions	● 1990 (Kyoto protocol for GHG emissions) ● 1970 (RAMSAR, IPBES global assessment) ● Red List of Ecosystems (50 years) ● Living Planet Index (1970) ● Date for the beginning of an accounting period.
7. Stable state or sustainable socio-ecological equilibrium	● Applicable for a range of human-modified ecosystems.	● May not exist, may be difficult to define objectively and sensitive to a range of assumptions. ● Direct measurements of reference levels are impossible. ● Reference might change due to societal or technological changes, or as scientific understanding improves. ● Definition of not undergoing degradation in terms of ecosystem characteristics or supply of ecosystem services, may be difficult to quantify.	● Long-term agricultural production systems
8. Prescribed levels or target levels in terms of legislated quality measures or expert judgement	● Has a strong and straightforward management applications and policy message. Provides a basis for direct policy responses, e.g., enforcement. ● Can reflect preferences for a particular use of an ecosystem taking into account social, economic and environmental considerations. ● A threshold value where there is evidence that an indicator value above or below the threshold represents sub-optimal ecosystem condition. ● A reference level quantifying an undesirable state can be required to define the zero end of the normalized scale, for example, where the ecosystem is no longer present or functioning.	● Can be subjective and influenced by policy and politics. ● Can be changed over time. ● May differ between countries and may not be consistent for all ecosystem types and indicators. ● Not available for all variables.	● Pollution levels ● Species recoveries ● Emissions reductions

SECTION C: Accounting for ecosystem services

6 Ecosystem services concepts for accounting

6.1 The purpose in accounting for ecosystem services

6.1 In the ecosystem accounting framework, ecosystem services serve as the connecting concept between ecosystem assets and the production and consumption activity of businesses, households and governments. The measurement of ecosystem services is thus central to describing an integrated set of ecosystem accounts.

6.2 Since the release of *Ecosystems and Human Well-being* (Millennium Ecosystem Assessment, 2005), there has been a significant increase in the number of studies focused on ecosystem services. These studies, involving researchers from a range of disciplines from all over the world, have focused on many aspects of definition and approaches to measurement, including at scales from local ecosystems and communities to global assessments. The potential of applying an ecosystem services approach to foster an understanding of the relationship between humans and the environment has been further strengthened through work in various initiatives including The Economics of Ecosystems and Biodiversity initiative (TEEB, 2010), the Mapping and Assessment of Ecosystems and their Services (MAES) framework (Maes et al., 2013); the Natural Capital Project at Stanford University; and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015); among many others. The approach to accounting for ecosystem services presented here builds on all of this research.

6.3 The measurement of ecosystem services is of particular interest in explaining the variety of contributions that ecosystems make to people and the economy. These contributions extend well beyond those to marketed goods, such as timber and fish, and include services such as air filtration, water purification, global climate regulation and recreation-related services. Commonly these types of services are supplied to communities outside market institutions. The focus of accounting for ecosystem services is to provide a clear understanding of the range of these services, the spatial heterogeneity of their delivery, and the local to global beneficiaries of these services, in order that this information can be readily compared between and connected to the different ecosystems that supply the services.

6.4 An important part of the rationale for accounting for ecosystem services is that while much economic production (for example, in agriculture, forestry and fisheries) uses inputs directly from ecosystems, those inputs (and any associated degradation) are not explicitly recorded in the national accounting framework. In ecosystem accounting, ecosystem services are clearly differentiated from the goods and services that are produced, i.e., the ecosystem services are recorded as the contributions of ecosystem assets to the production of those goods and services. In effect, this extends supply chains and treats ecosystem assets as suppliers or producing units.

6.5 The explicit recording the contribution of ecosystems to both current marketed production and wider benefits accruing to individuals and society, encourages a wider understanding of the role of ecosystems and the effects that may arise when ecosystems change (e.g., in terms of land-use, management planning, and protected status). This focus implies a general focus on those ecosystem contributions that may be at risk of being lost or becoming scarce.

6.6 As for any single ecosystem account, accounting for ecosystem services does not provide a complete assessment of the entire relationship between ecosystems and people. Nonetheless, it does provide an important piece of information in describing our use of ecosystems. Together with information the extent and condition of ecosystem assets, expenditure on environmental protection and resource management, and data on economic activity, a richer picture of the relationship can be portrayed. In this respect there is an important link to the data of the SEEA Central Framework and the SNA in understanding relevant environmental pressures and policy responses. How these factors impact on ecosystem assets and hence on the flows of ecosystem services is an important area for informing relevant aspects of policy-making.

6.7 This chapter provides descriptions and definitions of the various concepts and principles that are applied in accounting for the supply and use of ecosystem services. Using these concepts and principles, the chapter outlines a reference list of selected ecosystem services and associated definitions to support account compilation and comparison of methods and findings. The chapter also provides additional explanation on the treatment of specific services and associated environmental flows thus describing the measurement scope that is appropriate for ecosystem accounting.

6.2 Concepts and principles in accounting for ecosystem services

6.2.1 Ecosystem services

6.8 The key concepts of the ecosystem accounting framework related to ecosystem services concern (i) the supply of ecosystem services to users; and (ii) the contribution of ecosystem services to benefits (i.e., the goods and services ultimately used and enjoyed by people and society). The following paragraphs place these concepts in context for ecosystem accounting purposes.

6.9 Following the general framework of ecosystem accounting, each ecosystem asset supplies a set or bundle of ecosystem services. Following the framing described in Chapter 2, ***ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity***. In ecosystem accounting, ecosystem services are recorded as flows between ecosystem assets and economic units; where economic units encompass the various institutional types included in the national accounts, such as businesses, governments and households. Flows of ecosystem services are sometimes reflected in physical flows, such as when fish are removed from a marine ecosystem, but may also be reflected in the passive receipt of ecosystem services, such as flood control services.

6.10 Following the cascade model describing flows of ecosystem services,[42] the supply of an ecosystem service will be associated with an ecosystem structure or process or a combination of ecosystem structures and processes that reflect the biological, chemical and physical interactions among ecosystem components (Potschin & Haines-Young, 2017). Their characteristics can be aggregated into different groups of functional outcomes (Schneiders & Müller, 2017). These processes and characteristics are observable and measurable but are not themselves flows of ecosystem services as defined in ecosystem accounting since this requires a connection to be made to users. This alignment between supply and use is a foundational accounting concept (see SEEA Central Framework Section 3.2) and holds in both physical and

[42] This framing reflects the general framing of the well-recognised cascade model (Haines-Young & Potschin, 2012; Potschin & Haines-Young, 2016) and the framing provided by Boyd & Banzhaf (2007). Central to these framings is that ecosystem services are “contributions to benefits” rather than being “equivalent to benefits” which was the framing applied in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005). The language of contributions is also present in the approach of IPBES (Díaz et al., 2015) which adopts the term “nature’s contributions to people” although this is a concept very closely related to ecosystem services as generally applied in the ecosystem services literature. The focus on contributions also directly suits the accounting approach of the SEEA EA and the application of supply-use principles.

monetary terms. The recording of ecosystem services will pertain to total flows over an accounting period (e.g., one year) and thus an entry will reflect a total flow per unit of time.

6.11 In much of the ecosystem services literature, the term supply is used to refer to an ecosystem's potential or capacity to supply services irrespective of use, while the term use is applied to refer to the actual flow to people. In ecosystem accounting, following standard accounting treatments, the measure of the supply and use are equivalent and will be equal to the actual flow between the ecosystem asset and people. Nonetheless, the concept of ecosystem capacity is of significant relevance. Section 6.5 provides a discussion on this concept in the context of ecosystem accounting.

6.12 In many cases, ecosystem services will contribute to benefits in combination with other inputs such as labour and produced capital. These "joint production" contexts are an important feature of the relationship between ecosystem assets and economic and other human activity. They highlight the need to differentiate between ecosystem services and benefits. The types of benefits are discussed further in section 6.2.2.

6.13 The relationship between the supply of ecosystem services and the use of ecosystem services will not always be from one ecosystem asset to one economic unit or user. In some cases, ecosystem services will be supplied through a combination of ecosystem assets, for example flood control services involving a range of ecosystem types within a catchment. In other cases, one ecosystem service will be used by different economic units. For example, air filtration services will contribute to benefits used by households and businesses. The types of users are linked to different types of benefits and is discussed in section 6.2.2.

6.14 In some cases, the ecosystem services will be an indirect contribution to benefits, for example, where the nursery population service supplied by seagrass meadows is an input to the supply of fish biomass provisioning services, which in turn contribute to the benefit of marketed fish. In this case the nursery population service is treated as intermediate while the biomass provisioning service is final. Final and intermediate ecosystem services are discussed further in section 6.2.3.

6.2.2 Benefits

6.15 ***Benefits are the goods and services that are ultimately used and enjoyed by people and society.*** The use of the term benefit in ecosystem accounting derives from, but is applied more broadly than, the SNA definition of an economic benefit, namely "*an economic benefit is defined as denoting a gain or positive utility arising from an action*" (2008 SNA, 3.19) where an action or activity concerns production, consumption or accumulation and utility concerns the satisfaction of a human need or an improvement in well-being.[43] Thus, in ecosystem accounting, a benefit will reflect a gain or positive contribution to well-being arising from the consumption of ecosystem services.

6.16 Benefits are classified as either SNA benefits or non-SNA benefits. ***SNA benefits are goods or services that are included in the production boundary of the SNA.*** Examples of SNA benefits include food, water, energy, clothing, shelter and recreation services. As contributions to SNA benefits, ecosystem services are readily seen as inputs into an existing production process and consequently SNA benefits can be seen as resulting from a joint production process involving ecosystems and various other inputs including produced assets and labour. It will often be useful to distinguish between other inputs involved in the supply of ecosystem services (e.g.,

[43] As in the SNA, the term utility is used here in the sense of providing a conceptual reference point rather than a measurement objective.

the use of fertilizers in the growing of crops) and those involved in accessing or using ecosystem services (e.g., use of vehicles to drive to parks for recreation). In both contexts, the aim in ecosystem accounting is to isolate and record the ecosystem's contribution to the benefits received.

6.17 ***Non-SNA benefits are goods and services that are not included in the production boundary of the SNA.*** Examples of non-SNA benefits include clean air and flood protection provided by ecosystems. In line with the definition of benefits, the scope of non-SNA benefits for ecosystem accounting purposes is limited to the contributions to people and society. It therefore excludes contributions of ecosystems to their own longer-term condition and potential to supply ecosystem services in the future. While there may be benefits associated with maintenance of ecosystem condition, these are recorded in the ecosystem accounts via the ecosystem condition account or in terms of flows of ecosystem services and benefits recorded at the time they are used.

6.18 It is also relevant to consider the private and public nature of the ecosystem services and the link to benefits. Three situations can be described.

i. There are ecosystem services that contribute to benefits that are used by one user and it is feasible to exclude other users from its use (e.g., the supply of grazed biomass in rearing livestock on private land holdings). Such ecosystem services satisfy the economic definition of pure private goods being rival and excludable.

ii. There are ecosystem services that contribute to benefits that are used by one user but it is not feasible to exclude other users from it use (e.g., recreation-related services supplied by a public park). Such ecosystem services satisfy the economic definition of common pool resources being rival and non-excludable.

iii. There are ecosystem services that contribute to benefits that can be used simultaneously by multiple economic units and it is not feasible to exclude others from using the service (e.g., global climate regulation services). Such ecosystem services satisfy the economic definition of pure public goods being non-rival and non-excludable.

6.19 An application of these distinctions is that those ecosystem services that contribute to public goods can be treated analogously to those services treated in the SNA as collective consumption. These distinctions are relevant in the allocation of ecosystem services to users (as discussed further in Chapter 7) and in the integration of ecosystem services and ecosystem assets in the extended sequence of sector accounts described in Chapter 11.

6.20 As noted, there is a link between the definition of benefits and well-being. In a wider economic framing, well-being is commonly described in terms of welfare and utility which in turn may be linked to the consumption of goods and services[44] and the receipt of benefits. In this context, the assessment of changes in welfare and well-being will consider both positive and negative effects on utility.

6.21 From an accounting perspective, it is necessary to distinguish between outputs and outcomes and the focus of measurement for accounting purposes should be on outputs (see OECD (2008)). The concept of benefits applied in ecosystem accounting aligns with an output concept rather than on associated outcomes, e.g., concerning health, which will reflect a particular state or condition to which people attach utility. In measurement, the total supply of benefits will be constrained to those which contribute to outcomes and hence there

[44] In this context, "consumption" includes both the transformation of materials (e.g., use of timber to build houses or for energy) and the passive receipt of non-material ecosystem services (e.g., the aesthetic enjoyment of viewing landscapes).

remains a clear relationship between supply and use of benefits. There may be considerable analytical interest in estimating the value of health and other individual and social outcomes but this is not the focus of measurement for accounting.

6.2.3 Final and intermediate services

6.22 The primary focus of ecosystem accounting is on the measurement of final ecosystem services. ***Final ecosystem services are those ecosystem services in which the user of the service is an economic unit – i.e., business, government or household***. Thus, every final ecosystem service flow represents a transaction between an ecosystem asset and an economic unit.

6.23 To support integration with the SNA, the measurement scope of ecosystem services is set such that transactions in ecosystem services do not overlap with the transactions in goods and services recorded in the SNA (i.e., SNA benefits). The measurement scope of goods and services recorded in the SNA is defined by the SNA production boundary. In ecosystem accounting, ecosystem services (that are inputs to non-SNA benefits) are recorded as additions to the SNA production boundary.

6.24 A focus on accounting for final ecosystem services is appropriate where the focus of measurement is on the direct connection between people and ecosystems. However, there is a range of connections among ecosystem assets involving a range of ecosystem structures and processes that will be relevant in determining the supply of final ecosystem services. For example, populations of wild fish may be caught at sea while the associated nurseries are located in seagrass meadows closer to shore. Thus, while the overall contribution of ecosystems will be embodied in the catch of wild fish (a final ecosystem service), this recording will not reveal the indirect contribution of the seagrass meadows.

6.25 Conceptually, the ecosystem accounting framework allows the indirect contributions of ecosystem assets to be recorded as intermediate services. As for final ecosystem services, intermediate services are transactions and represent contributions to benefits. Thus, ***intermediate services are those ecosystem services in which the user of the ecosystem services is an ecosystem asset and where there is a connection to the supply of final ecosystem services.*** Since intermediate services are defined with respect to a sequence of inputs and outputs within the environment, there is the potential for them to be recorded both within and between ecosystem assets. For example, water purification services provided by a lake may be recorded as inputs to recreation-related services in the same lake and also as inputs to ecosystem services supplied further downstream by another ecosystem asset. This treatment allows the recording of intermediate services to be undertaken irrespective of the size of the ecosystem assets.

6.26 For ecosystem accounting purposes, measurement of intermediate services should generally focus on cases where there are observable connections between ecosystem assets that are of high analytical or policy interest, for example concerning the role of wild pollinators in supporting the production of crop biomass, or connections among trophic layers for fish species.

6.27 The concept of intermediate services is not equivalent to the wide array of biophysical flows within and between ecosystems that reflect ongoing ecological processes. These were referred to in the SEEA 2012 EEA as intra- and inter ecosystem flows. There is no doubt that these processes are fundamental to the supply of ecosystem services but a complete mapping of intra- and inter ecosystem flows is beyond the scope of ecosystem accounting. Nonetheless, there will be interest in understanding the extent to which the various ecological processes are well-functioning, for example in understanding the ability of an ecosystem to provide ecosystem services into the future. In ecosystem accounting, the maintenance of well-functioning ecosystems is considered in the measurement of ecosystem condition, ecosystem capacity and biodiversity.

6.2.4 Users and beneficiaries

6.28 In accounting, the supply and use of ecosystem services in the production of benefits can be considered, in many contexts, as the first step in a longer economic "supply" chain. For example, a water supply company's use of water purification services will be an initial step in the abstraction and distribution of water to a wide range of economic units, including businesses, governments and households. For clarity of expression, all of these economic units may be referred to as beneficiaries of ecosystem services but the economic unit that has the direct connection to the ecosystem, i.e., the unit that is the counterparty in the transaction with the ecosystem, is labelled the user of the ecosystem service. In this example, the user of water purification services is the water supply company while the other economic units would be beneficiaries.[45]

6.29 In recording flows of ecosystem services to various users and beneficiaries, it will be relevant to consider the location of use relative to the location of the supplying ecosystem. This will extend to consideration of imports and exports of ecosystem services and the associated benefits. The mapping of ecosystem service flows to users and beneficiaries is discussed further in Chapter 7.

6.2.5 Abiotic flows

6.30 The discussion and literature on ecosystem services has tended to focus on those flows that are primarily associated with an ecosystem's biotic components and processes, in general terms flows associated with living components such as plants and animals. However, since the definition of an ecosystem involves the interaction of biotic and abiotic components, a neat separation that treats ecosystem services as purely or predominantly "biotic," is not appropriate.

6.31 Further, there is a range of benefits that people obtain from the environment that reflect contributions which appear to fall outside the scope of ecosystem services. Examples include extraction of fossil fuels and mineral ores, abstraction of water, energy obtained from wind and solar sources and the role of the soils and bedrock in supporting buildings and transport infrastructure.

6.32 To support discussion of these flows and the appropriate and comparable recording with respect to ecosystem services, the framing of contributions from the environment that is shown in Table 6.1 is adopted in the SEEA EA. Key features of this framing are that:

- Ecosystem services are distinct from abiotic flows while both reflect contributions from the environment. All ecosystem services and abiotic flows may be categorized as provisioning, regulating and maintenance, or cultural.
- Ecosystem services are underpinned by various ecological characteristics and processes which will involve both biotic and abiotic components to varying degrees. Thus, ecosystem services encompass services which are both

[45] Note that there may be additional users of the water purification service.

predominantly “biotic” (e.g., air filtration services by forests) and predominantly “abiotic” (e.g., coastal protection services by sand dunes).

- ***Abiotic flows are contributions to benefits from the environment that are not underpinned by ecological characteristics and processes***. They arise through the abstraction/extraction of resources where a distinction is made between those flows related to geophysical sources, i.e., sources related to climate and the atmosphere; and those related to geological resources. Depending on the location of the resources and the point of abstraction/extraction, geological resources may be attributed as flows from ecosystem assets (e.g., sand and gravel) or from deep geological resources.
- Spatial functions are not treated as either ecosystem services or abiotic flows. Two main types are identified (i) the use of the environment for transportation and movement on land, water or through the air; and (iii) as the base for buildings and structures; and (ii) the use of the environment as a sink for pollutants and waste (beyond the mediation of such residuals by ecosystems which is treated as an ecosystem service).

Table 6.1: Abiotic flows and contributions from the environment

Contributions from the environment				
		Provisioning	Regulating and maintenance	Cultural
Ecosystem services		X	X	X
Abiotic flows	Geophysical sources Flows related to geophysical processes including abstraction of water (including groundwater), and capture of wind and solar energy.	X		
	Geological resources Flows related to geological resources including extraction of fossil fuel, mineral ores, sand & gravel.	X		
Spatial functions	Flows related to the use of the environment as the location for transportation and movement, and for buildings and structures.	X		
	Flows related to the use of the environment as a sink for pollutants and waste (excluding the mediation of pollutants and wastes recorded as ecosystem services),		X	

6.33 Compilers are encouraged to record abiotic flows from geophysical sources and from geological resources extracted from ecosystem assets together with ecosystem services since analysis of spatial areas may be enhanced greatly from consideration of these abiotic flows. This is particularly the case for flows of water. Indeed, the treatment of water abstraction and supply is very important and discussed explicitly in section 6.4.

6.34 There is no expectation that compilers will record abiotic flows from deep geological resources or relating to spatial functions. Concerning flows of pollutants and waste it is noted that there will be related entries in the ecosystem service flow accounts concerning the mediation of these residuals, and the accounts of the SEEA Central Framework provide the opportunity to record aggregate flows of these pressures. The impact of these pressures on ecosystem condition should be recorded in the ecosystem condition account.

6.35 The monetary value of abiotic flows will generally be captured in current economic valuations, for example in the value of resources extracted or in market land values, with the main exception concerning the use of the environment as a sink for pollutants and waste.

6.2.6 Identifying flows of ecosystem services

6.36 To support consistent application of the boundary between ecosystem services and benefits, a tool referred to as a "logic chain" is applied. The intent is to provide a standard framing for recording information relevant to the description and measurement of individual ecosystem services. A logic chain reflects a sequence in which an ecosystem asset supplies an ecosystem service to an economic unit who uses that ecosystem service as an input to a production or consumption activity which derives an SNA or non-SNA benefit. Logic chains can be shown graphically but may also be shown in a table as shown in Table 6.2. Additional examples of logic chains for a selection of ecosystem services are presented in Annex 6.1.

Table 6.2: Generic logic chain (with example of air filtration services)

Ecosystem type/s	**Factors determining supply**		**Factors determining use**	**Ecosystem Service**		**Benefit**	**Users**
	Ecological	**Human**		**Description**	**Physical metric/s**		
Mainly forest and woodland	Type and condition of vegetation; Ambient pollutant concentrations;	Ecosystem management; Release of air pollutants	Behavioural responses and location of people and buildings affected by pollution	**Air filtration services (air pollutant mediation)**	Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5)	Reduced concentrations of air pollutants (non-SNA benefit)	Households, Businesses, Governments

6.37 As shown in Table 6.2, each logic chain for a given ecosystem service has a number of components: (i) the ecosystem types; (ii) factors determining supply; (iii) the ecosystem service and the common metric for measurement; (iv) factors determining use; (v) the associated benefit/s and (iv) the users. The following points are highlighted in respect of each component:

- *Ecosystem types:*[46] All ecosystem services are treated as being supplied by ecosystem assets, either individually (e.g., forest providing air filtration services to a neighbouring town) or in combination (e.g., ecosystems within a catchment providing water flow regulation services).
- *Factors determining supply*: Both ecological and human factors should be considered in describing those factors determining supply. From an ecological perspective, particular

[46] Ecosystem types are defined in Chapter 3.

ecosystem characteristics may relevant to the supply of ecosystem services, for example the presence of particular species, or soil type; or aspects of ecosystem condition, such as pollutant concentrations and soil organic carbon levels. Human factors can determine the supply of regulating services, for example, the service of air filtration requires that there is some release of air pollutants. Further, where there are cases of joint production of benefits, for example in the growing of crops, it will be relevant to recognise the human inputs such as labour, produced assets (e.g., tractors) and intermediate consumption of goods and services (e.g., fuel, fertilizer).

- *Factors determining use*: In addition to describing the factors involved in supply it will be relevant to describe how people and economic units engage with the ecosystem in order to use the ecosystem service. In the case of air filtration, the relevant factors concerning use will be the number of people in proximity to the relevant forest or other type of ecosystem. Note that without a description and quantification of the use then no flow of an ecosystem services should be recorded.
- *Ecosystem services*: A logic chain should revolve around a single ecosystem service recognising that it may be supplied by a combination of ecosystem assets and may contribute to a number of benefits. A physical metric is needed that gives a clear focus for measurement recognising that this metric may be a proxy for the ecosystem service and will vary depending on the data availability. For example, for air filtration a suitable metric will be the tonnes of pollutant absorbed by type of pollutant (e.g., PM2.5, PM10).
- *Benefits*: While the focus of ecosystem accounting is on identifying the contribution of ecosystems reflected in ecosystem services, commonly it will be through the observation of the benefits that the identification of the role of ecosystems can be described. For air filtration, the benefit of reduced concentrations of air pollutants will be received by households with respect to improved health and building owners in terms of reduced damage to property.
- *Users:* Different economic units will use the ecosystem services, in some cases the same service may be used by different types of economic units. For example, air filtration services will be used by households, businesses and governments.

6.3 The reference list of selected ecosystem services

6.3.1 Principles of the reference list of selected ecosystem services

6.38 Within the conceptual scope of the ecosystem services definition there are a wide range of ecosystem services. Notwithstanding strong advances in the development of classifications of ecosystem services, in particular the Common International Classification of Ecosystem Services (CICES)[47] and the National Ecosystem Service Classification System (NESCS),[48] an internationally agreed classification of ecosystem services has not been finalized. In its absence, a reference list of selected ecosystem services has been developed by combining the findings from the CICES, NESCS and other work (e.g., MA, TEEB and IPBES-NCP) on the typology and classification of ecosystem services, with the outcomes of the consultation on the revised SEEA EA. The primary criterion for inclusion in the reference list of selected ecosystem services is that the service is considered to constitute a relevant and material ecosystem service in many countries and contexts.

[47] https://cices.eu/resources/
[48] https://www.epa.gov/eco-research/national-ecosystem-services-classification-system-framework-design-and-policy

6.39 The reference list of selected ecosystem services provides labels and descriptions for a set of key ecosystem services relevant for ecosystem accounting. It is intended to provide clarity on the measurement scope and focus with respect to ecosystem services and should therefore support consistency of measurement. In this way, the reference list will support discussion among ecosystem accounts compilers, the comparison of measurement and valuation techniques and the comparison of accounting results.

6.40 The reference list is a pragmatic grouping of ecosystem services to supporting accounting and does not provide a full ecosystem service classification system. It is intended that a complete and internationally agreed classification system for ecosystem services will be developed. To support this development and to allow those using existing classification systems to link to the reference list, correspondences to CICES and NESCS are presented in Annex 6.2.

6.41 Since it contains only selected ecosystem services, the reference list is not exhaustive. It does however, include categories for "other ecosystem services" to allow for services not included in the list to be recorded in the ecosystem accounts, subject to them satisfying the definition of ecosystem services. Where additional ecosystem services are included in a set of ecosystem accounts it is important that the definition, labelling and measurement of those ecosystem services is done in a mutually exclusive way to facilitate comparison to those ecosystem services included in the reference list.

6.42 Each ecosystem service in the reference list is defined to support measurement such that there is no double-counting of the ecosystem contributions of individual ecosystem services in the reference list. The focus in applying this principle will vary by type of ecosystem service. For provisioning services, the mutual exclusivity will be connected with using a classification of biomass outputs such as of agricultural products. For regulating services, the focus is on distinguishing the roles of different ecological processes. For cultural services, the focus is on the description of the types of interactions that individual have with ecosystems, for example whether they take place within ecosystems or outside.

6.43 Further, the reference list includes both final ecosystem services (i.e., used by economic units) and intermediate services (i.e., used by ecosystem assets). The distinction between final and intermediate is not a reflection on the type of ecosystem service but instead is a reflection of the user of the service (and hence affects where it is recorded in the supply and use table). Particularly in accounting for biomass provisioning services, care will be needed to ensure that the appropriate combination of inputs and outputs of ecosystem services are recorded such that the net contribution of the ecosystem assets is identified. Chapter 7 provides further discussion on the appropriate recording of ecosystem services flows following a supply and use table approach.

6.44 Following the requirements of ecosystem accounting, the reference list does not incorporate a distinction based on the type of supplying ecosystem asset or a distinction based on the nature of the use of the ecosystem service (e.g., whether for use by households or business, for nutrition or energy, etc.). The information on the supplying ecosystem assets and the using economic units will be evident from the place in the supply and use table where the ecosystem service flow is recorded. The supply and use tables will apply existing classifications of ecosystem types and economic units to organize information on each ecosystem service flow.

6.3.2 The reference list of selected ecosystem services

6.45 The reference list of selected ecosystem services and associated descriptions is shown in Table 6.3. The list is structured at the highest level into three broad categories: provisioning services; regulating and maintenance services and cultural services.

- ***Provisioning services are those ecosystem services representing the material contributions to benefits supplied by ecosystems.***
- ***Regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate and maintain climate, hydrological and biochemical cycles, and a variety of biological processes in ranges that benefit individuals and society.***
- ***Cultural services are the experiential and non-material services related to the perceived or realized qualities of ecosystem assets whose existence and functioning contributes to a range of cultural benefits derived by individuals.***

6.46 Within each of these broad groups a number of ecosystem service types are included with some sub-types also listed. The sub-types for regulating and maintenance services are grouped roughly according to the topics of climate, air, soil, water and habitat and species related services.

6.47 To ensure that the coverage of the ecosystem accounts is as comprehensive as possible, compilers are encouraged to include as many types of ecosystem services as possible. A progressive expansion in scope of measurement over time may be appropriate, considering data and resource availability and relative significance of the ecosystem services.

Table 6.3: Reference list of selected ecosystem services

ECOSYSTEM SERVICE		DESCRIPTION	USE
Provisioning services			**Final / Intermediate**
Biomass provisioning services	Crop provisioning services	Biomass provisioning services are the ecosystem contributions to the growth of plant, animal and other biomass (e.g., fungi) that are subsequently harvested by economic units for various uses. These uses include the production of food, fibre, energy, medicines and cosmetics. These services may be provided in cultivated production contexts and through the harvest or capture of unmanaged (wild) plants, animals and other biomass	Final In cultivated production contexts there may be many intermediate services that could be recorded.
	Grazed biomass provisioning services		
	Timber provisioning services		
	Non-wood forest products (NWFP)		
	Wild animals, plants and other biomass provisioning services (incl. those related to hunting and trapping and bio-prospecting activities		
	Fish and other aquatic products provisioning services		
Water supply		Water supply services reflect the combined ecosystem contributions of water purification, water flow regulation and other ecosystem services to the supply of water to users for various uses including domestic consumption.	Final
Genetic material services		Genetic material services are the ecosystem contributions from all biota (including seed, spore or gamete production) that are used by economic units (i) to maintain or establish a new population, (ii) to develop new varieties or (iii) in gene synthesis.	Final / Intermediate
Other provisioning services			
Regulating and maintenance services			
Global climate regulation services		Global climate regulation services are the ecosystem contributions to the regulation of the concentrations of gases in the atmosphere that impact on global	Final

ECOSYSTEM SERVICE		DESCRIPTION	USE
		climate, primarily through the retention of carbon in ecosystems.	
Rainfall pattern regulation services (at sub-continental scale)		Rainfall pattern regulation services are the ecosystem contributions of vegetation, in particular forests, in maintaining rainfall patterns through evapotranspiration at the sub-continental scale. Forests and other vegetation recycle moisture back to the atmosphere where it is available for the generation of rainfall. Rainfall in interior parts of continents fully depends upon this recycling.	Final / Intermediate
Local (micro and meso) climate regulation services		Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions (including micro and mesoscale climates through the presence of vegetation that improves the living conditions for people and supports economic production. Examples include the evaporative cooling provided by urban trees and the contribution of trees in providing shade for livestock.	Final
Air filtration services		Air filtration services are the ecosystem contributions to the filtering of air borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components, particularly plants, that mitigates the harmful effects of the pollutants.	Final
Soil quality regulation services		Soil quality regulation services are the ecosystem contributions to the decomposition of organic and inorganic materials and to the fertility and characteristics of soils e.g., for input to biomass production.	Intermediate
Soil erosion control services (includes also sediment retention services and landslide mitigation)		Soil erosion control services are the ecosystem contributions, particularly the stabilising effects of plants, that reduce the loss of soil (and sediment) and mitigate or prevent potential damage to human use of the environment or human health and safety. It is generally an intermediate service (contributing to biomass provisioning services) but it can also be a final ecosystem service (preventing damaging effects to buildings, infrastructure and land uses from off-site effects such as mass movement of soil).	Final / Intermediate
Water purification services (water quality amelioration)	Retention and breakdown of excess nutrients	Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown and storage of pollutants by ecosystem components that mitigates the harmful effects of the pollutants on human use or health.	Intermediate / Final
	Retention and breakdown of other pollutants		
Water flow regulation services	Baseline flow maintenance	Water regulation services are the ecosystem contributions to the regulation of river and groundwater flows. They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration. In the context of extreme events, peak flow mitigation will work in combination with river flood mitigation services. Services concerning baseline flows may be final or intermediate, while those concerning extreme events are generally final ecosystem services.	Final / intermediate
	Peak flow mitigation		Final / Intermediate

ECOSYSTEM SERVICE		DESCRIPTION	USE
Flood mitigation services	Seawater (Tidal) surge mitigation (Coastal protection services)	Seawater surge mitigation services are the ecosystem contributions of linear elements in the seascape, for instance coral reefs, sand banks, dunes or mangrove ecosystems along the shore, in protecting the shore and thus mitigating the impacts of tidal surges or storms on local communities.	Final
	River flood mitigation	River flood mitigation services are the ecosystem contributions of forests and other ecosystems in protecting the banks of rivers from floods by providing structure and a physical barrier to high water levels and thus mitigating the impacts of floods on local communities. This service complements the peak flow mitigation service in which ecosystems regulate water levels.	Final
Storm mitigation services		Storm mitigation services are the ecosystem contributions of vegetation, especially linear elements in the landscape, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities.	Final
Noise attenuation services		Noise attenuation services are the ecosystem contributions to the reduction in the impact of noise on people that mitigates its harmful or stressful effects.	Final
Pollination services		Pollination services (or gamete dispersal in marine contexts) are the ecosystem contributions by wild pollinators to the fertilization of crops that maintains or increases the abundance and/or diversity of other species that economic units use or enjoy.	Intermediate
Pest control services		Pest control services are the ecosystem contributions to the reduction in biological interactions of the incidence of species that may prevent or reduce the output of biomass from ecosystems or affect human health.	Intermediate / Final
Nursery population and habitat maintenance services		Nursery population and habitat maintenance services are the ecosystem contributions necessary for sustaining populations of species that economic units use or enjoy.	Intermediate
Solid waste remediation		Solid waste remediation services are the ecosystem contributions to the transformation of an organic or inorganic substance that mitigates its harmful effects.	Final
Other regulating and maintenance services			
Cultural services			
Recreation-related services		Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through physical and experiential interactions with the environment. A distinction can be made between local and tourism related services to reflect the type of visitor engaging with ecosystems.	Final
Aesthetic enjoyment services		Aesthetic enjoyment services are the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits (especially visual).	Final

ECOSYSTEM SERVICE		DESCRIPTION	USE
Education, scientific and research services		Education, scientific and research services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use the environment through intellectual and representative interactions with the environment.	Final
Spiritual, symbolic and artistic services		Spiritual, symbolic and artistic services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that are recognised by people for their cultural, historical, sacred or religious significance.	Final
Ecosystem and species appreciation		Ecosystem and species appreciation concerns the non-use connections of people to the environment that relate to preserving the environment for current and future generations.	

6.3.3 The link between biodiversity and ecosystem services

6.48 The SEEA EA adopts the CBD definition[49] which highlights ecosystem, species and genetic diversity (i.e., within species) as the broad components of biodiversity. These components of biodiversity are not considered ecosystem services in themselves but there are distinct elements within these components that can be directly linked to ecosystem service supply. For example, specific genes (DNA sequences) can be a provisioning service to the pharmaceutical industry; pollinator species can provide important pollinating services to the agricultural sector; and ecosystems, such as forests and beaches, can provide places for recreation. A diversity of genes, species and ecosystems thus provides a greater range of ecosystem service options.

6.49 More broadly, the interactions between different components of biodiversity are essential for cycling energy, nutrients and other materials through the environment (Mori et al., 2013). This is fundamental for maintaining the various ecosystem processes and functions that underpin ecosystem service supply (Bolt et al., 2016). Further, as biodiversity is lost, these ecosystem processes are impacted. For example, as different ecosystems are lost, ecosystem processes are altered at landscape scale; and as species and their populations are lost from ecosystems, so are the different functional roles they perform (e.g., decomposing, pollinating, dispersing seeds). Consequently, biodiversity loss directly threatens ecosystem processes and the supply of many ecosystem services across multiple scales.

6.50 Further, biodiversity plays a fundamental role in maintaining the ability of ecosystem assets to supply ecosystem services in the future. The presence of a diversity of organisms (e.g., multiple species, the genetic diversity within them) performing a given function within an ecosystem boosts the ability of that ecosystem asset to maintain functionality and supply ecosystem services. This is because different environmental changes or shocks will affect individual elements of this diversity in different ways. This ability of ecosystems to tolerate shocks and disturbance while maintaining the same level of functioning is often referred to as 'ecosystem resilience' (see for example Mori et al., 2013; Thompson et al., 2009; Walker, 2019) and may be considered to have an 'insurance value' (Baumgärtner, 2007).

6.51 Elements of biodiversity that do not provide ecosystem services at present may also provide valuable ecosystem services in the future. For example, a tropical tree species might prove to

[49] See Chapter 2 for reference.

be the only source of a drug capable of combating a major new human disease. This role of biodiversity can be linked to the concept of an “option value” (Faith, 2018; Weitzman, 1992).

6.52 The existence of biodiversity and the desire for its ongoing preservation is also connected to non-use values that people hold with respect to the environment. These include existence and bequest values. Section 6.3.4 discusses non-use values.

6.53 The connections between biodiversity and human activity operates in two directions. Thus, biodiversity itself will be impacted by the type of use made of ecosystems for example in terms of harvesting practices for timber and fish and the extent of tourism activity. Choices in restoration and protection activity will also have impacts on biodiversity.

6.54 There still remains considerable uncertainty around the specifics of the relationships between biodiversity and ecosystem service supply (P. A. Harrison et al., 2014; Mace et al., 2012). In particular, where ‘tipping points’ or boundaries for biodiversity loss may lie with respect to ecosystem service supply (Mace et al., 2015). This should encourage a precautionary approach to the management of biodiversity for sustainable ecosystem service supply. This aspect is relevant in consideration of ecosystem capacity discussed in section 6.5.

6.55 The strong emphasis on biological “variability” or “diversity” is clear in the CBD definition. In the context of ecosystem accounting, biodiversity can then be viewed as an emergent property of a set of ecosystem assets and the community assemblages within them. These interact and support multiple ecosystem processes that underpin the capacity for current and future ecosystem service supply. As such, the link between biodiversity and ecosystem service supply should consider the roles played by diversity across all three of its components (ecosystems, species and genes) and across scales. Options on how this can be accounted for are explored further in Chapter 13.

6.3.4 The treatment of non-use values

6.56 From an economic perspective, the relationship between people and the environment is commonly characterised as comprising both use and non-use values (Pearce, 1992). The incorporation of use values, i.e., values arising where the benefit to people is revealed through their interaction with the environment (e.g., harvesting food, hiking in forests, benefitting from cleaner air), into an accounting framework is relatively straightforward in concept and is the focus of measurement in the SEEA EA.

6.57 However, the treatment of non-use values in an accounting setting requires additional considerations. In the context of the environment, non-use values are those values that people assign to ecosystems (including associated biodiversity), irrespective of whether they use, or intend to use, the ecosystems. Two main types of non-use values are described: bequest value where the value is based on making sure the ecosystem is available to future generations; and existence value where the value is based on knowledge that the ecosystem is present now. In both cases the benefit of the non-use value accrues to an individual in the present day. Hence for accounting purposes the two values have the same treatment.

6.58 In the discussion of use and non-use values there is also discussion of option values. From an accounting perspective, these are considered a type of use value to the extent that the underlying motivation for these values is to ensure that ecosystems are able to provide ecosystem services in the future, including ecosystem services that may be currently unknown or not used. Option values thus capture situations in which ecosystems are not currently being used but this is different from the concept of non-use. Conceptually, option values will be associated with measures of ecosystem condition and biodiversity and with measures of the expected future flows of ecosystem services incorporated in measures of the net present value of ecosystem services.

6.59 Unlike flows of ecosystem services, there is no direct or indirect interaction with the environment associated with non-use values, and, while non-use values may be associated with environmental knowledge or information, it is not considered, from an accounting perspective, that a transaction has taken place consistent with the definition of an ecosystem service. Further, non-use values do not satisfy the definition of a benefit which requires them to be something ultimately used and enjoyed by people.

6.60 However, since this type of connection to the environment may be of considerable importance, a separate class of cultural services has been included in the reference list ecosystem and species appreciation – to allow compilers to record data that can be directly associated with non-use values. Further, since estimates of non-use values in monetary terms may be of particular policy interest, they may be presented in complementary valuations as discussed in Chapter 12.

6.3.5 The treatment of ecosystem disservices

6.61 Consistent with the accounting treatment of transactions, the recording of ecosystem services includes positive exchanges between ecosystem assets and economic units in a sense of contributing to benefits. This does not imply that all outcomes arising from transactions are necessarily all positive (e.g., the purchase of cigarettes can lead to poor health outcomes) or that all transactions are similarly motivated (e.g., some purchases such as fire alarms are made to limit potential negative consequences). However, the transactions themselves all involve exchanging positive quantities of a good or service.

6.62 There are a range of contexts in which the outcomes of interactions between economic units and ecosystem assets are negative from the perspective of the economic units. Examples include the results of pests on crop production, increases in disease from environmental vectors, such as mosquitoes, and the presence of flies at a social event. Collectively, these have been labelled ecosystem disservices. From an economic perspective, it appears natural to deduct these disservices from the positive ecosystem services to estimate the “net” connection between people and ecosystems. At the same time, the precise nature of the net connection at a societal level must recognise that different people may have different perspectives on the same ecosystem asset (e.g., trees that provide shade may also obstruct some people’s view).

6.63 From an accounting perspective however, none of these contexts can be considered to reflect a transaction embodied in an exchange of positive quantities of a good or service, although it is possible to record relevant physical flows such as the number of pests, or the number of people affected by malaria. While they are not transactions, the effects of ecosystem disservices can be reflected in accounting entries. Two main contexts can be considered. First, the effects of ecosystem disservices may be reflected in reduced flows of ecosystem services – e.g., reduced biomass provisioning services because of invasive pests. In this case the extent of the disservice may be determined by using the accounts to compare two different scenarios – with and without pests. This is an analytical step rather than an accounting entry.

6.64 Second, the impacts of disease and other effects on human health, can, in broad accounting terms, be reflected in a loss of human capital which in turn may be reflected in reduced production (e.g., days lost due to poor health). Again, analysis would be required to determine the extent of the contribution of the ecosystem disservice relative to other factors.

6.65 Thus, while the accounting approach does not allow for direct recording of ecosystem disservices, it does provide a framework for the analysis of their effects. Further, the same approach can be applied in the context of analysis of negative environmental externalities, such as emissions from peatlands, where the flows relate to the activities of economic units rather than being ecosystem-based in origin. For example, the loss of ecosystem services – such as global climate regulation services, arising from peatland emissions will be recorded in the accounts and there is potential for any health effects arising from the clearing of peatlands (e.g., linked to related forest fires and smoke) to be shown in a loss of human capital.

6.66 Thus, while the welfare effects themselves are not fully incorporated in accounting entries, the data from the accounts can underpin the assessment of their magnitude. This topic is discussed further in Chapter 12 where complementary accounting tables show how estimates of the monetary value of the externalities can be presented in a supply and use table format for both ecosystem disservices and negative environmental externalities.

6.4 The treatment of specific ecosystem services and other environmental flows

6.4.1 The treatment of biomass provisioning services

6.67 There is clear recognition that people source and use biomass from ecosystems in a wide variety of ways and for different purposes, including for food, fibre and energy. Sometimes the biomass is harvested directly by a final consumer (e.g., households picking berries in a forest) but the vast majority of biomass is grown, harvested or accessed by farmers, foresters and fishers (economic units both small and large) that supply it to other economic units. Determining the appropriate treatment of these biomass provisioning services is complicated by the variety of biomass types and the range of ways in which people grow and harvest biomass from the environment.

6.68 Biomass provisioning services are ecosystem contributions to SNA benefits that take the form of food, fibre and energy outputs produced by economic units. In line with treatments in the SNA, all biomass provisioning that is input to subsistence production of agriculture, forestry and fisheries should be included in the scope of ecosystem accounts. This includes for example the collection and harvest of non-timber forest products and the growing of vegetables in backyard gardens. While all biomass harvested can be considered an SNA benefit, the recording of these flows in the SNA makes a distinction between cultivated and natural (non-cultivated) production processes based on the extent to which an economic unit manages or controls the growth of the biomass.

6.69 In natural production processes, all of the biomass that is harvested is considered the ecosystem contribution. Examples include harvesting of timber from natural forests, capture fishing from wild fish stocks and wild animals trapped and hunted (including bush meat). The measurement of the ecosystem service should be aligned with the gross quantity of biomass that is harvested, i.e., the gross natural resource input, following the SEEA Central Framework (section 3.2.2). This will be different from the total stock of biomass available for harvest and from the biomass that is subsequently sold or otherwise used. Thus, for example, felling residues and discarded catch should be considered as part of the ecosystem service flow. This treatment applies irrespective of (i) the length of time over which the biomass has been growing; and (ii) the nature of the product, (e.g., the gross biomass harvested includes honey from wild bees). Thus, focus is solely on the quantity of the biomass that is harvested or accessed. The services associated with the biomass from natural production processes are recorded during the accounting period in which they are harvested.

6.70 In cultivated production processes, joint production is considered to occur in which the role of the ecosystem in supplying the biomass intersects with the activity (and associated human inputs) of people and economic units. The activities of economic units in this joint production process can be separated into those concerning the growth of the biomass (e.g., the application of fertilizers and pesticides) and those concerning the harvest of the biomass. The contribution of the ecosystem occurs up to the point of harvest.

6.71 There is a very wide range of cultivated production contexts. Thus, the extent of human activity in the management of biomass growth can be very high (e.g., for hydroponically grown strawberries) or very low (e.g., for lightly managed timber plantations). Depending on the type of biomass and the related product, the timing and context of the growth and harvest can vary significantly. Further, within each production context there is a wide variety of management practices and there may be more than one benefit that is generated. For example, the general activity of corn production may produce food as well as biomass for the production of energy; and cattle production will supply food as well as hides for leather and bones for fertilizer.

6.72 Notwithstanding this diversity of cultivated production contexts, the conceptual intent for ecosystem accounting is to identify the ecosystem contribution, i.e., to recognize that in different production contexts the relative role of ecosystem services will vary. This intent can be aligned with a framing in which there is a focus on the individual inputs such as nutrients, water, soil retention, pollination etc. which will be used in different combinations in different contexts.

6.73 Particularly when cultivated production is of high intensity, there may be a significant difference between the ecosystem contribution and the gross biomass harvested. This difference may increase due to, for example, additional fertilizer, enhanced seed varieties and intensified management even while the extent of the ecosystem asset under use decreases (e.g., through conversion to settlements). Biotic elements that contribute positively to biomass growth may also deteriorate (e.g., humus content). Compilers are thus encouraged to estimate the ecosystem contribution to cultivated biomass production processes especially where these might be changing over time.

6.74 However, in practice, there is a considerable measurement challenge in either identifying all of the relevant individual inputs or accurately measuring the ecosystem contribution to the gross biomass that is harvested that takes into account the diversity of cultivated production contexts. Thus, the gross biomass harvested is considered a suitable proxy measure for the flow of biomass provisioning services in cultivated production contexts, irrespective of the extent of human inputs and the intensity of management.

6.75 Whether the ecosystem contribution is measured directly or not, it is recommended to provide additional information on the cultivated production contexts including, for example, data on the gross biomass harvested in intensive and extensive production contexts or via organic farming. Further, measurement by biomass type and by relevant ecosystem characteristic (e.g., by soil type, climatic zone), and data on variables such as soil fertility, soil-water availability and fertilizer use is likely to assist in better understanding the relative ecosystem contribution.

6.76 In line with SNA time of recording treatments, ecosystem services in cultivated production contexts are recorded progressively over the life of the biomass. Thus, services associated with timber production from plantation forests should be recorded progressively as the timber resource grow in line with the recording of the growth of this resource in the national accounts as a work in progress.

6.77 Both the measurement of the ecosystem contribution and the gross harvested biomass require a clear target for measurement. A different focus of measurement is used for plants and livestock. For cultivated plants, the ecosystem services are measured in relation to the quantity harvested, for example quantities of corn, timber or apples. This flow is recorded as supplied by the relevant ecosystem and used by the economic unit managing the cultivation (e.g., farmer).[50]

6.78 For cultivated livestock, the measurement focus is on the extent of the connection between the livestock and relevant ecosystem assets, primarily natural and cultivated pastures. Hence, the supply of biomass provisioning services related to livestock is measured in relation to the quantity of grazed biomass. Other ecosystem contributions such as water supply and local climate regulation (e.g., trees providing shade and wind protection to livestock) may also be incorporated.

6.79 Consequently, for ecosystem accounting, the focus of measurement is not on livestock products (e.g., meat, milk, eggs) or on the growth of livestock. Further, where livestock production process does not involve direct connection with an ecosystem, as commonly occurs, for example, in some forms of chicken and pig rearing, no ecosystem services should be recorded. In these cases, the associated ecosystem services are limited to the ecosystem contribution to the production of feed and supplements (e.g., via hay, pellets, etc.).

6.80 By extension, the livestock treatment applies to other animals (mainly fish) raised in aquaculture facilities (both marine and freshwater) whose cultivation involves the provision of feed inputs, including fish meal. Thus, the gross biomass harvested from aquaculture should not be used as a proxy for the ecosystem contribution. An exception arises where no feed or other inputs are provided (e.g., the farming of oysters). In these cases, the ecosystem service can be appropriately measured using the gross biomass harvested. Aquaculture involving ponds where there is not direct connection to a surrounding ecosystem asset are assumed to involve no direct ecosystem contributions.

6.81 To complete the description of the treatment of biomass provisioning services, four other commonly considered issues are noted.

- *Links to recreation-related services.* There are many instances, especially with regard to fishing, where people catch wild animals as part of their recreational activities and sometimes as part of a paid service. From a national accounts perspective, if the catch is retained for consumption then it should be included within the production boundary of the SNA and hence the quantity and value of the associated biomass should be included as part of biomass provisioning services. At the same time, there will be a clear connection to the measurement of recreation-related ecosystem services, including hunting, trapping and fishing. The case of “catch and release” fishing is a specific example where no biomass is retained. In these instances, cultural services may be recorded in addition to biomass provisioning services.

- *Intermediate services in biomass production.* For cultivated biomass provisioning services it should be straightforward to attribute the service to a specific ecosystem asset since there will be a distinct location where the biomass is grown and harvested. For uncultivated biomass provisioning this may be more challenging, especially for fish biomass. In concept, for non-aquaculture fish biomass, the relevant supply location is the place at which the transaction in ecosystem services takes place – i.e., the place where

[50] The subsequent sale of harvested outputs by the economic unit along the supply chain is recorded in the standard SNA production accounts. Double counting is avoided by ensuring that there are entries for both the supply and use of the ecosystem service and hence the net effect with respect to the farmer’s value-added is unchanged but the contribution of the ecosystem is recognised.

the catch occurs. However, it is well recognized that there may be multiple ecosystems that are important in the growth of wild fish. To record their relative importance, intermediate services can be recorded reflecting the connections between ecosystem assets. This would include, for example, recording nursery services from seagrass meadows for certain species. The extent to which this measurement is possible will depend on the data available and levels of ecological knowledge.

- *Trade in biomass products.* Given the extent of international trade in agricultural, forestry and fisheries products, there will commonly be a large spatial disconnect between the location of harvest (where the ecosystem service is recorded), the location of subsequent processing and manufacturing, and the location of final household consumption. As explained further in Chapter 7, following accounting principles, the supply and use of ecosystem services is recorded in the location of harvest rather than recording the supply of ecosystem services in one location and use (albeit embodied in another product) in another location. Thus, there is no international trade in biomass provisioning services. It is possible using input-output techniques to trace the flow of associated/derivative products within the international economy, for example to derive ecosystem service footprints.
- *Losses in biomass production.* A common feature in the harvesting of biomass is that not all of the captured biomass is retained and used in the subsequent production process. These are referred to in the SEEA Central Framework as losses and include felling residues, discarded catch and harvest losses. In the SNA, the focus is on the output ultimately sold by the producer and thus, in physical terms, the measure of output will be net of these losses. In the SEEA Central Framework, compilers are encouraged to record the flows in gross terms (section 3.3.2), since this reflects the actual flow of inputs from the environment. For ecosystem accounting, it is recommended that the principles of the SEEA Central Framework should be applied such that quantity of biomass provisioning services should be equal to the harvest in gross terms, i.e., before harvest losses, felling residues and discarded catch are deducted.

6.4.2 The treatment of water supply

6.82 The treatment of the abstraction of water by economic units, including households, for use in production processes (e.g., irrigation, cooling) or for consumption, lies on the ecosystem service measurement boundary. There is no doubt that flows of water are highly relevant in both ecological and economic contexts, with the volume of water supply being largely determined by hydrological cycles. At the same time, the availability and quality of water in any given location is directly affected, to varying degrees, by ecosystem structures and processes. Consistent with the general definition of ecosystem services, it is the ecosystem contribution that is the primary focus of measurement in ecosystem accounting.

6.83 In ecological terms, there is a range of factors that contribute to the availability and quality of water. Two primary processes are (i) those related to the regulation of base flows of water including precipitation, runoff, infiltration and evapotranspiration leading to water absorption and release; and (ii) those related to the purification of water. In a catchment context, these and other relevant ecological processes are likely to involve multiple ecosystem assets of varying types within a catchment, e.g., forests, agricultural land, wetlands and rivers. These ecological processes can be considered inputs to water supply.

6.84 In compiling ecosystem accounts there are a number of flows that should be recorded in order to best reflect the relevant ecosystem contribution. First, a distinction should be made between different purposes for water abstraction. In particular, a distinction should be made between abstraction that is less dependent on the quality of the water abstracted, for example, water used for cooling, hydroelectric power generation or desalination, and cases where the quality of water is an important factor, e.g., for domestic consumption. Making this distinction allows the relevant ecosystem contributions to be appropriately targeted; e.g., water purification services will not be relevant inputs for non-quality dependent water abstraction.

6.85 Second, where the abstraction of water does not require or involve an ecosystem contribution it should be recorded as an abiotic flow, equal to the volume of water abstracted for those purposes. This would include, for example, the collection of rainwater in tanks.

6.86 Third, where ecosystem contributions are involved, ideally, these contributions should be measured directly and recorded as a final ecosystem service. This may involve recording flows of water purification services and water flow regulation services, for example. Where this direct measurement is possible, the actual flows of water abstracted should be recorded as abiotic flows, equal to the volume of water abstracted for those purposes.

6.87 Finally, if the direct contributions to water supply cannot be separately recorded, it is appropriate to record the volume of water abstracted as a proxy for the ecosystem contributions. This flow should be recorded as an ecosystem service. If this measurement approach is adopted, there should be no entry for abiotic flows relating to these volumes of water.

6.88 To support comparability across sets of accounts, irrespective of the measurement approach adopted, all flows of abstracted water should be recorded in the ecosystem accounts either as an ecosystem service or as an abiotic flow. Further, the recording of all flows of water abstraction should align with the definitions and treatments of the SEEA Central Framework, section 3.5 – Physical flows accounts for water.

6.89 Further, irrespective of the measurement approach, care is needed to ensure appropriate recognition of the connection of ecosystem services such as water purification and water flow regulation to other ecosystem services and benefits. For example, water purification and water flow regulation will be relevant in the supply of recreation-related cultural services when people swim in a lake or river. Thus, the measurement of these services only in terms of their input to water supply may not provide a full assessment of the contribution of these services. Further discussion on the appropriate recording of these combinations of flows is presented in Chapter 7.

6.90 A significant volume of water is abstracted from groundwater sources from both deep and shallow aquifers. The same treatments as outlined above apply to groundwater since all aquifers are considered as types of ecosystems. Water abstracted from marine ecosystems, for example for desalination or use as cooling water, should be treated as an abiotic flow, following the treatment outlined above.

6.91 Following the SEEA Central Framework, water used for hydroelectric power generation is treated as abstracted – i.e., it is removed from the environment into the economy, notwithstanding its immediate return and potential to affect water quality. Water abstracted for hydroelectric power generation will commonly be treated as an abiotic flow although in some contexts, surrounding landscapes may provide ecosystem services that support hydroelectric power generation, for example, through the retention of sediment. In these contexts, the treatment outlined above can be applied.

6.4.3 The measurement of global climate regulation services

6.92 The measurement and analysis of climate change commonly focuses on the release of greenhouse gases (GHG) as a result of economic and human activity and the associated changes in concentration of these gases in the atmosphere. Ecosystem accounting has a complementary focus of measurement on the role of ecosystems in helping to regulate the changes in the climate by virtue, primarily, of their capacity to capture (i.e., remove from the atmosphere) and store carbon and other substances such as methane and nitrous oxides. The measurement approach described here considers carbon but the principles can be applied to other substances.

6.93 All approaches to accounting for the role of ecosystems in global climate regulation are based on the comprehensive recording of stocks and changes in stocks of carbon (i.e., a physical carbon stock account). Ideally, this will encompass measurement of the opening and closing stocks of carbon stored in biomass (both above and below ground), debris and in soil, across the full range of ecosystem types within an ecosystem accounting area, including marine ecosystems as appropriate. This scope may be broader than required according to the reporting requirements of the UNFCCC but it will remain appropriate to follow the measurement advice of the Intergovernmental Panel on Climate Change (IPCC) guidelines for all relevant ecosystem types. Changes in the carbon stock will reflect the capture and release of carbon from these stocks for all reasons, including for example, reforestation activity, conversion of peatlands to agricultural production, natural regeneration of vegetation and the effects of wild fires.

6.94 For ecosystem accounting purposes, measurement of all stocks and changes in stocks of carbon is not required, for example concerning deposits of fossil fuels, releases of carbon through the consumption of fossil fuel, or the accumulation of carbon in the atmosphere. Nonetheless, a complete accounting for all carbon stocks and flows is highly recommended to support coherence in measurement and wider discussion on climate change and associated policy issues. Chapter 13 provides further discussion on accounting for carbon in supporting the discussion of climate change.

6.95 For ecosystem accounting, the ecological contribution of global climate regulation reflects the ability of ecosystems to retain the stock of carbon – i.e., ecosystems supply a carbon retention service through the avoided release of carbon to the atmosphere. Thus, to the extent that the carbon stock increases over time, for example through carbon capture, then the quantity of services provided will have increased. The reverse also holds.

6.96 The service is quantified by recording the stock of carbon retained in ecosystems over an accounting period. This is a proxy indicator for the flow of the service, analogous to the quantification of the services supplied by a storage company in terms of the volume of goods stored. As required, changes in the supply of global climate regulation services can be attributed to either capture or removal from the stock of carbon of ecosystems based on analysis of the changes in the stocks of carbon.

6.97 The total stock of carbon is very large, especially in some ecosystem types such as peatlands. To the extent that there is little to no risk of carbon removal then, in an accounting context, there is no direct ecosystem contribution to climate regulation to be recorded. By convention, the measurement scope of the carbon stock for the derivation of the indicator of the global climate regulation service is therefore limited to carbon stored in above ground (including sea bed) biomass in all ecosystems plus, in the case of peatlands and relevant organic rich soils, the carbon stored to a maximum of 2 metres below the surface. Inorganic carbon stored in freshwater, marine and subterranean ecosystems is excluded from scope in the measurement of the service. Within this measurement boundary, for a single ecosystem, the minimum service that can be supplied is zero when the stock of carbon (measured using the scope just described) is zero.

6.98 The carbon stored in fossil fuel deposits should not be considered an ecosystem service since these deposits are not ecosystem assets. Similarly, the storage of carbon in harvested wood products should not be considered an ecosystem service since this carbon is no longer stored as part of an ecosystem asset, but rather within products (e.g., houses, furniture) that are considered part of the economy. They should not be considered stocks of carbon within urban ecosystems and built environments. Note that this treatment is consistent in terms of physical flows with the recording of biomass provisioning services. That is, assuming no regeneration, the harvesting of biomass will correspond to a decline in global climate regulation services and an increase in biomass provisioning services.

6.99 An alternative measure for this service, and one that is commonly used in the ecosystem services literature is the sequestration of carbon by ecosystems. In many situations this measure will prove a suitable proxy for the carbon retention approach just described since where the net change in the stock is positive this will be equivalent to a measure of the net sequestration. However, where the net change in stock is negative, the use of a measure of sequestration will imply a negative transaction the recording of which is not consistent with accounting principles.

6.4.4 The identification of cultural services

6.100 There are important connections between people and ecosystems that are not provisioning or regulating in nature. The label cultural services is used to encompass many of these experiential and non-material connections. This label is a pragmatic choice and reflects its longstanding use in the ecosystem services community. It is not implied that culture itself is a service, rather it is a summary label intended to capture the variety of ways in which people connect to and identify with nature and the variety of motivations for these connections.

6.101 There are two key aspects in the identification of cultural services for ecosystem accounting purposes. First, it is necessary to determine the relevant set of benefits since these services can only be defined from a user perspective. Second, flows of cultural services, representing the contribution of the ecosystem to the benefits, will reflect the characteristics and qualities of ecosystems. For many cultural services, recognizing the richness and functionality of the space provided by ecosystems, for example to support recreation, is fundamental.

6.102 For ecosystem accounting, the cultural benefits to which cultural ecosystem services contribute comprise (i) benefits from undertaking activity (including recreation) within ecosystems (i.e., in situ) and (ii) benefits from having a cultural, spiritual or similar relational connection to an ecosystem or the biodiversity it contains. The first type of cultural benefits in which people experience nature directly is considered to encompass a contribution from the ecosystem accepting that there must also be human inputs of time and potentially resources (e.g., equipment, travel). Both of these types of benefits will encompass associated benefits to people’s physical and mental health.

6.103 The second type of cultural benefits covers the things in nature that people think should be conserved for a wide variety of motivations and can be reflected in a direct experience to which the characteristics and qualities of an ecosystem asset contribute. This type of benefit includes cultural and spiritual connections and may commonly be a focus of economic transactions such as donations to non-profit groups that are motivated to protect and conserve ecosystems.

6.104 However, cultural benefits arising from the remote experience of ecosystems (including via various media – e.g., television, music, photos, etc.) are not considered to be within scope of ecosystem accounting, aside from the more limited set of benefits enjoyed by the producers of the relevant content (e.g., artists, movie producers, etc.) who directly use the characteristics and qualities of the ecosystems and who, in some instances, may be required to pay for access or similar rights to complete the production process.

6.105 Given this scope of cultural benefits, cultural services are defined as the perceived or realized qualities of ecosystems whose existence and functioning enables a range of cultural benefits to be derived. Within this definition, cultural ecosystem services (i) reflect the ecosystem contribution in terms of providing places and opportunities for activity by people; (ii) are linked to flows from ecosystems to people that may be considered "experiential"; and (iii) are able to contribute to multiple benefits, i.e., one ecosystem and its characteristics/qualities can contribute to different cultural benefits and can be linked to varying motivations of different users.

6.106 Using this definition of cultural services, four cultural services are included in the reference list, namely: recreation-related services; amenity services; education, scientific and research services; and spiritual, symbolic and artistic services. A separate class - ecosystem and species appreciation - has also been included in the reference list to allow for recording data on non-use values. A description of these services is provided in Table 6.3 above. In recording these services, consideration should be given to the potential connections among them given that a single interaction (e.g., visit to a park) could potentially be recorded as reflecting a range of different services. In such cases, attribution should be made based on the primary purpose or motivation of the interaction.

6.107 Cultural ecosystem services contribute to processes involving different combinations of ecosystem assets, produced assets (e.g., access roads, on-site facilities, walking trails, residential location) and human capital (including people's time, experience and knowledge, capabilities (physical and perceptional)). Generally, human inputs will reflect the inputs required to use or access the cultural benefits, but some human inputs, for example concerning activities to restore or maintain ecosystem condition, will concern the supply of cultural benefits.

6.108 People undertake a range of activities in the environment for a range of purposes. Generally, the focus of cultural services is on activities of a recreational or personal purpose. However, for those people working outdoors – such as farmers, tour guides, landscapers and others that have a relatively direct connection with the environment in their jobs – they will likely derive some benefit from being outdoors that is similar to a recreation-related service. The potential ecosystem contributions to these benefits are not recorded explicitly in the ecosystem accounts but, where they arise (which will not be the case in all outdoor labouring contexts), estimates should be included in measures of aesthetic enjoyment services.

6.109 Where payments are made by people to economic units who manage ecosystems, e.g., managers of national parks, for access to ecosystems; or where payments are made to economic units who support activities in ecosystems (e.g., canoe rental businesses), connections can be made to entries in the standard national accounts and hence SNA benefits. The appropriate recording of these flows is described in Chapter 7.

6.4.5 The treatment of abiotic flows

6.110 As noted in section 6.2.5, there is a range of flows between the environment and the economy in which there may be discussion as to whether there is a material ecosystem contribution that should be recorded as an ecosystem service. In general terms, if there is a clear contribution of ecological characteristics and processes then the flow can be treated as an ecosystem service. However, if there is no distinct role, the flow is treated as an abiotic flow. This distinction is clear in many cases but there are also a range of boundary cases. As described in section 6.2.5, there are a number of groups of abiotic flows and it is useful to consider the boundary cases in the context of these groups.

6.111 The treatments described here are intended to give guidance to compilers as to the appropriate treatment to support comparability. However, it is not possible to conceive all possible contexts. Thus, in principle, compilers should return to the core definition of ecosystem services and ensure that the focus of measurement is on the ecosystem contribution to benefits. Further, in identifying ecosystem contributions the focus should be on the nature of the ecological characteristics and processes rather than on whether the ecosystem is more or less dominated by biotic or abiotic components, i.e., recognizing that deserts, with comparably little biota, and rainforests, with much biota, are both ecosystem types. Since ecosystems by definition are a combination of both biotic and abiotic components, and involve interactions across various scales, this variation should not be a key factor in determining whether an ecosystem service is supplied and used.

6.112 Compilers are encouraged to record abiotic flows where relevant to the analysis of ecosystem use since there are commonly trade-offs between ecosystem services and abiotic flows. This is particularly the case for geophysical services, including flows of water, wind and solar energy. However, where monetary valuation is undertaken (following the advice in Chapters 8-10) abiotic flows should not be included in the measurement of the value of ecosystem assets. The value of abiotic flows may commonly be able to be measured using observed market prices and the net present value of these flows can be recorded alongside the value of ecosystem assets in the extend balance sheet described in Chapter 11.

6.113 <u>Flows related to abiotic components of ecosystems in the supply of regulating and maintenance services.</u> Since, ecosystems are a combination of biotic and abiotic components, the following cases are treated as ecosystem services, notwithstanding that there may be a dominant role of abiotic components in some ecosystem types.

- Air filtration services (capture of air pollutants) by abiotic components (such as bare and rocky surfaces) – here pollutants are absorbed but not by active biotic components
- Coastal protection services provided by unvegetated shingle or sand dunes – here the predominant role of abiotic components in the landscape structure in providing the services is recognised.
- Water purification and regulation services from bare but unsealed soil – here water permeating through the soil may be improved in quality through water purification services and may also provide a more continuous supply of water to groundwater sources.

6.114 <u>Flows related to the generation of energy.</u> For flows of energy from non-renewable sources, such as fossil fuels and uranium, it is considered that these are abiotic flows from geological resources. Where peat is used as an energy source this should be recorded as a biomass provisioning service since the source reflects a biotic characteristic of an ecosystem, notwithstanding the fact that this implies the direct degradation of the ecosystem asset since the time for peat to regenerate is too long to consider that it is a renewable resource.[51]

[51] Note that peatlands will also supply other ecosystem services, such as global climate regulation and water purification services whose non-biomass flows will not imply the degradation of the ecosystem asset.

6.115 For flows of energy from renewable sources, three types can be distinguished:

- Energy from biomass, including round and brushwood, maize used for ethanol, etc. Here the flow involves an ecosystem contribution that should be captured as part of estimating the flow of biomass provisioning services.
- Energy from sources such as wind, solar, geothermal and tidal energy. Here the flows involve geophysical processes and hence they are considered abiotic flows from geophysical sources.
- Energy from hydroelectric power generation. For ecosystem accounting, it is considered that the source of the energy is related most strongly to the landscape structure and geomorphology (for example the fall in the river). Thus, while ecosystem services supplied by the surrounding landscape such as water regulation of base flows and soil erosion control are important final ecosystem services to be recorded, the generation of hydroelectric power itself is considered an abiotic flow from geophysical sources.

6.116 Flows related to residuals from economic activity. There is a range of residuals that are released through economic activity including emissions to air, soil and water and the generation of solid waste. In many cases, ecosystems act as sinks or receivers of these residuals. Three cases are considered here:

i. Where residuals are actively mediated, broken down or otherwise processed via ecological processes, for example through air filtration and water purification. In this case, an ecosystem service is measured equivalent to the quantity of residual that is mediated up to the ecological limit or threshold for the given ecosystem asset.

ii. Where residuals are stored in specific areas, such as with landfill or mining overburden. This is considered a case of using the ecosystem's location, i.e., a sink service, and it is treated as a spatial function of the environment. No ecosystem service or abiotic flow should be recorded.

iii. Where residuals are passed through an ecosystem, for example where contaminants from effluent flow into freshwater ecosystems and are subsequently deposited within the sediment or passed on to the marine environment, including in cases where the release of residuals exceeds the ecological limit of the ecosystem to mediate or process the residual. In this case, the storage of pollutants is not considered to reflect an ecosystem contribution but may be considered a sink service. As for case (ii) no ecosystem service or abiotic flow should be recorded unless some mediation occurs (as per case (i)).

6.117 In this third case, increasing concentrations of some residuals will be a significant factor in the decline of the condition of ecosystems – e.g., excess nitrogen leading to eutrophication of lakes and bays. These declines should be recorded in the condition account and may be reflected in decreases in future flows of ecosystem services supplied by the affected ecosystems. However, the presence of residuals in an ecosystem is not, of itself, considered to imply the supply of an ecosystem service.

6.118 In the context of case (i) above, the ability of ecosystems to mediate, dilute and store pollutants (e.g., releases of excess nitrogen) may be regarded as providing a benefit to the polluter since they do not need to otherwise capture and store the residuals themselves or otherwise change their practices. Consistent with the advice above, only the mediation role performed by an ecosystem asset is recorded as an ecosystem service for ecosystem accounting purposes.

6.119 The use of the relevant ecosystem services, e.g., water purification, may be assigned to the polluter where there is a direct economic benefit, generally a reduction in operating costs, to the polluter arising from this use of the ecosystem. However, in line with case two above, since the total release of the residuals may be greater than the ecosystem can mediate, only a portion of the direct economic benefit should be treated as an ecosystem service. Where the use of ecosystem services is recorded in this way, note that it is also possible to assign the use of the relevant ecosystem services, e.g., water purification, to other economic units who subsequently use the ecosystem and hence benefit from cleaner water, air and soil, e.g., water supply companies. That is, there can be multiple users of the same ecological process.

6.120 Flows related to the use of the environment for undertaking economic and other activities – spatial functions. These flows relate primarily to the fact that all activities take place in a location. Flows related to the use of environment for these activities are treated as spatial functions within the broader framing of abiotic flows. While ecosystems will, by definition, be present in those locations, there are no ecological processes providing a contribution to those activities that should be recorded as an ecosystem service. This implies that the benefits from land supporting buildings, houses, roads, railways and other structures and associated values related to location are not considered to incorporate ecosystem services. Further there is no abstraction or extraction from the ecosystem that would require recording abiotic flows. A unique case concerns navigation on rivers where the flow of water supports transportation of people and goods. In this case there may be a contribution of ecosystem processes, primarily concerning water flow regulation, that may be recorded as a final ecosystem service.

6.121 In many cases there will be a significant monetary value associated with these uses of the environment, including the value of land under houses. This value should be included in the value of land in the extended balance sheet described in Chapter 11.

6.5 Ecosystem capacity

6.5.1 Introduction

6.122 The general interest in the concept of ecosystem capacity stems from the desire to understand issues such as:

- The extent to which the current patten of use of an ecosystem is beyond current limits of regeneration and absorption thus affecting the wellbeing of current generations; and
- The extent to which the current pattern of use has an effect on the potential to generate ecosystem services in the future and meet the needs of future generations.

6.123 Generally, the underlying concern relates to the loss of the quantity and quality of ecosystem assets and the impacts on the current and future flows of ecosystem services. In some cases, the focus is on local limits with respect to regeneration and overuse, and in other the limits concern tipping points where there are substantive changes in ecosystem type or breaches of other broader systemic limits.

6.124 In an accounting context, the concept of ecosystem capacity has been most commonly envisaged as embodying a link between measures of ecosystem asset extent and condition on the one hand and measures of ecosystem services supply and use. Indeed, accounting provides a relatively natural measurement platform for considering the inherent systemic linkages between the current and future patterns of supply and use of ecosystem services supply and use and the current and future state of ecosystem assets. This section summarizes the relevant considerations.

6.5.2 Defining ecosystem capacity for accounting purposes

6.125 The following definition of capacity is proposed for the SEEA EA. ***Ecosystem capacity is the ability of an ecosystem to generate an ecosystem service under current ecosystem condition, management and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem.***

6.126 This definition builds directly on the definition of Hein et al. (2016) but given the variety of perspectives on ecosystem capacity the following notes are required to appropriately interpret the intention and meaning of the definition.

6.127 First, the focus of the definition is on capacity of an ecosystem asset to supply a single ecosystem service. It is relatively common for the concept of ecosystem capacity to be framed in a way that speaks to the ability of an ecosystem asset to generate a bundle of ecosystem services. In concept, this would be ideal and would link directly to a range of literature on ecosystems and biodiversity (e.g., Mori et al., 2013) concerning the maintenance of ecosystem functions, and option and insurance values of ecosystem assets. However, from a measurement perspective, a focus on individual ecosystem services is both more measurable and, while more limited in focus, can be of direct relevance in policy and decision making, for example in setting policy and management targets. At the same time, while there is a focus on a single ecosystem service in this definition, the measurement of capacity will require consideration of the management and use of the ecosystem asset as a whole. Consequently, for an individual ecosystem the capacities for each service within a bundle will be connected.

6.128 Second, this definition can be applied using two main approaches. In one approach, it is assumed that the current ecosystem asset context will not change into the future. This implies that no consideration is given to the potential effects of external drivers (e.g., population growth or climate change) on the ecological limits of an ecosystem with respect to a specific service or on the use of that service. This approach is likely more viable, at least in the short term

6.129 In an alternative approach, assumptions are made about future changes in the ecosystem asset itself and/or in the expected patterns of ecosystem service use. Also, relevant here would be assumptions regarding expected interactions (trade-offs and/or synergies) within the ecosystem in the supply of different ecosystem services – e.g., between timber provisioning services and air filtration services. Making different assumptions about future changes and interactions will alter the measures of the appropriate ecological limits and hence will affect the measurement of capacity. Ideally, these types of considerations would be applied in the monetary valuation of ecosystem assets using an NPV formulation as described in Chapter 10.

6.130 Other observations on the application of this definition are:

- That, in physical terms, the measure of capacity for an individual ecosystem service should be expressed in the same quantification/measurement units as the actual flow of the ecosystem service. Thus, capacity would mostly commonly be expressed in terms of a rate per year. When considering measures over multiple ecosystem assets (e.g., for a single ecosystem type), it will also be relevant to present measures in terms of rates per spatial unit (e.g., ha) which will also be relevant in allowing for changes in the extent of ecosystems.
- That, under the first approach, it will be appropriate to assume a longer-term cycle of management/disturbance. Thus, for example, rotational harvesting of timber over long management cycles (40-100 years) should be taken into account. Longer-term effects of patterns of disturbance, like fire and flood, and ecosystems' adaptation to these disturbances, are also relevant considerations, noting that under the second approach,

expectations on potential changes in these longer-term cycles would be taken into consideration.

- That if the ecosystem service is used at current capacity, (i.e., there is no use beyond the appropriate limit), then the condition of the ecosystem asset should remain stable compared to its current level. Note that the capacity of an ecosystem to provide an ecosystem service may be very low if the condition of the ecosystem is low relative to a given reference condition. Thus, ecosystem capacity should not be measured in relation to an ecological limit that is present only at high levels of condition. Note also that limits can change over time (e.g., due to climate change) and hence measures of capacity should be regularly reassessed.
- That where the supply and use of the ecosystem service is equal to or less than capacity, irrespective of the level of supply and use, then the situation regarding the use of that ecosystem service should be considered "sustainable". Depending on the context, the level of sustainable use may be far lower than the level of current actual use.

6.131 In applying this definition, no measure of capacity is recorded for ecosystem services that might potentially be supplied but are not within the current bundle of ecosystem services from an ecosystem asset. The same framework may be applied to estimate an ecosystem's capacity to generate other, potentially unknown, ecosystem services in the future or under alternative patterns of use and demand. However, these types of scenario analysis are not a focus of ecosystem accounting.

6.132 While there is an apparent logical connection between increases in ecosystem condition and increases in capacity this may not apply for all ecosystem services. For example, primarily for provisioning services, the capacity may be higher at levels of condition that are somewhat below the reference condition. Thus, while as a general observation, higher levels of condition would be associated with higher measures of capacity, this will not hold in all circumstances. Further, the precise nature of the relationship between falls in condition and falls in capacity may be unclear, at least in the short term.

6.133 There are two complementary concepts to ecosystem capacity - potential supply and capability. Potential supply refers to the ability to generate services without regard to their use. Capability is similar to capacity but is limited in the sense of not considering the connections to the supply of other ecosystem services. Data from the ecosystem accounts will likely be relevant in the derivation of these measures noting that slightly difference assumptions will be required in their measurement.[52]

6.5.3 Defining ecosystem capacity with respect to specific types of ecosystem services

6.134 The description and measurement of ecosystem capacity will vary across different types of ecosystem services. For provisioning services, capacity will relate to the rates of regeneration that are possible under current conditions.

6.135 For regulating and maintenance services, the underlying ecological assumption is that there are limits or thresholds to the supply of these services. These limits may present themselves in different ways. For services where there is mediation of pollutants, such as water purification, there will be a limit as to the quantity of pollutant that can be mediated and processed. In this case ecosystem capacity will reflect that limit. For services which may be described as providing "buffer" services, such as water flow regulation and flood control

[52] Additional references on this topic: Burkhard et al., 2014; Villamagna et al., 2013.

services, there will be associated maximum rates of infiltration and related ecological boundaries that may be used to determine ecosystem capacity.

6.136 For cultural services, the issue of capacity arises only in the context of in situ use of the ecosystem in which case capacity measures will relate to the maximum number of people able to visit or enjoy a particular site without loss of ecosystem condition.

6.137 In practice, it may not be necessary to measure ecosystem capacity for all ecosystem services. An initial focus could be on those ecosystem services whose overuse is most likely to have negative effects on ecosystem condition. From a risk management perspective, this might seem appropriate and it certainly provides a basis for prioritization of ecosystem services for measurement.

6.138 Further on the issue of measurement focus, the concept of ecosystem capacity will be less relevant in cases where there is no or very limited use of an ecosystem service, for example air filtration service by forests in northern Canada. Measurement of ecosystem capacity in these contexts may suggest a level of available capacity which is not consistent with current and expected patterns of use.

6.139 In this context, note that the reference in the definition to current management and uses implies that the measurement of capacity must take into account restrictions on access or use of ecosystems. For example, if a forest has been designated as a protected area and logging is not possible then the capacity to supply biomass provisioning services will be zero. Similarly, a beach to which no recreational access is allowed has zero capacity to supply recreation-related services.

Annex 6.1: Initial logic chains for selected ecosystem services

Ecosystem type/s	Factors determining supply		Factors determining use	Ecosystem Service	Physical metric(s)	Benefit	Users	Potential beneficiaries
	Ecological	**Human**						
Cropland	Soil fertility; Water supply; Pollination	Farm management at different stages of production process	Harvesting practices, Demand for biomass (e.g., for food)	**Crop provisioning services**	Gross tonnes of crop biomass harvested – e.g., wheat (proxy measure)	Crop products – e.g., harvested wheat (SNA benefit)	Agricultural producers, include household and subsistence production	Food processors, transport and retail; Households as final consumers
Forests	Soil fertility; Climate and water supply	Forest management practices	Harvesting practices, Demand for timber	**Timber provisioning services**	Gross tonnes of timber biomass harvested	Harvested timber (SNA benefit)	Forestry producers, Households	Forest product manufacturers; Households as final consumers
Primarily woody biomes, also marine	Ecosystem type and condition (e.g., density and age); Atmospheric carbon concentrations	Ecosystem management; GHG emissions	NA	**Global climate regulation services (carbon retention)**	Tonnes of carbon retained (captured & stored)	Reduced concentrations of GHG in the atmosphere leading to more stable (cooler) global climate (non-SNA benefit)	Collectively consumed by government on behalf of society	Individuals, households and businesses globally
Mainly forest and woodland	Type and condition of vegetation; Ambient pollutant concentrations;	Ecosystem management; Release of air pollutants	Behavioural responses and location of people and buildings affected by pollution	**Air filtration services (air pollutant mediation)**	Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5)	Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings (non-SNA benefit)	Individuals and households;	Business (through improved workforce participation/ reduced sick days)
Riparian ecosystems, Coastal margins	Extent and condition of vegetation	Ecosystem management	Extent of existing produced assets (e.g., flood barriers, dykes); location of properties	**Flood mitigation services**	Number of properties/ km of coast protected; change in degree of risk	Reduced impact of flood events (non-SNA benefit)	Property owners – Households, business, government	Local communities
Many ecosystem types	Extent and condition; Presence of iconic landmarks or species	Ecosystem management including facilities to support access	Expenditure on access to recreation sites; Location of users relative to ecosystem	**Recreation-related services**	Number and length of visits	Physical and mental health; Enjoyment	Households; Tourism and Outdoor Leisure sectors	

Annex 6.2: Correspondences between the reference list and other ecosystem service classifications and typologies

<<The development of correspondence tables is ongoing. It is expected for them to be developed after the global consultation for the final publication.>>

7 Accounting for ecosystem services in physical terms

7.1 Introduction

7.1 Accounting for ecosystem services in physical terms aims to record, in an accounting structure, the flows of ecosystem services over an accounting period in physical units such as cubic metres and tonnes. Physical quantification commonly focuses on measurement of ecosystem structures, processes and functions; i.e., the supply side of ecosystem service flows but quantification of ecosystem contributions can also take place through a focus on the use of ecosystem services, for example the number of visits to a national park. A key focus in accounting for ecosystem services is reconciling the supply and the use of ecosystem services across multiple ecosystem assets and multiple users.

7.2 Flows of the ecosystem services in the reference list (see Chapter 6) can be measured in physical or quantitative terms. Different ecosystem types will supply different bundles of ecosystem services to different users. The aim in ecosystem accounting is to provide as comprehensive coverage as possible of the supply and use of different ecosystem services within an ecosystem accounting area. With this aim in mind, choices about which ecosystem services should be the focus of measurement will depend in large part on the data and resources available for the compilation of estimates.

7.3 Ecosystem service flow accounts in physical terms recording the supply and use of ecosystem services may be compiled for a range of reasons and purposes. These include recording and monitoring the different bundles of ecosystem services supplied by different ecosystem types, identifying the users of the services, and assessing how these patterns of supply and use are changing over time. This information can underpin analysis of the significance of particular ecosystems as ecosystem service suppliers, support analysis of trade-offs between different ecosystem services as part of spatial planning and land management, and provide information to support delineation of areas for specific land use including conservation and environmental protection. While some of these applications will be appropriate at larger, national scales, in many cases the use of spatial data on ecosystem services supply and use will open up considerable analytical opportunities. Much work on accounting for ecosystem services has been conducted using spatial data and for some services, particularly regulating and maintenance services, this is the likely measurement entry point.

7.4 Further, the information on ecosystem services in physical terms can be used to demonstrate the nature of the extension in the SNA production boundary that is applied in ecosystem accounting. This can support engagement and discussion of the wider, non-private, benefits of ecosystems. The data in physical terms will also underpin monetary valuation of ecosystem services (see Chapter 9).

7.2 Ecosystem services flow accounts in physical terms

7.2.1 Overall structure of the ecosystem services flow accounts

7.5 The structure of the ecosystem services flow accounts in physical terms is displayed in Table 7.1. This structure follows that of a supply and use table (SUT) as described in the SNA and the SEEA Central Framework to flows of ecosystem services in physical terms.

7.6 The list of ecosystem services reflects the reference list of selected ecosystem services in Chapter 6. Conceptually, a supply and use table in physical terms would only contain entries recorded in the same measurement unit – e.g., energy accounts in terms of joules and water accounts in terms of cubic metres. Where this is done it is possible to aggregate across the rows of the tables. In the presentation here, a selection of ecosystem services is included each recorded using their own measurement units. Consequently, it is not possible to aggregate across the rows in the tables to obtain meaningful aggregates. While individual accounts for each ecosystem service could be presented, the conceptual considerations for the structure of the table and associated accounting entries would be identical to those discussed here.

7.7 A key principle of the supply and use table structure is that the supply of ecosystem services is equal to the use of those services during an accounting period. This is the application of the supply and use identity (SEEA Central Framework, 3.35). Thus, for example, both the supply and the use of air filtration services would be recorded using the same measurement unit, for example, tonnes of PM2.5 absorbed by vegetation.

7.8 The top section of Table 7.1 presents the supply table. It records the flows of different ecosystem services supplied by different ecosystem types. The bottom section of Table 7.1 presents the use table. It records the use of different ecosystem services by economic units (final ecosystem services) and by other ecosystem assets (intermediate services). For each ecosystem service, the total supply recorded in the top section must equal to the total use recorded in the bottom section. Details about the recording principles and specific treatments are described in the following sections.

7.9 The flows for each ecosystem service are recorded using a unit of measure that is appropriate for that ecosystem service. The column titled "Units of measure" provides an example of the type of unit that may be appropriate for each type of service. Common units include tonnes, cubic metres and number of visits. In practice, the unit of measure that is applied will depend on the data available and the measurement method that is used. There are no prescribed measurement units in the SEEA EA but relevant technical guidance is being developed (UNSD, n.d. forthcoming).

7.10 The units used to measure the supply of the service must also be used to measure the use of the service. This applies also where an ecosystem service is supplied by multiple ecosystem types and/or used by multiple economic units. Thus, across a given row (i.e., for a single ecosystem service), the same unit of measure should be applied. This enables a total supply and total use to be estimated for each individual ecosystem service. However, as noted above, since each ecosystem service will be measured using different units it is not possible to aggregate to provide an estimate of the total supply or use of multiple services for an ecosystem type or economic unit.

7.11 Each ecosystem service is recorded as being supplied by an ecosystem type. For the purposes of demonstrating the design of a supply table, Table 7.1 shows selected ecosystem types based on selected classes from the Ecosystem Functional Group (EFG) level of the IUCN Global Ecosystem Typology (see Chapter 3 for details). The set of classes shown is not exhaustive for that level. In practice, it is expected that countries will apply a national or regionally applicable classification of ecosystem types. This may show additional detail relative to the EFG level.

Table 7.1: Ecosystem services supply and use account in physical terms (physical units) – Supply table

				Selected economic units														
				Selected industries														
SUPPLY			UNITS OF MEASURE	Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	Total Industry				Imports - products	Total Supply products
Selected ecosystem services (reference list)																		
Provisioning services																		
	Biomass provisioning	Crop provisioning																
		Grazed biomass provisioning																
		Timber provisioning																
		Non-timber forest products and other biomass provisioning																
		Fish and other aquatic products provisioning																
	Water supply																	
	Genetic material																	
	Other provisioning services																	
Regulating and maintenance services																		
	Global climate regulation services																	
	Rainfall pattern regulation services																	
	Local (micro and meso) climate regulation services																	
	Air filtration services																	
	Soil quality regulation services																	
	Soil erosion control services																	
	Water purification services																	
	Water flow regulation services																	
	Flood mitigation services																	
	Storm mitigation services																	
	Noise attentuation services																	
	Pollination services																	
	Pest control services																	
	Nursery population & habitat maintenance services																	
	Soil waste remediation services																	
	Other regulating and maintenance services																	
Cultural services																		
	Recreation-related services																	
	Amenity services																	
	Education, scientific and research services																	
	Spiritual, symbolic and artistic services																	
	Ecosystem and species appreciation services																	
	Other cultural services																	

			Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
			Terrestrial												Freshwater			Marine						
			T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
			Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derivied semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	Total Supply resident ecosystem assets	Supply from non-resident ecosystem assets - Imports	Total Supply ecosystem services	TOTAL SUPPLY
SUPPLY			T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected ecosystem services (reference list)																								
Provisioning services																								
	Biomass provisioning	Crop provisioning																						
		Grazed biomass provisioning																						
		Timber provisioning																						
		Non-timber forest products and other biomass provisioning																						
		Fish and other aquatic products provisioning																						
	Water supply																							
	Genetic material																							
	Other provisioning services																							
Regulating and maintenance services																								
	Global climate regulation services																							
	Rainfall pattern regulation services																							
	Local (micro and meso) climate regulation services																							
	Air filtration services																							
	Soil quality regulation services																							
	Soil erosion control services																							
	Water purification services																							
	Water flow regulation services																							
	Flood mitigation services																							
	Storm mitigation services																							
	Noise attentuation services																							
	Pollination services																							
	Pest control services																							
	Nursery population & habitat maintenance services																							
	Soil waste remediation services																							
	Other regulating and maintenance services																							
Cultural services																								
	Recreation-related services																							
	Amenity services																							
	Education, scientific and research services																							
	Spiritual, symbolic and artistic services																							
	Ecosystem and species appreciation services																							
	Other cultural services																							

Table 7.1: Ecosystem services supply and use account in physical terms (Physical units) – Use table

				Selected economic units															Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
				Selected industries															Terrestrial												Freshwater			Marine						
																			T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
USE			UNITS OF MEASURE	Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	Total Industry	Government consumption	Household consumption	Gross capital formation	Exports - products	Total Use products	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derivied semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	Total use resident ecosystem assets	Exports - ecosystem services	Total Use ecosystem services	TOTAL USE
																			T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected ecosystem services (reference list)																																								
Provisioning services																																								
	Biomass provisioning	Crop provisioning																																						
		Grazed biomass provisioning																																						
		Timber provisioning																																						
		Non-timber forest products and other biomass provisioning																																						
		Fish and other aquatic products provisioning																																						
	Water supply																																							
	Genetic material																																							
	Other provisioning services																																							
Regulating and maintenance services																																								
	Global climate regulation services																																							
	Rainfall pattern regulation services																																							
	Local (micro and meso) climate regulation services																																							
	Air filtration services																																							
	Soil quality regulation services																																							
	Soil erosion control services																																							
	Water purification services																																							
	Water flow regulation services																																							
	Flood mitigation services																																							
	Storm mitigation services																																							
	Noise attentuation services																																							
	Pollination services																																							
	Pest control services																																							
	Nursery population & habitat maintenance services																																							
	Soil waste remediation services																																							
	Other regulating and maintenance services																																							
Cultural services																																								
	Recreation-related services																																							
	Amenity services																																							
	Education, scientific and research services																																							
	Spiritual, symbolic and artistic services																																							
	Ecosystem and species appreciation services																																							
	Other cultural services																																							

SEEA

7.12 The use table shows the use of ecosystem services by economic units – final ecosystem services - and by ecosystem types – intermediate services. Economic units are classified following the general structure of the SNA. Seven industry classes are shown in Table 7.1. Selected industry classes may be more detailed to allow for national contexts although it is recommended that the structure of the International Standard Industrial Classification (ISIC) be applied. The columns for Government and Households reflect their final consumption of ecosystem services while the column for non-residents reflects exports of ecosystem services. For analytical purposes, the column for households may be broken down to distinguish different types of households (e.g., by income quintile or rural and urban households) to provide further detail on the distribution of use of ecosystem services.

7.13 In the use table, the ecosystem types are shown for the four realms of the IUCN Global Ecosystem Typology that are within scope of ecosystem accounting. This higher-level presentation is used for demonstration purposes only and more detailed classes can be used. The recording of intermediate services by ecosystem type is not applicable for provisioning or cultural services; i.e., all of these services are final ecosystem services and hence cannot be used by an ecosystem type.

7.14 In general, the measurement scope of a supply and use account will be established on the basis of the ecosystem services supplied by all ecosystem types within an ecosystem accounting area (EAA). To ensure a balance in the recording of supply and use, this implies the need to record the use of ecosystem services by non-resident economic units, i.e., economic units who have a centre of economic interest outside of the EAA. This may arise, for example, in the case of cultural services being supplied to visitors living outside the EAA. The final column of the use table allows for these flows, considered to be exports of ecosystem services, to be recorded. Imports of ecosystem services supplied by ecosystem assets outside the EAA may also be recorded in the final column of the supply table. Section 7.2.6 provides additional discussion on the recording of imports and exports of ecosystem services.

7.15 A single SUT is compiled for one accounting period, usually one year. That is, the entries for supply and use show the total flows in each ecosystem service for that time period. Ideally, a time series of SUT would be compiled to enable analysis of changes in the patterns of supply and use over time. Where a time series of SUT are compiled, different presentations and arrangements of the components of the SUT may be developed to support showing time as one dimension.

7.16 There may also be considerable interest in the presentation of data on the supply and use of ecosystem services in the form of maps. Overlaying maps for different ecosystem services can provide a ready source of information on places that might be considered ecosystem services "hot spots." It is quite common, but not essential, for estimates of the supply and use of ecosystem services to be compiled using detailed spatial data such that the flows of ecosystem services can be attributed to specific locations and hence to associated ecosystem types. Where this compilation approach is used, the entries in the SUT which shows flows by ecosystem type, will be an aggregation of data from finer scales and thus the maps and tables are complementary outputs of the same underlying data.

7.17 Where top-down methods are used, for example where ecosystem service flows are based on aggregate visits to national parks or total volumes of timber harvested for a country, the attribution to ecosystem type may be more generic or stylised and there will be no accompanying mapped outputs.

7.18 In concept, where compilation of ecosystem services is undertaken using fine level spatial data, it would be possible to present information on the supply and use of ecosystem services for each individual ecosystem asset. However, in practice, there is no requirement for reporting at this level of detail, especially for accounts covering a national scale or large areas within a country. Thus, the SUT shown in Table 7.1 focuses on recording at the level of ecosystem types, regardless of their location.

7.2.2 *Applying general supply and use principles in ecosystem accounting*

7.19 In concept, ecosystem accounting considers that each ecosystem supplies, or contributes to the supply of, a set or bundle of ecosystem services. The following discussion retains a focus on explaining the principles and treatments of accounting for ecosystem services at the level of individual ecosystem assets although it is recognised that in practice, compilation may take place for ecosystem types and, as noted in the previous sub-section, the presentation of data in an SUT is likely to be for ecosystem types.

7.20 As described in Chapter 6, ecosystem services are defined as contributions to benefits and encompass a wide range of services provided to economic units (households, businesses and governments) and to other ecosystem assets. The distinction between services and benefits is meaningful, because:

- It facilitates the explicit recording of the relationship between final ecosystem service flows and existing flows of products (SNA benefits) currently recorded in the SNA.
- It allows distinguishing the role of human inputs in the production process and recognising that the contribution of ecosystem services to benefits may change over time (for example, due to changes in the methods of production).
- It helps to identify the appropriate target of monetary valuation, since the final ecosystem services will represent only a portion of the overall monetary value of the corresponding benefits.

7.21 These features also allow clear articulation and attribution of flows between ecosystem assets and economic units that are represented in accounting terms as supply-use pairs, i.e., transactions.

7.22 As described above, the ecosystem services flow account is structured to record the flows of ecosystem services supplied by ecosystem types and used by economic units during an accounting period. There is no accumulation of ecosystem services such that supply over an accounting period might be matched with an increase in accumulated ecosystem services available for use in future accounting periods. While measurement of the potential or sustainable level of supply that could be delivered by an ecosystem asset is highly relevant, this is not the focus of recording in the supply and use accounts. Section 6.5 provides a discussion on ecosystem capacity.

7.23 Recording supply as equal to use means that, from an accounting perspective, ecosystem services are revealed transactions or exchanges. Since, in concept, each recorded exchange is observable, it follows that each ecosystem service is separable even though the processes by which different ecosystem services are supplied are connected to each other.

7.24 In addition to requiring matched supply and use entries, the following key features of supply and use accounting are applied.

- Supply is attributed to an ecosystem type. Where an ecosystem service is jointly supplied by a combination of ecosystems, then it is assumed that, if required, the supply can be allocated/apportioned to individual assets using spatial allocation methods or measurement conventions. This topic is discussed further in section 7.4.
- Use of final ecosystem services is attributed to an economic unit (business, government, household).

- Use of intermediate services is attributed to an ecosystem type.
- For any single transaction of an ecosystem service (i.e., where there is a supply-use pair) the magnitude of the flow will be the same for supply and use in terms of both quantity and monetary value.

7.25 Using these principles allows the data recorded in the supply and use account to support monetary valuation of ecosystem services (described in Chapter 9) and to be considered in an aligned manner with the economic data recorded in the SNA supply and use table (see 2008 SNA, Chapter 14).

7.26 In some cases, the physical flows recorded in the ecosystem services flow account will be the same as those recorded in the physical supply and use tables (PSUT) and asset accounts in the SEEA Central Framework (Chapters 3 & 5). For example, the flow of timber resources harvested from non-cultivated forests will be the same in terms of the reduction in the stock of timber resources in the asset account and the flow of biomass provisioning services in the ecosystem services flow account. This does not represent double counting since each table is designed for a distinct purpose and the flow happens to be relevant in both cases.

7.2.3 Ecosystem services and benefits

7.27 Where the flow of ecosystem services is an input to the production of an SNA benefit, a supply and use pair is recorded for the ecosystem service in the ecosystem service supply and use account and a separate supply and use pair will be recorded in the standard, economic supply and use accounts for the transaction in the associated economic good or service, i.e., the SNA benefit.

7.28 For example, the supply of biomass provisioning services for rice from a farmland will be recorded as a use by the farmer of that ecosystem service in the ecosystem service supply and use account. Stylized entries for these flows are shown in Table 7.2.

Table 7.2: Basic Ecosystem services physical supply and use account #1

	Unit of measure	Economic unit (selected)			Ecosystem asset (selected types)		
		Farmer	Government	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (rice)	Tonnes					100	
USE							
ES #1: Biomass provisioning services (rice)	Tonnes	100					

Note: Grey cells indicate not applicable.

7.29 Separately, supply-use pairs for the harvested rice and other processed goods will be recorded in the economic supply and use accounts reflecting a series of transactions between a farmer manufacturers and households. This recording allows the supply and use of ecosystem services to be connected to entries for the supply and use of goods and services currently recorded in standard economic supply and use tables, recognizing that the entries in these tables are in monetary terms. The compilation of extended supply and use tables building on the ecosystem services flow accounts in monetary terms is described in Chapter 11.

7.30 Where the flow of ecosystem services is an input to the production of a non-SNA benefit, for example the contribution of air filtration services to cleaner air, a supply and use pair is recorded for the ecosystem service in the ecosystem service supply and use account by adding a row. Stylized entries showing flows for both air filtration and biomass provisioning services are shown in Table 7.3.

Table 7.3: Basic Ecosystem services physical supply and use account #2

	Unit of measure	**Economic unit (selected)**			**Ecosystem asset (selected types)**		
		Farmer	Government	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (rice)	Tonnes					100	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
USE							
ES #1: Biomass provisioning services (rice)	Tonnes	100					
ES #2: Air filtration services (PM2.5)	Tonnes			50			

Note: Grey cells indicate not applicable

7.31 For most ecosystem services that contribute to non-SNA benefits, the use of the ecosystem service is attributed to the receiver of the non-SNA benefit. In some cases, this is very direct, e.g., for recreation-related services. In cases where a single ecosystem service is used by a number of economic units but the benefits remain individual rather than collective – e.g., in the case of water regulation for mitigation of extreme events – this will mean that the supply of the service will be recorded as received by multiple economic units in the use table.

7.32 Where the ecosystem service contributes to a non-SNA benefit that is considered "collective", the use of the ecosystem service is attributed to government which is considered to use the service on behalf of society as a whole. Following the SNA, "*a collective consumption service is a service provided simultaneously to all members of the community or to all members of a particular section of the community, such as all households living in a particular region. … Collective services are the "public goods" of economic theory*." (2008 SNA, 9.4). Collective services will thus be both non-rival and non-excludable. The primary example of such an ecosystem service is global climate regulation, the benefits of which are obtained by all members of the community.

7.2.4 Recording intermediate services

7.33 Where there is a sequence of intermediate services and final ecosystem services, recording the supply and use of each service ensures that the appropriate net effect is shown. Using an example involving the ecosystem services of pollination and biomass provisioning services (in this example melons), the supply and use of pollination services from one ecosystem (natural grassland where the pollinators are assumed to live) to another (farmland where the melons are pollinated) is recorded as a supply and use of an intermediate service. Thus, the supply of the intermediate service of pollination is attributed to the grassland and there is a use of pollination services by the farmland (as an input to its supply of final ecosystem services) and supply of biomass provisioning services. The relevant entries are shown in Table 7.4.

Table 7.4: Basic Ecosystem services physical supply and use account #3

	Unit of measure	Economic unit (selected)			Ecosystem asset (selected types)		
		Farmer	Government	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (melons)	Tonnes					80	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
IS: Pollination services	# visits*						2000
USE							
ES #1: Biomass provisioning services (wheat)	Tonnes	80					
ES #2: Air filtration services (PM2.5)	Tonnes			50			
IS: Pollination services	# visits*					2000	

Notes: Grey cells indicate not applicable. ES - Final ecosystem services; IS - Intermediate services. * The number of pollinator visits is one potential measure of the quantity of pollination services. Other metrics may be used.

7.34 By ensuring that a sequence of supply and use entries are recorded for each type of ecosystem service, the overall contribution of each ecosystem can be determined. Thus, for example, by considering the column for farmland the output of biomass provisioning services can be seen to require the input of pollination services from grassland ecosystems. Note however that no aggregation across rows should be undertaken given that the entries reflect the use of different measurement units.

7.35 A specific context in which intermediate services may be recorded concerns flows associated with water supply as discussed in Section 6.4. Following the advice of that section, where water supply is recorded as a final ecosystem service, it may be appropriate to also record flows of related ecosystem services such as water flow regulation and water purification as intermediate services. Alternatively, these input services may be treated as final ecosystem services and water supply treated as an abiotic flow (see section 7.2.5). In any selected approach, care is required such that the links between ecosystem services are recorded once and that double counting is avoided.

7.36 Potentially, quite complex interlinkages between different ecosystems can be recorded within a supply and use accounting structure. For example, the connections between different fish species across marine ecosystems that reflect food webs underpinning the fish catch. However, the focus of ecosystem accounting should remain on recording final ecosystem services and entries for intermediate services should concern only those flows that can be clearly connected to a final ecosystem service – as in the example above. It is not the ambition in ecosystem accounting to provide a full documentation of all ecological processes or connections.

7.2.5 Recording abiotic flows

7.37 Chapter 6 identified a range of environmental flows, e.g., concerning the supply of energy, that do not meet the definition of ecosystem services and hence are considered abiotic flows. These abiotic flows may be relevant in the assessment of ecosystem services and the use of specific ecosystems. For example, in the production of solar energy it will be common to install solar panels which will reduce the potential to use the location for the generation of ecosystem services. Thus, recording abiotic flows and attributing their supply to individual locations can help to provide a more comprehensive picture on the use of ecosystems.

7.38 Where the incorporation of abiotic flows is desired, additional rows may be added to the supply and use table (Table 7.1) showing the supply of the abiotic flow from the relevant ecosystem type (e.g., electricity generated from wind turbines on farmland) and the use of that abiotic flow by economic units (e.g., electricity generators). Table 7.5 shows how such flows can be incorporated in the supply and use framing assuming an example where an electricity generator uses wind turbines on farmland to generate electricity.

Table 7.5: Basic Ecosystem services physical supply and use account #4

	Unit of measure	Economic units(selected)			Ecosystems (selected types)		
		Farmer	Electricity generator	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (melons)	Tonnes					80	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
IS: Pollination services	# visits						2000
AB: Energy from wind power	kWh					10000	
USE							
ES #1: Biomass provisioning services (wheat)	Tonnes	80					
ES #2: Air filtration services (PM2.5)	Tonnes			50			
IS: Pollination services	# visits					2000	
AB: Energy from wind power	kWh		10000				

Notes: Grey cells indicate not applicable. ES: Final ecosystem services; IS: Intermediate services; AB: Abiotic flows.

7.2.6 Exports and imports of ecosystem services

7.39 The measurement scope for ecosystem accounts is set by the ecosystem accounting area (EAA), for example the economic territory of a country including its exclusive economic zone. As noted above, for ecosystem services flow accounts this implies a focus on the ecosystem services supplied by all ecosystems within the EAA. There will be a range of situations in which the supply of ecosystem services will not be used by economic units resident[53] in the EAA and also cases where resident economic units use ecosystem services from outside the EAA. To ensure a balance between supply and use, the following treatments should be adopted. Six cases need specific consideration.

7.40 First, there are people visiting from outside an EAA, for example tourists, who will commonly be users of recreation-related services supplied by ecosystems within the EAA. In this case, measurement requires an allocation of the total supply of the service to that group of people as non-residents (i.e., exports).

7.41 Second, there are commonly exports of biomass and related products (e.g., rice, wheat, timber, fish) between countries. In ecosystem accounting, these flows of products are not considered flows of ecosystem services and hence are not recorded as exports in the ecosystem service supply and use account. Rather the ecosystem services can be seen to be embodied in the traded products with the flows of products recorded in the standard

[53] The concept of residency of economic units is applied based on the definitions and principles of the SNA and the Balance of Payments.

economic supply and use accounts and related balance of payments statistics. Analysis of the extent to which traded products have embodied ecosystem services can be undertaken and this may be an important part of understanding how consumption in one country may have impacts on other countries' ecosystems.

7.42 Third, there are commonly situations, particularly for regulating and maintenance services, where the users of the ecosystem service are located outside of the ecosystem supplying the service. For example, users of air filtration services provided by forests will usually not live in the forest but in neighbouring communities. Also, the supply of water flow regulation services will often involve a number of ecosystem assets across a catchment to communities located in just one part of the catchment. Where both the supplying ecosystem assets and the location of the users are in the same EAA, then no specific treatment needs to be noted. However, where the location of use is outside the EAA, an export of an ecosystem service should be recorded to ensure a balance between supply and use. Conversely, where the supply of the service is outside the EAA an import of a service may be recorded.

7.43 Fourth, a sub-set of the ecosystem services considered in the previous paragraph concern ecosystem services that are collective services that are not attributable to individual households or businesses but rather are treated as being used by the government on behalf of the community. The primary example concerns global climate regulation services and, indeed, this service can be considered to be of benefit to all people globally rather than only in a more local, ecosystem asset context. By convention, collective services are recorded as being used by the government that has jurisdiction over the supplying ecosystem assets – i.e., jurisdiction over the EAA – and no exports of collective services are recorded in the system.

7.44 Fifth, consistent with the treatments in the SNA and the SEEA Central Framework, the catching of fish by non-resident operators within a country's exclusive economic zone, is treated as production of the non-resident. In ecosystem accounting, an export of a biomass provisioning service should be recorded in the supply table recognising the input of that country's ecosystems to the production of other countries. A corresponding import of an ecosystem service should be recorded in the accounts of the country to which the fishing operator is resident.

7.45 Sixth, conceptually, there may be flows of intermediate services between EAA. Examples include fish nursery services provided by one marine ecosystem in one EAA to biomass provisioning services provided in another EAA; and the role of particular ecosystems in supporting the migration of species between countries which underpin recreation related services. However, these flows should only be recorded in very specific circumstances of analytical interest where the flow of the intermediate service into an EAA (recorded as an import) can be clearly linked to a final ecosystem service supplied by an ecosystem asset within the EAA.

7.46 Given that the measurement scope of an ecosystem services flow account is determined by the set of supplying ecosystem assets within an EAA, there is generally less focus on imports of ecosystem services which, by definition, are supplied by ecosystems outside of the EAA. Indeed, this reality implies there will likely be a larger measurement challenge in quantifying imports of ecosystem services. Thus, the measurement scope of imports should be determined by identifying flows of ecosystem services that are of particular interest, for example in establishing a more complete picture of the use of ecosystem services by resident economic units. For example, the use of recreation-related services by residents who visit locations outside of the EAA may be of interest. Where imports are recorded, they are entered in the supply table and a corresponding use is recorded by type of economic unit in the use table.

7.47 In all cases, appropriate allocation and recording of exports and imports of ecosystem services will require an understanding of the location of supply and use and the residency of the economic units involved. This will be particularly relevant when an ecosystem service is supplied from a combination of ecosystems within a landscape context in which the ecosystems involved are located on different sides of an administrative boundary (e.g., on opposite sides of a river). Further discussion on the spatial allocation of the supply and use of ecosystem services is provided in section 7.4.

7.48 The discussion in this section pertains to recording flows of exports and imports of ecosystem services. It does not include discussion of transactions in goods and services or financial products that may be associated with ecosystem services. For example, transactions in carbon credits and payments for ecosystem services that occur between countries are not recorded in the ecosystem services flow accounts. Their treatment should follow the advice of relevant sections of the SNA.

7.2.7 Recording cultural services

7.49 Cultural services involve an interaction between people and ecosystems. Consequently, the quantification of these services generally reflects measurement of the type, number and/or quality of the interaction. For example, recreation-related services are commonly quantified using the number of visits to a specific natural location. While these measures are not a direct quantification of the ecosystem contribution, they are considered a suitable proxy which can be improved by taking into consideration as far as possible the number and length of time of interactions with specific features and characteristics of the ecosystems concerned.

7.50 At the same time, for many cultural services, but primarily for recreation-related services, there are businesses involved in facilitating and supporting interactions between people and ecosystems. Broadly, the types of businesses that are involved either (i) supply access to the ecosystem, facilitate activities/experiences within the ecosystem (e.g., covering entry fees, guides, tour operators, etc.) or (ii) supply goods and services to visitors to support their travel to and time at an ecosystem (e.g., hotels, restaurants, transport companies, fuel suppliers).

7.51 To varying degrees, all of these businesses can be seen to have a connection to the ecosystem and may be considered to have an input of ecosystem services in their supply of goods and services to visitors. This interpretation is most appropriate in the context of the first type of business, for which it seems likely that, where payments are made by visitors to those businesses, (i.e., reflecting an economic transaction between visitors and the businesses), there is an implicit payment for an ecosystem service contribution. For transactions involving the second type of business, any ecosystem service contribution is likely to be much smaller. For accounting purposes, challenges lie in appropriately distinguishing the ecosystem service contributions to transactions already recorded in the standard economic accounts and identifying the additional contribution of the ecosystem to the overall benefits that arise from people’s interactions with ecosystems.

7.52 The recommended treatment for the ecosystem services supply and use account in physical terms is to record a supply and corresponding use for each visitor interaction, with the supply shown from the relevant ecosystem type and households as users of the service. This flow should be recorded irrespective of the degree to which there is involvement of businesses in facilitating or supporting the activity.

7.53 In addition, a supplementary row to the use of ecosystem services should be recorded showing the connection between the ecosystem and relevant businesses. This entry does not imply the need to record additional supply but provides complementary data on the use of ecosystem services. Both entries in the use table reflect final ecosystem services.

Table 7.6: Basic Ecosystem services physical supply and use account #5

	Unit of measure	Economic unit (selected)		Ecosystems (selected types)		
		Park operator	Households	Forest	Farmland	Grassland
SUPPLY						
ES #3: Recreation related services	# visits			180		
USE						
ES #3: Recreation related services	# visits		180			
Supplementary data						
Use of ES#3 by business	# visits	180				

Notes: Grey cells indicate not applicable. ES: Final ecosystem services.

7.2.8 Linking the supply of ecosystem services to economic units

7.54 The supply and use tables described in this chapter allow for the recording of flows between ecosystem types as suppliers and economic units as users. There may be interest in presenting the data in a complementary way in which the economic units that either own or manage the areas associated with the ecosystem types are shown as suppliers. For example, farmers may be shown as suppliers of biomass provisioning services, global climate regulation services and water flow regulation services depending on the bundle of ecosystem services supplied by the ecosystem assets within the boundaries of the farms that they own or manage.

7.55 Presentation of data in this way must be done with care since there is no necessary one-one link between ecosystem types and economic units. Most commonly, there will be a combination of ecosystem types within a single parcel of land that an economic unit owns or manages. In the first instance then, the starting point for organisation of data on the flows of ecosystem services should follow the approach described in Chapter 4 in the presentation of ecosystem extent data with respect to economic units.

7.56 With information on the relationship between ecosystem types and economic units an alternative supply table may be structured, building on Table 7.1 to show under each ecosystem type (e.g., forests), the range of different types of economic units, for example grouped by industry. Another option would be to show for each type of economic unit (e.g., agriculture), the range of ecosystem types they manage. Under either presentation the total supply of a given ecosystem service from a specific ecosystem type should be the same as that recorded following the structure of the standard supply and use table shown in Table 7.1. Note also that the entries in the use table are unaffected by the alternative presentations of the supply table.

7.57 Beyond presentation in tabular form, the presentation of this type of information in maps by overlaying data on links to economic units may be particularly useful for some policy and analysis.

7.3 Considerations in accounting for ecosystem services in physical terms

7.3.1 Spatial allocation of ecosystem services to ecosystem assets

7.58 A number of ecosystem services, particularly regulating and maintenance services but also some cultural services, are generated at landscape scale in the sense of involving a range of ecosystem assets of different types. Examples include the contributions of different ecosystems to water flow regulation and soil erosion control services which are commonly measured and modelled at a catchment scale rather than for individual ecosystem assets within the catchment.

7.59 For ecosystem accounting, it is appropriate for the measurement of the total supply of an individual ecosystem service to be undertaken at a larger, multi-ecosystem scale in order to get the best estimate of supply. However, the logic of ecosystem accounting further implies the allocation of total supply to the various ecosystem types involved and conceptually, to individual ecosystem assets. This allocation can in turn support, for example, understanding the critical ecosystems within a catchment.

7.60 In addition to allocation to ecosystem types, there is a general interest in mapping the supply and use of ecosystem services; i.e., in linking the supply and use of ecosystem services to the location of ecosystem assets as reflected in the measurement of ecosystem extent. Spatial allocation is conceptually feasible since ecosystem services are spatial phenomena.

7.61 Considerations in the allocation of ecosystem services to ecosystem types vary by type of ecosystem service. Provisioning services are treated as supplied and used in the same ecosystem since, in accounting terms, the exchange between ecosystem and economic unit takes place at the point of harvest which must take place *in situ*. Subsequent transactions involving the processing, transportation and sale (including potential export) of harvested materials are the subject of standard economic accounting and are not the focus of ecosystem accounting.

7.62 Regulating and maintenance services are commonly supplied by ecosystems, or combinations of ecosystems, in one location and used by economic units in other locations. Further there are a range of cases where a single service is supplied to a range of different economic units who are present in a single area. Specific examples here concern the services of ecosystems in mitigating the effects of extreme events. For accounting purposes there remains a need to ensure that total supply and total use are balanced but, in concept, allocation across locations involving multiple ecosystem assets and multiple users can be readily recorded using supply and use tables.

7.63 Many cultural services are supplied and used in situ since they are based on direct interactions between people and ecosystems. Recreation-related services are the clearest example. At the same time, there are a range of cultural services in which there are indirect connections and hence the locations of supply and use will be different.

7.64 For the purposes of compiling a supply and use table following the structure of Table 7.1, it is necessary to allocate the supply of ecosystem services to ecosystem types but it is not required to (i) allocate that supply to individual ecosystem assets in specific locations; or (ii) to record the location of the economic units using the ecosystem services. However, for a range of purposes, especially to support spatial planning and assessment, attribution of ecosystem services supply and use to locations is likely to be of considerable power. Further, for many ecosystem services, particularly regulating and maintenance services, the compilation methods are likely to involve the use of detailed spatial data in which case allocation to locations can be seen as a by-product.

7.65 The discipline of allocating ecosystem services to locations is known as ecosystem services mapping. Key concepts of relevance for ecosystem accounting are service providing areas (SPA) and service benefitting areas (SBA). For each ecosystem service, the delineation of SPA and SBA provides the location and spatial boundary that will reflect the location of supply and use, respectively. For accounting purposes, it will be appropriate to link SPA with maps of ecosystem extent classified by ecosystem type and to link SBA with information on the location of different types of economic units (businesses, government, households) for example using cadastral information. Guidance on ecosystem service mapping is available in (Burkhard & Maes, 2017).

7.3.2 Determining ecosystem service measurement baselines

7.66 Ecosystem service measurement baselines (baselines)[54] are needed in ecosystem accounting to ensure consistent quantification of ecosystem service flows in different contexts. They are especially relevant in the measurement of regulating and maintenance services but are implicit in the measurement of all ecosystem services.

7.67 Where it is possible to observe a direct interaction between people and ecosystems, i.e., for provisioning services and cultural services, the implicit baseline is zero – i.e., the quantification of the flow implicitly assumes the potential for no harvest or no interaction. The quantification of the ecosystem services is therefore appropriately focused on measuring the number and type of biomass harvested or cultural interactions.

7.68 On the other hand, quantification of regulating and maintenance services involves a focus on the extent to which ecological processes contribute to environmental conditions that are beneficial to people and their activities. These processes may involve mediation or mitigation of a potentially negative impact. For example, air filtration services reduce ambient air pollution concentrations. The negative impacts (i) may be caused by human activities (e.g., most forms of air pollution, greenhouse gas emissions), (ii) may be natural events (e.g., due to storm surges), or (iii) may be natural events but with an increased likelihood because of human activities (e.g., increased landslides because of deforestation activity).

7.69 Not all regulating and maintenance services involve mediating a negative impact. For example, the nursery service involves maintaining a favourable habitat for species reproduction and pollination may involve the transfer of pollen to enable plant sexual reproduction.

7.70 The quantification of the supply of regulating and maintenance services generally depends directly and strongly upon knowledge of the ecosystem type and its key characteristics since the role of the ecosystem in supplying services will vary as the type and characteristics change. Thus, in assessing the extent to which a particular ecosystem provides regulating and maintenance services, it is normal to make an assumption as to what services would be supplied if the ecosystem type or its characteristics were different. For example, forests are better at capturing air pollutants than grasslands, and forests with well-structured soil (having a high infiltration rate) are better in storing and regulating water flows compared to forests with degraded soils.

7.71 The comparison of two different ecosystem contexts, one being the measurement baseline, provides a basis for quantifying the role of the ecosystem in supplying a given service. Thus, ***an ecosystem service measurement baseline is the level of service supply with which a***

[54] Other labels that may be applied include reference levels and counterfactuals. The term measurement baseline is preferred for use in this context.

regulating or maintenance service provided by an ecosystem is compared in order to quantify the service.

7.72 For ecosystem accounting, the use of a common baseline is required to ensure comparability across ecosystem types and across different services. For this purpose, the default baseline is zero, i.e., assuming the ecosystem does not supply the regulating service. In cases where a zero level of service supply cannot be modelled or meaningfully identified, the baseline should be the amount of service supplied by bare land (i.e., where the ecosystem has no vegetation cover) or alternative worst-case ecosystem scenario. The application of this default baseline varies by type of service as shown in Table 7.7 and specific cases are discussed below.

7.73 For air filtration, it is possible to define more directly a 'no' or 'zero' air filtration level, and the differentiation is meaningful from a modelling perspective. In this case it can simply be stated that the baseline is when there is zero air filtration, i.e., zero capture of ambient air pollutant by an ecosystem. Thus, the supply of the ecosystem service is equal to the quantity of pollutant absorbed by the ecosystem.

7.74 In other cases, determining the baseline of no service supply independent of any land cover is difficult. For instance, the soil erosion control service is usually quantified using the Revised Universal Soil Loss Equation (RUSLE).[55] This approach compares actual erosion rates to those for bare land where the erosion rate in bare land is the maximum potential erosion rate (a worst-case scenario) in a given ecosystem, allowing for soil type and erosivity, slope characteristics, rainfall characteristics and land management factors. Thus, in this case, service supply is defined as the reduction in erosion rates compared to bare land and the baseline needs to be bare land since it represents the situation in which there is no ecosystem service supply.

7.75 In general, for services where the focus is on the regulation of flows (e.g., of water, soil), it is not generally possible to assess the service compared to a zero service baseline. This is because the flows will occur regardless of whether a service is being provided. Further, while the biotic components of ecosystems modify and affect the flows (of water, soil), the flows themselves cannot be conceptualized or modelled without there being abiotic components over which the flow occurs. In these cases, the baseline needs to be bare land.

7.76 In some cases, the use of bare land as baseline may not be considered to be conceptually very strong, may be counterintuitive, or cannot be meaningfully modelled. The recommendation therefore is to differentiate in a systematic way, between services for which the baseline is bare land and services for which the baseline is zero service supply. Clear communication and explanation of the chosen methods will be required.

[55] For more information see https://www.ars.usda.gov/midwest-area/west-lafayette-in/national-soil-erosion-research/docs/rusle/

Table 7.7: Baselines for selected regulating and maintenance services

Type of service	Baseline	Comments
Global climate regulation services	No/zero carbon retention	
Air filtration services	No/zero air filtration	
Water flow regulation services	Bare land	Overland and groundwater flows cannot be zero, and the effect of vegetation can only be compared to a situation without vegetation i.e., bare land.
Flood mitigation services	Bare land	Flood risks are influenced by geomorphology and can be reduced by tree cover (e.g., dunes, riparian forests or mangroves along a coast). There is no such a thing as no flood risk in coastal areas and the flood risk of the vegetation can be compared with a situation without vegetation.
Soil erosion control services	Bare land	The service can be quantified by comparing the erosion rate of the current vegetation cover to that in bare land, the difference is the amount of erosion control/sediment retained.
Water purification services	No purification (i.e., no breakdown of water pollutants in the ecosystem)	
Pollination services	No/zero pollination	
Rainfall pattern regulation services	Bare land	It is not possible to model rainfall patterns without assuming any rainfall and evapotranspiration across all components of the landscape. The role of vegetation therefore needs to be compared to a situation with no vegetation, i.e., bare land.
Nursery population and habitat maintenance services	No/zero nursery service	

Note: For descriptions of each service refer to Chapter 6, Table 6.2.

SECTION D: Monetary valuation and integrated accounting for ecosystem services and assets

8 Principles of monetary valuation for ecosystem accounting

8.1 The purpose and focus of monetary valuation for ecosystem accounting

8.1.1 The purposes for monetary valuation in ecosystem accounting

8.1 A number of motivations exist for the monetary valuation of ecosystem services and ecosystem assets depending on the purpose of analysis and the context for the use of valuations in monetary terms. The different motivations point to different requirements in terms of the concepts, methods and assumptions used for monetary valuation.

8.2 In ecosystem accounting, the primary motivation for monetary valuation using a common monetary unit or numeraire is to be able to make comparisons of different ecosystem services and ecosystem assets that are consistent with standard measures of products and assets from the national accounts. The availability of national accounts aligned monetary valuations can support: comparing the values of environmental assets (including ecosystems) with other asset types (e.g., produced assets) as part of extended measures of national wealth; assessing the share of ecosystem inputs to production in specific industries and their supply chains; comparing the trade-offs between different ecosystem services; deriving aggregates such as degradation adjusted measures of national income; improved accountability and transparency around the public expenditures on the environment by recognising expenditure as an investment rather than a cost; highlight the relevance of non-market ecosystem services (e.g., air filtration; provide an information base to support scenario modelling and broader economic modelling; and calibrating the application of monetary environmental policy instruments such as environmental taxes and subsidies.

8.3 Further, within the general ambition of making explicit the role of ecosystem services and assets in economic activity, the data generated from a set of ecosystem accounts that covers multiple ecosystem services and multiple ecosystem assets will support public awareness of ecosystem related issues, the derivation of performance indicators, benchmarking the activity of industries and sectors, and undertaking general policy framing and analysis especially considering connections across environmental and economic policies.

8.4 It is likely that more detailed and finer scale data and valuations are required for impact analysis of specific policy options and policy settings, project evaluation and incentive design. This may include detailed cost-benefit analysis and the assessment of compensation and damage claims. While such detailed analysis may not be directly supported by data from a set of ecosystem accounts, the SEEA EA accounts provide a robust framing for the collection and organisation of relevant data and can support understanding of micro-macro linkages and the assessment of changes over time.

8.5 As ecosystem services and ecosystem assets are in most cases not traded directly on markets, non-market valuation techniques will need to be used. The valuation of ecosystem services is a well-established field covering a wide range of ecosystem services and ecosystem context. Various databases of valuation studies, such as the TEEB Ecosystem Services Valuation Database, demonstrate the rich knowledge and experience that has been gathered in this area of work, itself building on an extensive research, development and application of techniques developed in environmental economics over many decades. Importantly from an accounting perspective, the research and application on the monetary valuation of ecosystem services encompasses ecosystem services closely connected to marketed goods and services as well as techniques for those more distant from markets. This continuum and the associated variations in techniques allows for a careful matching of different methods to the accounting context.

8.6 This chapter outlines the core principles of monetary valuation used in ecosystem accounting in applying the national accounting concepts for valuation. These principles are articulated to provide a common basis for discussing and interpreting monetary values in ecosystem accounting and to allow the available valuation techniques to be appropriately applied.

8.7 As introduced in Chapter 2, in describing its approach to monetary valuation in Chapters 8 to 11, the SEEA EA is cognisant of the fact that monetary values cannot reflect a comprehensive or complete value of nature and nor are monetary values appropriate for use in all decision making contexts. The following considerations are of particular relevance:

- There are multiple value perspectives, including intrinsic and instrumental values, and the monetary values described here do not encompass all of these values with respect to ecosystem services and ecosystem assets. Data on the physical flows of ecosystem services and on the extent and condition of ecosystem assets may support assessment of these other value perspectives.
- All monetary values are of most applicability in analysing changes that are marginal, i.e., concerning the effects of relatively small changes in stocks or flows of a particular asset, good or service. When there is a requirement to analyse large, non-marginal changes, monetary values are of less relevance and analysis should incorporate the assessment of physical changes in stocks in relation to appropriate thresholds.
- Monetary values for non-market goods and services, including for example government provided health, education and defence services, cannot be based on observed market transactions and hence are valued using alternative methods that approximate the value of the relevant goods and services. Since there is no explicit market, the resulting values cannot reflect precisely the general equilibrium effects on prices that would be expected if a market did exist. The extent to which the alternative valuation methods will provide a good approximation will vary noting that all methods will reflect prices of a partial equilibrium. It is therefore relevant that as much specificity as possible about the location and context of the transaction is incorporated in the application of alternative methods.

8.8 These considerations apply to all monetary values, not only those for ecosystem services and ecosystem assets described in these chapters. Therefore, while there are many contexts in which monetary values can support decision making as outlined above, there will also be situations in which non-monetary data will play a primary role. In this regard, the aligned recording of physical and monetary data in the SEEA EA should be of particular benefit.

8.1.2 The focus of monetary valuation for ecosystem accounting

8.9 Monetary valuation depends on two factors in an accounting context, namely (i) the definition and scope of goods, services and assets included; and (ii) the valuation concept that is used. In ecosystem accounting, the valuation concept that is applied is exchange values. This is the same as applied in the SNA and hence is a concept that supports comparison and integration with national accounts estimates and a range of analytical and indicator applications as described above.

8.10 The majority of research and policy on environmentally related monetary valuation has been conducted with a focus on measuring changes in welfare, for example as part of cost benefit analysis. A commonly applied framework to assess the economic value of ecosystems is the Total Economic Value framework (Pearce, 1992). It describes the range of direct use (e.g., biomass harvesting, recreation), indirect use (e.g., air filtration, water regulation) and non-use values (e.g., existence values of specific species) that are relevant in providing a comprehensive measure of economic welfare. Within this range of use and non-use values, it is usual to apply monetary valuation techniques that assess values of changes in welfare most commonly approximated using measures that include consumer and producer surplus.

8.11 Generally, where there is a focus of analysis on the inputs of ecosystems to the production of marketed goods and services, for example agricultural production, there is a good alignment between monetary valuations for accounting or welfare analysis. However, since values recorded in the accounts exclude consumer surplus and the coverage of ecosystem services in ecosystem accounting excludes non-use values, monetary valuation undertaken for the purpose of accounting will regularly differ from estimates of monetary values obtained in environmental economic studies.

8.12 While there are differences between monetary valuations responding to different analytical purposes, there are theoretical and practical connections between values recorded in the accounts and welfare values. These connections are summarised in Annex 12.1 (i) to support the understanding of account compilers in their use of non-market valuation methods for ecosystem services (as described in Chapter 9); and (ii) to build a common language among accountants and environmental economists.

8.13 Further, there will likely be important information contained in understanding the gap between accounting values and values obtained using alternative valuation concepts and assumptions. In this way, different monetary values can play complementary roles in supporting decision making. With this in mind, to complement the exchange value based approach to the monetary valuation of ecosystem services and ecosystem assets described in Chapters 8 to 11, Chapter 12 introduces a number of complementary approaches to deriving and presenting monetary values concerning the environment and the links to the economy. These approaches include the analysis of externalities and the restoration cost-based approach to the valuation of ecosystem degradation.

8.2 Valuation concepts and principles for accounting

8.2.1 Defining exchange values for ecosystem accounting

8.14 In ecosystem accounting, the monetary valuation concept that is applied is exchange values as defined in the SNA. ***Exchange values are the values at which goods, services, labour or assets are in fact exchanged or else could be exchanged for cash*** (2008 SNA, 3.118). This section outlines the principles from a general national accounting perspective and the following sections describe the application of these principles for ecosystem accounting.

8.15 Conceptually, a single transaction, reflecting a unit quantity, is recorded in the accounts at its exchange value and thus the exchange value is equal to the price. Over larger numbers of transactions and increased quantities, it is assumed that each transaction takes place at its own exchange value and the recorded accounting entry will reflect the sum of all exchange values over an accounting period.

8.16 For the vast majority of entries in the national accounts, the concept of exchange values is measured using data from observed transactions involving market prices. ***Market prices are defined as amounts of money that willing buyers pay to acquire something from willing***

sellers (2008 SNA, 3.119).[56] The use of observed market prices implies that the accounts embody information about the revealed preferences of the economic units involved.

8.17 Where market price-based transactions are not observable, alternative methods are used in the national accounts to estimate exchange values and hence allow aggregation across market and non-market goods and services in the measurement of production and consumption. Two primary alternative methods are described in the SNA in relation to transactions in goods and services namely (i) market prices of similar or analogous items (adjusted for quality and other differences as required) (2008 SNA, 3.123); and (ii) where no appropriate market exists, prices may be derived by the amount that it would cost to produce them currently (2008 SNA, 3.135).

8.18 Cost-based techniques are commonly applied in estimating the value of government supplied services including education, health and defence. Indeed, they are required in the context of measuring accounting entries for public goods. In these cases, it may be assumed that the amount of expenditure embodies information about the revealed preferences of a country or community. At the same time, it is accepted that these values for public goods will not reflect the full social benefit arising from the provision of these collectively enjoyed services.

8.19 Transactions in assets are valued using the same approaches just outlined either based on observed prices (e.g., sales of land) or using the two alternative methods. Exchange values of assets are also required to underpin entries in asset accounts and balance sheets, i.e., exchange values for each asset are required at the opening or closing of the accounting period. The ideal source of exchange values for assets at balance sheet dates are prices observed in markets (e.g., valuing share portfolios using market prices at balance sheet date). Where there are no observable prices from markets, the SNA describes two approaches for estimating the exchange value of an asset. The first is the written down replacement cost approach which recognises that the value of an existing asset (most commonly relating to produced assets such as buildings and machinery) at any given point in its life, is equal to "*the current acquisition price of an equivalent new asset less the accumulated depreciation*" (2008 SNA, 13.23).The second approach entails using *"the discounted present value of expected future returns"* (2008 SNA, 3.137). This second approach is of primary relevance for ecosystem accounting since there are no observable current acquisition prices of ecosystem assets encompassing the range of ecosystem services values.

8.20 Observed market prices are defined without expectation that the market in which exchanges take place satisfy a specific institutional arrangement or assumption. The 2008 SNA observes "*a market price should not necessarily be construed as equivalent to a free market price; that is, a market transaction should not be interpreted as occurring exclusively in a purely competitive market situation. In fact, a market transaction could take place in a monopolistic, monopsonistic, or any other market structure."* (2008 SNA, 3.119). Given this, the general interpretation of exchange values in accounting is that they should reflect the current institutional context, i.e., the current market structures and associated legal or regulatory arrangements. Consequently, exchange values will likely reflect the presence of various market imperfections from the perspective of economic theory.

8.21 As introduced above, entries in the accounts will usually be an aggregate of multiple transactions in a specific good or service over an accounting period (e.g., all sales of bread in one year) or an aggregate of multiple assets of a specific type at a balance sheet date (e.g., all registered trucks at 31 December). Further, accounting entries are recorded progressively over multiple accounting periods and balance sheet dates. In this way, time series of

[56] The 2008 SNA notes a number of cases where actual exchange values do not represent market prices (e.g., in situations of transfer and concessional pricing (see paragraphs 3.131-3.134)).

accounting entries based on exchange values will be compiled for various goods and services and types of assets. All accounting entries are recorded at the respective points in time at their nominal values – i.e., the prices applying at the time of the transaction or balance sheet entry.

8.2.2 *Monetary valuation of ecosystem services*

8.22 Accounting entries for ecosystem services in monetary terms reflect the contributions of ecosystem assets to benefits used in economic and other human activity. Building on the framing of supply and use of ecosystem services in physical terms described in Chapter 6, ecosystem assets are established as additional units in a wider accounting system, distinct from the standard economic units such as households and businesses. From an economic perspective, it may be helpful to consider that these additional units are accompanied by a new "owner" in the form of a steward or trustee, but this rationale is not required for accounting purposes.

8.23 From a national accounting perspective, flows of ecosystem services from ecosystem assets can be conceptualised in two ways. First, ecosystem assets may be considered as complex, and interacting, producing units that supply outputs of ecosystem services to various users – this reflects the societal benefit perspective described in Chapter 2. Alternatively, flows of ecosystem services may be considered analogous to flows of capital services supplied by produced assets as described in 2008 SNA, Chapter 20 – this reflect the future value perspective from Chapter 2. These two perspectives are reconciled for the purposes of monetary valuation by treating the output of ecosystem assets as producing units as consisting solely of capital services.[57]

8.24 Thus, in concept, ecosystem services should be valued for accounting purposes in a manner aligned with the valuation of capital services in the SNA. This value will be different from the rentals that would be charged following the definitions in the SNA (2008 SNA, 6.245). By way of example, the rentals paid by a tenant to a landlord will cover the capital services provided by the dwelling[58] as well as the direct operating costs (e.g., management and maintenance costs). Hence the output will be measured in terms of the rentals charged to the tenant and the direct costs must be deducted in order to determine the value of the capital services, and equivalently the gross operating surplus.

8.25 Analogously, in ecosystem accounting, ecosystem services are distinguished from the benefits to which they contribute, and hence the focus of valuation is on the contribution of the ecosystem asset (i.e., the input of ecosystem services) and not on the valuation of the benefits.[59] For example, in the valuation of ecosystem services associated with agricultural production, the direct operating and input costs associated with producing an agricultural output (e.g., rice) including fuel, fertiliser, labour and produced capital must be deducted from the value of the output.

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[57] For clarification, note that the output associated with the use of ecosystem services (for example, rice production) is distinctly recorded in the accounting system as the output of an economic unit. This economic unit will have intermediate, labour and capital costs that are deducted from output resulting in measures of gross value added and gross operating surplus that are different from output.

[58] These are commonly referred to as "user costs" and include both the consumption of fixed capital and the return on investment (opportunity cost) of the relevant asset.

[59] The selection of terms to convey the relevant concepts can be difficult. Here, the term benefits is used to reflect the concept of output (rentals) and is not intended to be considered in a context of a description of the outcomes or well-being associated with economic activity.

8.26 For each final ecosystem service, a single transaction can be envisaged between an ecosystem asset and an economic unit. Further, since there will be multiple supply contexts, (e.g., air filtration services may be supplied by different ecosystem assets) and different combinations of users (e.g., air filtration services may be used by both households and local building owners), it may be the case that a variety of different transactions need to be recorded for the same type of ecosystem service. This includes, for example, the potential to record imports and exports of ecosystem services.

8.27 More significantly, it will be usual for a single ecosystem asset to supply a bundle of ecosystem services. Following the definitions and principles for measuring ecosystem services in physical terms in Chapter 6, separate transactions should be recorded for each type of service supplied to each type of user. The approach thus assumes the separability of ecosystem services. In practice, if bundles of services cannot be clearly separated it will be appropriate to value the bundle as a whole and then apply appropriate allocation methods. This will reduce the potential for double counting of services.

8.28 In applying national accounting principles to accounting for ecosystems, and particularly in the context of the monetary valuation of ecosystem services, it must be recognised that transactions in ecosystem services are not recorded in the SNA and, indeed, ecosystem services lie outside the production boundary that defines the scope of measured gross domestic product. Using a reference to the SNA production boundary, two valuation contexts can be distinguished.

8.29 In some cases, flows of ecosystem services are inputs to the production of goods and services within the production boundary of the SNA, i.e., SNA benefits. In these cases, the values of ecosystem services are implicitly embodied within values of goods and services recorded in the national accounts. Examples include ecosystem services that contribute to agricultural output, such as pollination by wild bees. Monetary valuation therefore involves partitioning the values of the goods and services recorded in the national accounts to reveal the ecosystem contribution. The ecosystem service is then recorded as an output of the ecosystem asset and an input of the economic unit that uses the ecosystem service. In a system wide context, value added is unaffected by recording this transaction but both total output and total inputs are increased.

8.30 In other cases, ecosystem services contribute to benefits received by economic units including households and governments that are not within the production boundary of the SNA, i.e., non-SNA benefits. For example, air filtration services of forests contribute to cleaner air whose value is not included in national accounts measures of output. In this case, the estimating the accounting entries based on exchange values requires (i) determining the prices that would be charged on behalf of the ecosystem asset for the ecosystem services if a market existed; (ii) estimating the costs to obtain an ecosystem service that would need to be incurred by an economic unit to secure the benefits; or (iii) assessing the loss of benefits to an economic unit that would be incurred if ecosystem services were to be lost.

8.31 In practice, the non-market price based valuation methods used in the national accounts can be applied but additional methods are also available to cater for the range of ecosystem services and valuation contexts. Chapter 9, section 9.3, describes the valuation methods that can be used to estimate exchange values to underpin entries in the monetary ecosystem accounts.

8.2.3 Monetary valuation of ecosystem assets

8.32 Ecosystem accounting also incorporates recording entries for ecosystem assets based on their exchange values, together with associated changes in the value of ecosystem assets over an accounting period. These changes include ecosystem enhancement, ecosystem degradation, ecosystem conversions and revaluations. This section provides a framing for the valuation of ecosystem assets in monetary terms for ecosystem accounting. Definitions for the changes in ecosystem assets, including ecosystem degradation, are presented in Chapter 10, and Annex 10.1 outlines the approach to the valuation of these changes.

8.33 The ecosystem assets that are the focus of monetary valuation are delineated following the advice on spatial units and measurement of ecosystem extent as described in Chapters 3 and 4. To introduce the valuation principles, the focus is on a single ecosystem asset of a given ecosystem type (e.g., Cool temperate rainforests - IUCN Global Ecosystem Typology class T2.3). An ecosystem asset is considered to supply a number of ecosystem services (e.g., timber provisioning services, air filtration services, recreation related services) to different users (e.g., businesses, households, government). Each ecosystem asset will have a different capacity to supply ecosystem services that is closely linked to its extent and condition but will also be linked to existing and expected patterns of ecosystem management and use.

8.34 The approach adopted for ecosystem accounting is to value ecosystem assets by aggregating the net present value (NPV) of expected future returns for each ecosystem service supplied by an ecosystem asset. This approach implies that their value will be related to the capacity to supply ecosystem services and how this capacity is expected to change in the future. The capacity and expected changes in capacity will also reveal information on the expected life of the ecosystem asset. If the use of ecosystem services from an ecosystem asset is considered sustainable, i.e., there is no expected loss of condition, then the asset life will be infinite.

8.35 Application of the NPV approach requires (i) measuring the expected future returns for each ecosystem service; and (ii) applying a discount rate such that the future returns can be expressed in current period values. The selection of a discount rate can have a large effect on the estimated monetary values. Chapter 10 has a dedicated discussion on this topic.

8.36 To measure the expected future returns there are a number of considerations. These include (i) the scope of the returns (i.e., the number of ecosystem services to be included); (ii) the future patterns of flows in physical terms of each ecosystem service taking into consideration expected degradation and patterns of demand; (iii) the expected future prices for each ecosystem service; (iv) the expected institutional arrangements and (v) the expected asset life. Together with the discount rate, all of these factors are combined to yield an estimated NPV for each ecosystem service at a given point in time. The NPV of the ecosystem asset is equal to the sum of the NPV for each service. Chapter 10 provides additional details on these different factors.

8.37 As in the monetary valuation of ecosystem services, this approach assumes that the expected future returns for each ecosystem service are separable. It is nonetheless recognised that since there is a bundle of services from a single ecosystem asset, determining the expected future flows for each service requires consideration of the connections between ecosystem services. Thus, factors influencing the future supply of one ecosystem service will be linked to the future supply of other ecosystem services and expected patterns in the use of some ecosystem services will have direct implications for the potential availability of other ecosystem services. For example, regular use of a forest for harvesting timber will likely reduce the supply of global climate regulation services from the same forest.

8.38 Chapter 10 describes how the expected future flows of each service may be considered jointly in the compilation process (including through the use of commonly classified data sets on ecosystem extent) to allow inherent contradictions in expectations to be avoided, and such that meaningful estimates of the aggregate value of an ecosystem asset and the changes in this value over time can be derived. Chapter 10 also provides definitions for the accounting entries associated with changes in the NPV of ecosystem assets. These accounting entries include ecosystem enhancement, ecosystem degradation, ecosystem conversions, other changes in the volume of ecosystem assets (including catastrophic losses) and revaluations.

8.39 The description of the NPV approach at the level of an individual ecosystem asset implies the availability of data that can attribute the supply of ecosystem services to that level of detail and hence variations in context and location can be taken into account. In practice, it may not be possible to undertake valuation at this scale and instead valuation by ecosystem type may be required. While the same theory and approach applies at more aggregated scales, care will be needed to ensure that variations between contexts and location are considered, including changes in institutional context.

8.40 The application of the NPV approach does not require an assumption concerning the economic ownership of the ecosystem asset itself. Such an assumption is only required when integrating monetary values into the standard sequence of institutional sector accounts; a step described in Chapter 11. Nonetheless, there is commonly interest in understanding the relationship between ecosystem asset values and the economic ownership of associated spatial areas – particularly land. This relationship can be analysed by utilising data from the ecosystem extent account and associated data on land ownership and tenure.

8.41 For some ecosystem assets, primarily anthropogenic ecosystem types such as agricultural land and urban areas, there are active property markets that reveal prices for the areas. Generally, these prices will not incorporate all ecosystem services supplied from that property and hence should not be used directly to value an ecosystem asset. At the same time, it is likely that for certain ecosystem services, particularly provisioning services, there is a correlation between the market prices of properties (or the associated rental price) and the prices of the associated ecosystem services. Valuation methods that utilise this type of market information are described in Chapter 9.

8.42 While there are complexities in the measurement of ecosystem asset values in monetary terms, the underlying economic theory is consistent with that used in the measurement of the capital stock of produced assets as described in the SNA. Consequently, compilers familiar with the implementation of perpetual inventory models should recognise many of the requirements in relation to the valuation of ecosystem assets.

8.2.4 Volume and price measures

8.43 The analysis of nominal values (i.e., estimates expressed in prices of the accounting period) can be of interest, for example, to understand the relative structure of consumption or production, or to compare levels of expenditure to budget and fiscal constraints. In addition, for analytical purposes, it is standard practice in national accounting to also separate (or decompose) changes in accounting entries recorded at two points in time into changes associated with price and those associated with changes in volumes, reflecting both changes in quantity and quality[60]. Following decomposition, a time series is derived that excludes the

[60] The term volume is used in accounting since for many goods, services and assets, changes may be due to changes in quality, in addition to quantity and price. In accounting, volume reflects the combination of quantity and quality.

effects of price changes, i.e., a time series of changes in volumes. These estimates are commonly referred to as constant price measures.[61]

8.44 Since prices for most ecosystem services are not observable, standard practices for estimating price and volume measures which rely on the use of price indexes cannot be applied. While other techniques might be considered, at this stage, it is not recommended that compilers aim to develop volume estimates of ecosystem services and ecosystem assets in a manner aligned with estimates in the national accounts.

8.45 At the same time, since much economic analysis is undertaken using data that excludes price effects, it may be relevant to adjust the aggregate nominal values of ecosystem services and ecosystem assets using a general measure of economy wide price change, such as the consumer price index or GDP deflator. The resulting estimates are commonly referred to as "real measures" in the national accounting literature.

[61] There is an extensive literature on the theory and application of index numbers to accounting. The core elements are described in 2008 SNA, Chapter 15.

9 Accounting for ecosystem services in monetary terms

9.1 Introduction

9.1 Recording monetary values for ecosystem services underpins the compilation of two of the ecosystem accounts: the ecosystem services flow account in monetary terms and the monetary ecosystem asset account. This chapter describes the ecosystem services flow account in monetary terms and a range of matters concerning the valuation of ecosystem services applying the principles described in Chapter 8.

9.2 The monetary ecosystem services flow account records the monetary value of flows of ecosystem services based on their exchange values. The data from this account can be used to understand the relative economic significance of different ecosystem services (within the valuation framing of the national accounts), support aggregation of ecosystem services to compare the role of different ecosystem assets, understand changes in monetary value over time, underpin comparison of the inputs of different ecosystem services to different users, and support understanding the role of ecosystem services in different locations, e.g., across countries.

9.3 While the monetary values described here will fulfil a range of analytical needs, the valuation approach applied in ecosystem accounting does not provide a comprehensive measure of the value of nature. In particular, it is noted that the monetary values discussed in this chapter will likely reflect a sub-set of all ecosystem services and will exclude measures of consumer surplus that may be of analytical interest in some contexts. Chapter 12 considers complementary approaches to valuation.

9.4 Entries in the monetary ecosystem services flow account are recorded in line with the definitions, treatments and measurement boundaries for ecosystem services in physical terms described in Chapters 6 and 7. Key features of these treatments are discussed in Section 9.2. As noted in Chapter 8, the monetary valuation of ecosystem services requires the use of various valuation methods since, in many cases, prices for ecosystem services cannot be observed on markets. There is a wide range of environmental valuation methods that have been developed but not all are suitable for application in an accounting context. Section 9.3 summarizes and prioritizes the methods that can be applied and section 9.4 introduces the ways in which different methods can be applied for different types of services. Section 9.5 introduces the issue of value transfer which will be an important step in compiling monetary values for ecosystem services at larger scales.

9.2 Ecosystem services flow account in monetary terms

9.5 Estimates of the monetary value of ecosystem services are recorded in the ecosystem services flow account in monetary terms. This account follows the structure of a supply and use table and has the same underlying structure as the ecosystem services flow account in physical terms described in Chapter 7. The supply and use table format is used to record flows of different types of ecosystem services between ecosystem assets and economic units. The structure, classification and labelling of the various components (e.g., concerning ecosystem services and ecosystem assets) should be consistent between the physical and the monetary accounts.

9.6 The set of ecosystem services included in the monetary ecosystem services flow account should generally align with the set of ecosystem services included in the physical ecosystem services flow account. However, it is possible that some flows of ecosystem services are considered more difficult to value in monetary terms and hence the number of ecosystem services included in monetary terms may be smaller.

9.7 Thus, it is important that compilers document the scope of the ecosystem services included in the accounts and highlight ecosystem services that have been excluded from the scope of measurement and valuation. This is required so that users of the accounts can readily understand and interpret the aggregate measures of the monetary value of ecosystem services. Further, it highlights that data about non-priced ecosystem services will remain relevant for decision making.

9.8 The basic framing of a monetary ecosystem services flow account is shown in Table 9.1. The scope of the account is determined by the set of ecosystem assets located within the ecosystem accounting area (EAA). These are considered the suppliers of the ecosystem services. The set of users included in the account is focused on different types of SNA economic units (i.e., businesses, governments, households) that are resident in the EAA. However, the use table also allows for recording use by non-resident economic units (i.e., those economic units who are resident outside the EAA);[62] and for use by other ecosystem assets (i.e., flows of intermediate services). This scope of users is required to ensure that the supply of ecosystem services by resident ecosystem assets can be fully allocated.

[62] The definition of resident and non-resident economic units follows the definition and treatments of the SNA and the Balance of Payments, In broad terms, an economic unit is determined to have residency in a given economic territory if it has a centre of economic interest in that territory.

Table 9.1: Ecosystem services supply and use account in monetary terms – supply table

																		Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
			Selected economic units															Terrestrial												Freshwater			Marine						
			Selected industries															T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
			Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	**Total Industry**				Imports - products	**Total Supply products**	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	**Total Supply resident ecosystem assets**	Supply from non-resident ecosystem assets - Imports	**Total Supply ecosystem services**	**TOTAL SUPPLY**
SUPPLY																		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected ecosystem services (reference list)																																							
Provisioning services																																							
	Biomass provisioning	Crop provisioning																																					
		Grazed biomass provisioning																																					
		Timber provisioning																																					
		Non-timber forest products and other biomass provisioning																																					
		Fish and other aquatic products provisioning																																					
	Water supply																																						
	Genetic material																																						
	Other provisioning services																																						
Regulating and maintenance services																																							
	Global climate regulation services																																						
	Rainfall pattern regulation services																																						
	Local (micro and meso) climate regulation services																																						
	Air filtration services																																						
	Soil quality regulation services																																						
	Soil erosion control services																																						
	Water purification services																																						
	Water flow regulation services																																						
	Flood mitigation services																																						
	Storm mitigation services																																						
	Noise attentuation services																																						
	Pollination services																																						
	Pest control services																																						
	Nursery population & habitat maintenance services																																						
	Soil waste remediation services																																						
	Other regulating and maintenance services																																						
Cultural services																																							
	Recreation-related services																																						
	Amenity services																																						
	Education, scientific and research services																																						
	Spiritual, symbolic and artistic services																																						
	Ecosystem and species appreciation services																																						
	Other cultural services																																						
TOTAL SUPPLY																																							

NB: The list of ecosystem services presented is indicative only. In due course the table will include an agreed set of ecosystem services.

Table 9.1: Ecosystem services supply and use account in monetary terms (cont) – use table

			Selected economic units															Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
			Selected industries															Terrestrial												Freshwater			Marine						
																		T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
			Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	Total Industry	Government consumption	Household consumption	Gross capital formation	Exports - products	Total Use products	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	:	Temperate pyric sclerophyll forests and woodlands	:	:	:	Derived semi-natural pastures and old fields	Permanent upland streams	:	Intermittently closed and open lakes and lagoons	Seagrass meadows	:	Coastal saltmarshes and reedbeds	Total use resident ecosystem assets	Exports - ecosystem services	Total Use ecosystem services	TOTAL USE
USE																		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected ecosystem services (reference list)																																							
Provisioning services																																							
	Biomass provisioning	Crop provisioning																																					
		Grazed biomass provisioning																																					
		Timber provisioning																																					
		Non-timber forest products and other biomass provisioning																																					
		Fish and other aquatic products provisioning																																					
	Water supply																																						
	Genetic material																																						
	Other provisioning services																																						
Regulating and maintenance services																																							
	Global climate regulation services																																						
	Rainfall pattern regulation services																																						
	Local (micro and meso) climate regulation services																																						
	Air filtration services																																						
	Soil quality regulation services																																						
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	Water purification services																																						
	Water flow regulation services																																						
	Flood mitigation services																																						
	Storm mitigation services																																						
	Noise attentuation services																																						
	Pollination services																																						
	Pest control services																																						
	Nursery population & habitat maintenance services																																						
	Soil waste remediation services																																						
	Other regulating and maintenance services																																						
Cultural services																																							
	Recreation-related services																																						
	Amenity services																																						
	Education, scientific and research services																																						
	Spiritual, symbolic and artistic services																																						
	Ecosystem and species appreciation services																																						
	Other cultural services																																						
TOTAL USE																																							

NB: The list of ecosystem services presented is indicative only. In due course the table will include an agreed set of ecosystem services.

9.9 The supply and use table structure also allows for recording the use of ecosystem services by resident economic units in cases where these services are supplied by ecosystem assets that are located outside the EAA. For example, members of resident household units may travel to other countries and receive cultural ecosystem services in those countries; and resident economic units may receive regulating services such as flood control services that reflect contributions from ecosystem assets outside their EAA. Chapter 7 provides an extended discussion on the treatments concerning exports and imports of ecosystem services.

9.10 The entries recorded in the supply and use table should be based on the exchange value concept, apply a common currency unit and pertain to a single accounting period in which accounting entries are recorded in the prices of that period (i.e., nominal values). Separate supply and use tables can be compiled for different accounting periods to establish time series for the ecosystem service flows.

9.11 Generally, entries recorded in the monetary ecosystem services flow account should correspond directly to those recorded in the physical ecosystem services flow account described in Chapter 7. Thus:

- The definition and measurement scope of each ecosystem service is the same as in the physical supply and use table, including the treatment and recording of intermediate services, imports and exports of ecosystem services, subsistence production of agricultural and related products and abiotic flows.
- The flow recorded in quantitative terms should be consistent with the entry in monetary terms recognising that in some instances, e.g., aesthetic enjoyment services, the measurement unit used to record the physical flow may be a proxy for the implicit quantity underlying the entry in monetary terms.
- The allocation of ecosystem service supply to the various users of ecosystem services is consistent with the allocation in the physical supply and use table.
- The accounting period is the same as for the physical supply and use table.

9.12 Generally, accounting entries for each ecosystem service will be obtained by multiplying a measure of the service flow in quantitative terms by a price estimated using an appropriate method among those described in Section 9.3. Commonly, it will also be necessary to adopt value transfer techniques where an estimated price for an ecosystem service supplied in a sample of locations is applied across multiple locations, taking into account differences in environmental and socio-economic contexts.

9.13 Where the accounting entry is measured directly rather than by using separate price and quantity estimates, an estimate of the corresponding flow in quantitative terms should still be included in the physical supply and use table. This will serve to maintain coherence in the accounting system and will support assessment of changes in the ecosystem asset, including for example, ecosystem degradation.

9.14 Since the entries in monetary terms are in a common currency, and are measured using the common value concept of exchange values, it is possible to derive aggregate measures of ecosystem services. For example, for a bundle of ecosystem services supplied by an ecosystem type (e.g., all ecosystem services supplied by forests within an EAA); or for a bundle of ecosystem services used by an industry (e.g., the use of ecosystem services by the fishing industry).

9.15 The structure of Table 9.1 suggests that the supply of each ecosystem service is presented by ecosystem type. Most commonly in practice, as discussed in Chapter 6, flows of several ecosystem services are measured spatially using ecosystem modelling and geospatial data techniques as introduced in Chapter 7. Consequently, the presentation in the supply table in

Table 9.1 implies the attribution of ecosystem service flows to ecosystem type (e.g., by overlaying maps of individual ecosystem service supply with a map of extent by ecosystem type). Further, where a spatial approach is applied, it will be possible to disseminate maps of different ecosystem services showing where they are supplied within an ecosystem accounting area (EAA) as separate outputs supporting the ecosystem service supply table.

9.16 The compilation of the use table in Table 9.1 does not require knowing the location of the user. It is sufficient to record the type of economic unit, whether the unit is resident or non-resident, and the relevant class (e.g., type of industry). Nonetheless, the location of users relative to the location of the supplying ecosystem asset may be particular interest.

9.3 Techniques for valuing transactions in ecosystem services

9.3.1 Introduction

9.17 Section 8.2 describes the conceptual basis for valuing ecosystem services for ecosystem accounting. The intent is to obtain estimates of the value of ecosystem services as the output of ecosystem assets which are recorded as either final consumption or intermediate consumption of economic units.

9.18 Since prices for ecosystem services are not generally observed, a range of methods have been developed for estimating them. This section describes the methods that support the derivation of prices that are consistent with the exchange value concept and hence can be used to provide estimates for entry into the accounts. This section describes the methods in a preference order indicating those that are considered to align most closely to the target valuation concept. There is a strong preference for accounting purposes, in using methods that translate observable and revealed prices and costs (i.e., for related or similar goods and services) into the values required for accounting purposes. In order of preference the methods are:

- Those where the price is directly observable;
- Those where prices are obtained from markets for similar goods and services;
- Those where the prices (and associated values) are embodied in market transactions;
- Those where the prices are based on revealed expenditures (costs) in related goods and services;
- Those where the prices are based on hypothetical expenditures or markets.

9.19 The different methods are described below following these five groups. In addition, some other methods that have been applied in environmental valuation contexts are briefly summarised noting that they are not preferred for use in a SEEA EA context.

9.20 Some methods are more suited to the measurement of certain ecosystem services than others. For example, it is more likely that exchange values for provisioning services will be able to be estimated based on observed market transactions. The matching of methods to different types of ecosystem services is considered further in Section 9.4 and discussed in more detail in the Guidance on Biophysical Modelling for Ecosystem Accounting (UNSD, n.d., forthcoming).

9.21 Ideally, prices would be estimated for individual ecosystem service flows taking into account the distinct context for supply and use. In practice, it is most likely that such detail cannot be measured on the scale required. As result, ecosystem accounting will often employ value transfer techniques in which prices for a particular service in a particular context and accounting periods are applied to estimate prices in other contexts and accounting periods. Methods for value transfer have also been the subject of much research and development in past decades. Their use in ecosystem accounting is described in Section 9.5.

9.22 The valuation methods described in this section can be applied to the valuation of both final and intermediate ecosystem services. The connections between flows of final and intermediate services will however need to be clearly articulated such that double counting is avoided. For example, flows of pollination services can be inputs to biomass provisioning services but these are not additional to the value of the service of land as estimated in typical accounting contexts.

9.23 In an SEEA EA context, the aim is to record entries in the accounts for multiple ecosystem services across multiple ecosystem types. In principle, aggregation across ecosystem services and ecosystem types is possible even where different valuation methods are used, provided the different methods are focused on applying the same valuation concept and that a given ecosystem service is estimated using the same method in all cases. Furthermore, while all techniques involve some element of approximation, for each ecosystem service there is an order of preference across methods to elicit the exchange value. It is desirable to use the most preferred method given the data and other limitations.

9.3.2 Methods where the prices are directly observable

9.24 **Directly observed values**. The most direct method for measuring prices and estimating values for the accounts is based on the direct observation of exchanges in ecosystem services when they are available. For example, if a wetland provides services of water purification and the owners or managers of that wetland are able to charge the water company that abstracts the water for municipal uses, there is transaction in ecosystem services provided by the ecosystem that can be recorded. Stumpage values charged to timber logging businesses are also an example of directly observed values.

9.25 Another example of directly observed values relates to land rental prices in agriculture where markets exist to rent land for crop production or grazing. These rental prices may be used to derive prices for accounting purposes for the relevant biomass provisioning services. Prices associated with sales of agricultural land may also be used by converting the data into an annual flow using a net present value-based approach. In general, using land rental prices will reflect a bundle of ecosystem services. Thus, in applying this method it will be necessary to isolate the contribution of individual services, for example, using biophysical models that show the relationships among the different services.

9.26 The SNA does not require prices to come from competitive markets, for example transactions based on prices from monopolistic or oligopolistic markets are recorded in the national accounts without adjustment. However, where directly observed prices are considered not economically significant[63] (such cases may arise in the context of fees paid to enter a national park, for example), the observed price should not be used and alternative valuation methods should be applied. Further, care should be taken to understand the size of markets and their maturity. The use of prices from small or immature markets may not be sufficiently representative for use in ecosystem accounting.

9.27 Payments for ecosystem services (PES) may provide a direct measure of the value of ecosystem services. In certain circumstances this will be true and the payments, for example

[63] The relative significance of prices is considered in the SNA in the following way. *"Economically significant prices are prices that have a significant effect on the amounts that producers are willing to supply and on the amounts that purchasers wish to buy"* 2008 SNA, para. 22.28

from a government agency to a land manager, will embody an appropriate price for a particular service for accounting purposes. However, most commonly, payments for ecosystem services and the associated institutional mechanisms are not designed to reveal prices for specific services and instead are aimed at either supporting land managers in undertaking ecosystem restoration work or similar practices, or are aimed at implementing broader government social policies, for example concerning income support. Generally, the advice is not to use data from payments for ecosystem services schemes in the estimation of prices for ecosystem services, unless there is clear evidence that the scheme does target a specific service.

9.28 A specific market concerns observed prices from emission trading systems which may be used to estimate prices for global climate regulation services based on carbon retention. The number of countries with such trading systems is increasing, as is the quantity of carbon being traded and hence these markets may provide suitable price data.[64] If the trading system is not considered sufficiently mature, an alternative is to use data on the marginal costs of abatement, which is more widely available,[65] or data on the social cost of carbon when derived from models that are consistent with the exchange value concept.

9.29 While the use of directly observed values is the most preferred method, the resulting prices may provide accounting entries for the value of ecosystem services that might be considered low, i.e., where the monetary value of the contribution of the ecosystem is negligible. It is fundamental to recognise that this result is most likely a reflection of the existing institutional arrangements and is a result that is well-understood in the economic literature. For example, it is well documented that the prices for natural resources that are extracted in open-access contexts will tend to zero (Hartwick & Olewiler, 1998).[66]

9.30 Notwithstanding this result, the resulting prices should still be applied in ecosystem accounting since the core intent to show accounting entries that reflect the established market context. To the extent that the recorded values are considered "low", there may then be an interest in estimating complementary values on the basis of alternative institutional contexts and market settings. These hypothetical values should not be recorded in ecosystem accounts but may be presented in complementary accounts (see Chapter 12).

9.3.3 Methods where the prices are obtained from markets for similar goods and services

9.31 **Prices from similar markets**. When market prices for a specific ecosystem service are not observable, valuation according to market price equivalents may provide an approximation to market prices. Following the SNA, *"Generally, market prices should be taken from the markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. If there is no appropriate market in which a particular good or service is currently traded, the valuation of a transaction involving that good or service may be derived from the market prices of similar goods and services by making adjustments for quality and other differences"* (SNA 2008, para. 3.123).

9.32 For example, when non-wood forest products (e.g., mushrooms) from one forest are marketed but those from a similar forest are not, the prices observed in the former can be

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[64] Ideally the observed price from the emission trading system should be adjusted to take into account the impact that including the removals of carbon by the forestry sector would have on the price. The depth and maturity of these market should also be considered in these contexts.

[65] These costs vary by sector so the highest cost should be taken as the overall marginal cost of abatement.

[66] An assumption made here is that there is also an increasing scarcity of the underlying resource. Where there is no scarcity, a low or zero price would be appropriate.

used to value the non-wood forest products from the latter allowing for differences in products and other factors. Implicitly, it is assumed that the flows of (non-marketed) ecosystem services (in this example the harvest of mushrooms) are not significant enough such that they would alter the observed price of the good or service from the similar market. Note also that prices from similar markets will reflect prices of the existing institutional context in the same way as the directly observed values method.

9.3.4 Methods where the prices (and associated values) are embodied in market transactions

9.33 **Residual value and resource rent methods.** The residual value and resource rent methods[67] estimate a value for an ecosystem service by taking the gross value of the final marketed good to which the ecosystem service provides an input and then deducting the cost of all other inputs, including labour, produced assets and intermediate inputs (see formula from the SEEA Central Framework below). Depending on the scope of the data (e.g., pertaining to a specific location or to the activities of an industry as a whole), the estimated residual value provides a direct value that can be recorded in the accounts or can be used to derive a price may be applied in other contexts. The relevant considerations in deriving a price are described in the SEEA Central Framework (Annex 5.1).

Output
less intermediate consumption
less compensation of employees
less other taxes on production
plus other subsidies on production
Equals gross operating surplus
less consumption of fixed capital (depreciation)
less return on produced assets
less labour of self-employed persons
Equals resource rent
= depletion + net return on environmental assets

9.34 In practice, there can be a number of difficulties in applying these methods. First, the residual may reflect a combination of other non-paid and indirect inputs and thus distinguishing the ecosystem service contribution may be difficult. Second, the estimate is subject to errors in calculating the value of all the ´paid´ inputs. Third, and most importantly, the size of the residual will be directly affected by the institutional arrangements surrounding the use of the ecosystem. At the same time, since this method is applied based on observed data, the values and prices estimated using this technique will reflect the current institutional context.

9.35 **Productivity change method**. In this method, the ecosystem service is considered an input in the production function of a marketed good. Thus, changes in the service will lead to changes in the output of the marketed good, holding other things equal. The price is derived in two stages. First, the marginal product of the ecosystem service is estimated as the change in the value of production consequent upon a marginal change in the supply of the ecosystem service. Second, the marginal product is multiplied by the price of the marketed good. The relationships should be estimated for a single accounting period recognising that they may change over time.

[67] While similar in intent, there is a distinction between these methods in that the resource rent method will reflect an aggregate value of the rent in a given circumstance while the residual value method focuses on calculating the rental price, where the rent was determined in a market with a fixed supply and a competitive demand.

9.36 The productivity change method has been used to price the services provided by water and other inputs in agriculture, e.g., pollination, across locations where detailed data to estimate production functions are available. It is particularly suited for the valuation of ecosystem services that are inputs to existing SNA outputs. However, where there are multiple goods and ecosystem services involved, specifying the production function and marginal product of an individual ecosystem service may be difficult. Furthermore, it is data intensive and scaling up to a national level may be problematic.

9.37 **Hedonic pricing method**. The hedonic pricing method estimates the differential premium on property values or rental values (or other composite goods) that arises from the affect of an ecosystem characteristic (e.g., clean air, local parks) on those values. In order to obtain a measure of this affect, all other characteristics of the property (including size, number of rooms, central heating, garage space, etc.) are standardized and need to be included in the analysis. Moreover, properties must be completely described considering geographical, neighbourhood and ecosystem characteristics.

9.38 In the context of ecosystem accounting, the decomposition of these values into the part explained by the ecosystem service and the part explained by the remaining characteristics of the property can be used to estimate a value for the ecosystem service for a specific property. Associated prices for the ecosystem service can be derived for use in other contexts. This method may also be considered for use in other land value contexts such as for agriculture land in the context of biomass provisioning services.[68] It should be noted, that hedonic pricing will reveal a value for accounting purposes only in the case of a fully-informed and fluid market, where buyers are able to find properties with sets of characteristics optimally fitting their different preferences. Also, where the hedonic pricing method is applied to assets, the resulting prices need to be converted to relate to an annual service flow price using a suitable rate of return.

9.3.5 Methods where the prices are based on revealed expenditures in related goods and services

9.39 Where prices for ecosystem services cannot be estimated using the methods described above, it is possible to use data about revealed expenditures in related goods and services, commonly referred to as cost-based methods.

9.40 **Averting behaviour method.** The averting behaviour method is based on the assumption that individuals and communities spend money on preventing or mitigating negative effects and damages caused by adverse environmental impacts and this expenditure reveals the value placed on the associated ecosystem services. This is the case, for example, of incurring costs associated with extra filtration for purifying polluted water, air conditioning for avoiding polluted air, and so forth.

9.41 The expenditures incurred are considered a lower bound estimate of the benefits of mitigation, since it can be assumed that the benefits derived from avoiding damages are at least equal to the share of costs incurred to avoid them. An advantage of this method is that it is easier to estimate the expenses incurred than to estimate the avoided environmental damage. A disadvantage is that the expenditures may not be very sensitive to the differences in environmental quality, so they are not spatially sensitive in the way damage functions could be. Also, care is needed to align the expenditure to specific ecosystem services since they may reflect securing a bundling of services and to ensure that the expenditures reflect only the

[68] (Triplett, 2006) may be consulted for advice on the use of hedonic pricing approaches in a statistical context.

cost of avoiding environmental impacts rather than also reflecting matters of taste and consumption preferences.

9.42 **Travel cost method.** The travel cost method (TCM) estimates the demand function for recreation by observing the number of trips that take place at different costs of travelling to a recreational or cultural site. Costs of travelling include data on the expenditures incurred by households or individuals to reach a recreational site, entrance fees and the opportunity cost of time to travel and visit the site. One way to obtain an equivalent to the exchange value of trips to such sites is to add up all consumption expenditures This is sometimes referred to as the consumption expenditure approach. As there are different views as to whether the inclusion of the value of time is compliant with accounting principles, it is recommended to provide such estimates separately, in this would be included.

9.43 **Travel cost data.** The use of data on travel costs can be applied to estimate the value of various cultural services, in particular recreation-related services. Commonly, travel costs data are used to implement the travel cost method in which a demand function for recreation is estimated by observing the number of trips that take place at different costs of travelling to a recreational or cultural site. Costs of travelling include data on the expenditures incurred by households or individuals to reach a recreational site and entrance fees. The cost of time to travel to, and to enjoy time at, the site may also be included.

9.44 Travel cost data are ideally captured at a detailed level that considers the different features of the sites being visited and enjoyed. An alternative approach that may be suitable for aggregate measures of ecosystem services values is to add up all direct consumption expenditures. This is sometimes referred to as the consumption expenditure approach. Note that measures of consumer surplus which are commonly estimated using the travel cost method should not be included in accounting values.

9.3.6 Methods where the prices are based on hypothetical expenditures or markets

9.45 The final group of valuation methods that are available for accounting purposes are those based on estimating the expenditures that would be made if the ecosystem service was no longer provided or was sold on a market. Applying these methods is based on the logic that a loss of the ecosystem services would directly increase monetary costs (or reduce incomes) for economic units.

9.46 **Replacement cost.** The replacement cost method estimates the cost of replacing the ecosystem service by something that provides the same contribution to benefits. It is also known as the substitute cost or alternative cost approach. The substitutes can be either a consumption item (e.g., an air filtration unit for a household substituting for air filtration services of trees) or an input factor (e.g., sorghum substituting for non-priced forage in the case of a rangeland grazing ecosystem services) or a capital factor (e.g., water treatment plant). In all cases, if the substitute provides an identical contribution, the price of the ecosystem service is the cost of using the substitute to provide the same benefits as provided by a single quantity unit of the ecosystem service (e.g., price for a tonne of forage). If applied in a single context, a direct accounting entry may be estimated based on the total cost of using the substitute in that context, (e.g., for a single farm).

9.47 The validity of the replacement cost method depends upon three conditions being maintained: i) the substitute can provide exactly the same function as the ecosystem service being substituted for; ii) the substitute used is the least-cost alternative; and iii) there is a willingness to pay for the substitute if the ecosystem service were to be no longer supplied. Thus, in the example of the non-priced forage noted above, it should be evident that the sorghum is a good substitute for rangeland fodder, that it is cheaper than other substitutes (e.g., moving livestock elsewhere, using other types of fodder), and that livestock operations would be continued if the rangeland grazing activity was curtailed.

9.48 **Avoided damage costs.** The avoided damage costs method estimates the value of ecosystem services based on the costs of the damages that would occur due to the loss of these services. Similar to replacement costs, the focus will generally be on services provided by ecosystems that are lost if the ecosystem were not present or in sufficiently poor condition such that the services were not available. To obtain values and prices for accounting purposes, damages should be estimated using prices that are consistent with exchange value concept. The validity of the avoided damage cost method depends also on similar conditions as noted above with respect to the replacement cost method. The avoided damage method is particularly useful for regulating services such as soil erosion control and flood control, air filtration, and global climate regulation services.

9.49 In some contexts, prices based on both replacement costs and avoided damage costs may be able to be estimated. If this is possible the lower of the two estimated prices should be used.

9.50 **Simulated Exchange Value (SEV) method**.[69] The simulated exchange value method estimates the price and the quantity that would prevail if the ecosystem service were to be traded in a hypothetical market. It thus provides a direct estimate of the value, the SEV, required for entry into the accounts based on the exchange value concept.[70] The SEV method is applied by using results from demand functions for the relevant ecosystem service (for example estimated using the travel cost method, discussed above, or stated preference methods, discussed below). These are used to calculate the price for the ecosystem service that would occur if it was actually marketed. This requires combining the information on the demand function with a supply function and an appropriate market structure (institutional context). Standard microeconomic methods are then used to yield the simulated price, which can be used to estimate the value of the ecosystem services. It can be applied at various degrees of complexity and using alternative market structures, but it has not been as widely applied as the methods described above.

9.3.7 Other valuation methods

9.51 There is a range of valuation methods that are found in the environmental economics and ecosystem services valuation literature. They are described here for information but should not be applied in preference for any of the types of methods described above.

9.52 **Shadow project cost**. This is a variant of the replacement cost method focussing on the hypothetical costs of providing the same ecosystem service elsewhere. It is less suitable for the valuation of individual ecosystem services since it is not intended to capture individual flows. Possible alternatives for the design of a shadow project include: asset reconstruction (e.g., providing an alternative habitat site for threatened wildlife); asset transplantation (e.g., moving the existing habitat to a new site); or asset restoration (e.g., enhancing an existing degraded habitat). The three conditions noted above for the replacement cost method apply

[69] Based on (Caparrós et al., 2017).

[70] Where the simulated quantity differs from the observed quantity (e.g. in terms of the number of visits), simulated price can be adjusted in a subsequent step such that the simulated exchange value is unchanged.

to this method also noting that the method is only valid if the shadow project is actually realized or is planned to be realized.

9.53 This method is also linked to the restoration cost method which may be applied to value ecosystem degradation by estimating the hypothetical costs that would need to be incurred to restore an ecosystem to its condition at the beginning of the accounting period. The restoration cost method is discussed further in Chapter 12.

9.54 **Opportunity costs of alternative uses**. This approach estimates values of ecosystem services by measuring the forgone benefits of not using the same ecosystem asset for alternative uses. For example, the value of ecosystem services arising from not harvesting trees for timber (e.g., to supply global climate regulation services) can be measured by using the forgone income from selling timber. Thus, this approach measures what has to be given up for the sake of securing the ecosystem services. The opportunity cost approach is most useful when considering the ecosystem services that can be linked to certain purposes such as the protection of habitats, cultural or historical sites. The values obtained can be considered exchange values provided that (i) the valuation of the forgone benefits is based on exchange values and (ii) the institutional context considered is sufficiently realistic such that the alternative scenario can be analysed. A primary difficulty with the opportunity costs approach is determining an appropriate alternative use, since depending on the choice made the value of the foregone benefits could vary substantially.

9.55 **Stated preference methods**. Stated preference methods do not utilize information on the behaviour of people in existing markets but rather use information from questionnaires to elicit likely responses of people by asking them to state their preferences in hypothetical situations. Stated preference methods fall into two broad types: contingent valuation and choice experiments[71].

9.56 The contingent valuation (CV) method is a survey-based stated preference technique that elicits people's behaviour in constructed markets. In a contingent valuation questionnaire, a hypothetical market is described where the good in question can be traded. This contingent market defines the good itself, the institutional context in which it would be provided, and the way it would be financed. Respondents are asked about their willingness to pay for, or willingness to accept, a hypothetical change in the level of provision of the good, usually by asking them if they would accept a particular scenario. Respondents are assumed to behave as though they were in a real market (OECD, 2018).

9.57 Choice experiments are those where an individual is offered a set of alternative levels of supply of goods or services (typically two or three), in which the characteristics vary according to defined dimensions of quality and cost. By analyzing preferences across these different bundles of characteristics, it is possible to obtain the value placed by the individuals on each of the characteristics, provided (i) the bundles include a cost variable; and (ii) a baseline bundle is included that represents the status quo.

9.58 The information obtained from CV or discrete choice methods is the willingness to pay (WTP) for an ecosystem service or willingness to accept (WTA) payment for its loss. As such it is not an estimate of the value required for accounting purposes. However, by combining information on WTP or WTA of a range of recipients of the service, it is possible to derive a demand function for the ecosystem service and such a demand function may subsequently be used to derive an appropriate value.

9.59 **Prices from economic modelling**. Conceptually, it is possible to derive prices for ecosystem services from economic models that encompass relevant information on environmental and

[71] The pros and cons of different specifications are discussed in various publications; in particular, see (Johnston et al., 2017).

economic variables. For example, prices may be elicited from computable general equilibrium models. While potentially providing prices generated in more dynamic market contexts, the data requirements of applying these methods indicates that they are not likely to be suitable for use in ecosystem accounting.

9.60 **Qualitative methods**. There are a range of qualitative methods, including deliberative and group methods, that can be used in assessing the value of ecosystem services. However, since these methods are not designed for the derivation of monetary values they are not considered further here. It is likely however, that the framing provided for the measurement of ecosystem services in physical terms could support the application of these methods for use in decision making.

9.4 Valuation methods for different ecosystem services

9.4.1 Introduction

9.61 For the compilation of the ecosystem services supply and use account in monetary terms, the different valuation methods described in section 9.3 must be applied to individual ecosystem services. Table 9.2 provides an overview of the methods that are typically applied to different broad groups of ecosystem services. In practice, the method that is applied will often depend on data availability. The following sub-section provides general guidance on the issues to be considered in undertaking monetary valuation of different services.

Table 9.2: Summary of methods for estimating exchange values by ecosystem service type

Method	Provisioning services	Regulating & maintenance services	Cultural services
Directly observed values	X	X	
Prices from similar markets	X		X
Residual value & Resource rent	X		X
Productivity change	X	X	
Hedonic pricing		X	X
Averting behaviour		X	
Travel cost			X
Replacement Cost	X	X	
Avoided damage costs	X	X	
Simulated exchange value			X

9.4.2 Valuation of different types of services

9.62 Provisioning services include living resources harvested from unmanaged terrestrial and aquatic natural systems (uncultivated biomass) to highly managed plantations, aquaculture and livestock systems (cultivated biomass). While the ecosystem assets themselves may be involved in the generation of multiple services, including regulating and maintenance and cultural services, the valuation of provisioning services should deal only with estimating the value related to the physical flows (e.g., fish) that are harvested for non-recreational, consumptive use. The relevant measurement boundaries for provisioning services are described in Chapter 6.

9.63 The biomass harvested is within scope of the production boundary of the SNA and hence exchange values for the relevant products are included in current measures of economic production. The valuation of ecosystem services is therefore focused on identifying the contribution of the ecosystem to the biomass product values which are themselves based on data on quantities traded, market prices and input costs.

9.64 In a number of situations, there may be significant flows of ecosystem services associated with subsistence agriculture, forestry and fisheries, that is, when the outputs from growing and harvesting activities are not sold on markets but directly consumed by households. A broad range of products may be relevant in this regard, including all types of non-timber forest products. Following the conceptual scope of the SNA, the production associated with these activities should be included in the national accounts estimates of output, with exchange values estimated on the basis of the prices of similar goods sold on markets.[72] There will then be an associated ecosystem services contribution to the output that is recorded in the national accounts. The methods described above for estimating the value of biomass provisioning services can be used for the valuation of the ecosystem services associated with subsistence production and consumption on the basis of these estimated market prices.

9.65 There is a wide range of regulating and maintenance services. In some cases, the contribution of these services is an input to SNA benefits. For example, services of soil erosion control may be an input to agricultural production. In other cases, the services are contributions to non-SNA benefits, especially concerning improvements in human health, e.g., air filtration services. In all cases, there are few, if any, distinct markets for the services and identifying their relative contribution within existing market prices is likely to be challenging. Finally, most regulating and maintenance services exhibit considerable variation in their supply depending on local contexts and hence the measurement of the flows in biophysical terms will generally require biophysical modelling at relatively fine spatial scales.

9.66 Cost-based methods are the most commonly used methods for monetary valuation using the averting behaviour, replacement cost or the avoided damages methods. In some cases, regulating and maintenance services can be valued based on observed market transactions, such as in using data from payments for ecosystem services schemes or emissions trading schemes. However, there will be limits to where this approach can be used to estimate exchange values depending on the institutional arrangements involved or the way in which services are quantified within the schemes (e.g., often management actions are used as a proxy for quantities).

9.67 Generally, it is necessary to consider the monetary valuation of cultural services from a demand or consumption perspective. The most common methods for estimating the demand are revealed preference methods based on the travel cost method. Other approaches to estimating cultural services include hedonic pricing where, for example the value of aesthetic enjoyment services and local recreation services may be determined from the assessment of local house prices. Also, using residual value approaches, it is possible to estimate the value of ecosystem services as inputs to the businesses involved in facilitating people's interactions with nature, for example island resorts or canoe hiring firms.

[72] The handbook on measuring the non-observed economy (OECD et al., 2002) provides guidance on measurement approaches in this area.

9.5 Considerations in the monetary valuation of ecosystem services

9.5.1 Spatial variation and value generalisation for the purpose of ecosystem accounting

9.68 The discussion of monetary 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 monetary value of ecosystem services is fragmented, covering only specific services over a large area, or multiple services in a more confined area, or valuing changes in the flow of ecosystem services following a specific event. In general, care must be taken when monetary values for ecosystem services or ecosystem assets are applied in other areas.

9.69 To utilize data from specific, observed locations in the estimation of monetary values in other, target locations, a set of techniques can be applied, collectively referred to as value generalisation or value transfer techniques. There are three main types of approaches to value transfer: unit value transfers, value function transfers and 'meta-analysis' function transfers. A unit value transfer takes a single estimate of the monetary value of an ecosystem service (expressed in terms of a common measurement unit, e.g., hectare, tonnes, visits), or an average of several value estimates from different studies, to estimate the value of an ecosystem service in a different context. The use of a unit value transfer approach may be limited because there are differences between the value from the observed location and the target location concerning:

- The socio-economic and demographic characteristics of the relevant populations. This might include income, educational attainment and age.
- The physical characteristics of the two sites. This might include the ecosystem services that the location provides such as, in the case of a river, opportunities for recreation in general and angling in particular.
- The "market" conditions applying to the locations. For example, variation in the availability of substitutes in the case of recreational locations such as rivers. Two otherwise identical rivers might be characterised by different levels of alternative recreational opportunities. Other things being equal (by assumption in this case), the value of preventing a lowering of water quality at a river where there are few substitutes should be greater than the value of avoiding the same quality loss at a river where there is an abundance of substitutes. The reason for this is that the former is a scarcer recreational location than the latter.
- Changes in valuations over time, for example relating to increasing incomes and/or decreasing availability of clean rivers.

9.70 Since it is generally accepted that these conditions will not hold in practice adjustments are generally made to take the differences between locations into account. In the first instance adjustments are made to take into account income per capita and income elasticities to derive an adjusted unit value transfer. Meta-studies (such as (OECD, 2014)) indicate that adjusting for income per capita is a significant factor in being able to apply values from one location to others.

9.71 A more sophisticated form of value transfer is to undertake a value function transfer. In this approach to value generalisation, rather than transfer the single estimate of value adjusted only for income, a value function transfer takes the function estimated from a primary research study in one context and applies it in another context taking into account a wider variety of factors that influence the unit value. A value function may encompass factors such as the physical features of the location, changes in population age structure between the two sites and differences in population density.

9.72 A more comprehensive way to carry out value transfers is to use meta-analysis (e.g., (Bateman et al., 2000)), 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. 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. Application of meta-analysis to the field of non-market valuation has expanded rapidly in recent years. Studies have taken place in respect of urban pollution, recreation, the ecological functions of wetlands, values of statistical life, noise and congestion.

9.73 In terms of accuracy, research Kaul et al. (2013) suggests that value transfers are most effective when there is a degree of geographical proximity between the observed and target locations, when there is a focus on valuation of quantities rather than qualities of ecosystem services provided, and results can be improved by pooling estimates. Accuracy should also be considered in the light of the measurement objective wherein the type of decision-making context will influence the requirements. For example, if data are required for site level cost assessments it may be that value transfer itself is inappropriate and direct observation is required.

9.74 Fundamentally, the quality of value transfer approaches will be influenced by the number of observed valuation studies. In turn this will likely depend on the type of ecosystem and the type of ecosystem service being considered. For example, while there are many studies of recreational use of ecosystems, there are not as many studies on the value of wetlands. Since different valuation studies are also often based on different assumptions and use different methods there is a strong case for using the SEEA EA framework and its application through the practice of official statistics to develop consistently measured values across a variety of ecosystem services and locations. In developing these studies co-ordination with the requirement for organising data on ecosystem extent, condition and ecosystem service flows in physical terms is highly recommended since this information will assist in consistently differentiating and classifying locations and in ensuring appreciation of the supply and use context for the ecosystem services.

9.75 A final general comment that concerns value transfer but also all aspects of valuation of ecosystem services is the need for documentation of methods and the recognition and assessment of levels of uncertainty. The conceptual ideal of location-based pricing of individual ecosystem services is clear but this will likely be possible in only a few instances due to resource constraints, in much the same way as socio-economic statistics are commonly based on sampling techniques, for example of household expenditures and consumer prices. Clear documentation of the data sources, and the methods and assumptions applied in forming aggregate values for entry into the accounts will support informed interpretation and use of the accounting estimates.

10 Accounting for ecosystem assets in monetary terms

10.1 Introduction

10.1 The series of ecosystem accounts is completed with the ecosystem monetary asset account. This account records a monetary value of ecosystem assets in terms of the net present value of the ecosystem services supplied by the asset. The estimates of monetary value are compiled following the net present value principles described in Chapter 8 and using the exchange value concept. The estimates provide a measure of the exchange value related to the scope of ecosystem services recorded in the ecosystem services flow account and cannot be interpreted as reflecting a complete or universal measure of the value of nature.

10.2 The ecosystem monetary asset account also records the changes in the monetary value of ecosystem assets over an accounting period including changes due to ecosystem degradation, ecosystem enhancement, ecosystem conversions and revaluations.

10.3 Estimates of ecosystem assets in monetary terms can support discussion of the relative significance of different ecosystem assets and ecosystem types and, the monetary value of ecosystem assets can be combined with the monetary valuations of other types of assets, for example produced assets, to provide broader assessments of net wealth, such as in wealth accounting. Measures in monetary terms may also be related to general socio-economic drivers of change such as changes in economic activity and demographic trends.

10.4 Together with information about the assets in physical terms (e.g., measures of ecosystem condition) may be used as part of an assessment of the sustainability of the flows of ecosystem services. At the same time, as noted in Chapter 8, measures in monetary terms on their own will not be sufficient for the analysis of non-marginal changes in ecosystems and issues of sustainability that concern ecological thresholds and boundaries. Consequently, there is significant advantage in using the ecosystem accounting system which provides a clear "line of sight" between the physical data on ecosystem extent and condition, measures of ecosystem service flows and ecosystem capacity, and monetary values.

10.5 Measures of ecosystem degradation in monetary terms will be of particular interest in understanding changes in ecosystem assets relative to measures of economic activity such as industry value added. The derivation of degradation adjusted income measures is explained in Chapter 11, together with description of extended balance sheets and extended institutional sector accounts in an SNA context.

10.6 Section 10.2 sets out the structure of the ecosystem monetary asset account and the associated accounting entries. Section 10.3 describes the key components in valuing ecosystem assets using the net present value approach including the approach to valuing the accounting entries for changes in ecosystem assets over an accounting period.

10.2 Ecosystem monetary asset account

10.2.1 Structure of the ecosystem monetary asset account

10.7 The ecosystem monetary asset account records the monetary values of all ecosystem assets within an ecosystem accounting area at the beginning (opening) and end (closing) of each accounting period; as well as changes in the value of those assets over the accounting period. Changes in the monetary value of ecosystem assets are separated into five broad types: ecosystem enhancement, ecosystem degradation, ecosystem conversions, other changes in the volume of ecosystem assets, and revaluations as a result of price changes.

10.8 The description provided in this section reflects a framing in which individual ecosystem assets are able to be valued as a single entity reflecting the net present value of the set of ecosystem services it supplies as recorded in the ecosystem services flow accounts. Thus, the concepts concerning the change in value such as degradation and enhancement are defined by viewing the ecosystem asset as a single entity in line with the framing for the measurement of ecosystem extent and condition. In practice, as explained in section 10.3, it is necessary to estimate the net present value of each ecosystem service separately. The approach to reconciling the ecosystem services specific NPV estimates and the changes in ecosystem asset values described here are explained in Annex 10.1.

10.9 The basic accounting structure for the ecosystem monetary asset account is shown in Table 10.1. This table shows an account for an ecosystem accounting area classified by ecosystem type using selected EFGs from the IUCN Global Ecosystem Typology (see Chapter 3). Entries in the ecosystem monetary asset account are linked to the entries in the ecosystem extent account (Chapter 4). The additions and reductions shown in that account in physical terms will align with the additions and reductions in monetary terms that are recorded under ecosystem conversions. Further, the asset account entries are conceptually aligned with measures of the monetary value of other assets included in the balance sheet of the SNA, for example concerning produced assets.

10.10 As required, and where data are available, asset accounts showing the same accounting entries can be compiled for individual ecosystem assets (e.g., a specific grassland), for all ecosystem assets of a single ecosystem type (e.g., all Trophic savannas (EFG T4.1)) or for various types of ecosystem accounting areas (e.g., a country, a large administrative area or a protected area) that includes multiple ecosystem assets of different ecosystem types.

10.11 Depending on data availability it may be necessary to combine some accounting entries by netting the change in value. For example, net ecosystem conversions might be recorded rather than separately recording additions and reductions. Further, in many contexts there may be multiple potential entries over an accounting period reflecting a combination of enhancement, degradation and other types of changes. This section outlines the conceptual ideal for distinguishing the various entries recognising that making the distinctions in practice will commonly rely on the judgement of the compiler. At the same time, the measure of net change in ecosystem asset value should be well-bounded by measures of the opening and closing value and the various changes can also be linked to the measures in physical terms recorded in the ecosystem extent and condition accounts.

Table 10.1: Ecosystem monetary asset account (currency units)

	Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		TOTAL
	Terrestrial												Freshwater			Marine			
	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derivied semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	
	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	
Opening value																			
Ecosystem enhancement																			
Ecosystem degradation																			
Ecosystem conversions																			
Additions																			
Reductions																			
Other changes in volume of ecosystem assets																			
Catastrophic losses																			
Reappraisals																			
Revaluations																			
Net change in value																			
Closing value																			

10.2.2 Ecosystem enhancement

10.12 Ecosystem enhancement is the increase in the value of an ecosystem asset over an accounting period that is associated with an improvement in the condition of the ecosystem asset. Ecosystem enhancement will be reflected in a rise in the net present value of expected future returns of the ecosystem services supplied by that asset. Ecosystem enhancement will incorporate the effects of activities, including those related to a reduction in harmful activities, that have improved the condition of an ecosystem asset beyond activities that may simply maintain an ecosystem asset. Ecosystem enhancement will also arise as the result of natural and unmanaged improvements in condition.[73] There will not be a linear relationship between changes in condition and future flows of ecosystem services.

10.13 Not all increases in value should be recorded as ecosystem enhancement. The focus should be on recording increases in asset value resulting from improvements in ecosystem condition that can be reasonably expected to increase the future flows of ecosystem services in physical terms, based on the current and expected patterns of ecosystem management and use. Increases in value attributable to changes in the expected demand for ecosystem services should be recorded as upward reappraisals. Increases in value due solely to movements in the unit prices of ecosystem services should be recorded as revaluations.

[73] In a SEEA Central Framework context this will relate to the concept of natural growth of biological resources.

10.14 Ecosystem enhancement is measured in relation to the extent of an ecosystem asset as recorded at the beginning of the accounting period. Where there are changes in the extent of an ecosystem asset, that is where there is change (conversion) from one ecosystem type to another during an accounting period, a separate recording of that change should be undertaken, and recorded under the entry ecosystem conversions.

10.15 Three types of activities may be considered in the context of ecosystem enhancement: restoration, rehabilitation and reclamation. Each of these activities represents different degrees of expected effect on the ecosystems from the activity.[74] Restoration occurs where the aim is to re-establish pre-existing structure and function, including biotic integrity. Rehabilitation occurs where the aim is to reinstate ecosystem functionality with focus on supplying a range of ecosystem services. Both restoration and rehabilitation activities may be achieved by reducing the degree of human impact, for example by reducing stocking rates on grazing land, by reducing the release of pollutants, or by separating or re-zoning areas as being the focus of restoration and rehabilitation. Reclamation occurs where the aim is to return degraded land (e.g., desertified areas) to a useful state (e.g., for agriculture). Where restoration, rehabilitation or reclamation activities result in a change in ecosystem type during the accounting period, increases in value due to the activity should be recorded under ecosystem conversions.

10.16 Since measures of ecosystem enhancement are linked to activities undertaken in the landscape, the changes in extent, condition and value can be compared to estimates of expenditure and other measures of human input (e.g., volunteer hours) associated with that activity. However, it is not expected that the changes in net present value would be the same as the levels of expenditure on environmental protection or restoration activity. Thus, it becomes possible to complement measures of expenditure and provide an indication of the returns that may accrue in relation to a given level of expenditure. In this context, there will be a connection to the measurement of land improvements as recorded as a component of gross fixed capital formation in the SNA, and to the measurement of environmental protection and resource management expenditure as recorded in the SEEA Central Framework. There may be interest in comparing changes in asset value associated with these environmental activities with data on the ownership of the ecosystem assets.

10.2.3 Ecosystem degradation

10.17 Ecosystem degradation is the decrease in the value of an ecosystem asset over an accounting period that is associated with a decline in the condition of an ecosystem asset. Ecosystem degradation will be reflected in a fall in the net present value of expected future returns of the ecosystem services supplied by that asset. Ecosystem degradation will arise as the result of both managed and unmanaged declines in condition.

10.18 Not all decreases in value should be recorded as ecosystem degradation. The focus should be on recording decreases in asset value resulting from declines in condition that can be reasonably expected to decrease the future flows of ecosystem services in physical terms, considering the current and expected patterns of ecosystem management and use, and expected patterns of environmental variation.

10.19 Declines in condition may arise from a range of sources including the extraction and harvest of natural resources and the short and long-term effects of pollution and emissions. Where

[74] For details see the UNCCD Land Degradation Neutrality conceptual framework: https://www.unccd.int/actions/ldn-target-setting-programme

there is harvesting or extraction of resources from an ecosystem (e.g., of timber or fish resources), the assessment of the decline in condition should be considered at an appropriate scale and over an appropriate time frame wherein the level of harvesting or extraction can be assessed relative to a rate of regeneration of the resource. Only extraction at rates above the rates of regeneration should contribute to degradation.[75]

10.20 Decreases in value due to large scale, discrete and recognisable events that cause a significant loss in the condition of an ecosystem asset should be recorded as catastrophic losses. Decreases in value attributable to changes in the expected demand for ecosystem services should be recorded as downward reappraisals. Decreases in value due solely to movements in the unit prices of ecosystem services should be recorded as revaluations.

10.21 Ecosystem degradation is measured in relation to the extent of an ecosystem asset recorded at the beginning of the accounting period. Where there are changes in the extent of an ecosystem asset, that is where there is change (conversion) from one ecosystem type to another during an accounting period, a separate recording of that change should be undertaken, and recorded under the entry ecosystem conversions.

10.22 The measurement of ecosystem degradation can be undertaken for an ecosystem asset without specific regard to the legal or economic ownership of the ecosystem asset. However, for some analytical purposes and for integration of ecosystem accounts into the general sequence of institutional sector accounts of the SNA, it is necessary to attribute the cost of ecosystem degradation to an economic unit and institutional sector. Approaches to the attribution of ecosystem degradation to institutional sectors are discussed in Chapters 11 and 12.

10.23 The SEEA Central Framework, Section 5.4, defines the depletion of natural resources as "the decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units occurring at a level greater than that of regeneration." This definition can be seen as sitting within the definition of ecosystem degradation to the extent that the quantity of a stock of a natural resource is considered part of the structure and composition of an ecosystem asset. The term depletion is retained to refer solely to the cost of using up natural resources. This measure will be narrower in scope than ecosystem degradation since it will only relate to the loss of future provisioning services. However, an economy-wide measure of depletion will be broader in scope to the extent that it includes declines in the net present value of the stock of non-renewable resources due to extraction, in particular mineral and energy resources, since these fall outside of the scope of ecosystem assets.

10.2.4 Ecosystem conversions

10.24 Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services and different expected future returns.

10.25 In physical terms, ecosystem conversions that occur during the accounting period should be recorded as changes in ecosystem extent, e.g., a change from forest to agricultural land, following the advice in Chapter 4. An ecosystem conversion may commonly apply only to part of an existing ecosystem asset. In the ecosystem extent account, the increases in the area of

[75] This treatment is consistent with the definition of depletion in the SEEA Central Framework.

one ecosystem type and decreases in another ecosystem type at a given location will net to zero.

10.26 Consistent with the definition of ecosystem degradation, the assessment of the change in ecosystem type should be undertaken at an appropriate scale and over an appropriate time frame to allow for assessing the effects of, for example, harvesting or extraction of natural resources, or forest fires, relative to rates of regeneration. More generally, it will be relevant to consider changes in ecosystem condition since these will provide an indicator of potential changes in ecosystem type.

10.27 In monetary terms, a decrease in value will be recorded for the ecosystem type which the area has been converted from (e.g., forest) and an increase in value will be recorded for the ecosystem type which the area has been converted to (e.g., agricultural land). Both of these entries should be recorded in the rows for ecosystem conversions as additions or reductions.

10.28 There is no expectation that the value of expected future returns for additions and reductions will be offsetting. Thus, the net effect in monetary terms of ecosystem conversions may be positive or negative depending on the differences in the set of expected ecosystem services that are generated by the different ecosystem types.

10.29 Depending on the information available, it may be of interest to organise information on ecosystem conversions according to reasons for conversion including agricultural expansion, increased urbanisation or reclamation of desert areas to become grazing land.

10.2.5 Other changes in the volume of ecosystem assets[76]

10.30 Other changes in the volume of ecosystem assets refer to changes in the value of an ecosystem asset, other than those due to ecosystem enhancement, ecosystem degradation and ecosystem conversion, that are not solely the result of changes in unit prices of ecosystem services. The two types of other changes in volume are catastrophic losses and reappraisals.

10.31 Decreases in the value of ecosystem assets due to catastrophic losses are identified separately to provide scope for compilers to record decreases due to large scale, discrete and recognisable events that cause a significant loss in the condition of an ecosystem asset, i.e., significant losses of structure, function or composition, and hence affect the future flows of ecosystem services in physical terms. Examples include earthquakes, bushfires, cyclones and industrial disasters. While these events may be anticipated in general terms, the precise timing, location and magnitude cannot be foreseen in the same way as expectations may be formed about patterns of ecosystem use by people.[77]

10.32 Reappraisals should be recorded when updated information emerges that permits a reassessment of the expected condition of the ecosystem assets or the future demand for ecosystem services, such that the expected pattern of future returns at the end of the accounting period is different from the pattern that had been expected at the start of the accounting period. For example, the effects of changes in demographic projections that affect the future demand for ecosystem services should be recorded as reappraisals; and changes in the future flows of services due to rezoning of land or changes in the risk of extreme events.

[76] "Other changes in volume" is an SNA specific expression that has a specific meaning and reference as discussed in this section.

[77] See also 2008 SNA paragraphs 12.46 & 47 and SEEA Central Framework, para. 5.49.

10.33 Reappraisals concern changes in expectations and are materially different from the use of updated information to improve the quality of compiled estimates. The incorporation of new information concerning expectations does not lead to revisions in previous estimates.

10.34 Where improved or revised source data are used (e.g., through the use of more detailed ecological information and biophysical modelling) or where revised methods and classifications are adopted, the changes should be applied consistently across all relevant accounting entries and, as appropriate, revisions to past accounting entries should be made. A separate accounting entry to distinguish revisions due to changes in source data is not required but for data quality assessment purposes maintaining a history of revisions to accounts is strongly recommended.

10.2.6 Revaluations

10.35 Revaluations refer to changes in the value of ecosystem assets over an accounting period that are due solely to movements in the unit prices of ecosystem services. Following the SEEA Central Framework (paragraph 5.61), a change in the value of an ecosystem asset in response to a change in the quantity or quality of future flows of ecosystem services is not considered a revaluation and should be recorded, as appropriate as ecosystem enhancement, ecosystem degradation, ecosystem conversion or other changes in volume.

10.36 Revaluations reflect nominal holding gains over an accounting period and there may be analytical interest in decomposing these gains into the neutral holding gain – equivalent to the nominal gains associated with the general rate of inflation – and real holding gains. Holding gains may be positive or negative since the nominal gains may be greater or less than the general rate of inflation.

10.37 Revaluations should also incorporate change in the value of ecosystem assets due to changes in the assumptions made in the parameters that are used to estimate the net present value, such as the discount rate, to the extent that these effects can be isolated. Changes in estimated values that are due to changes in methods are treated as revisions.

10.3 Approaches to valuing ecosystem assets

10.3.1 General approach to valuing ecosystem assets

10.38 The net present value (NPV) approach to the valuation of ecosystem assets was introduced in Chapter 8. In mathematical terms, the value of a single ecosystem asset *V* is written as:

$$V_\tau(\boldsymbol{EA}) = \sum_{i=1}^{i=S} \sum_{j=\tau}^{j=N} \frac{ES_\tau^{ij}(\boldsymbol{EA}_\tau)}{(1+r_j)^{(j-\tau)}}$$

where ES_τ^{ij} is the value of ecosystem service *i* in year *j* as expected in base year τ generated by a specific ecosystem asset $\boldsymbol{EA}_\tau$; S is the total number of ecosystem services; *r* is the discount rate (in year *j*, and *N* is the lifetime of the asset, which may be infinite for some ecosystem assets if used sustainably. τ is the starting period or base year, which may be referenced to 0.[78]

[78] Preferably, the returns should be assumed to accrue to the midpoint of the accounting period. The assumption made here is that the returns accrue at the start of the accounting period and it is used to simplify the explanation and the associated notation. The assumption has no impact on the underlying relationships described.

10.39 In ecosystem accounting, an ecosystem asset generates a bundle of ecosystem services each valued separately. The NPV formula is applied at the level of individual ecosystem services and the resulting discounted values are aggregated to derive the monetary value of the ecosystem asset. A discussion on the various components of the equation is presented in the following sub-sections.

10.40 Each ecosystem service is considered separable in the sense of each ecosystem service (i) being able to be measured distinctly, i.e., in a mutually exclusive manner; and (ii) representing a distinct flow between an ecosystem asset and a relevant user. At the same time, in measuring the NPV for each ecosystem service, it is necessary to recognise that while each ecosystem service is generated from an ecosystem asset, different characteristics of that ecosystem asset will be relevant in the generation of each service. Thus, while there is a common location there is not a single distinct stock, in the sense usually applied in for example, using NPV to value mineral and energy resources or timber resources as in the SEEA Central Framework.

10.41 Consequently, while each ecosystem service flow and its associated NPV is considered separable, it is necessary that the inherent connections among ecosystem characteristics within an ecosystem asset in a given location are jointly considered when determining the expected future returns of each ecosystem service. General proposals for providing a reasonable baseline for consistency in measurement are set out below with the general aim of avoiding contradictions within a set of accounts. This ambition provides a suitable basis for meaningful interpretation for monitoring and decision making.[79]

10.42 Assuming that the expected future returns for each service are estimated based on the exchange value concept, the NPV for an ecosystem service will provide an exchange value for the capitalised value of that service, and the aggregate NPV will provide an exchange value for the ecosystem asset. In order to decompose the change in asset value from the beginning to the end of an accounting period, for example to record the value of ecosystem degradation, the changes in price and quantity of future returns for each ecosystem service are analysed. Annex 10.1 provides a description of the decomposition approach.

10.43 The general principles just outlined apply to the situation where ecosystem services are attributable to individual ecosystem assets. Commonly, the measurement and valuation of ecosystem services is undertaken using detailed spatial data which in turns supports the potential to undertake measurement at this level of detail. The spatial attribution of ecosystem services to different ecosystem assets is discussed in Chapter 7. Where ecosystem services are not attributed to a single ecosystem asset, it remains possible to estimate the NPV of each ecosystem service and aggregate to determine a total value of ecosystem assets for an EAA. Further, in practice, it may be necessary to undertake projections at a more aggregated scale (e.g., with respect to demography) rather than for individual ecosystem assets. Nonetheless, where possible, estimation should be undertaken for smaller, sub-EAA spatial areas to assist in recognising variations in local contexts, including differences in ecosystem characteristics and in institutional arrangements (see also section 10.3.6).

10.44 As introduced in section 8.2, the measurement of expected future returns involves consideration of five key aspects: (i) the scope and definition of returns; (ii) the valuation of returns; (iii) future flows of ecosystem services in physical terms; (iv) asset lives; and (v) expected institutional arrangements. Each of these aspects is considered in turn in more detail

[79] It will likely be possible with advances in biophysical science, and associated economic modelling, to better estimate expected interactions within ecosystems with respect to the supply of ecosystem services. Indeed, advances in this direction are occurring and an important area of future research will be connecting these advances to the task of improving the valuation of ecosystem assets.

in the following sub-sections. In practice, all aspects will be connected and an iterative process will be needed to establish a clear and agreed basis for estimating expected future returns across multiple ecosystem services. Importantly, the integrated approach used in ecosystem accounting, especially the use of consistent classes of ecosystem types to underpin the organisation of relevant data, provides the structure within which all of the relevant aspects can be consistently approached.

10.45 In addition to estimating expected future returns, the second key component is the discounting of these returns to their present value. Mathematically this is a straightforward calculation but the selection of an appropriate discount rate is a matter of considerable importance since it can have a significant effect on the resulting present value estimate and on its interpretation. The selection of discount rates is discussed in section 10.3.7.

10.46 To support the interpretation of estimates and comparison of results from different sets of accounts, it is necessary that all assumptions used to underpin the measures of the value of ecosystem assets and changes in value are clearly documented.

10.47 It is standard practice to record single, point estimates in the accounts. However, given the assumptions required to underpin valuation in monetary terms, it may be appropriate to provide a range of values that could be obtained under plausible alternative assumptions. For example, estimates of the value of ecosystem assets might be provided using different assumptions concerning the discount rate.

10.48 The description of the NPV approach in this chapter is aligned with the discussion in the SNA and the SEEA Central Framework. The key difference in application concerns the need to aggregate multiple future returns for a single asset value. The alignment in approach supports the compilation of extended balance sheets that incorporate ecosystem assets alongside other asset classes (see Chapter 11). Because the approach described here involves the aggregation of individual ecosystem services, it should be possible to integrate directly estimates from the SEEA Central Framework for natural resources provided they can be matched to the relevant provisioning service and ecosystem asset. This also means that alternative valuations for those services can be incorporated, potentially using directly observed data (for example on land values) or variations on the NPV formulation above such as the stumpage method for valuing timber resources.[80]

10.3.2 Scope and definition of returns

10.49 The scope of returns concerns the set of ecosystem services that is included in the valuation for any given ecosystem asset. In practice, the set of ecosystem services included for asset valuation should align with the set of services recorded in the monetary ecosystem services flow account for each ecosystem type. Compilers should include a comprehensive range of ecosystem services in order to best reflect the monetary value of the asset and its changes over time.

10.50 The returns included in the net present value calculation refer to the ecosystem services expected to be supplied by an ecosystem asset. As described in Chapter 8, ecosystem services are the contributions of ecosystem assets to benefits and hence ecosystem services and benefits must be clearly distinguished. By way of example, in the case of timber provisioning services, the ecosystem services will refer to the contribution of the ecosystem, for example

[80] The SEEA Central Framework describes alternative approaches to the valuation of timber resources (SEEA Central Framework, paras. 5.383 & 384) noting that they are NPV formulations under simplifying assumptions concerning the timber stock.

valued using a stumpage value or resource rent, and will be distinct from the benefits, namely the harvested timber, commonly in the form of logs, that is sold by the forester.

10.51 Following the treatments of ecosystem services described in chapter 6, the scope of ecosystem services included in the net present value calculation may include flows of intermediate services. Thus, in principle, the returns estimated for a given ecosystem asset should include the supply of intermediate services to other ecosystem assets and should deduct the use of intermediate services from other ecosystem assets.

10.52 For marine ecosystems, attention should be paid to determining the appropriate measurement boundary for fish stocks and other aquatic resources since these stocks may migrate through or straddle the EAA boundary if this is defined following, for example, a country's exclusive economic zone. The measurement boundary for fish stocks defined in the SEEA Central Framework (section 5.9) should be applied for these provisioning services.

10.3.3 Valuation of returns

10.53 Returns for each ecosystem service are valued based on exchange values consistent with the advice in Chapters 8 and 9. The value of ecosystem services focuses only on the contribution of the ecosystem following the methods described in chapter 9. Where the ecosystem service values are based on observed market prices for associated benefits (e.g., in the resource rent method) costs incurred in supplying the ecosystem services will be excluded such that the value used considers only the contribution of the ecosystem.

10.54 To determine the present value of the future returns, assumptions are required concerning the future prices for each ecosystem service. When valuing individual environmental assets, such as mineral and energy resources, it is common for national accounting purposes to assume that the current period price (or an average of prices in recent accounting periods) will apply in future periods. This is also an appropriate default approach for ecosystem accounting purposes.

10.55 Nonetheless, in valuing future returns of ecosystem services, assuming constant prices may not be valid in some situations in view of the wider interconnections and factors that will influence an ecosystem asset and which will affect future returns. Therefore, future price changes should be taken into account when expected changes in markets are well-understood and where sufficient information is available, such as with some aspects of climate change related effects.

10.3.4 Future flows of services in physical terms

10.56 The additional challenge in estimating future flows of ecosystem services in an asset valuation context is to allow for interactions and connections between ecosystem services. Thus, for example, if global climate regulation services are estimated under the assumption that a forest can sequester carbon over an infinite time frame, while for the same ecosystem asset, rates of timber provisioning are estimated under the assumption that the forest's timber resources will be fully depleted within a limited time frame (e.g., 30 years) with no likelihood of regeneration, then the two estimates of expected service flows will be considered internally inconsistent.

10.57 More specifically, the future flow of services depends upon the condition and regeneration of the ecosystem and future demand for ecosystem services. For example, the future flow of ecosystem services from a forest ecosystem in relation to air filtration services will depend in part on (a) the extent and condition of the forest; (b) the expected level of pollutants; and (c) the expected size and growth of the local population who benefit from air filtration services. There will be a set of factors to consider for each type of ecosystem service.

10.58 It is not anticipated that compilers will develop comprehensive models of future demand and supply considerations. However, it is reasonable to consider that some factors may be identifiable and quantifiable in certain contexts, for example the effects of increases in population or from the adoption of specific legislation that is expected to reduce pollution. Also, in some cases there may be bioeconomic and similar models that can support the development of estimates. In these cases, such information should be considered in the estimation of future flows for a given ecosystem service. Over time, as a time series of ecosystem accounts is developed, insights should emerge as to the factors of most relevance. The following points are set out to outline relevant considerations.

10.59 Since ecosystem services involve both the supply and use of services, the expected socio-economic context must also be considered in estimating the future flows of ecosystem services. This context will include general socio-economic factors (such as demography and incomes) as well as more specific factors, including those that are spatially relevant or relevant to individual ecosystem services, such as the changes in the demand for recreation related services following increases in accessibility of ecosystems; and changes in regulations that reduce the concentrations of pollutants will reduce the demand for air filtration services.

10.60 In considering both the future supply and demand of ecosystem services it will be helpful to frame the future flows differently depending on the type of service. Future flows of provisioning services are likely to be functions of natural resource and cultivated biological resource supply and demand considerations. On the other hand, future flows of regulating and maintenance services are more likely to be functions of changes in exposure to risks over time, for example from pollution and emissions and floods. Cultural services are likely to be driven by demand considerations including population growth and specific factors such as urban design and trends in tourism and recreation.

10.61 As introduced in Chapter 8, there are interactions among and within ecosystem assets that should be taken into account when considering the future flows of ecosystem services and their values. Assumptions concerning the expected future degradation which impact on specific ecosystem services will be of particular importance. For example, the flow of timber provisioning services may be expected to decline over time due to the impact of expected ecosystem use on regeneration rates. In national accounting, similar assumptions are made when estimating the stock of produced assets.

10.62 In addition, in order to avoid internal contradictions in the measurement of asset values, it should be recognised that some patterns of use, primarily concerning overexploitation of natural resources such as timber, soil or fish, will have detrimental impacts on the supply of other ecosystem services. These impacts may not be apparent immediately but will be subject to different environmental thresholds. In considering these issues the measurement of ecosystem capacity as described in Chapter 6 may provide valuable input.

10.63 Finally, it will be relevant to consider wider environmental changes, such as expected changes in rainfall and temperature patterns or ocean acidification associated with climate change, that will impact on the future flows of ecosystem services. Ideally, information from climate change related models may be applied. In estimating the expected future flow of services, it cannot be necessarily assumed that the flow will be ecologically sustainable, i.e., with no loss of ecosystem condition.

10.64 There are some contexts in which economic activity, including household consumption, has indirect and potentially delayed impacts on ecosystem condition. In a present value framing, the fact that the impacts on ecosystem condition (and hence ecosystem service flows) may be well into the future is conceptually straightforward to manage if the timing and magnitude of the impacts is known and can be incorporated into the estimation process. However, a common scenario might be that evidence of impacts emerges such that the expectations of future service flows change. From an accounting perspective, identifying such a change in expectations is possible. It is recommended that the change in value associated with these new expectations is recorded as a reappraisal of the value of the ecosystem asset.

10.3.5 Asset lives

10.65 ***The ecosystem asset life is the time over which an ecosystem asset is expected to generate ecosystem services.*** Estimates of the asset life should be based on consideration of the condition of the ecosystem asset and its capacity to supply the set of ecosystem services being considered in the valuation of the ecosystem asset. It is possible to assume an infinite asset life when it is expected that the ecosystem asset will be used long into the future. An alternative setting is to apply a maximum asset life of 100 years. Unless there is strong evidence to the contrary, it is recommended that estimates of asset life be based on patterns of ecosystem use that have occurred in the recent past rather than through the use of general assumptions about future sustainability or intended or optimal management practices.

10.66 For the application of the NPV formula, it is necessary to apply the same asset life for all ecosystem services supplied by an individual ecosystem asset. That is, the concept of the asset life should be applied in relation to the asset rather than the service. For ease of application of this requirement, it is most likely appropriate to assume a single asset life for all ecosystem assets and hence all ecosystem services. An infinite asset life might be most appropriate for this purpose. If there are some services for which the expectation is that services will no longer be supplied or used after a particular point in time, e.g., after 30 years, the subsequent tie periods can be filled with zeros.

10.3.6 Expected institutional arrangements

10.67 The final aspect in establishing the expected future returns is forming expectations about future institutional arrangements. The starting assumption for accounting purposes is that the current institutional arrangements will continue to apply. However, in cases where it is strongly expected that these arrangements will change in the future and the nature of the changes can be clearly understood, the effects of future changes in institutional arrangements and the timing of the changes should be factored in when estimating the future returns of ecosystem services. Examples of relevant institutional arrangements include natural resource management regimes, taxation arrangements, government environmental conservation programs and markets for environmental services (e.g., carbon markets).

10.3.7 Discounting

10.68 A discounting process involving selection of a discount rate is required to derive net present value estimates. Annex A5.2 of the SEEA Central Framework summarises key issues in the choice of discount rates and describes the mathematical and analytical implications of the choice of discount rates. In particular, it notes the distinctions between individual/private discount rates and social discount rates and also whether those rates are determined descriptively or prescriptively. Descriptively-determined discount rates are those based on the prices (and other measurable factors) facing either individuals or governments, while prescriptively-determined discount rates incorporate assumptions regarding the preferences of individuals and societies, particularly in respect of equity between and within generations.[81]

10.69 For individual ecosystem assets such as mineral and energy resources, and timber resources, the SEEA Central Framework concludes that for the purpose of alignment with the concept of exchange values as defined in the SNA it is necessary to use marginal, private, market-based discount rates. This reflects that the discount rates were being applied in the context of the preferences of economic units operating from a private, market-based perspective. In the SEEA EA, the preferences relating to a wider range of economic units and goods and services need to be considered.

10.70 In this context, the following conceptual framing should be applied in selecting a discount rate:[82]

- Individual, market-based discount rates should be applied in the valuation of ecosystem services whose users are private economic units;
- Social discount rates should be applied in the valuation of ecosystem services that contribute to collective benefits, i.e., received by groups of people or society generally.

10.71 The selection of a social discount rate for SEEA EA purposes should be based on rates available from government determined processes and further, they should be in active use in government decision making. These rates are likely to embody some assumptions on preferences of individuals and societies. Where such rates are not available, compilers may consider using long-term government bond rates.

10.72 In applying discount rates, it is recommended that compilers use a constant rate over the asset life. The primary alternative is to use declining discount rates including hyperbolic, gamma and geometrically declining rates. Declining rates may have some intuitive appeal in that they do not fix the relationship of preferences across generations and hence allow the preferences of future generations to be more explicitly considered. However, there are a range of theoretical (e.g., time inconsistency) and practical challenges, and hence these rates are not recommended for use in ecosystem accounting.

10.73 Care should also be taken to ensure that the discount rate applied is consistent with the assumptions made in projecting future returns of ecosystem services. Specifically, if future returns are estimated in nominal prices then the discount rate should include an allowance for expected inflation. Most commonly, future returns will be estimated in real terms and thus the discount rate applied should also be in real terms. Since the essential function of a discount rate is to reflect the time value of money, the appropriate measure of expected inflation is likely to be one that is economy-wide in scope, for example, the GDP deflator.

10.74 Compilers are encouraged to undertake an assessment of the sensitivity of monetary valuations to different assumptions, in particular through the application of alternative discount rates. Such assessments can be published as part of the general documentation of the accounts.

[81] SEEA Central Framework Annex A5.2 Discount rates, A5.52

[82] This framing is consistent with the idea of "dual discounting" (Baumgärtner et al., 2015; Weikard & Zhu, 2005) recognising that ideally this approach would also take into consideration the substitution effects between the types of services with different discount rates. These effects would generally be reflected in future prices.

10.3.8 Measuring changes in the net present value of ecosystem assets over an accounting period

10.75 Accounting for the change in the value of assets over an accounting period is a core part of asset accounting. As with the assessment of the value of an asset at the beginning and end of an accounting period, the valuation of changes in the asset value, such as those due to ecosystem enhancement, degradation and conversions, is also dependent on the impact that these changes have on expected future returns. Further, since these changes are not usually evidenced by transactions in the assets themselves, their valuation requires the use of the NPV approach to ensure alignment between opening and closing valuations and valuations of the changes.

10.76 A complete accounting for NPV and changes in NPV is presented in Annex 10.1. The annex highlights the relationships between the changes in the quantities of expected flows of ecosystem services, changes in the condition and extent of the ecosystem asset, and changes in the prices of ecosystem assets with respect to each ecosystem service. A key conclusion demonstrated in the annex is that it is incorrect to use the unit price of the ecosystem service in the current period to value the ecosystem assets and changes in those assets. Rather the relevant asset prices will be a function of the NPV formula in which expected future returns and discounting will have an effect. The relationship between unit prices for ecosystem services and ecosystem asset prices is also discussed in the annex.[83]

[83] This relationship was described in relation to the valuation of individual environmental assets in the SEEA Central Framework, Annex 5.1

Annex 10.1: Application of the net present value method for valuing ecosystem assets and changes in ecosystem assets

Introduction

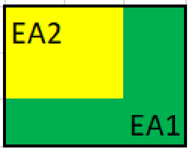
A10.1 This annex explains, in some detail, the steps involved in implementing a net present value (NPV) approach for the valuation of ecosystem assets, with a view to deriving valuations of the opening and closing values of ecosystem assets and consistent measures of ecosystem enhancement, degradation, conversions, other changes in volume and revaluations. The conceptual framing for the approach described here is explained in Chapter 10 together with definitions of the relevant accounting entries. A simple, stylized example is used to demonstrate the approach. It is recognized that the application of these principles will be more complex in practice and also that some variations in application will be needed for ecosystem services other than the ones used.

Stylized example

A10.2 In this stylized example the ecosystem accounting area (EAA) covers 9 hectares (ha) consisting of two ecosystem assets. At the beginning of the accounting period, t0 the composition is forest (EA1: green) covering 5 ha and cropland (EA2: yellow) covering 4 ha (see Figure 10.1). Initially, it is assumed that the extent of each ecosystem asset remains the same during the accounting period so the changes are driven by degradation/enhancement, later we will discuss the situation where ecosystem conversion takes place.

Figure 10.1: Extent

Area t0	
EA1 - forest	5
EA2 - crops	4



A10.3 The forest is assumed to supply two ecosystem services: climate regulation services (ES1) and nature-based recreation services (ES2), and the cropland supplies one ecosystem service: crop biomass provisioning (ES3). It is further assumed that each of these services is supplied only from the specific areas of each ecosystem asset (i.e., the service providing areas of each ecosystem service (denoted by a_0 and a_1) coincide with the areas of the respective ecosystem assets.

A10.4 As explained in Section 10. 3, the value V_t of each ecosystem asset is derived as the NPV of the future flows of each ecosystem service that the ecosystem asset supplies. In this example, as shown in Table 10.2, it is assumed that prices *p* and quantities *q* have been projected for each ecosystem service for a future period of 5 years.[84]

A10.5 Table 10.2 depicts the set of price and quantities as expected at the beginning of the accounting period – denoted by t_0 - and as expected at the end of the accounting period (also the beginning of the next accounting period - t_1 . To provide context, year 1 could be 2010

[84] In this example we have worked with a moving asset life of 5 years (For illustrative purposes), rather than assuming a fixed asset life end date, which has an effect on the results obtained. However, in more realistic applications, the asset life would be multiple decades (or infinite as we are dealing with renewable assets) and this effect would become minimal.

(which would start at t0 and end at t1) and year 2 could be 2011 (which would start at t1). The prices and quantities shown in Table 10.2 are the totals for the three ecosystem services supplied across the EAA.

Table 10.2: Input data and NPV calculations for three ecosystem services

Discount rate	5.0%		**year1**	**year2**	**year3**	**year4**	**year5**			
		discount factor	1.0	1.0	0.9	0.9	0.8	Q (cumulative stocks)		$\bar{q}_0^i$
	t0	ES 1 (carbon) -physical unit	40	39	38	37	36	190		38.0
	t0	ES 2 (recreation) - physical unit	10	10	9	8	8	45		9.0
	t0	ES 3 (biomass) - physical unit	50	50	50	50	50	250		62.5
	t0	ES 1 (carbon) - unit price	14	15	16	17	18			
	t0	ES 2 (recreation) - unit price	2	2	2	2	2			
	t0	ES 3 (biomass) - unit price	8	7	8	7	8			
								V0 (NPV)		p_0^i
	t0	ES 1 (carbon) - value (in discounted prices)	560	557	551	543	533	2745		14.4
	t0	ES 2 (recreation) - value (in discounted prices)	20	19	16	14	13	82		1.8
	t0	ES 3 (biomass) - value (in discounted prices)	400	333	363	302	329	1728		6.9
								4555		
								Q (cumulative stocks)		$\bar{q}_1^i$
	t1	ES 1 (carbon) -physical unit	30	28	26	24	22	130		32.5
	t1	ES 2 (recreation) - physical unit	10	10	10	8	8	46		11.5
	t1	ES 3 (biomass) - physical unit	65	65	65	64	65	324		64.8
	t1	ES 1 (carbon) - unit price	15	16	17	18	19			
	t1	ES 2 (recreation) - unit price	2	2	2	2	2			
	t1	ES 3 (biomass) - unit price	8	8	8	8	8			
								V1 (NPV)		p_1^i
	t1	ES 1 (carbon) - value (in discounted prices)	450	427	401	373	344	1995		15.3
	t1	ES 2 (recreation) - value (in discounted prices)	20	19	18	14	13	84		1.8
	t1	ES 3 (biomass) - value (in discounted prices)	520	495	472	442	428	2357		7.3
								4436		
					Change in value of EAA			**-119.2**		

A10.6 To simplify the presentation, the calculations are undertaken using discounted prices. Discounted prices are obtained by multiplying the unit price (shown in Table 10.2) in year *j* with the applicable discount factor for year *j* to express the unit price in the price of the base year. A discount rate of 5% is used to derive the discount factor. Table 10.2 shows the discount factors one obtains using a 5% discount rate.

A10.7 For the derivation of the NPV, using the equation provided in Section 10.3 - the value of the EAA, i.e., of all ecosystem services across all ecosystem assets – can be written as:

$$V_t \quad = \sum_{i=1}^{3} \sum_{j=1}^{5} p_t^{ij} * q_t^{ij} \qquad [1]$$

A10.8 Here *i* denotes the number of ecosystem services, and *j* the time period. The subscript t in equation [1] indicates that in order to estimate the value at time t we multiply prices and quantities as they were expected at the beginning of t. Note that it is assumed that the value of each ecosystem service is separable and hence the overall asset value of the EAA can be obtained by summing over all ecosystem services.

A10.9 To explain the calculation for an individual ecosystem service, consider the climate regulation service, ES1. Here the quantities range from 40 to 36 tonnes over the 5 years from t0 and the unit prices increase each year, from $14 to $18 per tonne of carbon (e.g., as the marginal damages of avoided carbon release increases). The value of this ecosystem service is derived by multiplying the quantity and the associated discounted unit price in each year (e.g., for t0 it is 40*14 = 560) and the NPV for climate regulation at t_0 is 2745.

A10.10 Using this approach across all ecosystem services and for both ecosystem assets, a total opening stock value at t0 of 4555 is obtained. This falls to 4436, the closing stock value at t1, a difference of -119. Note that in the calculations, an NPV for each ecosystem service is also obtained.

Decomposition of the change in NPV

A10.11 In order to compile the entries in the ecosystem monetary asset account that record changes in the NPV between opening and closing values, it is necessary to distinguish between changes due to prices and changes due to volumes (quantities). To distinguish these different changes, V_t^i (the value of the ith ecosystem service) is defined as the product of (i) the average (discounted) unit price (over all accounting periods) denoted by p_t^i and (ii) the total volume of ecosystem services supplied over the accounting periods) denoted by Q_t^i.[85]

A10.12 In the context of this example, consider the total value of the nature-based recreation service at t0 (82) which is equal to the total number of visitors over the life of the asset (45) multiplied by the average discounted unit price per visitor (1.8).

A10.13 Using this framing, equation [1] can be re-expressed to obtain:

$$V_t \quad = \sum_{i=1}^{3} p_t^i * Q_t^i \qquad [2]$$

$$V_1^i - V_0^i = p_1^i q_1^i - p_0^i q_0^i = (p_1^i - \ p_0^i) q_1^i + \ p_0^i q_1^i - p_0^i q_0^i \qquad [3]$$

$$= \ \underbrace{(p_1^i - \ p_0^i) q_1^i}_{\text{Price effect}} + \ \underbrace{p_0^i (q_1^i - q_0^i)}_{\text{Volume effect}}$$

[85] This average, discounted unit price is derived in a similar manner to the approach taken in the SEEA Central Framework (Annex 5.1) to derive estimates of depletion, where the *asset price in situ* for a subsoil asset was defined as the ratio of its NPV value V and the total stock S.

A10.14 Equation [3] reflects the decomposition of the change in NPV for each ecosystem service i, into changes due to price (price effect) and changes due to volume/quantity (volume effect).[86]

A10.15 Table 10.2 details the various p_t^i and Q_t^i for each ecosystem service. To illustrate the derivation of the p_t^i consider the climate regulation service, ES1. Here the NPV at t_0 is 2745 and the cumulative quantity Q_0^1 over the 5 years from t0 is 190. Dividing the NPV value by Q_0^1 gives the average discounted unit price p_0^1 for ES1 of 14.4.

A10.16 Using the various p_t^i and Q_t^i for each ecosystem service all decomposition effects derived using equation [3] can be calculated. The results for each ecosystem service are shown in Table 10.3. The key result is that the sum total of all decomposition effects (i.e., price and volume effects) is equal to the overall change in value of -119 shown in Table 10.2. In other words, the decomposition is exact.

A10.17 In terms of the example itself, the negative volume effect can be seen as explaining more of the observed change in overall value. For individual services, there is a large reduction in the value of climate regulation (-750), which is mostly explained as a volume effect (Q_t^1 drops from 190 to 130). At the same time, there is an upward price effect due to the increasing price path of the service. Note too that there is no price effect for ES2 reflecting that its expected price path does not change.

Table 10.3: Results of the decomposition analysis for three ecosystem services

	Volume	Price	Total
ES1 (carbon)	-893.7	143.3	-750.4
ES2 (recreation)	1.8	0.0	1.8
ES3 (biomass)	524.8	104.6	629.4
	-367.1	247.9	-119.2

Ecosystem monetary asset account

A10.18 The various decomposition elements can now be used to compile the ecosystem monetary asset account, as shown in Table 10.4. The account is structured to show the opening and closing values for each ecosystem asset (equal to the sum of ecosystem services relevant for that ecosystem)[87] and the various changes due to enhancement, degradation, conversions, revaluations or other changes.

[86] Please note that this decomposition form is not unique. We could have decomposed this into (p1-p0)*q0+(q1-q0)*p1, which results in slightly different factors. As in SEEA Central Framework Annex 5.1, we therefore average the 2 decomposition forms.

[87] In this example, the process is made more straightforward since there is a 1-1 correspondence between the EAs and the service providing areas of the ecosystem services. In more complex settings, the value of the individual ecosystem services would need to be apportioned to the underlying ecosystem assets (i.e., when an ecosystem service is supplied over a combination of EAs. This may be undertaken by pro-rating the aggregate supply of the ecosystem service using the share of areas of the relevant EAs in which case there is an assumption of homogeneous distribution of supply of the ecosystem service across the service providing area. More complex allocation methods might also be applied.

Table 10.4: The ecosystem monetary asset account

		Forest	Crops	Total
Opening stocks		$2,827	$1,728	$4,555
	Enhancement		$525	
	Degradation	($894)		
	Conversions			
	additions		$0	
	reductions	$0		
	Revaluation	$143	$105	
	Other changes	0	0	
	catastrophic losses			
	reappraisals	2		
Closing stocks		$2,079	$2,357	$4,436

A10.19 The estimates for the opening and closing values for each ecosystem asset can be readily obtained from Table 10.2. For Forests it is the sum of the NPV for ES1 and ES2 and for Cropland it is the NPV for ES3. To complete the other accounting entries the first focus is to estimate the entry for revaluations which is equal to the price effect shown in Table 10.3. This equality applies since the price effect measures the change in value that occurs solely due to the change in average (discounted) price (for each ecosystem service). A final section of the annex discusses the relationship between unit prices of ecosystem services and asset prices.

A10.20 The remaining change in value is associated with the volume effect which measures changes in the total quantity of expected future ecosystem services (for each ecosystem service) due to changes that occur during the accounting period, excluding the effects of price changes. The volume effects can therefore be used to determine the relevant entries for ecosystem enhancement, degradation, reappraisals and catastrophic losses depending on the cause of the change following the definitions provided in in Chapter 10. The process of establishing how a volume effect for a given ecosystem service is treated entails considering (i) whether the volume effect is positive or negative and (ii) the direction of change in ecosystem condition and demand for ecosystem services. [88] By considering the various combinations the appropriate treatment of the measured volume effect can be made following the guidance in Table 10.5.

Table 10.5: Attributing volume effects based on cause

Volume	**Condition**	**Demand**	
up	up	up	enhancement
up	up	down	enhancement
up	down	up	upward reappraisal
up	down	down	not possible
down	up	up	not possible
down	up	down	downward reappraisal
down	down	up	degradation
down	down	down	degradation

[88] In projecting p's and q's (as done in Table 10.2), it is reasonable to assume that ecosystem condition (and expectations how it will develop within the current management regime) and expected demand is taken into account. During the accounting period, many changes happen (changes in demand, but also changes in actual condition), with the end result that at the end of the accounting period there will be updated expectations about p and q's.

A10.21 To apply the guidance from Table 10.5 in the stylized example assume that the associated condition account indicates that the condition of the forest EA declined during the accounting period, but the condition of our cropland ecosystem asset increased. Considering each ecosystem service in turn

- For climate regulation services (ES1), Table 10.3 shows a negative volume effect (-894) and since the condition also declines, this volume effect is recorded as degradation.
- For nature-based recreation services (ES2), Table 10.3 shows a small positive volume effect (2). Since the condition declines, this is best explained as being due to an increase in demand (reflected in a slight increase in total expected visitor numbers (from Table 10.2)) and hence recorded as an (upward) reappraisal.
- For crop biomass provisioning services (ES3), Table 10.3 shows a positive volume effect (525), and since condition improves, this volume effect is recorded as ecosystem enhancement.[89]

A10.22 Although not a part of this example, it is noted that in case of significant unexpected changes in quantities (e.g., due to a hurricane uprooting trees) these changes in volume could be recorded as catastrophic losses rather than degradation. In this way, all possible entries of the monetary asset account can be obtained, in a manner that is aligned with and uses information from the extent accounts, condition accounts and ecosystem service supply and use accounts.

A10.23 The broader interpretation is that the overall value of the forest ecosystem asset has declined, while the cropland ecosystem asset has increased in value; the net effect is however a loss of 119 of the value of this EAA.

Accounting for conversions

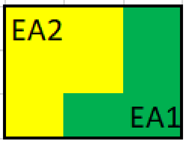
A10.24 In the stylized example, the areas of each ecosystem asset remained the same over the projection period. Consequently, there was no consideration of ecosystem conversions, i.e., changes in ecosystem extent where a particular location changes in ecosystem type during an accounting period. These changes are recorded in biophysical terms in the ecosystem extent account. The following explains the appropriate calculations for recording the monetary effects of conversions in the ecosystem monetary asset account.

A10.25 To explain, the stylized example is adapted such that the extent of the forest is reduced by 1 ha during the accounting period and converted to cropland (see Figure 10.2). To retain the connection with the previous context, all other details of expected quantities and unit prices remain the same and consequently the NPV for each ecosystem service and the total NPV for the EAA remains the same. The difference implied by the ecosystem conversion is therefore that the change values from forests to cropland must be accounted for.

[89] In case of biomass provisioning services, it may be reasonably assumed that an increase in expected quantities also reflects an increase in demand for biomass. However, as the focus in the asset accounts is on recording increases in asset value resulting from improvements in condition, it is proposed to record it as an enhancement.

Figure 10.2: Extent (t1 – end of accounting period)

Area t1	
EA1 - forest	4
EA2 - crops	5
	a1



A10.26 To incorporate changes in area of each ecosystem asset, the decomposition formula is re-worked such that changes in extent – denoted by a_t^i – are incorporated. This incorporation is shown in equation [4] which is a rewriting of equation [2].

$$V_t^i = p_t^i * \frac{Q_t^i}{a_t^i} * a_t^i = p_t^i * \bar{q}_t^i * a_t^i \qquad [4]$$

A10.27 Here $\bar{q}_t^i$ denotes the total (expected) volume of ecosystem service *i* per hectare. Using this expansion, the difference between the opening and closing value for each ecosystem service can be expressed as (suppressing the * signs):

$$V_1^i - V_0^i = p_1^i\bar{q}_1^i a_1^i - p_0^i\bar{q}_0^i a_0^i = (p_1^i - p_0^i)\bar{q}_1^i a_1^i + p_0^i\bar{q}_1^i a_1^i - p_0^i\bar{q}_0^i a_0^i \qquad [5]$$

$$= (p_1^i - p_0^i)\bar{q}_1^i a_1^i + p_0^i(\bar{q}_1^i - \bar{q}_0^i)a_1^i + p_0^i\bar{q}_0^i a_1^i - p_0^i\bar{q}_0^i a_0^i$$

$$= \underbrace{(p_1^i - p_0^i)\bar{q}_1^i a_1^i}_{\text{Price effect}} + \underbrace{p_0^i(\bar{q}_1^i - \bar{q}_0^i)a_1^i}_{\text{Volume (intensity) effect}} + \underbrace{p_0^i\bar{q}_0^i(a_1^i - a_0^i)}_{\text{Area effect}}$$

A10.28 That is, we have now decomposed the change in NPV (of each ecosystem service *i*) into 3 effects: a price effect, a volume (intensity) effect and an area effect.[90] As before, the price effect measures the change in average (discounted) unit prices that occurs during the accounting period. The volume (intensity) effect measures changes i n total quantity of future ecosystem services but now normalized to be shown per hectare, hence the reference to intensity. The area effect measures changes in value due to changes in extent of the assets.

A10.29 To calculate this decomposition, factors $\bar{q}_0^i$ are used that are obtained by dividing, for example, the total quantity of for climate regulation services at t0, i.e., Q_0^1, by the area a_0^1 (5) giving $\bar{q}_0^1$ of 38 (as shown in Table 10.2). Following the same steps as before, but with the extension to consider the effect of the change in area, the decomposition of the change in value can be calculated as shown in Table 10.6.

[90] As with the decomposition into price and volume, this decomposition form is exact but not unique. To see this, notice that in equation [3] the starting point was p1 as a difference, but we could have also started with q1. In equation [5] this is extended to also consider starting with a1. In fact, since equation [5] is a decomposition into 3 factors, there are 3! = 6 possible decomposition forms (see Dietzenbacher & Los, 1998 for a more general proof of this). In order to derive the proper weights, it is necessary to average over all 6 forms. In our example, the proper weight of the area effect is: 1/3* p0q0 + 1/6* p0q1+1/6*p1q0 +1/3*p1q1. With appropriate changes weights for the revaluation and volume effects can be derived.

Table 10.6: Results of the decomposition analysis (3 factors)

	Area	Volume	Price	Total
ES1 (carbon)	-524.7	-368.3	142.5	-750.4
ES2 (recreation)	-18.8	20.6	0.0	1.8
ES3 (biomass)	451.5	73.5	104.4	629.4
	-91.9	-274.2	246.9	-119.2

A10.30 Again, the decomposition is exact as the sum of the changes due to area, volume and price equals the total value change of -119. As expected, the differences in NPV for each ecosystem service are the same (e.g., -750 for ES1 as before), but we now have three explaining factors rather than two. Also as expected, the price effect is virtually the same as in the earlier decomposition, since we have essentially split the volume effect into two effects: a volume (intensity) effect, and an area effect. The area effect can now be interpreted as providing the entries for ecosystem conversions (additions and reductions) in the ecosystem monetary asset account. It should be noted that the area effect is completely consistent with the information in the ecosystem extent account. Note too that there will be some interactions between changes in volume and changes in price in a general equilibrium context but since most ecosystem assets will be price takers with respect to SNA benefits the effect of these interactions is likely to be minimal.

A10.31 The structure of the ecosystem monetary asset account remains unchanged – see Table 10.7 - but compared to the results shown in Table 10.4, there are now entries for ecosystem conversions. The main change is that the previously large entry for degradation of forests (894) is now more evenly split between degradation (368) and ecosystem conversion reductions (543). Thus, by adding an additional factor to the decomposition form, we can now better explain the change in value that occurred during the accounting period.

Table 10.7: Monetary asset account (with conversions)

		Forest	Crops	Total
Opening stocks		$2,827	$1,728	$4,555
	Enhancement		$73	
	Degradation	($368)		
	Conversions			
	additions		$452	
	reductions	($543)		
	Revaluation	$142	$104	
	Other changes	0	0	
	catastrophic losses			
	reappraisals	21		
Closing stocks		$2,079	$2,357	$4,436

Unit prices and asset prices

A10.32 Finally, a word on the interpretation of prices. In this valuation and decomposition, discounted unit prices have been used for each ecosystem service. These unit prices (p_t^i) should be considered as average prices for the supply of each of the different ecosystem services. After multiplying the discounted unit prices with their expected quantities (q_t^i) and summing over the asset life we obtain the NPV of each ecosystem service and from there the value of each ecosystem asset at each point in time can be determined.

A10.33 When calculating the NPV, the implicit quantity of the underlying ecosystem asset is 1, so that the NPV of the ecosystem asset (i.e., the sum over relevant services) is also the unit price of the asset (and its exchange value). Thus, the basic measurement unit remains the individual ecosystem asset, characterized by its extent (which will generally be greater than 1 ha) and its condition. Further, in this framing the price of the ecosystem asset can be considered an average asset price.

A10.34 It may also be of interest to calculate a marginal asset price defined as the change in NPV of the ecosystem asset with respect to a marginal change in extent of the ecosystem asset (e.g., a change of 1 ha).[91] In this framing, the intuition is that for a large asset (in terms of extent), say a forest, it may be reasonable to suppose that the marginal price of a hectare at the edge of the forest will be different from the marginal price of a hectare at the centre of the forest, i.e., there are different asset prices for different parts of an ecosystem asset and these asset prices might change as the overall size of the ecosystem asset changes. Put differently, losing a hectare acre when the extent is 100 may be less problematic than losing a hectare when the extent is 5.

A10.35 In the example, it is de facto assumed that the ecosystem services were distributed homogenously across the ecosystem asset. This implies that the marginal and average asset price coincide by assumption. This is why, in order to separate out the area effect in the decomposition, it was appropriate to normalize the ecosystem services using the area over which they were supplied.

A10.36 Of course, in real life most ecosystem services would not be supplied homogeneously across the ecosystem asset, and hence a difference between the marginal and average asset price would arise. In such instances, it would be theoretically possible to break-up the ecosystem asset into smaller units (e.g., units of 1 ha each), and for each obtain an average asset price following the approach described in this annex. Provided each small unit was homogenous an alignment would emerge between the average and marginal asset prices.

A10.37 Finally, the example provided here is framed in terms of specific ecosystem assets that provide ecosystem services, it is possible to apply the same approach at the aggregate scale valuing ecosystem types based on the bundles of ecosystem services they provide.

[91] The choice of extent for assessing marginal price is just one amongst several options, for instance it is also possible to consider ecosystem characteristics such as timber volume.

11 Integrated and extended accounting for ecosystem services and assets

11.1 Introduction

11.1 A key purpose behind ecosystem accounting is combining data on ecosystems with measures of economic activity. The combination of ecosystem and economic data supports a richer discussion of the connection between ecosystems and people, underpins the development of indicators showing the relationship such as the contribution of ecosystem services to measures of economic production and allows the derivation of adjusted national accounting aggregates such as degradation adjusted measures of net domestic product (NDP).

11.2 The discussion of combining ecosystem accounting data with standard economic data such as from the national accounts is increasingly relevant as countries, both nationally and multi-nationally, are recognizing the losses of some ecosystem services and are developing policy instruments to mitigate and reverse this trend. In some specific cases, for example with regard to payments for ecosystem services schemes and carbon markets, where new property rights are established and new transactions arise, there is a direct connections between the aim of accounting for environmental stocks and flows and the recording of transactions in the existing framework of the SNA.

11.3 Historically, the approaches to more detailed integration of ecosystem-related information with the national accounts have focused on the valuation of degradation and the appropriate recording of this "cost of capital" in the accounts of different sectors. This is a characteristic of the previous approaches outlined by national accountants (see, e.g., Council, 1999; Harrison, 1993; Vanoli, 1995). As explained in the SEEA 2012 EEA and the recent literature (e.g., Edens & Hein, 2013; Obst et al., 2016), the emergence and application of the concept of ecosystem services has enabled a reconceptualization of integration with the national accounts. This basis for integration underpins much of the discussion in this chapter.

11.4 The integration of data from the ecosystem accounts with the economic data from the SNA is a process involving many steps. These include the delineation of spatial areas, identifying and measuring the supply and use of ecosystem services and the monetary valuation of ecosystem services and assets. Data and accounts compiled for each of these steps are relevant in their own right but can be used in a wider variety of contexts by reflecting the links between economic units and ecosystems. In this regard, the process of integration provides a purpose and rationale for the selection and structuring of the ecosystem information.

11.5 Building on the ecosystem accounts described through Chapters 3 to 10, this chapter describes ways in which ecosystem accounting and economic data can be integrated with the standard accounts of the SNA. Integration is considered with respect to three types of accounts: the supply and use tables, national balance sheets and the sequence of institutional sector accounts. All of these accounts are labelled as extensions to the SNA accounts. Thus, in concept, the aim is to use the data recorded in the ecosystem accounts to extend the relevant SNA accounts. For the institutional sector accounts, the question of ownership of ecosystem assets is a key area of focus since it affects the ways in which ecosystem related transactions are recorded and the allocation of ecosystem assets and degradation to economic units.

11.6 While the monetary valuation of ecosystem services and ecosystem accounts provides one means of integrating with the national accounts, it should not be considered as an ultimate solution applicable in all decision-making contexts. As explained consistently through Chapters 8, 9 and 10, monetary values will support assessment of marginal changes in ecosystem services and assets but in many instances physical data such as from the ecosystem extent and condition accounts will be required to better understand relevant ecological thresholds and limits. In addition, the use of the exchange value concept will provide monetary values that are suitable for the compilation of extended accounts described in this chapter but, in other contexts, alternative valuation concepts and presentations may be more appropriate. Complementary approaches to monetary valuation are discussed in Chapter 12.

11.7 It is also highlighted that the ecosystem accounts should be seen as complementing data from the SEEA Central Framework especially concerning environmental pressures (e.g., concerning emissions) and policy responses (e.g., concerning environmental protection expenditure, environmental taxes and subsidies). These types of data will be needed for a complete assessment of the environmental-economic relationship. The ecosystem accounts and the extended accounts described here should therefore be considered as additional and complementary accounting information. The potential to combine data from the SEEA Central Framework and the SEEA EA is discussed in Chapter 13 using selected policy themes as the entry point.

11.2 Extended supply and use tables

11.8 Standard supply and use tables (SUT) show the relationships between economic units (households, business, governments) in terms of flows of goods and services. Each type of good or service is recorded as supplied by an economic unit and used by another, either for final consumption, intermediate consumption, investment or export. Inherent in the design of an SUT is the ability to record supply chains through the economic system by showing the gross output and intermediate inputs and how these are netted in each economic unit to derive measures of value added. SUT are commonly used to support the compilation of measures of GDP as they force a complete reconciliation between the supply and demand for goods and services and hence among the three different measures of GDP. To meet this purpose, the scope of goods and services included in a standard SUT is limited to the production boundary of the SNA.

11.9 Compiling extended SUT involves combining the ecosystem services SUT in monetary terms described in Chapter 9 with the standard SUT from the SNA as just described. Extended SUT thus require explicit consideration of the measurement boundaries between the economy and the ecosystem to ensure an appropriate structure for the accounts and that recorded data do not imply double counting. Extended SUT thus present the data on the supply and use of ecosystem services as extensions to the standard SUT compiled following the SNA.

11.10 The compilation of extended SUT can support range of purposes:

- showing the contribution of ecosystem services to the output and value added of different industries and the economy as a whole
- identifying the share of economy wide value added that is dependent on ecosystem services
- understanding the main users of ecosystem services and the relative contribution of ecosystem services to household and government final consumption expenditure
- describing ecosystem services as inputs to economic supply chains and understanding the ecosystem service dependent industries
- integration of ecosystem services data into analytical and modelling tools that use SUT data as primary data sources, for example input-output models and computable general equilibrium models.

11.11 There are two key aspects to consider in extending the SNA SUT to incorporate ecosystem services. First, since ecosystem accounting implies an extension to the standard production boundary, the set of goods and services within scope of the extended SUT will be broader and hence the dimensions of the standard SUT must increase. This would usually be carried out through the addition of new rows (each additional row representing an additional ecosystem service).[92]

11.12 The accounting requirement is to ensure that the ecosystem services are distinguished clearly from the goods and services (products) that are already recorded within the standard SUT. For the products to which ecosystem services are direct inputs (i.e., SNA benefits), ecosystem services are recorded as intermediate consumption of the associated user of the ecosystem service. For example, the ecosystem service of timber biomass provisioning is recorded as additional intermediate consumption by forestry units.

11.13 For ecosystem services that contribute to non-SNA benefits, there are no associated products with which to connect and it is sufficient to record the supply of the relevant ecosystem service (e.g., air filtration services) and the use of that service by the relevant economic unit following the advice in Chapter 6.

11.14 It is possible to design an extended SUT that also incorporates intermediate services supplied by ecosystems. For example, where pollination services are of relevance, an additional row might be added to recognize these flows as inputs to the generation of associated final ecosystem services, e.g., biomass accumulation of crops.

11.15 The second key aspect of the extended SUT entails the requirement that columns be added to reflect the source of the supply of ecosystem services. Thus, ecosystem assets (grouped by ecosystem type) are treated as additional producing units alongside the current set of industries (agriculture, manufacturing, etc.). A simple example is presented in Annex 11.1 to demonstrate the steps involved in these extensions.

11.16 Table 11.1 shows an extended SUT incorporating a selected set of product groups and using the list of ecosystem services from the monetary ecosystem services SUT from chapter 9. Note that after including additional rows for ecosystem services and additional columns for ecosystem assets, the extended SUT is completed by incorporating the standard value-added entries for industries and for ecosystem assets. Where ecosystem services are inputs to SNA benefits this has the effect of partitioning the operating surplus of the using industry (e.g., agriculture or forestry) such that the contribution of ecosystem services is deducted from that industry and shown as the output and operating surplus of the supplying ecosystem asset.

11.17 Extended SUT are different from environmentally-extended input-output tables (EE-IOT).[93] EE-IOT can readily incorporate flows of individual ecosystem services following the same methods that would be applied to incorporate flows of, for example, flows of greenhouse gas emissions, water use or solid waste. However, in an EE-IOT there is no inherent change or extension in the production boundary as is applied in the extended SUT and as a result there is no inherent extension of supply chains that record the links between the economy and ecosystems.

[92] SUT do not need to be square matrices – i.e. where the number of goods and services is equal to the number of supplying industries. The standard input-output matrix algebra that underpins input-output analysis has been adapted to allow standard, non-square, SUT data to be used in I-O analysis and this can be applied in the case of extended SUT. Note that the resulting I-O tables are square matrices.

[93] The connection between EE-IOT and the SEEA Central Framework accounts is described in the SEEA Applications and Extensions (United Nations et al., 2017).

Table 11.1: Extended supply and use account with ecosystem services – supply table

	Selected economic units											
	Selected industries											
Supply	Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	**Total Industry**	Imports - products	**Total Supply products**
Products												
Agricultural products												
Forestry products												
Fishery products												
Manufacturing products												
Electricity and gas products												
Water supply products												
Services												
Other products												
TOTAL												
Ecosystems services												
Provisioning services												
Regulating and maintenance services												
Cultural services												
TOTAL												
TOTAL SUPPLY												

	Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
	Terrestrial												Freshwater			Marine						
	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	…	Temperate pyric sclerophyll forests and woodlands	…	…	…	Derivied semi-natural pastures and old fields	Permanent upland streams	…	Intermittently closed and open lakes and lagoons	Seagrass meadows	…	Coastal saltmarshes and reedbeds	**Total Supply resident ecosystem assets**	Supply from non-resident ecosystem assets - Imports	**Total Supply ecosystem services**	**TOTAL SUPPLY**
Supply	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Products																						
Agricultural products																						
Forestry products																						
Fishery products																						
Manufacturing products																						
Electricity and gas products																						
Water supply products																						
Services																						
Other products																						
TOTAL																						
Ecosystems services																						
Provisioning services																						
Regulating and maintenance services																						
Cultural services																						
TOTAL																						
TOTAL SUPPLY																						

NB: Dark grey cells are null by definition

Table 11.2: Extended supply and use account with ecosystem services – use table

	Selected economic units															Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
	Selected industries															Terrestrial												Freshwater			Marine						
																T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
Use	Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	Total Industry	Government consumption	Household consumption	Gross capital formation	Exports - products	Total Use products	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	Total use resident ecosystem assets	Exports - ecosystem services	Total Use ecosystem services	TOTAL USE
																T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected products																																					
Agricultural products																																					
Forestry products																																					
Fishery products																																					
Manufacturing products																																					
Electricity and gas products																																					
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Ecosystems services																																					
Provisioning services																																					
Regulating and maintenance services																																					
Cultural services																																					
TOTAL																																					
TOTAL USE																																					
Gross value added																																					
Compensation of employees																																					
Gross operating surplus																																					
Consumption of fixed capital																																					
Net value added																																					

NB: Dark grey cells are null by definition

11.3 Extended balance sheets

11.3.1 Introduction

11.18 Ecosystem accounting data can be used to augment the economic accounts of the SNA through the compilation of extended balance sheets. Extended balance sheets allow the comparison and integration of the values of ecosystem assets with values of produced assets, financial assets (and liabilities), and other assets.

11.19 The development of extended balance sheets aligns with the general intent in the compilation of wealth accounts as has been driven forward by the World Bank[94] and United Nations Environment Programme.[95] In general terms there is a common desire to extend valuation of natural capital to incorporate a wide range of ecosystem services beyond those that are incorporated in the valuation of natural resources. Where the outputs of wealth accounting apply exchange value concepts in the valuation of different capitals, the values from the monetary ecosystem asset account included in the extended balance sheet described here will be appropriate. Note that wealth accounts will generally also include measures of human capital (and in some cases social capital) in addition to produced and natural capital and hence go beyond the scope of both the SEEA and the SNA.

11.20 Extended balance sheets encompassing monetary values of ecosystem assets can be applied in a number of contexts. These include understanding the changing composition of wealth, identifying imbalances in stocks of wealth, analyzing productivity and assessing returns on investment.

11.21 A concern regarding extensions made to balance sheets containing the monetary values of economic and ecosystem assets is that by presenting the different assets side by side it may be interpreted as meaning that all assets are substitutable. In theory, estimates of all asset prices should take into account the extent to which there are developing shortages in the availability of certain “critical” resources, where the effect should be that asset prices reflected in the accounts rise over time, and the relative value of these assets becomes much higher. However, in practice, since the future trends in the availability of various assets and their interactions cannot be well anticipated, the extent to which shortages and imbalances will be reflected in estimated asset prices will be more limited.

11.22 Compiling extended balance sheets involves integrating the opening and closing values of ecosystem assets as described in Chapter 10 with SNA balance sheet values described in SNA Chapter 13. In some cases, there may be significant overlap between the scope of SNA asset values and the scope of ecosystem assets, for example with regard to the values of biological resources and land. To avoid a double counting of asset values, clear treatments of different assets is required. These treatments are discussed in sub-section 11.3.3.

11.3.2 Structure of an extended balance sheet

11.23 Conceptually, an extension of the SNA balance sheet requires that the values of ecosystem assets over and above those currently recorded in the SNA balance sheets be included. However, since the value of ecosystem assets commonly includes the value of natural

[94] See the World Bank Changing Wealth of Nations project and related outputs (World Bank, 2018). See https://www.worldbank.org/en/news/infographic/2018/01/30/the-changing-wealth-of-nations

[95] See the UNEP Inclusive Wealth (UN Environment (UNEP), 2018). See https://www.unenvironment.org/resources/report/inclusive-wealth-report-2018

resources (such as timber resources) and components of land values, there are a range of ways in which the additional values might be combined and presented.

11.24 The approach adopted here, presented in Table 11.3, is to distinguish a high-level asset class of environmental assets and to describe the next tier of asset classes around ecosystem types at the level of the main realms (terrestrial, freshwater, marine and subterranean) plus other environmental asset classes of deep geological systems and atmospheric systems. At the next level in the structure connections are made to SNA asset classes as appropriate. In an extended balance sheet, environmental assets are then shown alongside produced assets and non-produced assets (both excluding environmental assets), financial assets, financial liabilities and net worth.

11.25 For each realm, the total monetary value including all ecosystem services is recorded, thus reflecting an aggregation of the monetary values compiled in the ecosystem monetary asset account. Further, for each realm "of which" entries are included which highlight the relevant portion of that value which is currently recorded as an economic asset following the SNA. While in many contexts this framing wherein the value of the economic asset is a sub-set of the value of a corresponding environmental asset (e.g., timber resources as a sub-set of the value of forest ecosystems), there is a range of boundary cases. These borderline cases are considered below and conventions are described to support comparable measurement.

11.26 An extended balance sheet would most commonly be compiled at a national level building from a country's national SNA balance sheet. Thus, the geographic scope of the extended balance sheet would be defined by the country's economic territory which, in geographic terms is broadly limited to its land area and marine areas within the exclusive economic zone. Conceptually, it would be possible to define extended balance sheets for alternative geographic scopes, for example encompassing a wider coverage of marine ecosystems.

Table 11.3: Structure of an extended balance sheet for non-financial assets

Asset class			Monetary value	
			Opening value	Closing value
Produced assets	Fixed assets	Dwellings		
		Other buildings and structures		
		Machinery and equipment		
		Weapons systems		
		Intellectual property products		
	Inventories*			
	Valuables			
Environmental assets	Terrestrial ecosystems			
		Of which: Timber resources (natural and cultivated)		
		Of which: Cultivated biological resources – non-timber, non-aquatic*(incl livestock, orchards both WIP and fixed assets)		
	Land (as provision of space)	Of which: Land under buildings		
	Renewable energy resources*	Of which: Captured in land		
	Freshwater ecosystems			
		Of which: Water resources*		
		Of which: Freshwater aquatic biological resources		
	Marine ecosystems			
		Of which: Marine aquatic biological resources		
	Subterranean ecosystems			
	Deep geological systems			
		of which: Mineral and energy resources*		
	Atmospheric systems			
		of which: Radio spectrum		
Other non-produced assets	Contracts, leases and licenses			
	Goodwill and marketing assets			
Financial assets				
Financial liabilities				
Net worth				

Note: * These entries are boundary cases for which specific measurement conventions apply as discussed in section 11.3.3.

11.3.3 Aligning ecosystem asset values with the values of economic assets

11.27 As highlighted in the previous sub-section, there are a number of potential overlaps between the SEEA measurement scope for ecosystem assets and the SNA measurement scope of economic assets (labelled here "SNA assets"). To articulate the overlaps and differences the appropriate starting point is the definition of assets in the SNA. The SEEA Central Framework (section 5.2.3) provides a useful overview from an environmental-economic accounting perspective. It notes that,

> *"In the Central Framework, consistent with the SNA, the scope of valuation is limited to the benefits that accrue to economic owners. An economic owner is the institutional unit entitled to claim the benefits associated with the use of an asset in the source of an economic activity by virtue of accepting the associated risks. Further, following the SNA, an asset is a store of value representing a benefit or series of benefits accruing to the economic owner by holding or using the entity over a period of time." (SEEA Central Framework 5.32)*

11.28 At an aggregate level, for example for a country, where the aim is to convey information about the total stock of assets and their monetary value, the inclusion of assets in an extended balance sheet without clear attribution of economic ownership is possible. In effect, the aggregate measures in this situation assume attribution of the environmental assets to the country of reference. In turn this implies that establishing a total value for environmental assets requires, in the first instance, the identification of a set of benefits. The focus in aligning the scope of valuation for various asset classes is thus on aligning the extended set of benefits with the relevant asset classes. Issues concerning the ownership of ecosystem assets are considered in sub-section 11.3.4.

11.29 The definition of benefits in the SNA is potentially broad in concept, since they *"reflect a gain or positive utility arising from economic production, consumption or accumulation" (2008 SNA, 3.19).* However, in practice, the scope of the SNA with respect to benefits from environmental assets is limited to those:

> "*(i) in the form of operating surplus from the sale of natural resources and cultivated biological resources; (ii) in the form of rent earned on permitting the use or extraction of an environmental asset; or (iii) in the form of net receipts (i.e., excluding transaction costs) when an environmental asset (e.g., land) is sold." (SEEA Central Framework 5.33).*

11.30 In ecosystem accounting, a broader set of benefits is included through the recognition of non-SNA benefits. The inclusion of the monetary value of ecosystem services that contribute to non-SNA benefits increases the value of environmental assets relative to the SNA and hence extends the balance sheet relative to the scope of the SNA. Nonetheless, the inclusion of these additional monetary values does not provide a complete measure of value or wealth.

11.31 To clarify the nature of the extensions to the balance sheet due to considerations about the scope of benefits, the following paragraphs describe the treatment of a range of SNA assets with respect to incorporating ecosystem assets. In practice, since relatively few countries compile full SNA balance sheets of non-produced assets, the following considerations may be relevant in developing such accounts in the first instance or in refining initial estimates.

11.32 <u>Treatment of biological resources</u>. In general terms, the value of all natural (non-cultivated) and cultivated biological resources will be in scope of both ecosystem assets and SNA assets. The relevant values are those related to biological resources that provide inputs to agriculture, forestry and fisheries production, including household production on own account. These values will be reflected in relevant measures of operating surplus and biomass provisioning services.

11.33 For cultivated timber resources (i.e., plantation timber), the value of the resources will be recorded as produced assets in the SNA and will be classified under inventories as work-in-progress. The valuation of these resources will align with the value of the associated provisioning services supplied by ecosystem assets and hence should be recorded together with the value of natural timber resources under terrestrial ecosystems.

11.34 For cultivated biological resources related to agriculture, there is a range of types to be considered including annual crops, plantation crops (e.g., orchards, vineyards), livestock for slaughter, and livestock for breeding and ongoing production (e.g., dairy cows, sheep for wool). The SNA value for these assets, whether treated as inventories or fixed assets, is included in the scope of environmental assets as defined in SEEA Central Framework. However, this value will differ from the value of ecosystem services, for example the value of livestock will be greater than the value of the associated contribution of ecosystem services to the growth of livestock (e.g., grazed biomass). This situation also applies for cultivated aquatic resources (e.g., aquaculture). By convention, the SNA values for livestock and aquatic resources should be deducted from the value of produced assets and recorded against the total value of terrestrial ecosystems (or freshwater and marine ecosystems in the case of cultivated aquatic resources).

11.35 The value of natural biological resources including timber, fish and wild animals should be recorded against the relevant ecosystem type.

11.36 Treatment of mineral and energy resources. These natural resources are defined in the SEEA Central Framework but are not considered a part of ecosystem assets since the benefits they provide are not the result of ecosystem processes. They are recorded in the extended balance sheet under environmental assets – deep geological systems.

11.37 Special note is made of peat resources which may be used as a form of fossil fuel (and hence may be considered a part of mineral and energy resources). However, peatlands are an important type of terrestrial ecosystem supplying a range of ecosystem services. Hence, in this balance sheet their value remains allocated as part of terrestrial ecosystems.

11.38 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.

11.39 Consistent with the advice of the SEEA Central Framework, the monetary value associated with the ongoing capture of energy from wind and solar sources is considered to be embedded in the values of the associated area (e.g., land), reflecting the specific characteristics of the location in which the renewable energy is captured. In the extended balance sheet, by convention, the value of location (including both terrestrial and marine locations) that is linked to the capture of wind and solar energy should be included in the value of land (as provision of space).

11.40 For energy generated through hydroelectric power generation, the monetary value associated with the capture of energy is also considered to be embedded in the values of the surrounding area that will incorporate water resources and land formations. In the extended balance sheet, by convention, the value of the location that is linked to hydroelectric power generation should be included in the value of land (as provision of space).

11.41 For energy generated from geothermal resources, relevant values should be included under deep geological systems.

11.42 Treatment of inland water resources (i.e., excluding marine ecosystems). The valuation of water resources is recognized in the SNA in cases where *"surface and groundwater resources used for extraction to the extent that their scarcity leads to the enforcement of ownership or use rights, market valuation and some measure of economic control" (2008 SNA 10.184).* It is recommended that this value should be recorded as additional to the value of ecosystem services of freshwater ecosystems.

11.43 Groundwater resources are considered within scope of ecosystem assets either as distinct ecosystem assets (e.g., confined aquifers) or as part of the surface ecosystem. By convention, the value of all ecosystem services and abiotic flows from all groundwater resources should be attributed to the value of the terrestrial and freshwater ecosystem asset to which they are most directly connected (e.g., based on the location of a bore or well).

11.44 Treatment of land. A key function of land is to provide space. Land, and the space it represents, define the locations within which economic and other activity is undertaken and within which assets are situated. This role of land is a fundamental input to economic activity and has significant value in many locations.

11.45 However, the provision of space is not considered as an ecosystem service and consequently the value of ecosystem assets, particularly terrestrial ecosystems, excludes the value of the provision of space. Thus, depending on the location and ecosystem type, the total value of an area may be greater than the value of the aggregated ecosystem services. Particularly note is made of urban ecosystems and agricultural land. For urban ecosystems, the value of the provision of space may be the predominant component of the total value of environmental assets. For agricultural land the distinction may be less evident, i.e., the value of provisioning ecosystem services may be closer to the total market value of the land as recorded in the SNA. However, the value of the ecosystem asset as whole may be larger than the SNA based land value, through the inclusion of the value of non-provisioning services (e.g., water regulation) which are supplied by agricultural land but are not recognized in the market value of land. For areas of government-owned or public land, it is likely that no value is recorded following the SNA and in this case the value associated with the relevant ecosystem assets will reflect the total value of the area.

11.46 In the extended balance sheet, the approach taken is to record the aggregated value of ecosystem services following the advice in Chapter 10 against the relevant ecosystem type and then where relevant, record the value of land in terms of the provision of space as a separate asset class. In a number of cases, most notably for urban ecosystems and agricultural land, it will be necessary to partition the value of land as recorded in the SNA to extract that component of value that is attributable to ecosystem services (e.g., in relation to amenity services embodied in land values).

11.47 Treatment of the atmosphere and high seas: The scope of ecosystem assets excludes the atmosphere, and for national level accounting purposes, generally marine areas beyond the exclusive economic zone would also be outside the ecosystem accounting area that defines the scope of the extended balance sheet. The values of these environmental assets will therefore not be captured in the value of ecosystem assets. SNA values relevant to these environmental assets include the radio spectrum and fish stocks on the high seas over which ownership rights may exist. The value of the radio spectrum (as defined in the SNA) should be included under atmospheric systems in Table 11.3 and the value of fish stocks on the high seas that satisfy the definition of economic assets in the SNA should be included under marine ecosystems.

11.48 As noted in the previous section, an alternative scope for an extended balance sheet that incorporates a wider range of ecosystem assets such as marine areas beyond the exclusive economic zone and the atmosphere could be compiled. Such accounts could recognise the important functions of these ecosystems, for example the role of the ozone layer, and the role of marine ecosystems in regulating global climate.

11.49 Treatment of permits and licenses to use natural resources. In the SNA the value of permits and licenses associated with the use of natural resources, including for example resource leases and transferable quotas, is recorded separately from the value of the underlying resource. In recording this value separately, the total value of the natural resource is considered to be partitioned with the value of the permit or license reducing the value of the resource that is recorded as part of natural resources. In the extended balance sheet, by convention, the total value of the natural resource is recorded as part of environmental assets and, if required, the value of the associated permit or license, should be recorded as an 'of which' item.

11.4 Assigning economic ownership and allocation of degradation and enhancement

11.4.1 Considerations in assigning economic ownership

11.50 The compilation of the ecosystem accounts in physical and monetary terms does not require a statement or assumption concerning the ownership of ecosystem assets. This is important since it highlights that accounting for ecosystem assets, their services and their links to the economy can be undertaken from the perspective of ecosystems being distinct ecological entities. This neutrality with respect to ownership enables the set of ecosystem accounts to support a wide range of decision-making contexts.

11.51 This perspective on ecosystem assets is consistent with the wider definition of environmental assets from the SEEA Central Framework in which environmental assets are defined with respect to the components of the biophysical environment and the potential delivery of benefits (SEEA Central Framework, 2.17).

11.52 Nonetheless, understanding the legal and economic ownership context of ecosystem assets is of high relevance in developing, enacting and monitoring policy with respect to ecosystem management and use. There is thus a clear policy relevance in cross-classifying data from the ecosystem accounts with data on legal and economic ownership. For example, data from ecosystem extent accounts may be cross-classified with data from cadastres to assess the connections between different ecosystem types and the types of economic units that manage them. Another example is the cross-classification of data on the supply of ecosystem services with data on economic ownership of land and other areas. Undertaking this type of work using spatial data is likely to also be of significant benefit in applying the results from the ecosystem accounts.

11.53 From a national accounting perspective, integration of the ecosystem accounts with the institutional sector accounts of the SNA requires a treatment or appropriate convention to be applied such that the relationship between ecosystem assets and economic units can be consistently recorded. Of particular focus for SEEA EA is integration with the income, distribution of income, capital and financial accounts of the SNA which are structured by institutional sectors and sub-sectors, including corporations, households and general government. To support integration with these accounts and also to underpin derivation of degradation adjusted measures of income and saving, ecosystem assets must be assigned to an institutional sector.

11.4.2 The institutional sector for ecosystem assets

11.54 In the national accounts, the discussion and determination of ownership distinguishes between legal and economic ownership. The SNA defines the legal owner as "*the institutional unit entitled in law and sustainable under the law to claim the benefits associated with the entities"* (2008 SNA, 10.5) Entities include goods and services, financial assets, natural resources, etc. The economic owner is *"the institutional unit entitled to claim the benefits associated with the use of the entity in question in the course of an economic activity by virtue of accepting the associated risks"* (2008 SNA, 10.5).

11.55 Further, all buildings and structures and almost all land and marine areas within the economic territory of a country are deemed, by convention, to be owned by economic units that are considered resident in that territory.[96] Where a non-resident unit is the legal owner, a notional resident unit is created which is considered to own the relevant asset, and the non-resident unit then holds a financial asset equal to the value of the notional resident unit. This treatment underpins the recording of flows between ecosystem assets and economic units resident in the rest of the world including with respect to imports and exports of ecosystem services but it is also relevant in the attribution of value in a balance sheet context.

11.56 In many cases the legal and economic owner are the same but there are a range of situations in which there may be a lack of clarity. Such situations include government ownership of entities, such as public roads, national parks, natural resources; situations involving financial leases; and assets built under private finance initiatives.

11.57 Using these national accounting principles of ownership, and solely for the purpose of integrating ecosystem accounts data with the standard sector accounts of the SNA, it is considered appropriate to partition the ownership of ecosystem assets using a focus on the users of different types of ecosystem services. Thus, where an ecosystem asset supplies ecosystem services that contribute to SNA benefits (i.e., primarily provisioning services), that part of the value of the asset will be considered to be owned by the sector that uses those ecosystem services. Most commonly, this will be the legal and economic owner of the ecosystem asset who is using the ecosystem for private returns; e.g., in agriculture and forestry.

11.58 At the same time, where an ecosystem asset supplies ecosystem services that contribute to non-SNA benefits (i.e., primarily regulating and maintenance services and cultural services), that part of the value of the asset will be considered to be owned by a new sub-sector of general government titled the "ecosystem trustee". In this treatment, the ecosystem trustee is considered the supplier of those ecosystem services.

11.59 In the situation where an ecosystem asset does not contribute to non-SNA benefits, the treatment will align with the assignment of ownership of the relevant area in the SNA. Further, where an ecosystem asset does not contribute to any SNA benefits the ecosystem trustee is assigned complete ownership, for example in remote areas of a country. Commonly, there will be some partitioning of ownership recognising that many ecosystem assets will contribute to both SNA and non-SNA benefits. Note that areas that are commonly owned (e.g., for grazing livestock) or are under government or public sector ownership will contribute to SNA benefits and in this case ownership is not assigned to the ecosystem trustee but to the economic units deemed to own the areas following SNA principles.

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[96] A small exception applies to the treatment of land and buildings of foreign governments such as embassies which are treated as outside the economic territory of a country. This matter is not considered material to the development of integrated environmental-economic accounts and hence is not considered further here. As required the treatments in the 2008 SNA should be applied.

11.60 This approach to the allocation of ownership allows the resulting institutional accounts to align most closely to the existing understanding of the economic and financial situation of the current set of SNA institutional sectors with the main differences being the recognition of the use of ecosystem services as inputs to their production of SNA benefits and recognition of any costs of ecosystem degradation associated with that use of those services.

11.61 Two alternative ownership allocation assumptions might be applied where either all ecosystem assets are assigned to an ecosystem trustee or where all ecosystem assets are assigned to relevant economic units. While accounting entries and sequences of accounts can be developed under either of these assumptions, the partitioned asset approach aligns most closely to the accounting principles inherent in the SNA.

11.4.3 Allocation of degradation and enhancement to economic units

11.62 Chapter 10 described approaches to the valuation of ecosystem degradation and enhancement in the context of the ecosystem monetary asset account. In that account the focus of measurement is on degradation and enhancement for individual ecosystem assets and ecosystem types within an EAA.

11.63 When integrating ecosystem accounts with economic accounts the allocation of ecosystem degradation and enhancement to economic units is required. For both degradation and enhancement, this allocation is directly related to the approach applied to the assigning of ownership as explained above. Thus, ecosystem degradation and enhancement of an ecosystem asset is partitioned and recorded in the accounts of either the economic unit that receives the SNA benefits or the new ecosystem trustee sector in relation to contributions to non-SNA benefits.

11.64 For integrated economic accounting in the SEEA, a costs borne approach for recording ecosystem degradation is followed meaning that the cost of capital is attributed to the economic unit who is assigned ownership of the asset. This is consistent with general accounting practice. An alternative is to allocate degradation on the basis of costs caused (polluter pays) by determining the appropriate "source" economic unit. This may be challenging, for example due to factors of distance (i.e., when impacts of causing economic units are felt in distant ecosystems) and time (i.e., when the impacts become evident well after the causing activity occurred). Nonetheless, it is recognized that there is likely to be substantial policy interest in providing estimates of an allocation of degradation that is attributable to causing or polluting economic units. Chapter 12 includes discussion of the presentation of such complementary estimates. It is noted that the aggregate measure of degradation from the ecosystem accounts is not affected by the choice of allocation approach.

11.5 Integrated sequence of institutional sector accounts

11.5.1 Introduction

11.65 As introduced in the previous section, ecosystem accounting data can be used to augment the economic accounts of the SNA through the compilation of an extended sequence of accounts for institutional sectors. The extended sequence of accounts shows how entries for the values of ecosystem services, and changes in ecosystem assets (including ecosystem degradation and enhancement) can be combined with standard measures of production, income and consumption and associated accounting aggregates such as saving and net lending.

11.66 One of the main functions of the sequence of accounts is to demonstrate the linkages among incomes, investment and balance sheets. In this regard, a key feature of the standard SNA sequence of accounts is the attribution of consumption of fixed capital (depreciation) to economic activities and institutional sectors as a cost against income. The equivalent outcome from an extended sequence of accounts is the attribution of ecosystem degradation as a cost against the income of institutional sectors. Thus, the extended sequence of accounts describes the relevant accounting entries for the derivation of adjusted measures of value-added, domestic product, national income and net worth. Section 11.5.3 describes adjusted income measures.

11.5.2 Structure of the extended sequence of accounts

11.67 The design of an extended sequence of accounts reflects the ownership structure described in section 11.4. The extension thus requires the inclusion of the ecosystem trustee as a new sub-sector within the general government sector.

11.68 This extended sequence of accounts is shown in Table 11.4 where a simple example is used to show the different accounting entries. The example shows a simple economy consisting of a farm that produces wheat (with an output value of 200). The wheat is purchased and consumed by households. The cropland used by the farmer provides a mix of ecosystem services (gross ecosystem services supply of 110) of which 80 are used by the farmer as input to wheat production (i.e., crop provisioning services as inputs to SNA benefits) and 30 are recreation-related services which are inputs to the non-SNA benefit of physical and mental health. For simplicity, all production of the farmer (200) is recorded as final consumption of households and no other production, intermediate consumption or final consumption is recorded. Furthermore, it is assumed that compensation of employees is 50, and that the consumption of fixed capital of a tractor by the farmer is 10.

11.69 For the purpose of comparison, the accounting entries following the recording principles of the SNA are also shown. In this case, no transactions in ecosystem services are recorded as this activity lies outside the production boundary. Following the SNA, the economy in this example has a value added (gross domestic product) of 200 and the farmer has a net saving of 140.

11.70 Following the partitioned ownership approach described in section 11.4, the ecosystem asset is partitioned such that flows of ecosystem services are shown (i) as supplied by farmers in the case of the crop provisioning services (thus increasing the measure of gross output of the farmer) and (ii) as supplied by the ecosystem trustee in the case of recreation-related services . The crop provisioning services are immediately deducted in the accounts of the farmer as intermediate consumption.

11.71 The use of the recreation-related services is shown in two steps. In the allocation/use of accounts an ecosystem services transfer in kind is recorded as payable by the ecosystem trustee and receivable by the subsequent recipient. In this example, the final recipient of recreation-related services is the household sector but in other cases multiple recipients may be recorded. In a second step, the use of the ecosystem services is shown as the final consumption of the household sector.

Table 11.4: Models for including ecosystem services in the sequence of accounts (excluding financial account and change in balance sheet entries) (currency units)

			SNA treatment			Extended sequence of accounts			
			Sector		Total	Sector			Total
			Farmer	Household		Farmer	Household	Ecosystem trustee	
Production and generation of income acccount									
	Output	Products (wheat)	200		200	200			200
		Ecosystem services (crop provisioning)				80			80
		Ecosystem services (recreation)						30	30
	Total output		200		200	280		30	310
	Intermediate consumption	Products	0		0	0		0	0
		Ecosystem services (crop provisioning)				80		0	80
	Gross value added		200		200	200		30	230
	less Consumption of fixed capital (produced assets)		10		10	10		0	10
	less Ecosystem degradation					10		5	15
	Degradation adjusted net value added		190		190	180		25	205
	less Compensation of employees		50		50	50		0	50
	Degradation adjusted net operating surplus		140		140	130		25	155
Allocation / Use of income accounts									
	Degradation adjusted net operating surplus		140		140	130		25	155
	plus Compensation of employees			50	50		50		50
	Ecosystem service transfer in kind payable							30	30
	Ecosystem services transfer in kind receivable						30		30
	Degradation adjusted disposable income		140	50	190	130	80	-5	205
	less Final consumption	Products (wheat)		200	200		200		200
		Ecosystem services (recreation)					30		30
	Degradation adjusted net saving		140	-150	-10	130	-150	-5	-25
Capital account									
	Degradation adjusted net saving		140	-150	-10	130	-150	-5	-25
	plus Consumption of fixed capital (produced assets)		10		10	10			10
	plus Ecosystem degradation					10		5	15
	Net lending/borrowing		150	-150	0	150	-150	0	0

11.5.3 Adjusted income aggregates

11.72 A key focus in the development of the extended sequence of accounts is the derivation of various measures of economic activity including valued added, operating surplus, disposable income and net saving which take into account the cost of ecosystem degradation. Table 11.4 shows how these measures are derived and the relationships between them. Importantly, to retain accounting consistency, in addition to deducting measures of ecosystem degradation it is necessary that the income measures themselves are extended to incorporate the generation and use of ecosystem services (i.e., the flows that are not captured within the standard SNA production boundary).

11.73 The discussion of adjusting measures of GDP and other SNA aggregates for environmental factors is much broader than the degradation adjusted measures just described. Some considerations on the theoretical relationship between national accounts and welfare are relevant as discussed in Annex 12.1. There is also a range of approaches to measurement coverage and valuation that have led to development of a variety of alternative and complementary measures of the environment-economy relationship. Chapter 12 provides an overview of the approaches and the relationship to the measures described in the ecosystem accounts and in the extended accounts presented in this chapter.

Annex 11.1: Example of an extended supply and use account

A11.1 The Table 11.5 shows a small, stylized series of SUT using timber production as an example. Part A of the table presents the standard SUT recording of timber production for furniture purchased by households, i.e., no ecosystem services are recorded. It shows the production of logged timber by the forestry industry (50 units), the use of that timber by the manufacturing industry and the ultimate sale of the furniture to households of 80 units. Total value added of 80 is recorded equal to both the sum of the value added for forestry and manufacturing and the total household final consumption expenditure.[97]

A11.2 Part B extends this recording to include the flow of provisioning services (30 units) from the ecosystem asset (a forest) which is recorded as an input to the forestry industry. There is thus an additional row and an additional column in the SUT relative to the standard SUT in Part A. The main effect of this extension is to partition the value added of the forestry industry between the industry (previously 50, now 20) and the ecosystem asset (now 30, equal to the supply of ecosystem services). Overall value added through the inclusion of the ecosystem asset remains unchanged however (at 80 currency units) even though the total supply for all units has increased by 30. This reflects the extension of the production boundary and demonstrates how the accounting framework deals with the challenge of double counting.

A11.3 Part C introduces a second ecosystem service, air filtration, which is supplied by the same ecosystem asset (i.e., the forest). In this case a second additional row is required but no additional columns. In this third case total supply is further increased (by 15 units), but in this case, total value added also rises (to 95 units) because the additional production is not an input to existing products. Rather the supply of air filtration services is recorded as an increase in the final consumption of households.

A11.4 An important result of integrating the flows of ecosystem services in the extended SUT is that it becomes clear how the commonly discussed topic of double counting can be managed. Quite commonly, there is concern that integrating ecosystem services with the national accounts will result in double counting (in terms of the impacts on value added and GDP), if the final ecosystem services that contribute to SNA benefits are recorded. The gross basis of recording – i.e., recording both supply and use of ecosystem services - that is used in Table 11.1 is the most transparent means of dealing with double counting.

[97] The recording presented here ignores all other inputs and potentially relevant flows (e.g., labour costs, retail margins, taxes, etc.).

Table 11.5: Stylised example of an extended SUT (currency units)

	Ecosystem asset (forest)	Forestry industry	Manufacturing industry	Household final demand	Total
PART A: Standard SUA					
Supply					
Logged timber		50			50
Furniture			80		80
Use					
Logged timber			50		50
Furniture				80	80
Value added (supply less use)		50	30		80
PART B: Extended SUA (SNA benefits)					
Supply					
Ecosystem service – growth in timber	30				30
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – growth in timber		30			30
Logged timber			50		50
Furniture				80	80
Value added (supply less use)	30	20	30		80
PART C: Extended SUA (non-SNA benefits)					
Supply					
Ecosystem service – growth in timber	30				30
Ecosystem service – air filtration	15				15
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – growth in timber		30			30
Ecosystem service – air filtration				15	15
Logged timber			50		50
Furniture				80	80
Value added	45	20	30		95

SECTION E: Complementary valuations, thematic accounting and indicators

12 Complementary approaches to valuation

12.1 Introduction

12.1 The primary purpose of ecosystem accounting is to integrate information on ecosystems with measures of economic activity. To align with SNA principles, the ecosystem accounts in monetary terms as described in Chapters 8 to 11 record entries based on the exchange value concept. While this approach supports alignment with the accounting values of the national accounts, and hence with macro-economic policy, there are other monetary approaches and valuation concepts such as welfare values/willingness to pay and total economic values that have been extensively used in other policy contexts such as for cost-benefit analysis or within environmental policy.

12.2 The alignment with SNA principles also implies that the monetary values recorded in the ecosystem accounts reflect the current use of ecosystems. They are based on the existing management regimes and institutional arrangements regardless of whether the associated patterns of use may be considered (un)sustainable or (in)efficient. In other words, accounting entries are always ex post. However, in many policy contexts it is important to assess policy scenarios reflecting alternative management regimes or institutional arrangements for ecosystems, and this requires taking an ex ante approach. For example, to analyze how certain negative externalities (e.g., pollution) might best be internalized. The monetary values of the ecosystem accounts will not provide these estimates.

12.3 In this context, this chapter considers how the monetary ecosystem accounts presented in chapters 8-11 can be related to and potentially support other approaches and applications in monetary terms. Section 12.2 describes a set of complementary tables that can be obtained when taking a welfare-based approach to valuation, and explains the links between these approaches and the ecosystem accounts. Section 12.3 describes alternative measures of income, wealth and degradation that can be derived when making different assumptions regarding the attribution of costs or the institutional arrangements underlying valuation. Section 12.4 describes linkages with corporate assessments of natural capital.

12.2 Building links with welfare values

12.2.1 Introduction

12.4 The relationship between measures of national income and social welfare has long been a discussion point among prominent economists.[98] Some economists, such as Pigou and Hicks sought to relate observed market values to the framework of utility theory but this approach proved difficult (see Hicks (1975)). An alternative approach, following Kuznets, considered the final objectives of economic activity and hence looked to adjusted measures of aggregate economic activity, most commonly GDP. This approach was pioneered by Nordhaus & Tobin (1972) and their macro-economic welfare index. However, application of this approach has proved challenging due to the difficulties of selecting and measuring the range of possible adjustments for all aspects of social welfare, as demonstrated by the range of alternative indicators that have been proposed subsequently.

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[98] See for example the summaries in (Obst et al., 2016; Vanoli, 2005).

12.5 In light of these challenges, the 2008 SNA that warns against a welfare interpretation of the accounts. It notes that “GDP is often taken as a measure of welfare, but the SNA makes no claim that this is so and indeed there are several conventions in the SNA that argue against the welfare interpretation of the accounts.” (United Nations et al., 2010, para. 1.75). Indeed, it is clarified that the main objective of the SNA is to “compile measures of economic activity in accordance with strict accounting conventions based on economic principles.” (ibid., para 1.1). This is not to say that connections do not exist between entries in the national accounts and measures of welfare. This topic is discussed in more detail in Annex 12.1.

12.6 The development of SEEA has also frequently touched upon its relationship with welfare measures, mostly in the context of assessing the cost of degradation which would provide the means to adjust GDP and other national accounts measures of income and wealth along the lines followed by Nordhaus and Tobin. For instance, the 1993 SEEA contained various extensions including one in which the repercussion costs of households of a deteriorated environment would be assessed using contingent valuation, especially willingness-to-pay. The 2003 SEEA contains both cost-based and damage-based methods for assessing degradation, concluding that adjusting macro-aggregates for the latter “is the furthest removed from the normal SNA conventions and impinges on the realm of welfare measurement”.

12.7 The approach taken in the SEEA EA (as explained in Chapter 8) is to align the ecosystem accounts with the valuation basis of the SNA. In this section, complementary tables are discussed that support welfare analysis, namely a bridge table linking accounting values to welfare values, and tables that make negative externalities and ecosystem disservices visible.

12.2.2 Bridge table between accounting and welfare values

12.8 To support understanding of the links between accounting and welfare values in the context of ecosystem services, the following bridge table, Table 12.1, can be compiled. The table lists the various additions/subtraction to be made in going from one value concept to the other, for selected ecosystem services. The table also serves to illustrate why accounting values are smaller than welfare-based values.

Table 12.1: Bridge table between accounting and welfare value of ecosystem services

	ES1 (biomass)	ES2 (recreation)	Total flow	Asset
1. Accounting value	*10*	*5*	*15*	300
2. Consumer surplus	*0*	*20*		
3. Welfare use-value	*10*	*25*	*35*	700
4. Welfare non-use value		*15*	*15*	300
Total welfare value				1000

12.9 In the example given the following assumptions are made:

- An area of land provides provisioning services (of 10) by producing crops.
- The same land area also offers some recreation facilities for people living nearby. There is no charge for using the area but individuals have to travel some distance to get to it, which can be used to value the service (at 5). The users of the site for recreation, however, obtain a consumer surplus as they would be willing to pay more than they do implicitly by travelling to the site. This amount is assumed to be 20.
- In addition, other people who do not visit the site have a non-use value for it (of 25).

- Asset values are the PVs of the value of a constant flow of services over an indefinite future at 5%. No changes in prices of inputs or outputs are expected. The corresponding asset values are: (i) 300 based on accounting values – this is the value that would be included in the extended SNA balance sheet, (ii) 700 when based on welfare use values and (iii) 1,000 based on use and non-use values. The latter value would be the value that would be included when compiling wealth accounts on a welfare basis.
- An additional reason (not listed in the table) for differences between accounting values and welfare values is that the latter sometimes value the benefit (e.g., using market prices for crops) rather than the contribution to the benefit (as per SEEA EA).
- In real applications, the bridge table should describe a comprehensive set of ecosystem services generated by the EAA.

12.10 For certain policy applications, the difference in values between accounting and welfare-based valuations may provide relevant information about so-called *unrealized values*. These may be obtained when comparing the current situation to a situation with changed economic institutions / management regimes for ecosystem assets. For instance, the current management of an ecosystem may result in low exchange values (e.g., an open access ecosystem), whereas the welfare value (elicited by the willingness to pay (WTP) by people for the same ecosystem services may be very high.) Large unrealized values may provide a rationale for policy intervention.

12.11 From a measurement perspective, in order to populate the table, for provisioning and (most) of the regulating and maintenance services, it may be reasonable to assume that no consumer surplus exists. This assumes the final consumer would only be willing to pay the final price (say of the crops) and nothing more. For cultural services, the non-market valuation techniques applied (as described in Chapter 9) are commonly used to estimate welfare values. Non-use values (which can be very significant) would need to be assessed by stated preference approaches. For macro-type scale applications, a starting point would be to use value transfer techniques.

12.2.3 Assessing externalities, ecosystem disservices and health outcomes

12.12 Perhaps the most commonly discussed framing for examining the link between the environment and the economy concerns externalities. Frequently, there is the call for frameworks and information that allows decision makers to "internalise environmental externalities", which is a general demand to ensure that the negative impacts of business, government and people on the environment are taken in account.

12.13 ***Externalities are impacts that "arise when the actions of an individual, firm or community affects the welfare of other individuals, firms or communities [and the] agent responsible for the action does not take full account of the effect"*** (Markandya et al., 2001). Externalities may be both positive or negative, although much focus in environmental economics is on negative externalities such as the effects of pollution or emissions. They are measured in terms of the social costs and benefits on other economic units.

12.14 Accounting approaches explicitly do not account for externalities, at least not directly. Accounting, as a transaction-based system, focuses on recording exchanges between units. The measurement of externalities by contrast considers the magnitude of effects which are not exchanges but rather outcomes that arise as a consequence of other activities. In effect, accounting is designed to record stocks and flows as they are – i.e., the world with the externality. Indeed, the estimates recorded in the accounts will reveal any actual costs or changes in income that may be associated with externalities even if not directly associated with a specific externality.

12.15 A common focus of externality assessment is cost-benefit analysis wherein there is measurement of the expected effects, both positive and negative, of a particular project, activity or policy change. The analysis, when undertaken for decisions in the public sphere, requires a comparison of the wider social costs and benefits of a given project, activity, or policy.

12.16 From a measurement perspective, a key feature of assessing externalities is the assessment of the effect on welfare arising from the specific activities. In this analysis, welfare is generally measured in terms of consumer and producer surplus – thus negative externalities have a negative effect on the total surplus of other economic units. As discussed in Annex 12.1, there are conceptual links between measures of welfare based on total surplus and the exchange values recorded in accounting, but the concepts are not equivalent.

12.17 While the analytical framing and the valuation concept is different in externality assessments, ecosystem accounting information can provide inputs to the assessments through its recording of changes in ecosystem condition and changes in ecosystem services flows that arise as a result of a particular activity (e.g., impacts of the use of fertiliser and pesticides on water bodies and biodiversity). Thus, the accounts can provide baseline information for the derivation of total surplus measures.

12.18 <u>Positive externalities</u>. With respect to positive externalities, a conceptually simple extension to the ecosystem services flow account in monetary terms is to measure the flows of services in terms of their total surplus, i.e., producer plus consumer surplus, rather than using values described in Chapter 9. For example, the exchange value of pollination services can be identified through analysis of market values of pollinated agricultural outputs while the full economic value of pollination, potentially measured in the context of a change in the pollinator population, can be measured in welfare terms. These complementary valuations based on total surplus may be presented alongside estimates in exchange value terms. The bridge table shown in Table 12.1 is an example of this application.

12.19 <u>Negative externalities and ecosystem disservices</u>. While the accounts do not directly adjust or measure negative externalities as a distinct concept, the data in any set of accounts will track over time, the effects of externalities to the extent that the effects are within the prescribed accounting boundaries. Thus, additional costs associated with water purification resulting from excess fertiliser use will be recorded in the accounts of the water supply and distribution company; and degradation in soil quality through overcropping will be reflected in reduced output of an affected farmer. The primary difference is that the accounts themselves to do not record the reason for the change in value of output of the sectors (or associated attribution of costs); nor do they aim to measure what might have happened under an alternative set of circumstances.

12.20 Ecosystem disservices fall into a similar category as negative externalities in that there are negative effects on people and economic units. A useful distinguishing feature is that disservices may be characterised as being caused by environmental factors (e.g., mosquitoes causing malaria), whereas negative externalities are caused by the activities of economic units (e.g., land clearing spreading zoonotic diseases). While ecosystem services can be readily interpreted as positive exchanges between ecosystems and economic units and hence amenable for recording in accounts, ecosystem disservices cannot be interpreted in this way. The appropriate framing from an accounting point of view is to consider capturing the wider effects of the ecosystem disservices implicitly, for example in terms of a reduction in the flows of ecosystem services (e.g., pests destroying crops and reducing biomass provisioning services; algal bloom reducing the opportunities for recreational activities in lakes).

12.21 The following tables demonstrate the potential to provide alternative recordings using an accounting structure that highlight ecosystem disservices and negative externalities. Table 12.2 illustrates how a disservice could be shown. Suppose we have an economy in which there are only 2 activities ISIC A – agriculture and ISIC C - manufacturing, producing respectively two products X (say crops) and Y (canned crops). In addition, assume that an ecosystem service is being provided (as in Table 11.1) to agent A. Further, suppose a disservice B is introduced – an example is of elephants trampling agricultural produce and thus reducing output.

12.22 Table 12.2 recognizes both the ecosystem services of biomass provisioning and the disservice. The disservice effectively causes a reduction of 20 in the value of the ecosystem service, which is why it is introduced as a negative. Now the net value of the service is 50, which is intermediately consumed by agent A. An income transfer is also recorded to ensure that the ecosystems does not have an income. After income transfers, the same disposable income results as in the situation without the recording of the disservice (as in the 2008 SNA). The advantage of this table is that compared to Table 11.1 we have the same outputs, but we have made the value of the disservice explicit. This accounting treatment can be also applied where there is no off-setting ecosystem service, for instance GHG emissions could be recorded as negative output of an ecosystem, finally consumed by households, reducing their final consumption.

Table 12.2: Complementary table with ecosystem disservice in SUT

Adjusted SNA	Ecosystem	ISIC A	ISIC B	Household	Total
Supply					
Ecosystem Service A	70				70
Ecosystem Disservice B	-20				-20
Product X		200			200
Product Y			80		80
Use					
Ecosystem Service A		70			70
Ecosystem Disservice	0	-20			-20
Product X			25	175	200
Product Y				80	80
Value Added (Supply-Use)	50	150	55		255
Transfer	-50	50			0
Disposable Income	0	200	55	255	255

12.23 Table 12.3 builds on the example of the ecosystem disservice to show a recording for negative externalities. Suppose the farmer disposes agricultural wastes into the river, causing costs to downstream users of the water bodies (say ISIC E, a water supply company) who use it as a source of drinking water. The externality can be recorded as a negative output of the farmer thereby suppressing its output (and value added). In the use table, the externality can be recorded as (negative) intermediate consumption by the ecosystem, reflecting that in this situation, the ecosystem is the subject of the externality. This has the effect to show the value added of the ecosystem in the absence of the externality, while still portraying the actual ecosystem services used. The income transfer ensures as in the previous recording that the ecosystem has no disposable income, and that the activities have the same value added as without the ecosystem service and the externality. If the externality is not recorded (but only the ecosystem services), a description of the actual ecosystem services being supplied and used is provided.

Table 12.3: Complementary table with externality in SUT

Adjusted SNA	Ecosystem	ISIC A	ISIC E	Household	Total
Supply					
Ecosystem Service A	55				75
Externality		-20			-20
Product X		200			200
Product Y			300		300
Use					
Ecosystem Service A		25	30		70
Externality	-20				-20
Product X			25	175	200
Product Y				300	300
Value Added (Supply-Use)	75	155	245		475
Transfer	-75	45	30		0
Disposable Income	0	200	275		475

12.24 In many situations the discussion of negative externalities and ecosystem disservices relates to the effects on human and population health. It has long been established that the national accounts do not place a direct value on health outcomes and instead the focus is placed on measuring the inputs to human health, e.g., outputs related to doctors and hospitals. Similarly, in ecosystem accounting, there is measurement of the contribution of ecosystems to health outcomes (e.g., via air filtration services) but not measurement of the health outcomes themselves.

12.25 An important area of analysis beyond the ecosystem accounts therefore lies in direct measurement of these outcomes. This has been undertaken, for example, by the World Bank and the OECD among others under the generic heading of measuring the costs of environmental degradation (COED). [99] Such work will involve some form of monetary valuation but may also involve the measurement of dose-response functions that track the changes in population health in relation to changes in, for example, ecosystem condition (e.g., involving measures of water quality). It should be apparent that the structure of ecosystem extent and condition accounts, together with the biophysical modelling required for

[99] See for example the World Bank Changing Wealth of Nations reports, the OCED database on these costs and Muller et al. (2011).

measuring many ecosystem services, may be applied usefully in the derivation of health-related metrics and the related analysis.

12.26 There are also a range of approaches within the private sector wherein the monetary value of externalities is added or subtracted from an existing measure of financial income or profit. These approaches are commonly labelled as environmental profit and loss (EP&L) statements. In general, these seek to assess the overall (or net) cost or benefit that a company contributes to society, for example by deducting the social cost of carbon associated with its emissions from its measure of financial profit.

12.3 Alternative measures of income, wealth and degradation

12.3.1 Restoration cost-based approaches to measuring degradation.

12.27 Earlier iterations of the SEEA focused not on valuing ecosystem (or environmental) assets per se but rather on measuring degradation directly in terms of the environmental cost associated with recorded levels of economic activity. For this purpose, there was no requirement to extend the production boundary as described in ecosystem accounting.[100] The 1993 SEEA recommended to use the so-called maintenance cost approach to value degradation, i.e., the costs required to restore the environment to its previous state. Further, as explained more fully in SEEA 2003, Chapter 9, the conceptual focus assumed that environmental assets – air, water, soil – were effectively fixed in quantity and focus should therefore be placed on either the costs involved in combating declines in the quality of these assets (restoration costs) or the damages incurred as a result of declines in quality.

12.28 In terms of monetary valuation there are a number of considerations that emerge from this framing that are not present in the framing of the core ecosystem accounts. First, in a situation where the environmental quality meets or exceeds a suitable threshold – e.g., there is sufficient clean air – then it is posited that there is no additional value to be incorporated into the accounts. Put differently, it is only when there is insufficient clean air that it obtains a scarcity value that needs to be considered.

12.29 Second, the non-market benefits that people obtain from nature should not be equated to exchanges between economic actors. Hence there is no rationale for extending the production boundary in a way that implies there are transactions between economic units and ecosystems. Indeed, the distinct focus of the restoration-cost approach is not on articulating the contribution that ecosystems make to well-being but on highlighting the costs of reducing ecosystem condition below acceptable thresholds.

12.30 Third, it was considered that there was no market or institutional mechanism by which the restoration costs are confronted with the benefits (reductions in damages) associated with the change in environmental quality. The consequence of this was that the SEEA 2003 described both cost-based methods and damage-based methods for estimating the monetary value of degradation. The damage-based methods described in SEEA 2003 have much in common with the measurement of welfare values as applied in the measurement of negative externalities and these are not further discussed here. In an environmental accounting context, most focus has been retained on cost-based approaches.

12.31 Following SEEA 2003, cost in relation to environmental degradation can either be preventative – avoidance and abatement costs – or aim to reverse the effects – restoration costs. In the context of accounting for the cost of degradation in any given period, as

[100] Similar approaches were noted in Vanoli (1995) and the SEEA 2003 (para 10.130) but not developed

described in Chapter 10, the avoidance and abatement costs may have been incurred in which case the quantity of degradation will be reduced (ceteris paribus) and further they will already be recorded in the accounts. (The SEEA Central Framework Chapter 4 describes the framework for identifying and recording these costs in the context of environmental protection expenditure accounts.) Placing a value on the actual change in environmental quality therefore must focus on restoration costs, the expenditure required to return the environment to a given quality. This quality could be the quality at a previous (or sustainable state), or the quality defined as a societally desired state (e.g., as expressed in multilateral environmental agreements). This focus thus captures any “residual” degradation not reflected in measures of actual avoidance and abatement costs.

12.32 Measuring these costs may be challenging for two reasons. First, they are estimates of future expenditure which will of course be subject to the use of appropriate assumptions concerning prices and quantities of inputs required. A core assumption is that the costs will reflect the least cost estimate. In some cases, quite extensive information may be available, for example mining companies may be required to estimate the cost of rehabilitating mine sites. It is also recognized that measurement in this area is related to an emerging issue in the context of the SNA concerning the recording of provisions wherein liabilities may be recognised in relation to potential future costs. While provisions are a common feature of corporate accounting, they are not recorded in the national accounts.[101] To the extent that some of these costs are actually incurred, an accounting-based dataset may be maintained to support the estimation of these costs for future periods.

12.33 Second, it is necessary to assume an appropriate environmental quality to which the condition can be restored. Ideally, it should involve an understanding of the benefits obtained from the ecosystem (e.g., ecosystem services, intrinsic values); an understanding of relevant ecological thresholds and boundaries; identification of the socially desired state; and connections to relevant environmental regulations, standards and policy which can be used as indicators of social preferences. Based on this information the estimated costs would reflect a social willingness to pay. However, a simple assumption might be applied wherein the degradation is the estimated cost associated with restoring the ecosystem to its condition at the beginning of the accounting period. In all cases, there is a clear role for the ecosystem condition account in supporting the assessment of degradation and the associated restoration costs. Note that if these costs were actually paid then, in theory, condition would be unchanged and no degradation would be recorded. Therefore, taking such a cost-based approach may arguably be better understood as an example of applying the accounts for scenario analysis.

12.34 In general, the estimate of the monetary value of degradation obtained using this approach could be integrated into the accounts as a macro adjustment. Recognizing the nature of these costs, Vanoli (2015) proposed to add the monetary value of degradation of ecosystems as “unpaid ecological costs” to the final expenditure categories, thus arriving at final consumption and gross fixed capital formation on a “total costs” basis. Further, where the costs accrued remain unpaid in subsequent periods, they would be recorded as a negative into saving, and subsequently as an increase in a new liability category, “ecological debt of the economy”. Table 12.4 below shows how unpaid ecological costs and ecological debt may be incorporated into a sequence of accounts.

12.35 As noted, this approach can provide a means to estimate a cost of degradation but it cannot be easily combined with direct measures of the value of ecosystem services and associated values of ecosystem assets as described in the ecosystem accounts since there is no particular reason that the estimated restoration costs will align with the estimated loss of future flows

[101] Although the recognition of these costs is an active area of research in an SNA context.

of ecosystem services. However, one option may be to apply this approach in cases where no underlying ecosystem asset is recognized such as in the case of the atmosphere and fisheries in the high seas. Restoration costs for these environmental assets could be recorded as unpaid ecological costs alongside measures of degradation for ecosystem assets as described in the core ecosystem accounts.

12.3.2 Polluter pays presentation of degradation

12.36 The recording in the SEEA EA is based on the cost borne perspective in which the cost of degradation is allocated to the economic unit considered to own the ecosystem asset since they are the unit that suffers from the loss. An alternative perspective is to allocate the costs of degradation to the economic unit that is considered to have caused the degradation, for example costs may be assigned to a polluter.

12.37 To support this alternative presentation, Table 12.4 illustrates how it is possible to include both cost caused and cost borne presentations in the sequence of accounts, compared with the sequence of accounts displayed in Table 11.3. It is done by allocating degradation on the basis of cost caused in the production account, and then transferring degradation costs between sectors in the distribution of income account through two additional rows (a degradation transfer in kind payable and receivable). The transfer ensures that the same degradation adjusted disposable income is obtained as in Table 11.3. In Table 12.4, it is assumed that the farmer is responsible for all degradation taking place.

12.38 This presentation has an advantage that in the capital account and balance sheet, the ecosystem asset value underpinning the supply of services that is allocated to the economic owner, reflects the costs borne, while measures of production and value added reflect a costs caused perspective that has the effect of showing a lower measure of net value added.

12.39 These allocations to causing units may be difficult to assign in practice, for example in cases where the effects of degradation arise some distance from the cause, where there are multiple economic units contributing to the degradation and when there is a significant time lag between the activities causing the degradation and the incurrence of costs by other economic units.

Table 12.4: Alternative recording of degradation costs in the sequence of accounts (excluding financial account)

			Extended sequence of accounts			
			Sector			
			Farmer	Household	Ecosystem trustee	Total
Production and generation of income acccount						
	Output	Products (wheat)	200			200
		Ecosystem services (crop provisioning)	80			80
		Ecosystem services (air filtration)			30	30
	Total output		280		30	310
	Intermediate consumption	Products	0		0	0
		Ecosystem services (crop provisioning)	80		0	80
	Gross value added		200		30	230
	less Consumption of fixed capital (produced assets)		10		0	10
	less Ecosystem degradation (polluter pays)		15		0	15
	Degradation adjusted net value added		175		30	205
	less Compensation of employees		50		0	50
	Degradation adjusted net operating surplus		125		30	155
Allocation / Use of income accounts						
	Degradation adjusted net operating surplus		125		30	155
	plus Compensation of employees			50		50
	Ecosystem service transfer in kind payable				30	30
	Ecosystem services transfer in kind receivable			30		30
	Degradation transfer in kind payable				5	5
	Degradation transfer in kind receivable		5			5
	Degradation adjusted disposable income		130	80	-5	205
	less Final consumption	Products (wheat)		200		200
		Ecosystem services (air filtration)		30		30
		Unpaid ecological costs		25		25
	Degradation adjusted net saving		130	-175	-5	-50
Capital account						
	Degradation adjusted net saving		130	-175	-5	-50
	plus Consumption of fixed capital (produced assets)		10			10
	plus Ecosystem degradation		10		5	15
	Net lending/borrowing		150	-175	0	0
Changes in balance sheet						
	Changes in fixed capital (SNA)		10			10
	Changes in ecosystem assets (non-SNA)		10		5	15
	Changes in ecological debt (non-SNA)			15		15

Note: In yellow: cells changed / added in a polluter pays recording; In orange: cells added/changed when including unpaid ecological costs.

12.3.3 Defensive expenditures

12.40 Another long-standing framing in the economics literature is adjusting aggregate measures of income for expenditures incurred to avoid bad or negative outcomes. This includes, for example, the purchase of equipment to filter polluted air. These so-called defensive expenditures add to measures of national income following the SNA (i.e., there is increased production and consumption of relevant goods and services) but may be considered not to enhance overall welfare. Thus, for a more appropriate measure of national income in terms of welfare, defensive expenditures may be deducted.

12.3.4 Alternative measures of environmental income

12.41 The ecosystem accounts involve treating the monetary value of flows of ecosystem services as output, and hence income, and expectations of future income flows will affect the monetary value, and changes in value, of ecosystem assets. As described in chapter 10, there is a range of entries to record the change in value of ecosystem assets including changes in value due to ecosystem enhancement, ecosystem degradation, ecosystem conversions and other changes. These various changes in asset values (which may be labelled collectively as capital gains) are accounted for following national accounting treatments as either other changes in volume (e.g., resulting from catastrophic losses) or revaluations.

12.42 An alternative framing[102] is to define income such that it also includes capital gains, i.e., changes in asset values. Such an approach has many similarities to the ecosystem accounting approach described in the SEEA EA with the primary difference concerning the use of a Hicksian measure of income that explicitly incorporate capital gains in a manner that is not aligned with the SNA. All of the underlying accounting entries and valuations are however aligned, including the use of the exchange value concept.

12.3.5 Alternative approaches to asset valuation

12.43 The extension of the standard production boundary using the monetary value of ecosystem services and the consequential extension in the monetary value of ecosystems under a net present value framework is consistent with the central logic of wealth accounting as described in, for example, Barbier (2013). At the same time, there are a range of alternative assumptions that can be applied in implementing the central logic of wealth accounting compared to the treatments and boundaries described in the core ecosystem accounts. Of particular note are the following:

- For some biological resources, especially fish stocks, where there is limited regulation and open access fishing is possible, the resource rent which reflects the price of the asset will fall to very low levels. In these contexts, it may be of interest to estimate the value of the fish stocks and the associated ecosystem using an alternative institutional context in order to evaluate the effects of making such a change. These values might be considered "unrealized values."
- Also for biological resources, but indeed for all ecosystem services, it may be of interest to estimate the present value of future returns using alternative institutional arrangements for example assuming some optimal management of the resources. Generally these values might be considered "unrealized values". A specific case would be values of assets under an assumption of long-term sustainable use of the ecosystem which might be considered "sustainability-based values".
- Alternative valuation concepts may be applied wherein estimates of consumer surplus are included in the value of future flows of ecosystem services

[102] See Caparrós et al. (2003).

- When valuing individual ecosystem assets, there may be interest in deducting the value of ecosystem disservices to the extent that these are understood to have a negative overall effect on the value of the asset in terms of its contribution to society.
- When defining future income flows alternative treatments/interpretations of capital gains and depreciation may be applied compared to standard national accounting principles

12.44 In the context of these various assumptions and treatments for wealth accounting, the values obtained from the ecosystem accounts can be considered one alternative. In all contexts, it will be relevant to clearly describe the selected assumptions and treatments such that the differences between various wealth accounting estimates can be clearly understood. This documentation should also extend to a clear articulation of the set of ecosystem services used to measure natural capital in the wealth accounts as well as information on, for example, the selected discount rate and asset lives.

12.3.6 Extended modelling/green economy modelling

12.45 A general concern for all measures and aggregates in monetary terms when using an extended income framing is that the values of the environmental variables reflect the current imperfect institutions and regulations for managing the environment-economic system. In this context, one alternative approach is to undertake extended modelling to estimate an alternative GDP (and other income measures) under the assumption that alternative environmental constraints (e.g., restrictions on pollution) 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.

12.46 More generally there are a range of possible applications of the accounts in scenario analysis. Guidelines on the use of ecosystem accounts in policy scenario analysis in the context of SEEA EA are forthcoming (UN and UNEP, forthcoming).

12.4 Corporate natural capital assessments

12.47 In parallel with the advances in environmental-economic accounting in the public sector there have been strong advances in natural capital accounting in the corporate sector in the past 10 years. In general, these approaches have tended to focus on considering the impact of corporate activities on the environment, with a particular focus on GHG emissions and other pollutants, but there is an increasing shift towards understanding dependencies on water and increasingly on ecosystems and biodiversity.[103] Most commonly this has been taken forward using an externalities framing as described in the section above, particularly in the compilation of environmental profit and loss accounts. However, there are also a number of approaches being used at corporate level that are closely aligned to the ecosystem accounting framework described here (e.g., Corporate Natural Capital Accounting).[104] In large part, the differences arise around the type of analytical question posed which, in the corporate space has been driven by reporting on businesses' impacts on society, and in the extent to which data used to underpin the compilation of SEEA based accounts is sufficiently detailed for corporate scale measurement and analysis.

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[103] See https://seea.un.org/sites/seea.un.org/files/background_paper_release_for_unseeaforum.pdf

[104] See eftec (2015).

12.48 Given the potential for collating consistent and spatially detailed physical and monetary data using the ecosystem accounting approach, there is likely considerable potential for cross-fertilisation of efforts in collating environmental data to underpin shared measurement of ecosystem extent, condition and ecosystem service flows. It is likely that issues of monetary valuation will continue to be an area of discussion but this is equally true in the context of public sector accounting and analysis. Further engagement on the development of accounting principles and their harmonisation at national and corporate levels, as well as on the potential for the development of rich datasets to underpin accounting at all scales is an important part of the research agenda.

Annex 12.1: Exchange and welfare values in a national accounting context

A12.1 This annex summarizes in a technical sense how exchange, welfare and accounting values can be related to each other.

Monetary valuation of individual goods and services

A12.2 To establish the concepts, the initial focus is on the valuation of a single marketed good and a single consumer and producer. The basis of the monetary valuation in the neo-classical economics literature assumes that people and businesses have preferences that can be represented in quantitative terms using money values as a common unit or numeraire. The preferences are based on the willingness of individuals to pay (WTP) for a given good or service or on individuals, firms, or resource owners' willingness to accept a payment (WTA) for giving up a good or service.

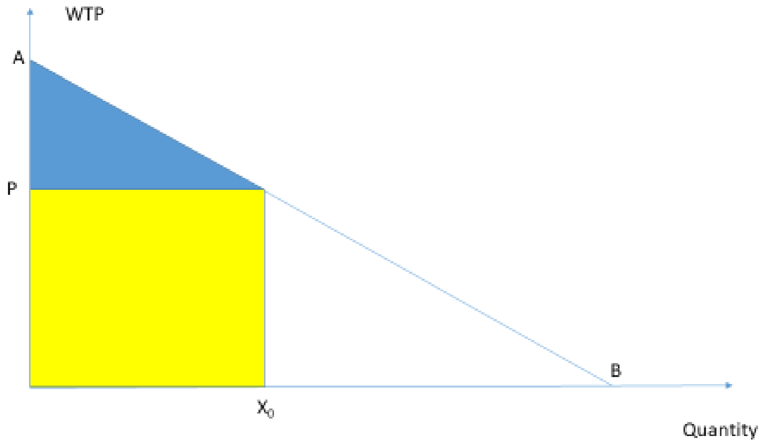
A12.3 The WTP and WTA for a good or service can be represented as a demand curve for the good or service under consideration. In Figure 12.1 the horizontal axis represents the quantity of the good and the vertical axis the WTP. For most goods, an individual's WTP decreases with each additional unit that they obtain. Or conversely, the quantity they demand decreases as the price increases. The line AB is referred to as the individual´s demand curve because it illustrates the quantity demanded relative to price. The total WTP for quantity X0 is the area under the demand curve. If the good or service were sold in a market at a price P, the individual would purchase quantity X0 as she is willing to pay more than P for all the units before X0 but her WTP for an additional unit (X0+1) is less than P, so she will not purchase another unit at that price.

A12.4 In that case, the sum of money exchanged is the yellow area and is referred to as the ***accounting value*** reflecting the value that is recorded in the accounts. The blue area is a benefit that individuals who obtain the good or service enjoy over and above what is paid and is called the ***consumer surplus.***[105] If the good is provided for free and there are no costs associated with supplying the service, then the consumer surplus is equal to the whole area under the demand curve (i.e., triangle A, B, 0).[106] For further details on consumer surplus, WTP and WTA see (Markandya et al., 2002).

[105] Economic theory distinguishes between the Hicksian and Marshallian approaches to estimating demand curves the former aligning demand and preference to the concept of utility and the latter to the concept of income. Ideally, Hicksian demand curves based on utility would be measured but in practice income is the more measurable concept. Consumer surplus is thus an approximation to the ideal.

[106] For essential goods like water the consumer surplus can be very high (arguably infinite) as a person´s WTP for the amount needed for survival will be very large– this has been also called the zero problem (Nordhaus, 2006) as it would mean that the consumer surplus is also infinite. This is one of the reasons welfare analysis usually focuses on assessing welfare changes (e.g. between q1 and q2, rather than between q1 and 0).

Figure 12.1: WTP, Exchange Values and Consumer Surplus



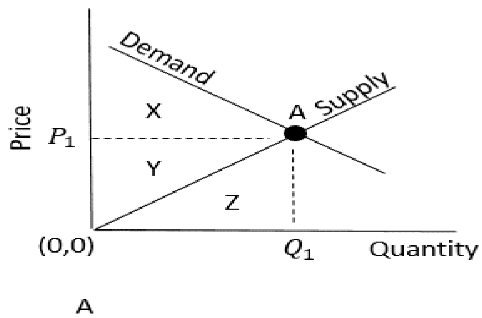
Source: own elaboration.

A12.5 To complete the picture of a market for a single good, a supply curve (Figure 12.2) can be described which reflects the preferences of the supplier in providing a good for sale again in terms of a combination of prices and quantities. Since the supplier will be willing to supply more of a good as prices rise, the supply curve will be upward sloping. The nature of the supply curve will be affected by the costs of supply, i.e., a supplier will only be willing to accept a price for their goods that covers the costs.

A12.6 The transactions in ordinary goods and services are based on prices whereby the price is determined by the point at which the marginal WTP is equal to the marginal cost of producing a good or service. This is the point of intersection of the supply and demand curve, denoted as point A in Figure 12.2, which provides both an exchange price and the quantity of the good exchanged. Such transactions data form the foundation of all SNA accounts.

A12.7 Area Z reflects the costs of supply. The ***producer surplus*** (area Y) is the additional benefit that a producer receives from selling quantity X_0 at price P given costs of Z.

Figure 12.2: Static one-good market



Source: own elaboration.

A12.8 The welfare value or total surplus, as understood in welfare economics, is equal to the area X + Y, i.e., the sum of the consumer surplus and producer surplus. It represents the total benefit accruing to consumers and suppliers in this one good market from exchanging the quantity of the good at price P. If preferences change, costs change, incomes change then the measured total surplus will change. Commonly, welfare analysis involves assessment of the change in total surplus that would arise in a different context, for example as the result of a policy change (e.g., tax rates).

A12.9 Two key implications emerge from this result. The first concerns the link between price and accounting value. In short, the price of a good is what is paid for it. It is not the full value of the good to the purchaser because there is normally some consumer surplus derived from the purchase. If there is no rationing involved, people will continue buying goods until their WTP equates to the price at which the goods are offered. The price can therefore also be referred to as the marginal value of the good. A similar logic can be applied from the perspective of the producer of the good, i.e., the price will reflect the marginal value of the good to them also.

A12.10 Second, from the discussion in this section, the welfare derived from a good or service is equal to the total WTP for it, which includes the payment made and the consumer surplus. As is well understood in the national accounts' literature, the accounts do not include the consumer surplus and instead record accounting values. A link with welfare does nonetheless exist because the price is also the marginal value of a unit, which is the welfare that unit provides. Thus a small increase in the availability of a good will generate welfare approximately equal to the change in the accounting value. This insight is the basis of a formal proof in the literature that **variations in material wellbeing** in society are reasonably well represented by the changes in Net Domestic Product (NDP) (See Weitzman (1976)). Thus the change in Gross Domestic Product (GDP) less any change in depreciation, which gives the change in NDP, is an approximation for the change in wellbeing generated in society.

A12.11 This result did however require a restrictive set of assumptions and while they have been partially relaxed in subsequent studies (see Harberger (1971) for a previous and similar result and Löfgren (2010) for a survey of this literature and a discussion about the assumptions needed), the link between changes in GDP/NDP and changes in societal welfare needs careful reflection. Of particular note is that the result obtained assumes the absence of externalities and that all services are provided through competitive markets. As well, there are connections to wealth distribution and relative poverty which will be important in determining individual wellbeing.

A12.12 From an ecosystem accounting perspective, an important assumption in the Weitzman result is that it assumes that the products included in the income measure (i.e., GDP) all correlate positively with wellbeing. In turn, this places a focus on the production boundary both as to whether it includes some things that have a negative link to wellbeing but also whether there are missing goods and services that contribute positively to wellbeing. It is the potential of ecosystem accounting to consider some of these missing good and services, and the effects of losing the access to them as a result of ecosystem degradation, that is one of the motivations for its development.

2. Extension to non-market values

A12.13 So far we have considered supply and demand curves of a single consumer and producer. The demand curves for all individuals in a given market can be added together to construct a total or market demand curve. The summation is done horizontally if the good is a private good. So, for any given WTP, the quantity that different individuals with that WTP demand is added up to get the total demand for the good. For (quasi-)public goods, such as recreation-related services, the aggregate demand is not the horizontal summation as for private goods, but the vertical summation. That is, for any given amount of the good the WTP of each individual is added to get a total WTP. This happens when the supply is (relatively) inelastic (e.g., in case of a protected area that supplies cultural services, in case of a surge in demand it may take time to adjust lodging / parking places / access roads).

A12.14 The average cost of producing a good or service does not directly relate to its value to the consumer, although the more expensive it is to produce the higher its price is likely to be, making the marginal value higher. In the SNA a number of goods are valued at cost of production because there is no market for them and hence no price. This is the case with public goods such as defense or public health provided by the government and other authorities. The use of cost data in this context, however, does not mean that levels of provision are unrelated to values; the link can come about through the political process that determines the level of provision. Thus a given level of spending on health, education, transport etc. reflects societies´ collective willingness to pay for these services through taxes and user charges. That said, the relationship between public expenditure data and the true value of the goods and services is subject to ongoing discussion.

A12.15 A key characteristic of ecosystem services is that there is often no accompanying exchange of money that can be used to quantify the preferences for the services in the same manner as for the marketed goods just described. As a result, to support analysis of ecosystem services, and many other non-market goods and services, there is a wide range of valuation techniques that have been developed for use in environmental economics for pricing ecosystem services (by estimating proxy prices) in case market prices are not available.

A12.16 While these techniques may be commonly applied to estimate changes in welfare values, they all involve the estimation of the marginal WTP for a good or service. Consequently, using the framing described above, these techniques can also be applied to estimating prices for accounting purposes. That is, a marginal WTP multiplied by a revealed quantity exchanged will provide an estimated accounting value.

A12.17 A key criteria in understanding the potential to use marginal prices concerns the assumptions applied concerning the institutional arrangements or market structure. Generally, it is expected that prices will be estimated assuming the current institutional arrangements applying in the context of the transaction in ecosystem services. Hence, prices need not align with estimates of marginal WTP made using theoretically preferred institutional arrangements or market structures, such as perfect competition.

A12.18 Where there is a close connection to a marketed good or services, the potential to infer preferences and hence a marginal WTP will be relatively high. Further in these cases it will likely be reasonable to assume that the institutional arrangements underpinning the observed price of the related good or service can be applied in estimating the marginal WTP (provided that the contexts (ecosystem, location, etc) are sufficiently similar). However, there will be other cases where there is no close connection to a marketed good or service in which case establishing preferences and determining the appropriate institutional arrangements will be difficult. Different techniques have developed to consider these different contexts as discussed in Chapter 9.

13 Accounting for specific environmental themes

13.1 Introduction

13.1 The framing provided by ecosystem accounting is systematic and comprehensive with respect to ecosystem extent, ecosystem condition and ecosystem services and provides one perspective on monetary values of ecosystem services and ecosystem assets. Collectively this data set allows for broad scale assessment of trends in ecosystems and their services and supports the incorporation of ecosystem related data into standard economic reporting and analysis. These aspects emerge from the series of core ecosystem accounts, complementary accounts and other presentations described in Chapters 3 to 12. However, policy and analysis about the environment and human connection to it can be framed in many ways and is often not couched in a broad context but rather by considering specific environmental themes, such as biodiversity and climate change.

13.2 This chapter introduces ways in which the ecosystem accounting framework, together with other accounts from the SEEA Central Framework and the SNA, can be applied to support discussion and analysis from a thematic perspective. Section 13.2 describes some general principles in linking accounts and sections 13.3 to 13.6 present four examples of thematic accounting: biodiversity, climate change, oceans and urban areas. Each of these have been of wide-spread policy interest. Section 13.7 completes the discussion of ecosystem related accounts in detailing adaptations to the individual stock and flow accounts of the SEEA Central Framework that are required to support compilation of core ecosystem accounts and thematic accounts.

13.2 General principles of thematic accounting

13.3 All SEEA accounts, both in the Central Framework and in Ecosystem Accounting, build from the national accounting principles described in the SNA. While much focus is placed on the consistent approach to valuation concepts across these accounting frameworks, of more importance is the consistent application of rules and treatments concerning measurement boundaries and the use of consistent classifications. These features allow accounts from any of the three frameworks to be adapted to suit specific purposes and hence place relevant data in context. This section describes these features and how they can be used to develop thematic accounts.

13.4 Three features are of most significance in developing thematic accounts. First, it is essential to have a clearly agreed geographical area. In ecosystem accounting this is referred to as the ecosystem accounting area. At national level this will align with the concept in the SNA of economic territory, extending to include a country's exclusive economic zone. For thematic accounting a focus on a more targeted area may be appropriate – for example coastal and marine ecosystems in ocean accounting. Delineating this area allows for the relevant set of ecosystem assets, economic units and other entities to be appropriately attributed and the measurement focus of the accounts to be clearly defined and aligned with other accounts.

13.5 Second, it is necessary to have a set of entities that are the focus of accounting. In ecosystem accounting this focus is ecosystems, in the SNA this focus is economic units and in the SEEA Central Framework the focus is individual stocks and flows. Commonly, in a set of accounts a number of different types of entities will be integrated. Once the entities are selected, it is then appropriate to choose a classification. In ecosystem accounting, the relevant classifications concern ecosystem type and ecosystem services. In the SNA, the relevant classifications concern the classification of economic units by economic activity (ISIC) and institutional sector and also the classification of products. In the SEEA Central Framework, the classifications relate to details of specific individual stocks and flows, for example classifications of land, soil, minerals and energy resources and air pollutants. The selection of entities and their classification enables accounts to be structured to organise and present the relevant information for the theme.

13.6 Third, it is unlikely that in accounting for a theme a single account is sufficient. It is evident from the SEEA and SNA frameworks that multiple accounts are required to organise the relevant information – there is no single ecosystem account or economic account. The number of accounts developed to support discussion of a given theme will vary depending on the analytical questions and the data availability. Of importance, is that each account has relevance and merit in accounting terms in its own right by reflecting relevant accounting principles. For example, asset accounts will provide an opening and closing position and a full description of changes in the relevant stock. Supply and use accounts will balance the supply and use between two entities.

13.7 Collectively, links between the various accounts for a theme are possible within an accounting framing because of the use of a clearly delineated and consistently applied geographical boundary and consistent application of classifications for agreed entities. This will allow for the accounts for one theme to convey a coherent narrative. These features also allow for the derivation of consistent indicators and support the integration of data into models and other analytical tools.

13.8 For any given thematic account there is no *a priori* restriction on the geographical area, type of entity or classification that must be applied. However, it is likely to be advantageous to link the selection of geographical areas, definition of entities and classifications to existing information data and decision-making processes. This will allow existing data to be more readily incorporated and more importantly, will facilitate the use of data from the thematic account in decision making. Further, where common classifications can be used (e.g., concerning classification of ecosystem types, economic units) it will support (i) comparison of information across themes; and (ii) improved and streamlined data collection and reuse.

13.9 Note that the accounting principles themselves are equally applicable across different spatial scales and entities and are unaffected by the choice of classification. These choices should therefore be made with a focus on the use of the accounts, including the potential to compare results over time and in different locations.

13.10 In practice, thematic accounts are most likely to be developed in one of the following ways:

- By extending or adapting an existing account from the SEEA to provide additional detail or to use alternative classifications. For example, for the theme of forests it may be appropriate to compile adapted extent and condition accounts at the level of particular species and making distinctions between different types of land use and management arrangements.
- By focusing on a specific entity or group of entities and building associated accounts. For example, in accounting for the theme of climate change the likely core focus is on accounts for stocks and flows of carbon, and in accounting for the theme of biodiversity, it will likely be relevant to compile accounts for a target group of species or taxa.
- By focusing on a type of area that has specific management and policy relevance. Examples in this space include protected areas, urban areas and coastal and marine areas. Often there will be a link to some ecosystem types but the framing of thematic accounting will look beyond the ecosystem accounts to consider the relevance of other SEEA and SNA accounts in supporting the design of a more comprehensive data set.

13.11 Under each of these approaches, which themselves may be combined, there remains a need to specify the relevant geographical area for the set of thematic accounts. Thus, thematic accounts can be compiled at a national level, for large administrative regions within a country, or at relatively detailed landscape and catchment scales. Further, for some environmental themes the compilation of global scale accounts may be of relevance, for example for climate change or for the assessment of environmental and economic outcomes on the high seas, beyond national jurisdiction. Whatever scale is chosen, accounting designs can be adapted.

13.3 Accounting for biodiversity

13.3.1 Introduction

13.12 Achieving a coherence with existing national biodiversity objectives and associated international commitments will be fundamental if the SEEA EA is to support 'Accounting for Biodiversity' in a meaningful way. This will be a reciprocal process, in that the compilation of SEEA EA accounts will be using and integrating information from existing national and international biodiversity reporting frameworks, as well as delivering information to inform them. As such, the ministries responsible for the development of the National Biodiversity Strategy and Action Plans, delivering on the Convention on Biological Diversity (CBD) commitments and achieving other biodiversity objectives must be involved in the accounts design at an early stage. This will be essential for the SEEA EA to deliver an effective tool to support mainstreaming biodiversity into economic and other planning processes.

13.13 This subsection aims to support such cooperation by illustrating the role of the SEEA EA and national accounts when 'Accounting for Biodiversity'. This includes informing conservation and enhancement of biodiversity as an environmental management objective in its own right, as well as for securing ecosystem services supply. The subsection considers both the CBD emphasis on biological variability, as well as the array of different components of biodiversity valuable to society (e.g., natural ecosystems, pollinators, iconic species, threatened species and genetic material) and the links between economic activity and changes in biodiversity. This subsection also introduces one particular class of accounts, 'species accounts', demonstrating the potential of accounting approach to support co-ordination of data on biodiversity.

13.3.2 Using SEEA accounts to support assessment of biodiversity

13.14 The SEEA EA provides a link between biodiversity and economic activity by providing an articulation of the relationship between ecosystems, and the species that comprise them, and the SNA and non-SNA benefits that ecosystems provide. Description of this relationship is complemented by data from the SEEA Central Framework, where the focus is on tangible material and financial flows about the environment and the economy (e.g., provisioning ecosystem services, pollutant emissions, environmental protection expenditure). Accordingly, across this suite of accounts many aggregates and indicators are relevant to accounting for biodiversity. A non-exhaustive set of key indicators and aggregates are summarized in Table 13.1.

13.15 Supplementary accounts showing the extent of ecologically important areas that support significant biodiversity will also provide useful information to supplement the indicators presented in Table 13.1. These include areas determined by: policy designations such as concerning Ramsar wetlands or the European Union Habitat Directive areas, scientific determinations such as Key Biodiversity Areas (KBAs, including Alliance for Zero Extinction

(AZE) sites), and broad scale regional prioritizations such as biodiversity hot-spots identified by Conservation International. Similarly, compiling accounts showing the extent of important ecosystems for biodiversity in protected areas is a relatively straightforward step in identifying where biodiversity is most a risk and where the risk of biodiversity loss is managed. Ecosystem condition accounts track changes in several biodiversity indicators which can also be used to understand trends in biodiversity.

13.16 The physical and monetary values presented in ecosystem service flow accounts reveal to decision-makers the importance of different species and their diversity, particularly in relation to provisioning services[107], and ecosystems to economic activity and well-being. In this way, in some cases, data on ecosystem services can be used to make the case for investment in biodiversity conservation and restoration. Publicly available information on the multiple ways ecosystems support well-being can inform more holistic planning approaches. For example, by encouraging nature-based solutions that benefit multiple sectors, deliver better social outcomes and achieve conservation objectives.

Table 13.1: Linking SEEA accounts to biodiversity

Framework	Account	Aggregate / Indicator	Relevance
SEEA EA	Extent	Extent of Ecosystems	Trends in the extent of ecosystems important for biodiversity can be used to infer implications for species and species loss.[108] They also provide an insight into habitat loss, a key driver of biodiversity loss.
SEEA EA	Condition	Biotic characteristic indicators	These indicators distinguish ecosystem assets of higher biodiversity value. For example, identifying areas of grassland with high values for species-based indicators or patches of forest with 'good' structural characteristics. They can also provide indicators of where biodiversity threatened, based on trends or on indicators of poor condition (e.g., invasive species abundance).
SEEA EA	Condition	Abiotic characteristic indicators	These indicators can track where pressures on biodiversity may be manifesting (e.g., where pollutant concentrations are increasing). They can help highlight potential relationships between ecosystem degradation and species loss.
SEEA EA	Services	Physical Supply and Use	Aggregates for provisioning services can identify where overexploitation of biodiversity is occurring (e.g., where sustainable yields are being exceeded). This can also include illegal use, such a poaching, where sustainable yield may be zero.
SEEA Central Framework	Land Use	Areas of biodiversity impacting or enhancing activities	Data on land use and land use change allows information on spatial biodiversity loss to be linked to different sectors and economic activities.
SEEA Central Framework	Emissions Accounts	Spatially disaggregated emission flows	Emission flows can identify where pollutant pressures on biodiversity are likely to manifest. These insights are enhanced by (potentially) linking to spatially disaggregated accounts.
SEEA Central Framework	Environmental Protection Expenditure	Expenditure on biodiversity conservation and enhancement	Where these financial transactions can be linked to changes in ecosystem and species status or indicators of biodiversity at scale can have significant policy implications. In particular, they will be useful in understanding the ecological and economic benefits from

[107] See for example, (FAO, 2019).

[108] Even without ongoing species monitoring, the species-area curve can reasonably estimate species loss based only on change in ecosystem extent.

			public and private expenditure on the environment and biodiversity
SNA	Production and consumption	Monetary transactions involving biodiversity related goods and services	A number of monetary aggregates relevant to biodiversity exist in the SNA (e.g., provisioning services, wildlife tourism, recreational activities in nature). These aggregates can also be linked to the elements of biodiversity supporting their supply via the SEEA EA. They can also inform on the opportunity costs for biodiversity conservation (e.g., revenues foregone). They can also inform on monetary trade-offs / opportunity costs associated with different management approaches for biodiversity (conservation versus development)

13.17 Indicators for ecosystem resilience, insurance, option, existence and bequest values: It is also the case that some aspects of biodiversity that are essential to consider for development to proceed in balance with nature will not be well-reflected in ecosystem service flow accounts. Two major means by which biodiversity contributes to maintaining future ecosystem-service delivery are worth distinguishing here:

- The diversity of species constituting an ecosystem may be vital to the long-term maintenance of fundamental ecosystem processes (or 'ecological functions') underpinning services supply, particularly in the face of significant environmental fluctuation and/or change (e.g., climate change). This characteristic of ecosystems is often referred to as 'ecosystem resilience' and has an 'insurance value'.
- Elements of biodiversity (e.g., particular species) which may not provide services at present could be needed to provide these same services, or new services not yet envisaged, in the future. This is the concept of "option value" (Faith, 2018; Weitzman, 1992).

13.18 It is likely that assessment of ecosystem assets with respect to insurance and option values will need to be based on the assumption that the overall level of species diversity and abundance present within an ecosystem is a reasonable indicator. Accordingly, the ecosystem biotic condition indicators highlighted in Table 13.1 can be employed to reflect resilience and insurance values of ecosystem assets. Ideally, these indicators should be supported within additional indicators that reflect the diversity of ecosystem assets (and redundancy of the functional units) at scale.

13.19 Further, as noted in Chapter 6, society also places significant value on the continued existence of biodiversity for spiritual, religious or non-use reasons. Related to this are bequest values, associated with endowing future generations with adequate biodiversity. Services such as "Ecosystem and species appreciation services" are grounded in the biophysical characteristics of ecosystems but are hard to quantify in terms of a 'flow'. Thus, biophysical indicators will often need to be relied upon to reflect changes in the elements of biodiversity relevant to these types of values (e.g., natural ecosystem extent, as highlighted in Table 13.1). Indicators from the species accounts will also be highly relevant.

13.20 Combined presentations. A key advantage of the SEEA EA is that it adds an integrated systems approach to how the many existing indicators of biodiversity can support decision-making. Combined presentations of indicators for the different components of biodiversity with wider economic statistics is an immediate means of using information organized by the SEEA EA for mainstreaming biodiversity. Presenting trends for ecosystems of high biodiversity value in their economic context can assist in making informed decision-making for biodiversity conservation. For example, presenting the opportunity costs of conserving mangrove forests and their biodiversity in terms of forgone value from establishing shrimp farms as an alternative land use. In these ways, multiple stakeholders in biodiversity can be mobilized and more cost-efficient solutions for delivering on economic and environmental objectives realized.

13.21 The broad intention of using the SEEA EA as part of a biodiversity measurement and mainstreaming system is to inform macro level decision making, rather than detailed conservation planning. However, at landscape scales, government policies alone are often unable to resolve trade-offs or mobilize synergies that emerge between different stakeholders. There is clear potential for the SEEA EA to provide an effective, transparent and robust information system to inform sustainable development planning at these finer scales. In this way the SEEA EA can support integrated landscape management approaches that deliver multifunctional landscapes, building resilience to climate change and help reconcile trade-offs and recognize synergies across multiple users of ecosystem assets.

13.3.3 Role of species accounts in supporting decision making about biodiversity

13.22 In order to provide a more coherent picture on different components of biodiversity, species accounts may be compiled. Species accounts measure changes in species stocks (e.g., abundance), distribution or status / extinction risk over an accounting period.[109] Three possible, high level, species accounting concerns emerge: species important for ecosystem services; species of conservation concern; and, species important for ecosystem condition (or functioning).

13.23 The logic of accounting for abundance and/or persistence of species important for ecosystem services is well established in the context of provisioning services (such as concerning harvest of fish and timber) via the SEEA for Agriculture, Forestry and Fisheries (FAO & UNSD, 2020). Clearly, for species to be harvested on a sustainable basis, their stocks need to be quantified and assessed in the context of the supply and use of the services. Commercial fishery species are an obvious example here. There are also some regulating services where understanding the stocks of particular species groups is important for understanding the sustainability of ecosystem services supply, populations of pollinator species being an important example.

13.24 As highlighted previously, species accounts provide indicators for cultural ecosystem services that are challenging to measure. For instance, providing indicators for services involving relations to sacred plants, totemic animals or other species linked to spiritual, symbolic and artistic services. Species accounts will also provide useful indicators to represent elements of biodiversity that society assigns other types of existence or bequest values too (e.g., via ecosystem and species appreciation services).

13.25 Species accounts can also be relevant for informing on ecosystem condition (e.g., concerning ecosystem asset's compositional, functional and landscape/seascape characteristics). Finally, they can provide a structure to organize information and derive indicators of ecosystem condition (e.g., abundance indexes, such as the Living Planet Index, synthesis into Red Lists documenting extinction risk; or diversity indicators, such as the Shannon's or Simpsons Indexes); and to track the status of invasive species and infer where associated pressures on biodiversity may be manifesting.

13.26 Development of Species Accounts. The compilation of SEEA EA accounts will commonly be based on existing data and monitoring programs. This 'Direct Observation' approach may be informed by large sample surveys (such as national surveys), stock assessments for commercially valuable species or more focused efforts (e.g., Census of Protected Areas and

[109] It is highlighted that species assemblages are a defining characteristic of ecosystems, as such there is also a reciprocal relationship between species and ecosystem extent accounts.

nature reserves). Where sampling densities are sufficient and spatially referenced, species accounts can be aligned to ecosystem types and, potentially, ecosystem assets and integrated with information in the ecosystem accounts.

13.27 Where 'Direct Observation' data on species are limited, an alternative approach based on observations of changes in the spatial extent and configuration of habitat required by individual species or communities of species may be employed (UNEP-WCMC, 2016). More sophisticated measures of associated species status can also be applied to estimate species persistence or proportions of species retained in communities. In this way, a relationship between ecosystem extent, condition and services with species status can be made explicit in the SEEA EA.

13.28 The general structure for a species account is shown in Table 13.2. The structure reflects a typical 'asset account', and is similar to the ecosystem extent account. The scale at which the species account is compiled is flexible. However, in practice, it is likely that species accounts will be compiled at the scale of EAAs, either in aggregate or by ecosystem type. The columns in Table 13.2 organize information on selected species (e.g., lions, elephants, gazelle, etc.) or species groups (i.e., taxa, functional groups such as pollinators, etc.). An opening measure and a closing measure for each column is recorded for the accounting period. Additions and reductions to those measures also recorded due to natural, management or reappraisal reasons. For example, additions could be due to population growth, reintroductions / translocations and improved population data estimates in an EAA. Although it is recognised this information is unlikely to be available in many situations.

13.29 Ideally, the species' measures recorded in each of the columns of the account should be comparable and aggregable. However, the heterogeneous nature of species data, is likely to preclude this form of comparison in most cases (hence the need to specify measurement units for each column in Table 13.2). The most pragmatic approach is to aggregate species data by using a consistent reference level. This is the approach used for the Living Planet Index, where species measures are normalised against their value at a reference point in time (i.e., 1970) and their trends aggregated over time. This approach reflects the method described in Chapter 5, with respect to ecosystem condition indicators.

Table 13.2: Species account for an Ecosystem Accounting Area, ET within an EAA or EA

	Species or Species Group 1	Species or Species Group 2	Species or Species Group 3	Species or Species Group 4	Species or Species Group 5	Species or Species Group 6	Species or Species Group 7	Species or Species Group 8	Species or Species Group 9	Species or Species Group 10
UNITS OF MEASURE										
Opening measure										
Additions										
Natural										
Managed										
Upward reapprisals										
Reductions										
Natural										
Managed										
Downward reapprisals										
Net change										
Closing measure										

13.30 Adaptations of species and extent accounts. The strong emphasis on biological "variability" or "diversity" is clear in the CBD definition of biodiversity. Generally, the SEEA EA applies this definition of biodiversity at the scale of ecosystem assets (technically a measure of alpha diversity). However, from the CBD biodiversity perspective, it is also important to assess not only species-diversity within ecosystem assets (as just discussed) but also the genetic diversity of species and the diversity in species assemblages between ecosystem assets (i.e., variation in the composition of assemblages both within and between ecosystem types).

13.31 Genetic diversity is the variety of genes between and within species populations. Maintaining genetic diversity overall (i.e., a gene pool) is important for various commercial activities. For example, further development of crops or livestock that are well-adapted to different and changing conditions. There are also option values linked to gene pools associated with future medical applications or other bio-mimicry technologies and their development. As IPBES identifies, maintaining phylogenetic diversity is a key indicator for maintaining these gene pool option. Further, genetic diversity within species populations is also linked to the condition of those populations. As meta-populations become fragmented and individual populations isolated, exchanges of genetic material are restricted.

13.32 Although an application is yet to be developed, the basic framing of a species account shown in Table 13.2 could be adapted to support discussion of these issues by recording the abundance of phylogenetically diverse species or species groups (where phylogenetically diverse reflects measuring sets of species with different evolutionary histories). In addition, if the results can be presented with appropriate spatial detail, species accounts could be used to help track trans-locations of species where meta-populations become isolated (e.g., transfers of iconic species between protected areas).

13.33 Concerning species assemblages, the focus is on accounting for their complementarity. In this sense, complementarity (beta diversity, the diversity between two ecosystem assets) regulates how the richness (alpha diversity) of the species assemblage in an ecosystem asset combines to generate the species diversity at the whole, larger scale (gamma diversity). This concept is totally scalable, for example in relation to species assemblages in the root systems and canopies of individual trees to the pattern of species assemblages in landscapes.

13.34 Since different species, and species assemblages, will perform different functional roles and have varying degrees of resilience to different pressures, understanding complementarity is a key long-term concern if ambitions for resilient multi-functional landscapes are to be realized. This includes the maintenance of capacity for future ecosystem-service delivery at landscape (rather than ecosystem asset) scale.

13.35 Measures of the diversity of ecosystem types derived from the ecosystem extent accounts may help in quantifying gamma diversity in EAAs, particularly when the ecosystem typology provides a reasonable representation of the distribution of different species communities (e.g., when typologies are well linked to vegetation communities and habitats). However, this is unlikely to yield a satisfactory metric of the variation in species-level assemblages at scale in EAAs, particularly when rather broad ecosystem typologies are employed (as is often the case in ecosystem accounting). To support improved measurement in this area, extensions of the current ecosystem extent and condition accounts may be considered that speak to issues of variation across the compositional, structural and functional perspectives of ecosystems.

13.3.4 Potential biodiversity indicators

13.36 Thematic accounts for biodiversity set out a general accounting approach for using SEEA EA, associated entities and relevant ecosystem account areas to support decision making about biodiversity. Biodiversity indicators from existing national and international biodiversity reporting framework provide useful summary-level information on the state and condition of biodiversity in terms of ecosystem diversity and species diversity that not only are standalone in their own rights to support decision making, but also be useful integrated into core accounts of the SEEA EA for further compilation and analysis. Indicators on biodiversity for SEEA EA can be selected based on the following characteristics.

- Species distribution and population abundance
- Taxonomic diversity, which could be split into species richness and species composition.
- Habitat structure
- Disturbance regime
- Ecosystem extent and fragmentation
- Ecosystem composition by functional type
- Biodiversity footprints

13.4 Accounting for climate change

13.4.1 Role of accounting in supporting decision making about climate change

13.37 Climate change is one of the major global challenges of our time. Ecosystem accounting provides an important tool to understand the key role ecosystems play in greenhouse gas (GHG) cycling on global, national and regional scales that underpin the carbon concentration in the atmosphere. In addition, ecosystem accounting helps to understand the impact that climate change is having on ecosystems and biodiversity. SEEA as an integrated statistical framework thus can play an important role in supporting international and national policy discussions related to climate change. Furthermore, it can provide the underlying data that link climate change to other environmental topics – e.g., biodiversity, circular economy.

13.38 The SEEA EA accounts in combination with the accounts from the SEEA Central Framework and SNA can support various aspects of climate change policy – e.g., carbon stock assessment and management, carbon markets, linking air emissions and economic activity, recording and modelling climate change outcomes on ecosystems, ecosystem services and economic activity, sector based assessments (e.g., agriculture), ecosystem focused planning (e.g., peatlands), inform on the co-benefits of carbon projects and policies, impacts of mitigation responses

13.4.2 Applying the SEEA EA to inform climate policies

13.39 Several of the accounts from SEEA EA provide useful information to support climate change policies. This section describes how the ecosystem accounts can be used to inform on climate change. Furthermore, the carbon stock account is introduced, which brings together in a comprehensive framework all relevant carbon stocks and flows, including some flows not covered in the SEEA Central Framework or SEEA EA accounts like CO_2 and CH_4 emissions from ecosystems. Finally, some of the SEEA Central Framework accounts relevant for climate change and their relation with the SEEA EA accounts are briefly described.

SEEA EA accounts

13.40 The extent account shows the managed and unmanaged conversions in ecosystem types that directly underpin changes in carbon uptake and release from ecosystems. Data from extent accounts can therefore be linked to the assessment of GHG emissions arising from land use, land use change and forestry (LULUCF).

13.41 The condition account contains ecosystem characteristics and indicators that are highly relevant for climate change. Relevant physical state characteristics that that relate to carbon stored in ecosystems include carbon in biomass, soil organic carbon, etc. Carbon stock indicators for biomass provide a direct link to the carbon stock account described below. Condition indicators are also particularly relevant to describe the impact of climate change on ecosystems, for example the effects on local temperatures, rainfall patterns and ocean acidification.

13.42 The reference list for selected ecosystem services (Table 6.2) includes several ecosystem services that are particularly relevant for climate change policies. Global climate regulation services are the ecosystem contributions to the regulation of the concentrations of gases in the atmosphere that impact on global climate, primarily through the retention of carbon in ecosystems. The physical and monetary ecosystem service flow accounts (chapters 6, 7 and 9) show what ecosystem types play an important role in carbon sequestration and retention and how these change over time. Physical data on carbon retention and sequestration by ecosystem type are embodied in the carbon stock account described below.

13.43 Furthermore, there are several regulating ecosystem services that mitigate the effects of climate change. Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions. Examples include the evaporative cooling provided by urban trees and the contribution of trees in providing shade for livestock. Rainfall pattern regulation services are the ecosystem contributions of vegetation at the sub-continental scale, in particular forests, in maintaining rainfall patterns through evapotranspiration. Flood mitigation services, including both seawater surge and river flood mitigation, are the ecosystem contributions in the protection river banks and seashores and thus mitigating the impacts of floods on local communities. Storm mitigation services are the ecosystem contributions of vegetation, especially linear elements in the landscape, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities. The accounts indicate what ecosystem types are the main contributors to mitigating the effects of climate change, but also who the main beneficiaries are of these ecosystem services.

13.44 Finally, flows of several ecosystem services, including provisioning and cultural services, will be impacted by climate change e.g., water supply, biomass provision, recreation services etc, although isolating the precise contribution of climate change to the flows of ecosystem services is not the ambition in the accounts.

Carbon stock (and change in stock) account

13.45 Carbon has a central place in ecosystem and other environmental processes and hence accounting for carbon stocks and transfers between them is an important aspect of environmental-economic accounting. The carbon stock account provides a comprehensive overview of all relevant carbon stocks and flows on a national or sub national level.

13.46 Carbon stock accounts are closely linked to the SEEA EA accounts. The carbon stock account provides partial indicators of ecosystem condition such as net carbon balance and primary productivity. In addition, carbon accounts can also provide information to support measures of the ecosystem services of carbon sequestration and storage of carbon. Finally, they are also closely linked to accounts of the SEEA Central Framework (e.g., physical assets of fossil fuels an minerals, carbon emissions to air, physical product flows to and from the rest of the world).

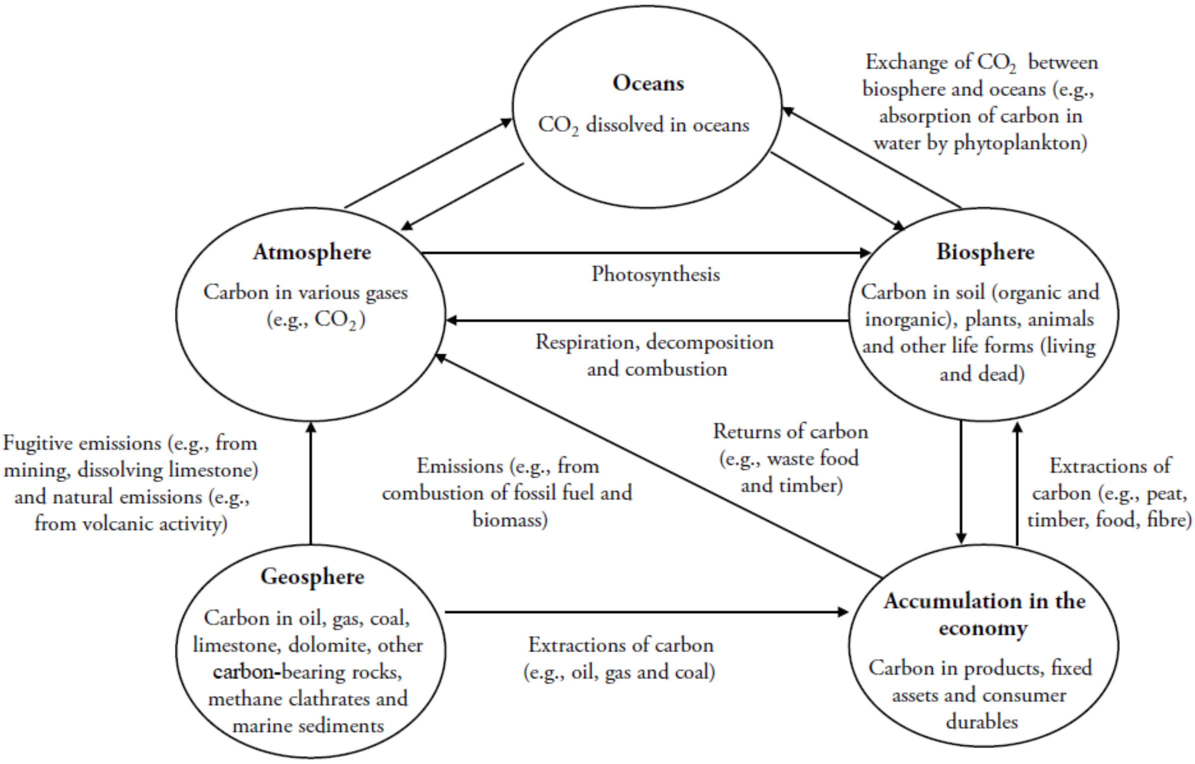
13.47 The measurement of stocks and flows of carbon can support discussion of many policy relevant issues. These issues include the analysis of greenhouse gas emissions, sources of energy, deforestation and land use change, loss of productivity and biomass, and sources and sinks of carbon emissions. For example, carbon stock accounts can complement the existing flow inventories developed under the United Nations Framework Convention on Climate Change and the Kyoto Protocol thereto. Since carbon is also a common focus of policy response, for example carbon taxes, its direct measurement is of high relevance.

13.48 Further, carbon stock accounts can provide consistent and comparable information for policies aimed at, for example, protecting and restoring natural ecosystems, that is, maintaining carbon stocks in the biosphere. Combined with measures of carbon carrying capacity and land-use history, biosphere carbon stock accounts can be used to:

- Investigate the depletion of carbon stocks and the resulting CO_2 emissions due to conversion of natural ecosystems to other land uses
- Prioritize use of land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration and improved land management, taking account of differing trade-offs in respect of food, fibre and wood production
- Identify land uses that result in carbon removal and storage

13.49 The fact that carbon plays an extensive role in the environment and the economy calls for a comprehensive approach to its measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon of the geosphere, the biosphere, the atmosphere, oceans and the economy. Figure 13.1 presents the main components of the carbon cycle. It is these stocks and flows that provide the context for carbon accounting. The same accounting principles can also be applied to account for other GHG including NO_x.

Figure 13.1: The main components of the carbon cycle



Source: SEEA 2012 EEA, Figure 4.1 (United Nations et al., 2014b).

13.50 The structure of a carbon stock account is presented in Table 13.3. 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, or reductions in, the stock. A more detailed description of the carbon account is provided in Annex 13.1.

13.51 Carbon stocks are disaggregated into: geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass), carbon in the oceans (carbon stored in seawater, can in sediments is part of biocarbon or geocarbon), carbon in the atmosphere and carbon accumulated in the economy.

13.52 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 unmanaged expansion and contraction. The net carbon balance equals addition to stock minus reductions in stock.

13.53 All values in the carbon stock account should be in equivalent carbon weights (e.g., ton carbon). Accordingly, methane (CH_4) and carbon dioxide (CO_2) emissions should be expressed in ton carbon, not in the actual mass of CH_4 and CO_2. Similarly, for products like recycled plastic or paper the equivalent carbon content should be determined, using the average composition of these materials to determine the carbon content. For emissions to the atmosphere, a bridge table may be compiled both in ton carbon and in CO2 equivalents, as the latter links to the SEEA Central Framework air emission accounts.

Table 13.3: Carbon stock account structure

	Geocarbon					Biocarbon			Carbon in the economy			Carbon in the seas	Carbon in the atmosphere	Total
	Oil	Gas	Coal	Limestone and marl	Other	Terrestrial	Freshwaters and saline wetlands	Marine	Inventories	Fixed assets, cosumer durables	Waste	Total	Total	
Opening stock														
Additions to stock														
Natural expansion														
Managed expansion														
Discoveries														
Upwards reappraisals														
Reclassifications														
Imports														
Reductions in stock														
Natural contraction														
Managed contraction														
Downwards reappraisals														
Reclassifications														
Exports														
Net carbon balance														
Closing stock														

GHG emission accounts

13.54 The SEEA Central Framework air emission account records the generation of air emissions by resident economic units by type of substance. These include the greenhouse gasses CO_2, CH_4, N_2O and the F gasses. All emissions by establishments and households as a result of production, consumption and accumulation processes are included.

13.55 Included in the scope the of SEEA Central Framework air emission accounts are emissions from cultivated livestock due to digestion (primarily methane), and emissions from soil as a consequence of cultivation, or other soil disturbances such as a result of construction or land clearance. Emissions from natural processes such as unintended forest and grassland fires, emissions from peatland, but also human metabolic processes are excluded. Emission from these sources, however are included in the carbon stock accounts.

13.56 In order to permit effective linking of physical flow data to monetary data, the physical flows of emissions should be classified using the same classifications used in the SNA. For household consumption, it is necessary to consider both the purpose of the consumption and the actual product being used by households. This requires consideration of data classified by COICOP (the Classification of Individual Consumption by Purpose) and using the Central Product Classification (CPC).

13.57 The GHG emissions by economic activities, as provided by SEEA, differ from the total emissions on a national territory or the emissions calculated according to the compilation guidelines of the IPCC. This is because different concepts and calculation methods underlie the different emission data. Bridge tables provide insight in the relations between the different emission concepts.

13.58 The emissions recorded for CO_2 end CH_4 in the SEEA Central Framework air emission account directly link to the uptake (managed expansion) of carbon by the atmosphere and release (managed contraction) of carbon by the economy as recorded in the carbon stock account.

Monetary accounts for climate change related transactions

13.59 The SEEA CF environmental activity accounts record transactions in monetary terms between economic units that may be considered environmental. Generally, these transactions concern activity undertaken to preserve and protect the environment. As well, there are a range of transactions, such as taxes and subsidies, that reflect efforts by governments, on behalf of society, to influence the behaviour of producers and consumers with respect to the environment.

13.60 Transactions in environmental activity accounts are classified by the classification for environmental activities (CEA). Two classes are particularly relevant for climate change: EP 1 Protection of ambient air and climate, which includes activities aimed at the control of emissions of greenhouse gases, and RM 10 Management of mineral and energy resources, which includes activities related to energy saving and renewable energy production. Selecting these classes from the accounts provides data on the mitigation costs for climate change, the economic benefits that result from the energy transition with regard to labour and the contribution to GDP.

13.4.3 Indicators derived from accounts concerning climate change

13.61 There is a wide range of indicators that may be derived from the various SEEA accounts concerning climate change. They can focus on linking levels of GHG emissions to levels of economic activity, presenting levels of GHG emissions from consumption and production perspectives and showing levels of expenditure on climate change related responses. The SEEA Applications and Extensions from provides a range of guidance in this area in particular concerning the potential to undertake relevant structural decomposition analysis and footprinting. There is also the potential for data from the accounts to support climate change modelling in terms of implications of projected climate change scenarios on economic activity.

13.62 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.

13.63 An indicator that can be derived from the carbon stock account is the ‘net carbon balance’. This indicator relates to the change in the stock of carbon in selected reservoirs over an accounting period. Commonly the focus of net carbon balance measures is on biocarbon but, depending on the analysis, the scope of the measure may also include parts of geocarbon, carbon in the economy and carbon in other reservoirs. There are also links that can be made to supporting the measurement of to SDG 13 “Take urgent action to combat climate change and its impacts”.

13.5 Accounting for the ocean

13.5.1 The role of accounting in supporting decision making about oceans

13.64 The ocean, earth's coastal and marine areas is large, deep and mostly unknown. Yet, it is an essential source of natural resources and its health is critical to the climate and global ecosystems. Demand for ocean space and resources, and associated anthropogenic pressures on ocean systems, are increasing rapidly. Fish stocks are increasingly over-exploited, while at the same time growing pollutant loads (including plastics, nutrients, CO_2 emissions) are impairing the capacity of these stocks to survive. There is concern, especially in Pacific Small Island Developing States that, not only fish depletion, but the growing impacts of climate change will decimate the livelihoods of coastal populations. The ocean is seen as a source of oil and minerals, yet this exploitation may risk the existence of ocean ecosystems that we have not yet discovered. Only about 20% of the ocean has been mapped in terms of depth (bathymetry), while only about 0.001% has been sampled in terms of seafloor cover and biota. Although concerns about ocean ecosystems may seem first in mind, others including currents, chemical and climatic processes are also being affected by human activities.

13.65 In recent years, a growing number of countries have established ambitious policies and programs designed to accelerate ocean-based development and conservation. Decision-makers are increasingly confronted with complex challenges and pressures to balance the social, environmental and economic interests of present and future generations. Many countries are embarking on ocean strategies, marine spatial planning and designating marine protected areas. In this context, an integrated and standardized set of accounts that record economic activity, social conditions, and environmental conditions empower decision-makers to make and justify balanced decisions for near-term policy and long-term sustainability.

13.66 At the global level, 2021 will mark the beginning of the Decade of Ocean Science,[110] declared by the International Ocean Commission of UNESCO; UN Oceans is in the process of updating the First Global Ocean Assessment;[111] the OCED is continuing to support the assessment of the ocean economy;[112] the High Level Panel for a Sustainable Ocean Economy[113] is developing an action agenda for transitioning to a sustainable ocean economy; and the IPCC recently released an assessment of the "Ocean and Cryosphere in a Changing Climate".[114] All of these initiatives have in common the need to integrate fragmented data and the objective of advising national governments on sustainable use of the ocean.

13.67 Conceptually, the ocean is included in the SNA, SEEA Central Framework and SEEA Ecosystem Accounting, at least to the limit of the exclusive economic zone (EEZ). However, information on the ocean is more fragmented than for terrestrial and freshwater areas. This requires a special focus to strengthen our understanding of the ocean, the governance of our activities that impact it, and the coordination of ocean data within and outside of national territories.

13.5.2 A set of ocean accounts

13.68 A comprehensive set of ocean accounts enables decision-makers to monitor several critical trends: (1) changes in ocean wealth, including produced assets (e.g., ports) and non-produced

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[110] https://en.unesco.org/ocean-decade

[111] https://www.unenvironment.org/resources/report/first-global-integrated-marine-assessment-world-ocean-assessment-i

[112] http://www.oecd.org/ocean/topics/ocean-economy/

[113] https://www.oceanpanel.org/about-the-panel

[114] "Cryosphere" refers to areas of water that are frozen for at least part of the year. See: https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf

assets (e.g., mangroves, coral reefs); (2) ocean-related income and welfare for different groups of people—e.g., income from fisheries for local communities; (3) ocean-based economic production—e.g., GDP from sectors deemed to be ocean-related; (4) changes in how oceans are governed and managed—e.g., ocean zoning, regulatory rules and responsibilities, and social circumstances.

13.69 These are important inputs to a range of ocean governance processes including marine spatial planning, integrated coastal zone management, development planning for ocean sectors, and collaborative resource management.

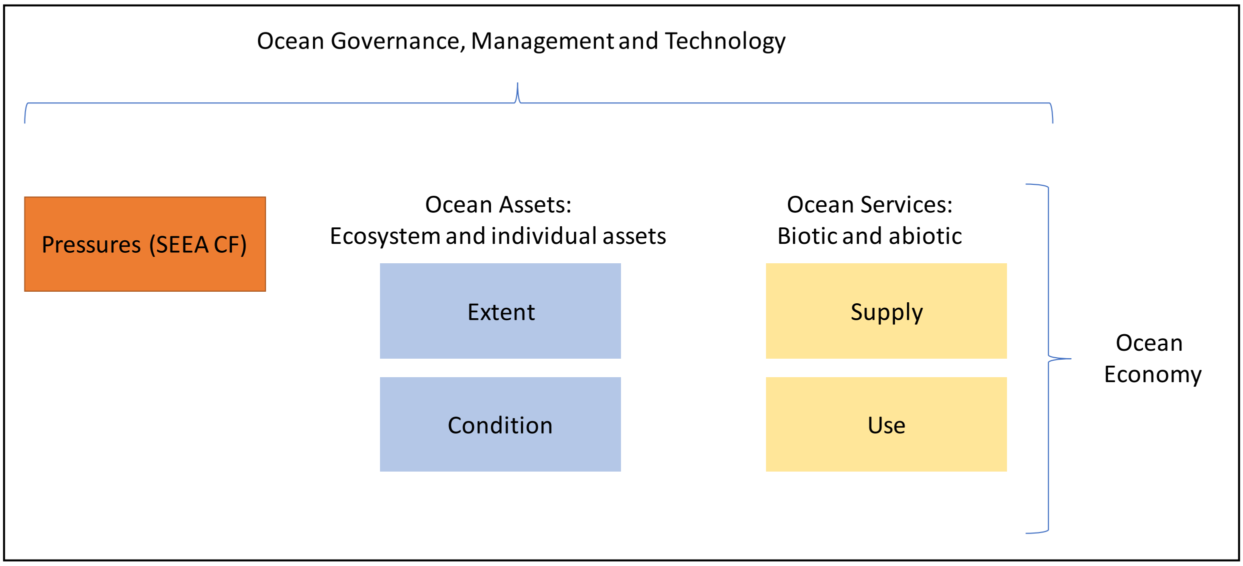
13.70 The Ocean Accounts Framework (Figure 13.2) builds on the components of the SEEA. Ocean accounts add the perspective of the ocean economy, governance, management and technology to the SNA and SEEA core accounts.

13.71 The SEEA Central Framework provides guidance on measuring **Pressures on the ocean**, particularly air emissions, water emissions and solid wastes. For ocean accounts, these are spatially detailed by catchment area to estimate the quantities flowing to the ocean.

13.72 **Ocean Assets** are a combination of accounts for individual environmental assets (minerals, energy and aquatic resources) from the SEEA Central Framework and ecosystem assets from the SEEA EA. Individual environmental assets are distinguished between terrestrial and marine and located spatially. This provides input to a separate calculation of Ocean Assets and changes in them.

13.73 Marine ecosystems are treated according to the SEEA EA. Extent and condition accounts describe the coastal and marine ecosystems. For transitional ecosystems, such as estuaries and tidal flats, applying the IUCN Global Ecosystem Typology (GET) provides a link to terrestrial and freshwater ecosystem accounts.

Figure 13.2: Simplified Ocean Accounts Framework



13.74 **Ocean services** include biotic ecosystem services, but also the abiotic (environmental) services obtained from, for example, mineral extraction and energy capture.

13.75 The ocean economy is the contribution of characteristic ocean-related activities (marine transportation, coastal tourism, marine fishing, offshore minerals and gas, etc.) to the national economy. At the core of **Ocean Economy Satellite Accounts** are the contribution to GDP and Gross Value Added (GVA) of the sectors already in the SNA. More detail is added from estimates of the proportions of sectors (shipping, boatbuilding, etc.) partially related to the ocean. Potentially, the economic value of ecosystem services not counted in these sectors (e.g., charitable contributions to ocean conservation organizations) could be added.

13.76 The objective of the **Ocean Governance Accounts** is to provide spatially-explicit (that is, by ecosystem type) summary information so that decision makers and planners can make the most effective decisions in ensuring the sustainable use of the ocean. It includes combined presentations of the elements mentioned above, but also explicit consideration of the institutional and legal frameworks such as zoning, rules and decision-making institutions, social circumstances of affected populations, and measures of ocean-related risk and resilience to them.

13.77 Much of the information required to compile ocean accounts is common to other communities of practice including marine spatial planning, disaster risk and climate change. One objective of the ocean accounting community[115] is to ensure that these common data are standardized and shared.

13.78 Terrestrial and freshwater ecosystems are largely within national jurisdictions. However, the ocean is mostly beyond national jurisdictions (ABNJ or Areas Beyond National Jurisdiction). This raises the opportunity to compile global ocean accounts, where much of the data are already collected by international agencies. A Global Ocean Data Inventory[116] was compiled by ESCAP and is organized using the components of the Ocean Accounts Framework. It shows that substantial data are available on ABNJ to compile ecosystem extent and condition accounts, but data on pressures, services, and beneficiaries are under-represented.

13.79 Adjacent coastal countries could also compile comparable Ocean Accounts to better understand transboundary impacts, including flows to and from ABNJ.

13.5.3 Indicators derived from ocean accounts

13.80 In terms of ecosystems, the ocean maybe viewed as a set of marine, coastal, and transitional ecosystem types and any indictors derivable from the SEEA EA can be derived for the ocean. By focusing on one biome, ocean accounts can provide specific indicators for ocean conditions such as acidification and concentrations of marine debris. As well, ocean accounts can provide indicators for ocean-related beneficiaries, such as income of small-scale fishers.

13.81 Linking to the SEEA Central Framework adds the capacity to include indicators of sub-national sources of pressures (such as solid waste supply and use by catchment area), separate accounts for individual environmental assets for the ocean (such as marine fish and offshore oil and gas), and for environmental protection and other expenditures on the ocean.

13.82 The ocean economy satellite accounting component provides means to calculate the contribution of ocean-related sectors to national economies. As well, the focus on governance adds indicators on actors/institutions, norms and behavioural relationships. For example, knowing the location of ocean assets, the degree to which they are used and the designated use of that area provides useful information for the management of that area. A listing of indicators derived from ocean accounts is presented in Annex 13.2.

[115] https://www.oceanaccounts.org/ and https://communities.unescap.org/environment-statistics/tools/regional-ocean-accounts-platform

[116] http://communities.unescap.org/system/files/global_ocean_data_inventory_v1.0_text_20191213_compressed.pdf

13.83 The Global Ocean Accounts Partnership has been working with several ocean-related communities of practice, including oceanographers and ocean ecologists to produce a draft set of "Core Ocean Statistics".

13.84 What may be of most interest to ecosystem accounting, are the scientifically supported statistics of ocean ecosystem condition, which are categorized by biodiversity, ecosystem fitness, biogeochemical cycling, physiochemical quality and GHG retention. These characteristics are represented by different metrics in different ecosystems (Table 13.4).

Table 13.4: Example Core Ocean Statistics for Category: Asset Condition: Biogeochemical Cycling (most common variables measured) (in progress)

Ecosystem type					
Coral reef (M1.3)	**Mangrove (MFT1.2)**	**Kelp forest (M1.2)**	**Salt marshes and estuaries (FM1 Transitional freshwater-marine)**	**Sediment (M1 marine shelf and M3 deep sea)**	**Open Ocean (M2 pelagic ocean)**
Nitrate concentration	Soil Nitrogen	Nitrate Concentration	Sediment Redox Potential	Nitrate Concentration	Thermocline
Total Alkalinity	Turbidity	Ammonium Concentration	Hypersalinity	Sulphate Concentration	Pycnocline
Offshore: Inshore DIC ratio	Sediment Accumulation: Sea Level Rise	Kelp Growth Rate	Inundation Depth	Sediment Redox Potential	Vertical Profile: Oxygen
Aragonite Saturation State	Particulate/Dissolved Organic C:N	Dissolved Oxygen Concentration	C:N Sediment ratios	Particulate/Dissolved Organic C:N	Vertical Profile: Nitrate
Dissolved Oxygen	Dissolved Oxygen	C13 Stable Isotopes	Submerged Plant Growth Form	Dissolved Oxygen	Vertical Profile: pH
pH (total scale)	Soil and Water pH	N15 Stable Isotopes		pH (total scale)	Vertical Profile: DIC

13.85 While seemingly complex, the broad palate of the Ocean Accounts Framework has proven effective in supporting several pilot studies, each of which has aimed to answer policy-relevant questions. The pilot studies in Samoa, Thailand and Viet Nam centred around sustainable tourism by linking tourism income, natural resources use, land-based pollution, and ecosystem impacts. China's pilot focused on developing harmonised mangrove maps as well as improving the understanding of environmental assets of the mangrove ecosystems in Beihai Bay, one of China's important marine ecological sites. Malaysia examined food security risk (i.e., fish) along the Straits of Malacca under expected future climate variability. All pilots depended on available and, often limited data. One important aspect of the Ocean Accounts Framework was to guide the search for and integration of the data.

13.6 Accounting for urban areas

13.6.1 Role of accounting in supporting decision making about urban areas

13.86 Urban areas can occur in most terrestrial settings—whether highland or lowland, in forest, grassland, desert, tropical or tundra regions. They are defined chiefly by the presence of people and by their alteration of the underlying environment. They consist of a wide array of heterogeneous materials. Combinations of buildings (e.g., low- and high-rises), impervious surface covers (e.g., roads and parking lots), vegetation (e.g., parks and sports fields), bare soil (empty lots and unattended garden plots) and water (e.g., wetlands and streams) are fundamental components of the urban ecosystem. Accounting for ecosystem assets and services in urban areas is of increasing importance considering the large and growing proportion of the world population living in cities.

13.87 Specific thematic accounts for urban areas can be developed to support inclusion of ecosystem considerations in policy and decision making. These urban ecosystem accounts would include the extent of urban ecosystem sub-types, with a particular focus on quantifying urban green and blue areas, and associated condition variables and indicators (e.g., urban tree canopy cover, urban air quality) and related services (e.g., local climate regulation, water regulation, nature-based recreation). These thematic accounts can be compiled for ecosystem accounting areas that cover all cities, a subset of cities (e.g., large cities) or individual cities, depending on policy needs.

13.88 Depending on the scale of underlying datasets and the aggregation level at which the accounts are compiled, urban ecosystem accounts can support various aspects of international, national, sub-national, and municipal level policy on urban areas such as strategic planning and policy setting; communication and awareness raising; economic accounting; urban planning including peri-urban and coastal development. The application of accounting could extend further to consider management of water resources, water treatment, regulating services (e.g., local climate regulation, air filtration, flood mitigation), renewable energy sources and management of recreational opportunities.

13.89 Urban ecosystem accounts with sufficient spatial detail (potentially down to property level resolutions) can provide data to support trade-off analysis or benefit-cost analysis for spatial planning and design of policy instruments such as ecosystem service users' charges. If ecosystem asset and condition mapping have sufficient resolution (e.g., individual tree canopy size and height) ecosystem accounts can also provide support for compliance monitoring and litigation of environmental damages (e.g., illegal tree felling).

13.6.2 A set of urban accounts

13.90 Urban ecosystems are an ecosystem type included in the SEEA EA ecosystem classification and changes in urban extent are tracked in aggregate relative to other ecosystem types in the ecosystem extent account. However, the compilation of a thematic account for urban areas provides the opportunity for a more detailed accounting for urban area sub-types with the broader framing provided by the IUCN Global Ecosystem Typology which defines a broad ecosystem functional group covering urban ecosystems (Class T7.4). This compilation follows the same general guidelines as ecosystem accounting more generally, including the development of extent, condition and services accounts. However, reporting on urban green and blue assets at a more detailed scale within the continuous urban extent can be seen as a distinguishing factor. Different boundaries and variable spatial resolutions of basic statistical units and reporting units can also be considered for thematic accounts, in order to address different purposes.

<u>Delineating the urban ecosystem accounting area (EAA) boundary and urban ecosystem types</u>

13.91 There are several approaches for defining the ecosystem accounting area for urban ecosystem accounts. Accounts can be compiled for cities based on administrative boundaries (i.e., local government boundary), functional boundaries (e.g., based on commuting flows as defined by census data), or morphological criteria, such as the extent of the built-up area plus a buffer zone. This selection will depend on the anticipated purpose and users of the urban accounts being compiled.

13.92 Urban areas often follow a gradient from less developed and even rural peripheral areas, into a more developed urban core. Even areas with a higher degree of built-up area may contain significant areas of urban green covers, such as yards, parks, cemeteries, street trees or green roofs. The two main approaches for the classification of urban areas into subtypes are (i) a landscape approach; or (ii) an individual asset approach.

13.93 Landscape approach: This approach disaggregates the entire urban area and categorizes larger patches with common characteristics, classifying these areas according to different urban sub-types. For example, a classification of urban sub-types would break down the variety of built-up and semi-natural types within the city into contiguous areas with common shared characteristics (e.g., compact high-rise, compact low-rise, open low-rise, sparsely built, paved as illustrated in Figure 13.3 and Figure 13.4). Following the landscape approach, information on condition characteristics (e.g., percentage of impervious/pervious surfaces, soil contaminant concentrations) could be included in the condition accounts as measures of landscape-level characteristics of these sub-classes. A landscape approach will tend to support municipal planning and zoning integrating across sector concerns.

13.94 Individual asset approach: This approach tracks various individual asset types at as fine a scale as possible (e.g., lines of street trees, playgrounds, allotment gardens, green roofs, drainage and storage systems, airsheds, etc.) based on available very high resolution (10 m or less) satellite imagery or other spatial data sets. In this case ecosystem assets in urban accounts can be defined as areas of green and blue infrastructure that provide ecosystem services. This approach also permits reporting on the condition of these green/blue assets in the associated condition accounts. An asset approach tends to support targeted thematic and sector policies specific to municipal sector agencies, such as urban forestry, urban agriculture, stormwater management.

Figure 13.3: Applying landscape approach for classifying urban ecosystems using Stewart & Oke (2009) local climate zone classification

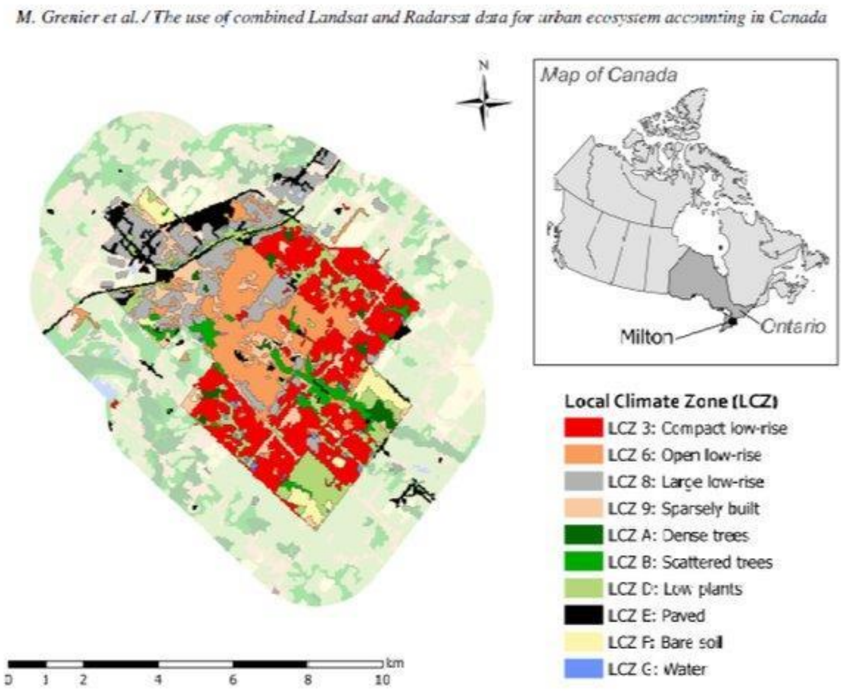
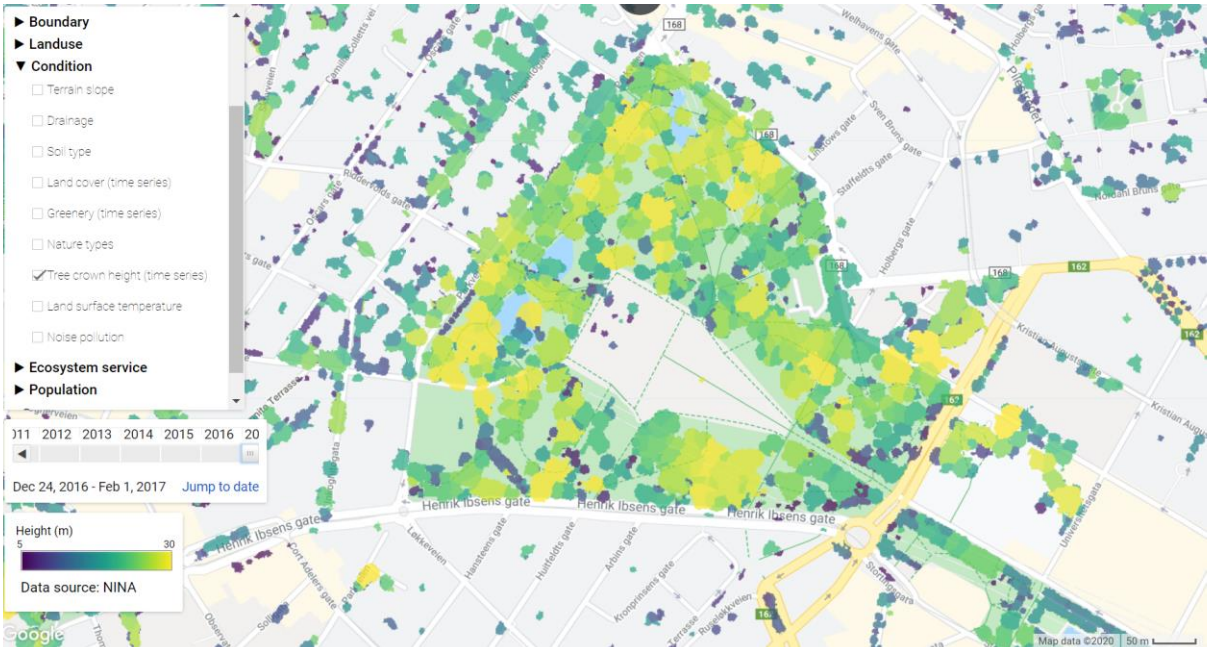


Fig. 1. Milton urban local climate zones – 2019.

Source: Grenier et al. (2020).

Figure 13.4: High resolution thematic focus mapping of urban tree canopy asset extent and height (condition)



Source: *Urban Nature Atlas Oslo*, n.d.

<u>Measuring the extent and condition of urban ecosystems</u>

13.95 The classification approach and level of aggregation will determine the distinction between extent accounts and condition accounts. Condition indicators that are predictors of urban ecosystem services should be selected. This does not prevent users from compiling thematic environmental quality and biodiversity indicators for other purposes. Extent table and condition table options following the landscape approach are shown in Table 13.5 and Table 13.6, whereas Table 13.7 provides an example of the individual asset approach.

13.96 The urban airshed above the accounting area should be considered an ecosystem asset, similarly to waterbodies. Air and water quality indicators for ecosystem accounting purposes should focus on predictors of recreation and amenity services.

<u>Measuring ecosystem services for urban ecosystems</u>

13.97 Urban ecosystem service supply and use accounts may focus on a different basket of ecosystem services, given the differing functions and conditions of urban ecosystems as the physical place people live and work. Some key ecosystem services that will likely be considered include: water regulation, local climate regulation, air filtration, noise regulation, recreation and amenity services (Table 13.8).

Table 13.5: Example – extent account presentation using landscape approach

	Example ecosystem types in urban areas													
	Urban/built-up type and example sub-classes						Natural and semi-natural types							Total EEZ
	Compact high-rise	Open high-rise	Compact low-rise	Open low-rise	Sparsely built	Paved	Cropland	Grassland	Shrubland	Forest	Barren	Wetland	Inland water	
Opening extent (km2)														
Additions to extent														
Reductions in extent														
Net change in extent														
Closing extent (km2)														

Table 13.6: Example – condition account presentation using landscape approach

		Example ecosystem types in urban areas																									
Example condition variables		Compact high-rise		Open high-rise		Compact low-rise		Open low-rise		Sparsely built		Paved		Cropland		Grassland		Shrubland		Forest		Barren		Wetland		Inland water	
Variables	Unit of measure	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock
Water quality	g/l																										
Air pollutant concentrations	ppm																										
Soil contaminant concentrations	g/kg																										
Soil sealing / Imperviousness	%																										
Greenness	%																										
Canopy cover	m^2																										
Street trees	km																										

Table 13.7: Example – extent account presentation using the individual asset approach

	Example ecosystem types and assets in urban areas																		
	Example urban ecosystem assets									Natural and semi-natural types								All other (grey) areas	**Total EEZ**
	Allotment garden	Street trees	Sports field	Playground	Cemetery or religious grounds	Public park or garden	Green roof	Private green space (e.g., yards)	Beach	Cropland	Grasslan d	Shrublan d	Forest	Barren	Wetland	Inland water	Total		
Opening extent (km2)																			
Additions to extent																			
Reductions in extent																			
Net change in extent																			
Closing extent (km2)																			

Table 13.8: Example – service account presentation using landscape approach

Example list of services	Unit of measure	Urban/built-up type and example sub-classes						Natural and semi-natural types							Total EEZ
		Compact high-rise	Open high-rise	Compact low-rise	Open low-rise	Sparsely built	Paved	Cropland	Grassland	Shrubland	Forest	Barren	Wetland	Inland water	
Provisioning services															
Crops															
Regulating services															
Water regulation															
Climate regulation															
Air filtration															
Noise regulation															
Cultural services															
Recreation															
Amenity services															

Other considerations

13.98 There are many important issues and limitations that should be considered in the measurement of urban ecosystem services that differ compared to other ecosystem types. For example, accurate change detection at the small spatial scales inherent in urban areas will be particularly important given that areas of change can be finer than the precision of the land cover classification used as input to ecosystem service models. Substitution possibilities between ecosystem services and man-made services may be more apparent in urban areas. As well, spatial patterns in urban ecosystem service supply are driven by biophysical variation in ecosystem conditions, while spatial variation in demand may not be detectable at the same resolution. Heterogeneous use factors—related to population density, socio-economic and cultural diversity in cities, as well as substitution possibilities, qualitative values and non-linear distance decay of benefits can result in variations in beneficiaries and valuation results, particularly for recreational and amenity services.

13.99 For applications at municipal levels, urban ecosystem accounts need to align closely with the way municipal environmental administration is organized in order to address both integrated and sector specific municipal policy and planning needs. For this reason, a combined landscape and asset approach will often be required.

13.100 In some situations, for example cost benefit analysis of zoning and user charges, monetary valuation of ecosystem service supply and use by landscape types and calculation of asset values is undertaken. Monetary accounts may also provide support for municipal budget allocation to asset investment and maintenance, taking care to be relevant for municipal policy agenda's such "green and blue infrastructure" and "nature-based solutions".

13.101 Where monetary valuation is undertaken for municipal level applications, higher temporal and spatial resolutions and change detection is required compared to the requirements for national level accounts. This may be addressed using different methods, for example by pooling data across a large number of decision-making units. With this in mind, monetary urban ecosystem accounts will therefore often need to be thematic and policy purpose specific (Gómez-Baggethun & Barton, 2013).

13.6.3 Potential indicators for urban ecosystems

13.102 Certain indicators can provide useful summary-level information on the state and condition of urban areas. For example, the change in extent of lands converted from natural or semi-natural ecosystem types to residential areas with associated infrastructures, tracked over time, provides a snapshot of urban expansion and ensuing loss of natural and semi-natural areas. Other related indicators could focus on the concept of land degradation (e.g., percentage of contaminated or brownfield areas and reclaimed areas). Indicators drawn from these accounts can also track the role urban green and blue spaces play in providing ecosystem services, including moderating air and water pollution and mitigating heat islands, and can support the measure of accessibility to green and blue spaces.

13.103 Thus, urban ecosystem accounts provide information that is relevant at many levels including for reporting internationally, nationally and at sub-national levels. For example, the change in extent and condition of lands converted to residential areas with associated infrastructures is relevant for SDG 15.3.1 Proportion of land that is degraded over total land area. As well, ecosystem accounting for urban areas is particularly relevant for SDG 11: Sustainable Cities and Communities, including for the following indicators (UN Habitat, n.d.; UNSD & UN Environment (UNEP), 2019):

- SDG 11.3.1 Ratio of land consumption rate to population growth rate SDG 11.4.1 "Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector and sponsorship)".
- SDG 11.6.2 Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted).
- SDG Target 11.7: By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.
- SDG target indicator 11.7.1: Average share of the built up area of cities that is open space for public use for all, by sex, age and persons with disabilities.
- SDG 11.7.1 (modified) Average share of the built up area of cities that is Blue Green space for public use for all, by income distribution, by sub-municipal area.

13.104 Beyond broad indicators, to support municipal planning and policy analysis purposes, such as equitable distribution of municipal (ecosystem) services, urban ecosystem accounts will need to disaggregate statistics to different administrative areas such as districts, councils, boroughs, census tracts.

13.7 Accounts for individual stocks and flows

13.7.1 Introduction

13.105 The SEEA Central Framework describes a range of different accounts for recording individual stocks and flows. There are two main types of account structures that are used – supply and use (or physical flow) accounts and asset accounts, both of which may be compiled in physical and monetary terms. This section provides a brief summary of these accounts and describes how they can be adapted to support compilation of core ecosystem accounts and thematic accounts.

13.7.2 Physical flow accounts

13.106 The general principles of physical flow accounts are described in SEEA Central Framework Chapter 3. Account structures for five physical flows are provided: water, energy, air emissions, emissions to water and solid waste. Depending on the type of substance, these accounts describe flows from the environment to the economy, within the economy, and from the economy to the environment. They are primarily designed to record the connections between each type of substance and various economic units and hence are well aligned with objectives, such as footprinting, where the use of specific substances can be traced through economic activities and products.

13.107 In concept, the principles of physical flow accounting can be used to record flows for all, elements, substances and materials. Examples include flows of nitrogen, phosphorus, heavy metals and carbon at an elemental level and economy-wide material flows (all measured in mass) at a macro scale. The main requirement in applying accounting principles is that the same unit of measure is applied within a single account – e.g., tonnes, cubic metres.

13.108 For SEEA Central Framework purposes the description has a focus on measuring flows for each substance at a national level and thus integrating with national level measures of economic activity. Macro indicators concerning issues such as water use in agriculture, energy use in manufacturing and air emissions from the transport industry are thus readily derivable.

13.109 For use in ecosystem and thematic accounting there will be a need to target the scope of the accounts described in the SEEA Central Framework to align with the requirements in terms of geographical area, spatial detail and economic units. For example, if there was interest in ocean accounting to understand emissions to marine areas, this flow account would follow the same general framing of the physical flow account for emissions to water but would require additional detail concerning the location of the emissions – i.e., providing a breakdown of the SEEA Central Framework entry for flows to the environment by location, e.g., by catchment (see SEEA Central Framework, Table 3.8). Additional detail might also be incorporated on the industries generating the releases to water and on the types of emissions.

13.7.3 Asset accounts

13.110 Asset accounts are described in SEEA Central Framework Chapter 5. They are presented for land use and land cover and for a range of natural resources including mineral and energy resources, soil resources, timber resources, fish and other aquatic resources and water resources. The general logic is to record, in physical or monetary terms, the opening and closing stocks of the relevant individual resource and then the various additions and reductions in stock, including regeneration and depletion. The relevant accounting identity is that the opening stock plus additions less reductions must equal to the closing stock.

13.111 For thematic accounting the principles of asset accounting are applied in the description of species accounts and carbon accounts in the sections above. The same principles can be applied to any individual stock to support both thematic and core ecosystem accounting. For example, an asset account for key fish species by location might be used to support compilation of ecosystem services accounts.

13.112 As for the physical flow accounts, having selected a single type of stock, the key requirement in applying asset accounting principles is establishing the geographical area to which the account relates. This may be small or large but needs to be clearly defined such that the focus of measurement is clear and that linkages can be made to other data. It may be relevant to cross-classify data on the opening and closing stocks by types of area within the wider accounting area. For example, stocks of carbon might be cross-classified by ecosystem type.

13.113 For ecosystem accounting purposes, in addition to carbon and species accounts, the primary asset account of relevance is the water resources asset account, described in SEEA Central Framework section 5.11. This account records the opening and closing stocks of water for various types of inland water bodies including lakes, rivers and streams and groundwater. It then records additions to the stock of water through precipitation, inflows and transfers between other water bodies and returns from the economy; and reductions due to abstraction by economic units, evaporations and outflows (e.g., to the sea) and transfers to other water bodies.

13.114 The stocks and flows recorded in the water resources asset account document comprehensively the hydrological cycle as it pertains to inland water resources. Flows related to wastewater are also captured. Since stocks and flows of water are important aspects in understanding ecosystem condition and ecosystem services, there is likely to be significantly relevance in the compilation of water resources asset accounts to support the compilation of ecosystem accounts.

13.115 The measurement challenge to overcome is the need for ecosystem accounting to have data compiled at a relatively high level of spatial detail. This is possible through standard hydrological modelling which is commonly used to underpin the measurement of a range of ecosystem services including water regulation, flood mitigation and soil erosion control. The task therefore is to adapt the framing provided in the SEEA Central Framework to suit a higher level of spatial detail – in particular incorporating more detail on transfers of water between different parts of a catchment or water body. Ecosystem account compilers are encouraged to work with hydrological modellers to compile detailed water resources asset accounts, in part because the accounts can be a useful tool in ensuring coherence in water modelling between opening and closing stock positions.

Annex 13.1: Carbon stock account

A13.1 The rationale for carbon stock accounting in the context of ecosystem accounting was discussed in section 13.4. The present annex provides some additional details on the structure and accounting entries related to the carbon stock account as presented in Table 13.3. The carbon stock account presented in that table provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and, in particular, the differences in the nature of specific carbon reservoirs. Opening and closing stocks of carbon are recorded, together with the various changes occurring between the beginning and end of the accounting period recorded as either additions to or reductions in the stock.

A13.2 Carbon stocks are disaggregated into geocarbon, biocarbon, carbon accumulated in the economy, carbon in the oceans (inorganic only) and carbon in the atmosphere.

A13.3 Geocarbon includes all carbon stored in the lithosphere, excluding all organic carbon stored in dead biomass.[117] Basically, carbon that is part of the Earth's lithosphere is considered as geocarbon (or geological carbon: carbon present in the Earth's bedrock and sediments, primarily from marine sediment deposits), as well as carbon formed originally in the Earth's biosphere millions of years ago, that, after geological metamorphosis due to high pressure and temperatures in the Earth's crust, was transformed into e.g., oil and gas (organic geocarbon). Organic carbon in soils and in peat deposits is included in biocarbon.[118] Where the information generated from the accounts is policy-focused, the priority should be given to reporting those stocks that are being impacted by human activity (e.g., fossil fuels).

A13.4 Biocarbon includes all organic carbon in the biosphere, i.e., carbon in living biomass (plants and animals) and dead biomass (soil organic matter and sedimentary organic matter)[119] Biocarbon includes biomass in crops, grass in meadows, which is thus not considered as carbon accumulated in the economy. Carbon stored in livestock, however, is considered as part of 'carbon in the economy'.

A13.5 Biocarbon is classified by type of ecosystem, at the highest level according to the three main realms of the Global Ecosystem Typology (marine, freshwaters and saline wetlands, terrestrial). This high-level classification can be further broken-down using level 3 of the IUCN GET. Furthermore, it is recommended to separately record on at the highest-level carbon in agricultural systems, to allow the distinction between carbon uptake and release between natural and semi natural ecosystems and agricultural; ecosystems.

A13.6 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 millenniums, 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.

A13.7 The atmosphere contains carbon mainly in the form of CO2 and methane. The atmosphere is a receiving environment with regard to carbon from the primary reservoirs geocarbon and

[117] Geocarbon is further disaggregated into oil, gas, coal resources, rocks (primarily limestone and marls), and minerals, e.g., carbonate rocks used in cement production, methane clathrates and inorganic carbon in marine sediments

[118] Soil is the layer of fine material covering the Earth's land surface influenced by and influencing plants and soil organisms.

[119] For biocarbon in soils, for practical reasons only the top 30 cm were included in this study. In particular for peat and peaty soils, this results in a strong underestimation of the total stock of biocarbon in soils. This shortcoming in the current models also potentially influences C flows in the case of water table changes exceeding this depth.

biocarbon but also from emissions from carbon used in the economy. On the other hand, carbon uptake from the atmosphere may take place by carbon sequestration in biocarbon. As CO2 and methane act as greenhouse gasses in the atmosphere, accounting for these flows is highly policy relevant.

A13.8 The oceans are the receiving environments for carbon released from primary reservoirs and for from its accumulations in the economy. Carbon in oceans includes only inorganic carbon: carbonates dissolved in seawater. Living and non-living organic carbon in oceans are part of biocarbon. Carbonate particulates (e.g., shells) in sediments are part of geocarbon.

A13.9 Accumulations in the economy, which are the stocks of carbon in anthropogenic products, are further disaggregated into the following SNA components: fixed assets (e.g., concrete in buildings, bitumen in roads, livestock); inventories (e.g., petroleum products in storage, excluding those included in agricultural ecosystems); consumer durables (e.g., wood and plastic products); and waste. In turn, these main asset categories can be further disaggregated into biobased (i.e., derived from plants or animals) and non-biobased (i.e., fossil fuels, mineral (inorganic) products and synthetic materials (plastics)). Accounting for waste follows the conventions of the SEEA Central Framework, where waste products (e.g., disposed plastic and wood and paper products) stored in controlled landfill sites are treated as part of the economy.

A13.10 The flows of carbon that occur within the economy are very significant and essential for understanding the interaction between economy and environment. The level at which geocarbon and biocarbon stock changes can be linked to the economy will determine the policy usefulness of the carbon stock account. This is particularly relevant in cases where raw materials can be extracted from more than one ecosystem type (e.g., biomass fuel from natural ecosystems or agricultural ecosystems; meat from agricultural ecosystems or semi-natural ecosystems) or from geocarbon reservoirs with different carbon contents and emissions profiles.

A13.11 Carbon stored through geo-sequestration (i.e., the managed injecting of gaseous CO2 into the surface of the Earth) is treated similarly, as a flow within the economy (resulting in an increase in accumulations). Any subsequent release of carbon to the environment is treated as a residual flow with a reduction in accumulations in the economy matched by a corresponding increase in carbon in the atmosphere.

A13.12 The presentation of the row entries in the account follows the basic form of the asset account in the SEEA Central Framework; the entries being opening stock, additions, reductions and closing stock. Additions to and reductions in stock have been split between managed and natural expansion and contraction. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account.

A13.13 There are five types of additions in the carbon stock account:

- Unmanaged expansion, which reflects increases in the stock of carbon over an accounting period due to natural growth or the indirect effects of human activities. Effectively, this will be recorded 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 fertilization effect (where higher atmospheric CO_2 concentrations cause faster plant growth).

- Managed expansion, which reflects increases in the stock of carbon over an accounting period due to direct human activities. This will be recorded for biocarbon in ecosystems and accumulations in the economy, in inventories, consumer durables, fixed assets and waste stored in controlled landfill sites, and also includes greenhouse gases injected into the earth. Basically, these reflect all increases in carbon stock due to carbon input flows from other reservoirs which are directly related to human activities.

- Discoveries of new stock, encompassing the emergence of new resources added to a stock, which commonly arise through exploration and evaluation. This applies exclusively to geocarbon.
- Reclassifications of carbon stocks, which will generally occur in situations where an ecosystem asset is used for a different purpose. For example, increases in carbon in semi-natural ecosystems following the establishment of a national park on an area previously used for agriculture would be offset by an equivalent decrease in agricultural ecosystems. In this case, it is only the particular land use that has changed, that is, reclassifications may have no impact on the total physical quantity of carbon during the period in which they occur.
- Imports are recorded to enable accounting for imports of produced goods (e.g., petroleum products) that contain carbon.

A13.14 There are five types of reductions recorded in the carbon stock account:

- Unmanaged contractions, which reflect natural 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. Unmanaged contraction includes losses from episodic events including drought, some fires and floods, and pest and disease attacks, and also includes losses due to volcanic eruptions, tidal waves and hurricanes.
- Managed contractions, which are reductions in stock due to direct 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 is recorded net of those quantities of stock that are immediately returned to the environment after extraction because they are unwanted—for example, felling 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.
- Reclassifications of carbon stocks, which generally occur in situations where another environmental asset is used for a different purpose. For example, decreases in carbon in agricultural ecosystems following the establishment of a national park on an area used for agriculture would be offset by an equivalent increase in semi-natural ecosystems. In this case, it is only the particular land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon during the period in which they occur.
- Exports are recorded to enable accounting for exports of produced goods (e.g., petroleum products) that contain carbon.
- Catastrophic losses, which are not shown as a single entry but are allocated between managed contraction and unmanaged contraction. Catastrophic losses in managed contraction would include fires deliberately lit to reduce the risk of uncontrolled fires. 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.

Annex 13.2: Indicators derived from Ocean accounts

	Ocean-related biomes [Note h]										
	SM1 Subterranean tidal biome	FM1 Transitional waters biome (Freshwater Marine)	M1 Marine shelf biome	M2 Pelagic ocean waters biome	M3 Deep sea floors biome	M4 Anthropogenic marine biome	MT1 Shorelines biome	MT2 Supralittoral coastal biome	MT3 Anthropogenic shorelines biome	MFT1 Brackish tidal biome	Total
Physical ocean assets											
Ecosystem assets											
Area (ha)											
Change in area from previous accounting period (%)											
Individual environmental assets											
Minerals (tonnes)											
Energy (PJ)											
Fish (tonnes)											
Timber (e.g., mangrove) (m^3)											
Other flora available for harvesting (e.g., seaweed) (tonnes dry weight)											
Monetary ocean assets (NPV of expected flow of services) (currency units)											
Ecosystem assets											
Value (currency units)											
Change in value from previous accounting period (%)											
Individual environmental assets											
Minerals											
Energy											
Fish											
Timber (e.g., mangrove)											
Other flora available for harvesting (e.g., seaweed)											
Condition of ocean assets [Note a]											
For ocean ecosystems											
Acidification (pH)											
Eutrophication (BOD, COD, Chlorophyll-A concentrations)											
Temperature (°C)											
Plastics density (g/m^3)											
Biodiversity (Shannon index)											
Health (index)											
For individual environmental assets											
Minerals (quality, accessibility)											
Energy (quality, accessibility)											
Fish (quality in terms of size, age, health)											
Timber (e.g., mangrove) (quality, accessibility)											
Other flora available for harvesting (e.g., seaweed) (quality, health)											
Physical ocean services											
Ocean ecosystem services											
As in SEEA-EA services list (specific units)											
Other ocean services (examples)											
Seawater for cooling (m^3)											
Sand (tonnes)											
Petroleum (megalitres, PJ)											
Monetary ocean services											
Ocean ecosystem services											
As in SEEA-EA services list (appropriate valuation techniques)											

	Ocean-related biomes [Note h]										
	SM1 Subterranean tidal biome	FM1 Transitional waters biome (Freshwater Marine)	M1 Marine shelf biome	M2 Pelagic ocean waters biome	M3 Deep sea floors biome	M4 Anthropogenic marine biome	MT1 Shorelines biome	MT2 Supralittoral coastal biome	MT3 Anthropogenic shorelines biome	MFT1 Brackish tidal biome	Total
Other ocean services (examples)											
Seawater for cooling (market or equivalent value)											
Sand (market or equivalent value)											
Petroleum (market or equivalent value)											
Pressures (Flows to the environment) [Note b]											
Water emissions flows to the ocean											
BOD/COD (tonnes)											
Suspended solids (tonnes)											
Bilge (m^3)											
Heavy metals (tonnes)											
Solid waste flows to the ocean											
Chemical and health care waste (tonnes)											
Metallic waste (tonnes)											
Mineral waste and soil (tonnes)											
Mixed residential and commercial waste (tonnes)											
Plastics (tonnes)											
Radioactive waste (tonnes)											
Other waste (tonnes)											
Wastewater flows to the ocean (m^3)											
Air emissions flows to the ocean (examples) [Note c]											
CO_2 (tonnes)											
Methane (tonnes)											
Ocean economy											
Contribution of ocean sectors to the national economy (GVA, %GDP) [Note d]											
By sector (fishing/aquaculture, offshore oil and gas, boat and ship building, etc.)											
Contribution of ocean sectors to the national employment (FTE, %)											
By sector (fishing/aquaculture, offshore oil and gas, boat and ship building, etc.)											
Ocean governance											
Zoning											
Jurisdictional zone: internal waters, territorial sea, EEZ (area)											
Management or planning zone: protected area, private property, use designation (area) [Note e]											
Rules and decision-making institutions											
By activity: fishing, wind farm development, marine spatial planning (institution)											
Social circumstances of resident populations (examples) [Note f]											
Health (index), economic equity (GINI), poverty (% below low income)											
Risk and resilience (examples)											
Flood/storm surge, sea level rise, coastal storm risk (vulnerability, occurrence)											
Resilience: disaster plan in place, adequate supplies and facilities (yes/no)											
Environmental protection expenditures ($)											

	Ocean-related biomes [Note h]										
	SM1 Subterranean tidal biome	FM1 Transitional waters biome (Freshwater Marine)	M1 Marine shelf biome	M2 Pelagic ocean waters biome	M3 Deep sea floors biome	M4 Anthropogenic marine biome	MT1 Shorelines biome	MT2 Supralittoral coastal biome	MT3 Anthropogenic shorelines biome	MFT1 Brackish tidal biome	Total
Value of environmental goods and services sector ($, see Ocean Economy) [Note g]											
Environmental taxes less subsidies ($)											

Notes:

a: The Technical Guidance for Ocean Accounting provides specific condition indicators for each ecosystem type.

b: should account generation by terrestrial catchment area, marine sources, inflows from other territories, outflows to other territories (including international waters)

c: air emissions should be estimates of quantities deposited in the ocean, distinguished by national and international territory

d: OAF provides a comprehensive list of ocean-related sectors. Economic activities could be located by ecosystem type.

e: Other examples of "use designation" is aquaculture, energy development, submarine cable corridor, locally managed marine area, etc.)

f: Resident population includes those dependent on the ocean economy and those living near the ocean.

g: the environmental goods and services sector may be embedded in the Ocean Economy as ocean dependent sectors. It may also be distinct if disaggregated from national EG&S surveys.

h: Indicators may be presented for larger groupings or in more detail by ocean-related Ecosystem Functional Units. Note there may be vertical overlap of some of the biomes (e.g., subterranean tidal biomes with shoreline biomes). In this case, ideally, the indicators would be presented separately for the intersection of those biomes (e.g., subterranean below shoreline).

14 Indicators and combined presentations

14.1 Introduction

14.1 Given the variety of analytical and policy contexts that are present around the world, it is to be expected that people will consider combining accounts in different ways, or more commonly, focus on combining a subset of accounts that are most relevant for their specific needs. This is perfectly appropriate and should not be seen as suggesting that other combinations of accounting information for different applications or policy framings are inferior or irrelevant. In all cases, there is a need to ensure fitness for purpose both in terms of the accounting integration and the quality of the data required.

14.2 This chapter describes a range of ways in which data from the ecosystem accounts can be combined with other environmental-economic accounting data and national accounting data to demonstrate the links between the economy and the environment and to compare trends over time. Section 14.2 provides a general introduction to the development of combined presentations in which data from different accounts are presented alongside each other. These presentations may be particularly relevant in the derivation of indicators.

14.3 The most common entry point to accounting data is via the lens of indicators that summarize accounting data and convey trends on topics of specific policy relevance. There is a wide array of environmental and sustainability related indicators that have been, in most cases not based on data that has been filtered through an accounting framework. Sections 14.3 and 14.4 explain approaches to the development of aggregates and indicators that can be derived from the ecosystem accounts with a particular focus on the links to reporting on progress towards various global environmental goals.

14.2 Combined presentations for ecosystem accounting

14.2.1 Introduction

14.4 Combined presentations are a way of showing changes in stocks and flows of ecosystems in the context of standard measures of economic activity, without undertaking a valuation of ecosystem services and ecosystem assets in monetary terms. There is room for considerable flexibility in the design of combined presentations. The following sub-sections describe common areas of interest rather than an exhaustive list. While they do not encompass a full integration of information in accounting terms, they can support a more informed discussion of the relationship between ecosystems and economic activity in a manner that takes into account spatial and environmental contexts. Further, they may help support the presentation of indicators for monitoring trends in ecosystem-related outcomes.

14.2.2 Information on environmental activities

14.5 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 on relevant economic activity is organized to refer to the same spatial areas and/or ecosystem types, this would facilitate the monitoring of the effect of expenditures on changes in ecosystems.[120] For example, information may be combined showing expenditure to restore coastal wetlands with associated changes in ecosystem condition and associated ecosystem services linked to improved ecosystem condition.

14.6 As defined in the SEEA Central Framework,[121] environmental activities are economic activities that have a primary purpose of either environmental protection (the prevention, reduction and elimination of pollution and other forms of degradation); or resource management (preserving and maintaining the stock of natural resources).

14.7 Over time, information gathered on the actual expenditure on restoring ecosystem assets might be complemented by information on flows of ecosystem services, through which a more complete picture of the relationships between ecosystem condition and ecosystem services could emerge. Further, links may be made to analysis of positive and negative externalities, ecosystem disservices and the extent to which expenditures and other policy responses are reducing any negative effects. Indeed, one of the key roles of the ecosystem accounting model is to facilitate the organization of these types of information and thereby furnish support for more detailed analyses in the future.

14.8 The compilation of targeted statistics on the production of ecosystem related environmental goods and services, using the framework of the environmental goods and services sector (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 related to ecosystems and biodiversity (sometimes called the biodiversity economy).

14.2.3 Information on environmental pressures

14.9 Following the same logic as described for environmental expenditures, data concerning environmental pressures such as air emissions, emissions to water and solid waste, may be compared to ecosystem accounting data on ecosystem condition or flows of ecosystem services. The recording of data on environmental pressures such as those just listed is described in the SEEA Central Framework, Chapter 3. Importantly, using a SEEA based recording allows for presentation of the source of the pressure (e.g., emitting industry) to be recorded, in turn supporting the analysis of externalities. To support effective combination and interpretation the information on environmental pressures should be compiled at a sub-national scale that aligns with the ecosystem assets of interest.

14.2.4 Economic dependence on ecosystems

14.10 Although the focus of ecosystem accounting is on the 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. For example, it may be of interest to understand the dependency of current measures of agricultural production on ecosystem service such as pollination. Such dependency measures could be focused around the direct impact (e.g., GDP 'at risk' in the absence of the pollination service), but may also take indirect (or supply chain) effects into account by measuring multiplier effects within the economy, using the extended supply and use table described in Chapter 11. In situation where the total

[120] It may be difficult to allocate survey data collected at national level to specific ecosystem assets. Thus, it may be necessary to consider alternative approaches to collecting site specific expenditures, for example through administrative sources.
[121] For details see the SEEA Central Framework, Chapter 4.

value of ecosystem services (expressed as percentage of GDP) is low, it is possible that economic dependency could still be very high.

14.11 It should be accepted that the allocation of economic activity to sub-national spatial areas (such as administrative regions, or catchments) can be conceptually difficult. 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. Further economic connections may also be identified by tracing supply chains – a topic discussed below in relation to extended supply and use tables.

14.2.5 Information on policy instruments

14.12 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. From a general environmental management perspective a comparison of environmental expenditures and environmentally related revenues may be of interest.

14.3 Indicators derived from the SEEA EA

14.3.1 Introduction

14.13 A clear understanding of the environment-economy nexus is critical for a wide range of today's policy questions and global policy initiatives, including the 2030 Agenda for Sustainable Development, Post-2020 Global Biodiversity Framework, Paris Agreement and more, particularly with regard to informing synergies and trade-offs with regard to policy formulation. However, today's policy questions require an understanding of the relationship between the environment and economy that goes beyond information on individual environmental assets (e.g., timber, energy etc.). Increasingly, policy makers are defining sustainability in ways that also incorporate ecosystems and the services they provide to humanity

14.14 These sections describe how information from ecosystem accounts and related accounts can be organized and integrated to provide policy-relevant indicators and aggregates. This is the focus of section 12.4. Section 12.5 reviews how ecosystem accounts can contribute global monitoring frameworks (e.g., SDGs, post-2020 global biodiversity framework) and a range of other indicator frameworks and applications.

14.3.2 Roles and functions of SEEA EA indicators

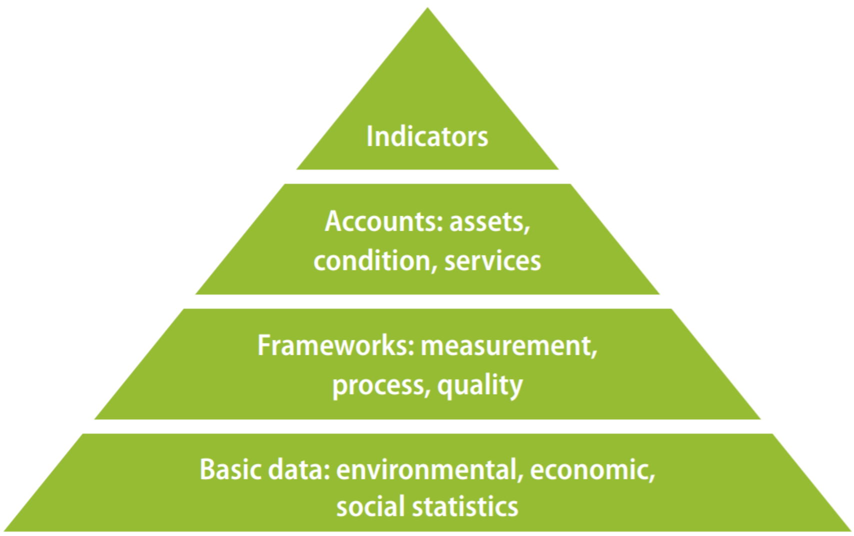
14.15 A statistical indicator is the representation of statistical data for a specified time, place or any other relevant characteristic, corrected for at least one dimension (usually size) so as to allow for meaningful comparisons. It is a summary measure related to a key issue or phenomenon and derived from a series of observed facts. Indicators can be used to reveal relative positions or show positive or negative change in a regular interval. Indicators are usually a direct input into national and global policies. In strategic policy fields, they are important for setting targets and monitoring their achievement. By themselves, indicators do not necessarily contain all aspects of development or change, but they greatly contribute to explaining them. If consistent methodology is employed, they allow comparisons over time and between, for instance, countries and regions, and in this way assist in gathering 'evidence' for decision making.

14.16 Statistical indicators can serve many purposes, depending on the scale at which they are applied, the target audience, and the quality of the underlying data. Indicators derived from the SEEA EA are useful tools for tracking progress with regards to ecosystems and biodiversity and for mainstreaming these issues into public policy. In doing so, these indicators can help promote the sustainable use of ecosystems and ecosystem services.

14.17 The target audience of SEEA EA indicators usually comprise decision and policy makers in business and government, non-governmental organizations, environmental economists, ecologists, academia and the general public. Thus, it is important that any indicators derived from the SEEA EA are consistent, coherent, and accurately synthesize the underlying data, but are also understandable and meaningful to non-statisticians. SEEA EA indicators must therefore be statistically accurate as well as being straightforward and user-friendly. Indicators derived from the SEEA EA should therefore be seen as summary measures which are fit-for-purpose and are embedded within larger information systems (e.g., accounting frameworks, databases, monitoring systems and models) following consistent methodologies and workflows.

14.18 The relationship between different types of information within the context of the SEEA EA is shown in Figure 14.1. The base of the pyramid comprises a full range of basic statistics and data from various sources including surveys, scientific measurements, administrative entities and censuses. Generally, these data are collected for several purposes and utilize different scopes, frequencies, definitions and classifications.

Figure 14.1: Information pyramid



Source: United Nations et al. (2017), Figure 2.1.

14.19 The role of the SEEA EA is to integrate those data to provide a coherent and unified understanding of ecosystems and their relationship to the economy. This means that compilers of SEEA EA accounts must reconcile and merge data from disparate sources, taking into account differences in scope, frequency, definition and classification, as appropriate. Once the data have been integrated within a single framework, indicators can be derived that provide insights into the changes in composition or structure of the specific concept of interest, changes in relationships between ecosystem stocks and flows, and other features, taking advantage of underlying relationships between the accounts.

14.20 Just as a myriad of indicators such as GDP, national saving and national wealth all emerge from a single national accounts framework, so too can a wide range of indicators be derived from the SEEA EA. Moreover, the use of an accounting framework such as the SEEA EA provides significant benefits to the resulting indicators. These benefits include:

- Providing a stable conceptual framework that allows for new indicators to be developed from a coherent source to respond to new policy demands while also allowing for improvements in data collection and methods.
- Providing a broad framework such that different indicators can be seen in context and, as necessary, summary information conveyed in the indicator can be disaggregated to better understand the reasons for change.
- Allowing analysis, including forecasting and projections to build from the same coherent source data as the indicators.
- Support the derivation of early estimates using various assumptions based on benchmark data from the accounting system.

14.21 While indicators can be sourced directly from basic statistics, using an accounting framework necessitates reconciling and harmonizing the underlying data, which results in coherent and consistent indicators. This has the potential to better clarify the demand and priority needs for data – which can better link policy needs to data generation -thereby creating a more sustainable and linked data to decision structure. Further, the alignment of the SEEA EA with the SNA facilitates a consistency between economic and environmental information which ensures the robustness of the indicators sourced from accounts.

14.22 Three main types of indicators are considered:

- Aggregates are statistics for related categories that can be grouped together or aggregated in order to provide a broader picture. Thus, an aggregate is the combination of related categories, usually within a common branch of a hierarchy, to provide information at a broader level to that at which detailed observations are taken. In accounting, the aggregation is usually completed by simple addition, for example summing the areas of ecosystem types across an ecosystem accounting area.
- Composite indices in which different variables are combined using a weighting pattern or aggregation rule to communicate the overall movement or trend. In the SEEA EA, an example of a composite index are measures of ecosystem condition which involve weighting together relevant ecosystem condition indicators.
- Ratio indicators derived by combining data from different accounts, for example the flows of ecosystem services per hectare from different ecosystem types.

14.3.3 Indicators from the ecosystem accounts

14.23 Information from ecosystem accounts can be organized and integrated to provide policy-relevant indicators and aggregates. This section provides an overview of aggregates and indicators that can be derived from the core accounts and some of the thematic accounts. It also highlights the relevant indicators in the SDGs and the post-2020 global biodiversity framework that can be directly derived from each of the ecosystem and thematic accounts.

14.24 Majority of indicators presented in this section are output indicators that can be directly generated from the SEEA EA accounts for tracking national and global progress. It also contains indicators that have been developed and implemented by the scientific communities, but nevertheless can be derived from the ecosystem or thematic accounts using additional further compilation and analysis.

14.25 Considering the underpinning spatial framework of the SEEA EA and its integration with the SNA, indicators from each ecosystem and thematic account have the potential to crosswalk with other accounts and socio-economic measures to provide integrated measures on the inter-connectiveness and linkage for a range of topics, such as adjusted macro-economic measures, costs of restoration, ecosystem capacity, etc. Thus, indicators from the SEEA EA could also be designed to address distributional and environmental justice issues. Aggregation and disaggregation to administrative units would respond to this ambition.

14.26 Indicators from ecosystem extent accounts. The ecosystem extent account describes the extent of the various ecosystem types presented in an accounting area and how the extent changes within the accounting period. The ecosystem types are based on the IUCN Global Ecosystem Typology (GET), which provides a top level of 4 realms, a 2nd level of 24 biomes and a 3rd level of 89 ecosystem functional groups. Depending on the application, alternative aggregations may be developed to align with the reporting requirements at the national and international level.

Table 14.1: Potential indicators on ecosystem extent

Extent indicators	Spatial unit	Disaggregation	Unit of measurement
Percentage of ecosystem accounting area covered by specific types, including: urban areas (IUCN GET T7.4) agricultural areas (IUCN GET T7.1, T7.2, T7.3) forests (IUCN GET T1, T2) wetlands (IUCN GET F1, F2, TF1, FM1, MFT1)	Ecosystem accounting area	Ecosystem type	Hectares; % of opening
Change of area covered by specific ecosystem types during an accounting period, including: urban areas (IUCN GET T7.4) agricultural areas (IUCN GET T7.1, T7.2, T7.3) forests (IUCN GET T1, T2) wetlands (IUCN GET F1, F2, TF1, FM1, MFT1)	Ecosystem accounting area	Ecosystem type	%
Percentage of area unchanged (opening stock – reduction),	Ecosystem accounting area	Ecosystem type	Hectares; % of opening
Percentage of area changed (additions + reductions),	Ecosystem accounting area	Ecosystem type	Hectares; % of opening

14.27 Indicators from ecosystem condition accounts. The ecosystem condition account records data on the state and functioning of ecosystem area within an ecosystem accounting area using a combination of relevant variables and indicators. The selected variables and indicators reflect changes over time in the key characteristics of each ecosystem asset. Ecosystem condition accounts are compiled in physical terms. Ecosystem condition indexes and sub-indexes are composite indicators that are aggregated from (ecosystem condition indicators. The use of compatible reference levels (e.g., through a common reference condition) underpins the aggregation process. Many condition indicators are developed and implemented by the scientific communities that can be integrated into the condition accounts of the SEEA EA for further aggregation.

Table 14.2: Potential indicators on ecosystem condition

Ecosystem condition indicators	Further description	Spatial unit	Disaggregation	Unit of measurement
Overall ecosystem condition index		Ecosystem accounting area	Ecosystem type, ecosystem condition classes	Index
Physical state indicator	Overall physical state characteristics of an ecosystem asset (including characteristics on soil structure, water availability)	Ecosystem type	Ecosystem condition sub-classes	Index
Chemical state indicator	Overall chemical state characteristics of an ecosystem asset (including characteristics on soil nutrient levels, water quality, air pollutant concentrations)	Ecosystem type	Ecosystem condition sub-classes	Index
Compositional state indicator	Overall compositional state characteristics of an ecosystem asset (including characteristics on species diversity)	Ecosystem type	Ecosystem condition sub-classes	Index
Structural state indicator	Overall compositional state characteristics of an ecosystem asset (including characteristics on vegetation, biomass, food chains)	Ecosystem type	Ecosystem condition sub-classes	Index
Functional state indicator	Overall functional state characteristics on an ecosystem asset (including characteristics on ecosystem process, disturbances regimes)	Ecosystem type	Ecosystem condition sub-classes	Index
Landscape / seascape indicator	Overall characteristics on landscape (including landscape diversity, connectivity fragmentation, embedded semi-natural elements in farmland)	Ecosystem type	Ecosystem condition sub-classes	Index

14.28 Indicators from the physical ecosystem services flow account. The physical ecosystem services flow accounts describe the ecosystem services generated by ecosystem asset in volume terms. The ecosystem services are classified as provisioning, regulating and maintenance, and cultural services. Indicators from the accounts commonly focus on measuring the supply side of ecosystem service flows in physical units such as cubic metres and tonnes, but quantification of ecosystem contributions can also take place through a focus on the use of ecosystem services.

Table 14.3: Potential indicators on physical ecosystem services flows

Physical ecosystem services flow indicators	Further description	Spatial unit	Disaggregation	Unit of measurement

Amount of biomass generated	Biomass provisioning services	Ecosystem accounting area	Ecosystem type; Type of biomass	Tonnes
Water abstracted for use by household and industry (proxy measure)	Water supply services	Ecosystem accounting area	Ecosystem type	Cubic metres
Tonnes of carbon retained (captured and stored/trend in the carbon sequestered)	Global climate regulation services	Ecosystem accounting area	Ecosystem type	Tonnes
Tonnes of airborne pollutants captured (e.g., PM10; PM2.5)	Air filtration services	Ecosystem accounting area	Ecosystem type; type of pollutant	Tonnes
Tonnes of waterborne pollutants removed (e.g., chemical oxygen demand) from wastewater	Water purification services	Ecosystem accounting area	Ecosystem type, type of pollutant	Tonnes
Number of properties/ km of coast/shoreline/riparian zone protected; change in degree of risk	Flood mitigation services	Ecosystem accounting area	Ecosystem type	Count/km
Number of tourist/recreation visits	Recreation-related services	Ecosystem accounting area	Ecosystem type	Count

14.29 Indicators from the monetary ecosystem services flow account and ecosystem asset account. The monetary ecosystem services flow accounts describe the ecosystem services generated by the ecosystem asset in monetary term. The monetary ecosystem asset account describes the opening and closing monetary value of ecosystem assets over an accounting based on the net present value of the bundles of ecosystem services, under their current use/institutional regime. When compiled for multiple years, the asset account identifies the share of the cost of degradation and /or enhancement (e.g., restoration) of ecosystem assets that can be identified by exchange value.

Table 14.4: Potential indicators on monetary ecosystem services flows account and ecosystem asset accounts

Monetary indicators	Further description	Spatial unit	Disaggregation	Unit of measurement
Gross Ecosystem Product (GEP)	The economic value added of all ecosystem services generated	Ecosystem accounting area	Ecosystem type, ecosystem services classes	Local currency
Value of ecosystem services linked to industry value added	Value added of industries with direct inputs of ecosystem services	Ecosystem accounting area	Ecosystem type	Percentage
Monetary ecosystem asset value		Ecosystem accounting area	Ecosystem type, per capita by administrative areas, planning areas	Local currency
Ecosystem asset value as a percentage of total national wealth		Ecosystem accounting area	Ecosystem type	Percentage

Cost of degradation		Ecosystem accounting area	Ecosystem type, per capita by administrative areas, planning areas	Local currency

14.3.4 Indicators from thematic accounts

14.30 The SEEA EA Chapter 13 provides an introduction to a range of thematic accounts covering biodiversity, climate change, oceans and urban areas. In each of these themes various data are brought together within an accounting umbrella and demonstrate the potential of the suite of SEEA accounts, including those of the SEEA Central Framework, to provide a broad range of data to support discussion of these and other themes. In addition to the above-mentioned accounts, thematic accounts on protected areas and the expenditure accounts from the SEEA Central Framework can support the derivation of related headline indicators for SDGs and post-2020 global biodiversity framework.

14.31 In the discussion of each theme there is a short description of indicators relevant to that theme that can be drawn from the accounts. In addition, on the theme of biodiversity the discussion in Section 14.4 on the links between SEEA EA and global monitoring frameworks highlights relevant connections.

14.4 Indicator frameworks and the SEEA EA

14.4.1 SEEA EA and global indicator monitoring frameworks

14.32 The approach of the SEEA enables countries to adopt a holistic and integrated approach to develop sets of indicators to support the implementation, monitoring and reporting of sustainable development agenda and post-2020 global biodiversity framework. The United Nations Statistical Commission at its 51st Session in March 2020 "*welcomed the background document on interlinkages …… and stressed the importance of the System of Environmental Economic Accounting for monitoring the Goals*".[122] At the same session it "*stressed the importance of the SEEA Experimental Ecosystem Accounting in supplying a common measurement framework for the post-2020 global biodiversity framework and related indicators that are currently being negotiated and are expected to be adopted at the fifteenth meeting of the Conference of Parties to the Convention on Biological Diversity*".[123]

14.33 Post-2020 Global Biodiversity Framework. The post-2020 global biodiversity framework builds on the Strategic Plan for Biodiversity 2011-2020 and sets out an ambitious plan to implement broad-based action to bring about a transformation in society's relationship with biodiversity and to ensure that, by 2050, the shared vision of living in harmony with nature is fulfilled. The framework has four long-term goals for 2050 related to the 2050 Vision for Biodiversity. Each of these goals has an associated outcome for 2030. The framework also has 20 action-oriented targets for 2030 which will contribute to the outcome-oriented goals for 2030 and 2050. Under each goals and targets, there are a set of components and monitoring elements to be monitored in assessing progress towards them.

14.34 The SEEA can support the post-2020 global biodiversity framework as it focuses on measuring ecosystems diversity, their extent, condition and services generated while also helps make

[122] E/2020/24, E/CN.3/2020/37, 51/101, para (g)

[123] E/2020/24, E/CN.3/2020/37, 51/110, para (c)

the case for protecting and conserving biodiversity by providing a full picture of its connection to the economy. In particular, the information generated by the SEEA can be used to inform biodiversity policies in an integrated and holistic manner and develop indicators for monitoring progress toward the biodiversity target. It also plays an important role in streamlining reporting requirement by countries through the adoption of a common framework. This can, in turn, also facilitate better integration between national target tracking and global target tracking.

14.35 Table 14.5 and Table 14.6 list potential headline indicators for a selected set of 2050 Goals and 2030 Targets, which can be compiled from SEEA based accounts and are potentially available via global database.

Table 14.5: Potential indicators for the 2050 Goals (incl. links to related SDG indicators)

Goal	Potential SEEA Indicators
A. The area, connectivity and integrity of natural ecosystems increased by at least [X%] supporting healthy and resilient populations of all species while reducing the number of species that are threatened by [X%] and maintaining genetic diversity	Extent of selected natural ecosystems (forest, savannas and grasslands, wetlands, mangroves, saltmarshes, coral reef, seagrass) (Link to SDG 6.6.1, 11.3.1, 15.1.1)
	Biomass of selected natural ecosystems (forest, savannas and grasslands, wetlands, mangroves, saltmarshes, coral reef, seagrass)
	Red List Index (Link to SDG 15.5.1)
B. Nature's contributions to people have been valued, maintained or enhanced through conservation and sustainable use, supporting the global development agenda for the benefit of all people	The economic value added of all ecosystem services generated (Gross Ecosystem Product)
	Tonnes of carbon retained (captured and stored/trend in the carbon sequestered) in natural ecosystem
D. Means of implementation is available to achieve all goals and targets of the Framework	Government expenditure on protection of ecosystem, biodiversity and landscape

Table 14.6: Potential indicators for the 2030 Targets (incl. links to related SDG indicators)

Target	Potential SEEA Indicators
1. By 2030, [50%] of land and sea areas globally are under spatial planning addressing land/sea use change, retaining most of the existing intact and wilderness areas, and allow to restore [X%] of degraded freshwater, marine and terrestrial natural ecosystems and connectivity among them	Proportion of land that is degraded over total land area (SDG 15.3.1)
2. By 2030, protect and conserve through well connected and effective system of protected areas and other effective area-based conservation measures at least 30% of the planet with the focus on areas particularly important for biodiversity	Coverage of key biodiversity areas by terrestrial protected areas (Link to SDG 14.5.1, 15.1.2 and 15.4.1)
	Coverage of key biodiversity aeras by protected areas in relation to marine areas (SDG 14.5.1)
3. By 2030, ensure active management actions to enable wild species of fauna and flora recovery and conservation, and reduce human-wildlife conflict by [X%].	Red List Index (Link to SDG 15.5.1)
4. By 2030, ensure that the harvesting, trade and use of wild species of fauna and flora, is legal, at sustainable levels and safe.	Proportion of fish caught within biologically sustainable levels (Link to SDG 14.4.1)
5. By 2030, manage, and where possible control, pathways for the introduction of invasive alien species, achieving [50%] reduction in the rate of new introductions, and control or eradicate invasive alien species to eliminate or reduce their impacts, including in at least [50%] of priority sites.	Adoption of relevant national legislation and adequately resourcing the prevention or control of invasive alien species (Link to 15.8.1)
6. By 2030, reduce pollution from all sources, including reducing excess nutrients [by x%], biocides [by x%], plastic waste [by x%] to levels that are not harmful to biodiversity and ecosystem functions and human health	Proportion of bodies of water with good ambient water quality (SDG 6.3.2)
	Hazardous waste generated per capita (SDG 12.4.2a)
7. By 2030, increase contributions to climate change mitigation adaption and disaster risk reduction from nature-based solutions and ecosystems based approached, ensuring resilience and minimising any negative impacts on biodiversity	Tonnes of carbon retained (captured and stored/trend in the carbon sequestrated) in natural ecosystems
	Number of properties/area of coast protected (coastal protection services) by nature ecosystem.
9. By 2030, support the productivity, sustainability and resilience of biodiversity in agricultural and other managed ecosystems through conservation and sustainable use of such ecosystems, reducing productivity gaps by at least [50%].	Increase yield of crops from pollination
10. By 2030, ensure that, nature based solutions and ecosystem approach contribute to regulation of air quality, hazards and extreme events and quality and quantity of water for at least [XXX million] people.	Tonnes of nitrogen and phosphorus removed from wastewater
	Tonnes of airborne pollutants captured by natural ecosystem
11. By 2030, increase benefits from biodiversity and green/blue spaces for human health and well-being, including the proportion of people with access to such spaces by at least [100%], especially for urban dwellers	Share of green spaces over of the built-up area of cities (Link to SDG 11.7.1)
13. By 2030, integrate biodiversity values into policies, regulations, planning, development processes, poverty reduction strategies and accounts at all levels, ensuring that biodiversity values are mainstreamed across all sectors and integrated into assessments of environmental impacts	Integration of biodiversity into national accounting and reporting systems, defined as implementation of the System of Environmental Economic Accounting (SDG 15.9.1b)

15. By 2030, eliminate unsustainable consumption patterns, ensuring people everywhere understand and appreciate the value of biodiversity, make responsible choices commensurate with 2050 biodiversity vision, taking into account individual and national cultural and socioeconomic condition	Material footprint per capita (SDG 8.4.1, 12.2.1)
	Domestic material consumption per capita (SDG 8.4.1, 12.2.1)

14.36 Sustainable Development Goals. The 2030 Agenda for Sustainable Development was adopted by all United Nations Member States in 2015. It is built around 17 Sustainable Development Goals (SDGs) and 169 targets that represent an ambitious plan for achieving sustainable development and serves as the basis for countries to shape their national policies and priorities. At the heart of the agenda is the recognition that true development must combine economic growth and poverty alleviation with strategies that improve health and education, reduce inequality, while addressing climate change and protecting nature. Thus, the interlinked nature of the SDGs calls for an integrated approach to policy decisions. As the international statistical standard for measuring the environment and its relationship with the economy, the SEEA is well positioned to support integrated policies based on a better understanding of the interactions and trade-offs between the environment and economy.

14.37 Progress toward the 17 goals and 169 targets of the 2030 Agenda are monitored through 244 indicators, entailing the collection of substantial amounts of data. The UN Statistical Commission (UNSC) has encouraged the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs), the body tasked with developing and implementing the global indicator framework for the 2030 Agenda, to consider existing standards and frameworks that can improve SDG monitoring, including the SEEA. Recently, the CBD Secretariat, UN Environment and the UN Statistics Division brought a proposal on upgrading the status of Indicator 15.9.1 to the tenth meeting of the IAEG-SDGs, where the group agreed to the proposal and reclassified the indicator from Tier III to Tier II.

14.38 The systems approach of the SEEA make it an ideal framework for directly measuring several SDG indicators and provide supplemental information for numerous others. The United Nations Commission of Experts on Environmental-Economic Accounting (UNCEEA) has spent considerable effort to align the SEEA framework with the SDGs and currently 40 indicators for nine Sustainable Development Goals can be evaluated using SEEA data. Out of the 40 indicators, the UNEP-WCMC & UNSD (2019) assessment of linkages between global indicators and the SEEA, identified a list of 21 indicators, as shown in table 3, that have full alignment with the SEEA, where the SEEA has obvious potential to provide all, or most, of the information required to calculate the indicator or when the indicator clearly represents an input data for an accounting item of interest

Table 14.7: SDG indicators that have full alignment with the SEEA

SDG indicators
6.3.1 - Proportion of wastewater safely treated
6.3.2 - Proportion of bodies of water with good ambient water quality
6.4.1 - Change in water-use efficiency over time
6.4.2 - Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
6.6.1 - Change in the extent of water-related ecosystems over time

8.9.1 - Tourism direct GDP as a proportion of total GDP and in growth rate
11.3.1 Ratio of land consumption rate to population growth rate
11.7.1 Average share of built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities
14.1.1 - Index of coastal eutrophication and floating plastic debris density
14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations
14.4.1 - Proportion of fish stocks within biologically sustainable levels
14.5.1 - Coverage of protected areas in relation to marine areas
14.7.1 - Sustainable fisheries as a proportion of GDP in small island developing States, least developed countries and all countries
15.1.1 - Forest area as a proportion of total land area
15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
15.2.1 - Progress towards sustainable forest management
15.3.1 - Proportion of land that is degraded over total land area
15.4.1 - Coverage by protected areas of important sites for mountain biodiversity
15.4.2- Mountain Green Cover Index
15.5.1 - Red List Index
15.8.1 - Adoption of relevant national legislation and adequately resourcing the prevention or control of invasive alien species
15.9.1 - Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020

14.4.2 Other indicators and applications

14.39 National indicator initiatives. In addition to supporting the reporting of the global indicator initiatives, the approach of the SEEA EA also enables countries to adopt a holistic and integrated approach to develop sets of indicators to support the reporting on progress towards national commitments, policies or strategy. The spatially explicit information generation of SEEA EA enables the effective targeting of policy efforts at both national and sub-national level and across terrestrial, freshwaters and marine areas. The modular and flexible approach allows countries to compiled SEEA EA indicators based on national priorities and data availability.

14.40 The connectivity and coherence of information sourced from the accounts of the SEEA EA Framework and its flexible approach are particularly important when the indicators are designed to support national policies related to sustainable development and conservation of ecosystem and biodiversity.

14.41 National Indicators that benefit most from having their foundation in the SEEA EA include those relate to:

- Contribution of ecosystems and their services to the economy, social wellbeing, jobs and livelihoods
- The condition and health of ecosystems and biodiversity changing over time and the main areas of degradation and enhancement
- Management of natural resources and ecosystems to ensure continued services and benefits such as energy, food supply, water supply, flood control, carbon storage and recreation opportunity
- Progress towards targeted conservation efforts
- Expenditure and the development of economic instrument on nature conservation
- Estimation of a nation's wealth and economic potential once the state of nature is considered
- Assessment of government performance on sustainable development

14.42 The design and implementation of the SEEA EA indicator to support national policy requires strategic planning and the establishment of appropriate institutional mechanisms and arrangements for the ongoing compilation of accounts and subsequent calculation of target indicators. Ultimately, the design implementation of the national indicator monitoring framework should aim to define a coordinated, long term, national programme of work involving a range of users of the accounts and a number of different source data agencies. The national statistical office (NSO) has the fundamental role in coordinating this process.

14.43 Land Degradation Neutrality. The structure of the SEEA EA, with its emphasis of spatial analysis of ecosystems in terms of their extent, condition and ecosystem services, corresponds well to the data needs for monitoring land degradation neutrality (LDN). The three global LDN indicators (land cover, land productivity, and carbon stocks) that are used to derive SDG Indicator 15.3.1 — proportion of land that is degraded over total land area — can all be derived from existing core SEEA accounts:

- SEEA land accounts present detailed spatial data on land cover.
- SEEA ecosystem condition accounts measure the overall quality of an ecosystem asset with a range of variables including soil organic carbon (SOC).
- SEEA ecosystem services accounts measure the global climate regulation services provided by the ecosystem.

14.44 The UNCCD encourages countries to supplement their monitoring with additional indicators for ecosystem services and social outcomes that address their national or sub-national priorities. The SEEA's alignment with the System of National Accounts means that data organized under the framework can be integrated and used with existing economic accounts relatively easily. As the principle of neutrality will usually involve offsetting degradation in some areas with improvements in others, the SEEA's comprehensive framework provides information for helping identify key trade-offs and the spatial targeting of restoration efforts.

14.45 Intergovernmental and Science policy Platform on Biodiversity and Ecosystem Services (IPBES). The overall objective of the IPBES is to provide policy relevant knowledge on biodiversity and ecosystem services to inform decision making, with four agreed functions on assessment, policy support tools development, capacity building and knowledge development. A conceptual framework has been developed to support the analytical work of the Platform, to guide the development, implementation and evolution of its work programme, and to catalyse a positive transformation in the elements and interlinkages that are the causes of detrimental changes in biodiversity and ecosystems and subsequent loss of their benefits to present and future generations. It includes six interlinked elements constituting a social-ecological system that operates at various scales in time and space:

14.46 A task group on indicators was established to advise on the indicators and metrics to be used in IPBES products and on the standards necessary for capturing and managing associated data. It aims to provide the authors of ongoing assessments with a set of indicators that cover all elements of the IPBES conceptual framework. The IPBES set of indicators includes two types of indicators: 1) a list of core indicators, which authors are urged to use (in addition to other indicators or data sources they may choose) in their work; 2) a list of highlighted indicators, which authors may be interested in using, but with no expectation regarding their consistent use in the assessments. A number of IPBES indicators were identified as being able to be supported by SEEA based accounts:

- Total wood removals
- Inland fishery production
- Nitrogen use efficiency
- Trend in Carbon Intensity
- Land under cereal production

14.47 RAMSAR Convention on Wetlands. The Ramsar COP in 2005 agreed an initial set of 8 ecological outcome-oriented indicators, for assessing the effectiveness of aspects of the Convention's implementation. 8 indicators were available during the 2006-2008 triennium - they covered wetland resource status and threats, Ramsar site status and threats, water resources status, wetland management, species/population status, threatened species and Ramsar Site designation progress. An additional 2 sub indicators were developed to further examine the status of wetlands - status and trends in ecosystem extent, and trends in conservation status.

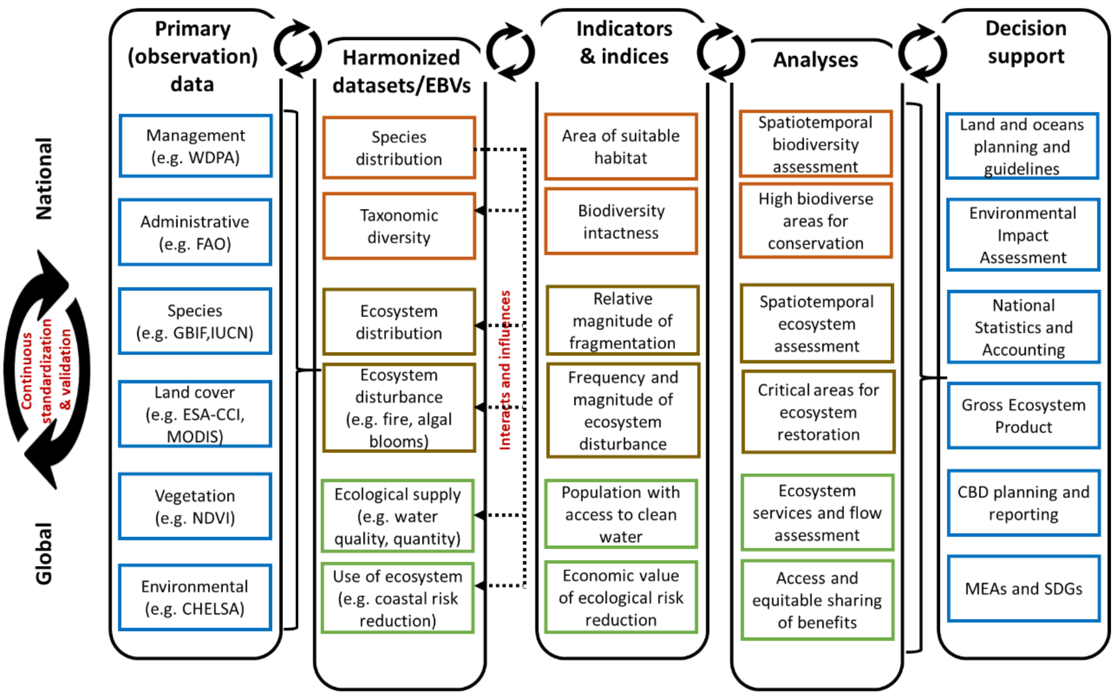
14.48 Across the 4 strategic goals a total of 19 targets are specified in the strategic plan. In order to track progress towards the Strategic Targets of the convention, a series of indicator questions are posed to countries in Section 3 of the national report template for the Ramsar Convention, which should be completed for each conference of contracting parties. A number of indicators were identified as being able to be supported by SEEA based accounts:

- Trend in wetland condition
- Number of households linked to sewage system
- Percentage of sewage coverage in the country
- Number of wastewater treatment plants

14.49 The Group on Earth Observations – Biodiversity Observation Network (GEO BON). GEO BON is a global network working to improve the acquisition, coordination and delivery of biodiversity observations for decision-making. As a network representing key biodiversity data providers operating at local, national, regional and global scales and through its efforts to design and implement structured and interoperable, national biodiversity observation networks, the GEO BON network has direct utility to the implementation of the SEEA EA process as a whole and in particular with regard to the production of natural capital accounts and related indicators. Of particular relevance is the establishment of a scalable and interoperable framework for biodiversity observations, using the concept of Essential Biodiversity Variables (EBVs). The EBVs cover the key dimensions of biodiversity spanning six classes (Species populations, Species Traits, Genetic Composition, Community Composition, Ecosystem Structure, and Ecosystem Function). In addition, a new framework is being developed for Essential Ecosystem Services Variables (EESVs) that provide a flexible means for measuring change in a wide range of material, non-material and cultural services that biodiversity and ecosystems provide.

14.50 The EBVs and EESVs are being implemented via structured and repeatable workflows that can be applied at multiple scales that connect primary observation data to multiple biodiversity information products (see Figure 14.2 for examples). These workflows are being utilized to develop a new suite of time-series indicators for tracking the status and trends in key dimensions of biodiversity change and patterns. Therefore, both the EBVs themselves and their integrated outputs (e.g., indicators) are of direct relevance to many of the indicators for the SEEA EA indicators initiative. Through the SEEA EA frameworks, which allow flexible, context-relevant and user-specific indicators for development, EBVs and EESVs can provide underlying data products to inform a wide range of policy frameworks, including the CBD, SDGs, MEAs (see Table 14.8 for SEEA EA and GEOBON EBVs crosswalk). Continuous interactions and exchange between biodiversity data developers and national to global statistics authorities will be instrumental in generating demand driven, science-based, and timely SEEA EA indicators in a coherent and consistent manner across scale and sectors.

Figure 14.2: Workflow of Essential Biodiversity Variables (EBVs) from primary data to decision support



Source: Kim & Navarro, n.d., forthcoming.

Table 14.8: Crosswalk of SEEA EA and GEOBON EBV & EESV frameworks (September 2020 version)

		SEEA EEA Framework	Ecosystem Extent Account	Ecosystem Condition Account						Ecosystem Services Account		
GEOBON EBV Framework				Abiotic Ecosystem Characteristics		Biotic Ecosystem Characteristics			Landscape level characteristics			
Type	Class	EBVs / EESVs		Physical state	chemical state	Compositional state	Structural state	Functional state	Landscape and Seascape	Provisioning	Regulating	Cultural
EBV	Species Populations	Species distribution				x		x				x
EBV	Species Populations	Population abundance				x		x				x
EBV	Community Composition	Taxonomic diversity				x						
EBV	Community Composition	Phylogenetic diversity				x						
EBV	Community Composition	Multi-trophic interaction diversity				x						
EBV	Community Composition	Biomass distribution					x					
EBV	Ecosystem Structure	Ecosystem distribution	x									
EBV	Ecosystem Structure	Ecosystem live cover					x					
EBV	Ecosystem Structure	Ecosystem vertical profile					x					
EBV	Ecosystem Functions	Disturbance						x				
EBV	Ecosystem Functions	Ecosystem phenology						x				
EBV	Ecosystem Functions	Net primary productivity						x				
EBV	Ecosystem Functions	Secondary productivity						x				
EESV	Ecosystem Services	Ecological supply		x	x					x	x	
EESV	Ecosystem Services	Anthropological contribution to supply								x		
EESV	Ecosystem Services	Demand										
EESV	Ecosystem Services	Use								x	x	x

* The table includes those EBVs and EESVs that are currently available for use and excludes Genetic Composition and Species Trait classes. They may fit better with the Biodiversity thematic accounts of SEEA EEA. The EBVs also include marine data products, which can be used in the Oceans thematic account.

Source: Kim & Navarro, n.d., forthcoming.

14.51 Biodiversity Finance Initiative (BIOFIN). BIOFIN provides an innovative approach enabling countries to measure their current biodiversity expenditures, assess their financial needs in the medium term and identify the most suitable finance solutions to bridge their national biodiversity finance gaps. BIOFIN is currently active in 30 countries and has produced intermediate guidance on the categorization of biodiversity expenditures based on 9 categories.

14.52 Ongoing effort is currently undertaken to harmonize the classification system for biodiversity expenditures between BIOFIN, the Environmental Expenditure Accounts of the SEEA Central Framework and the SDG indicators related to expenditure on conservation and sustainable use of biodiversity and ecosystems.

14.53 Inclusive Wealth. The Inclusive Wealth Index is a sustainability index that measures wealth using countries' natural, manufactured, human and social capital. These can be used to complement existing national accounts (which takes GDP into account). Inclusive Wealth Index takes into account natural capital, human capital (e.g., education and wealth) and produced capital (e.g., equipment, machineries, roads) - while taking into account changing factors such as carbon damage, oil capital gains and total factor productivity. These factors are measured within countries, and therefore show rates at national levels. Monetary value of ecosystem asset derived from the monetary ecosystem asset account of the SEEA EA can support the measures of the natural capital component of Inclusive Wealth

14.54 Biophysical modelling. Modelling for SEEA EA is important as there are several challenges in assembling ecosystem accounts to derive indicators. First, the data needed to assemble ecosystem accounts are not typically captured in data sources that statistical offices rely on, such as surveys, administrative data, and censuses. The second challenge is that the SEEA EA is a spatially explicit framework, which ultimately requires mapping of both ecosystems and ecosystem services. Consequently, even measurements of ecosystem services that are regularly collected through household or agricultural surveys need to be spatially explicit. Finally, reporting environmental data in a way that integrates into accounting frameworks without oversimplifying complex ecological and socioeconomic processes underpinning ecosystem services is challenging. SEEA EA is an attempt to merge disciplinary perspectives from ecology, economics, and accounting by providing a spatially explicit accounting framework for ecosystem services, while also avoiding double counting of the economic contributions of ecosystem benefits.

14.55 Biophysical modelling can fill gaps where information is not readily available, as well as spatially allocate data that is not regularly spatially explicit. Diverse models and tools to estimate the physical supply of ecosystem services have proliferated over the past decade and are quickly evolving, which means uptake for statistical agencies is increasingly feasible. While most biophysical models were not developed specifically for accounting, many models produce results that can be used directly in SEEA EA or produce results that can be modified for use in SEEA EA. Identifying which tools and modelling platforms produce results that align with SEEA EA can facilitate faster adoption of ecosystem accounts.

14.56 <u>Scenario analysis.</u> SEEA EA can be deployed in the application of scenario analysis to support policymaking. The increasing interconnectedness between the natural environment, human societies and their economies implies new challenges and opportunities for policymakers. To adequately take account of such complexities, policymakers require new sources of data and indicators, based on coherent statistical frameworks, that can be transformed into decision-relevant information through the application of innovative, sophisticated modelling techniques.

14.57 The creation and quantification of scenarios with mathematical simulation models allows for the creation of quantitative estimates for various scenarios (e.g., of implementing or not implementing a proposed policy) that can be used to inform the policymaking process. This is policy scenario analysis i.e., an exercise that aims at informing decision making and makes use of scenarios to assess the outcomes and effectiveness of various policy intervention options.

14.58 The SEEA EA, by providing a standardized approach, consistent and coherent data, and, by targeting policy relevance and the involvement of local stakeholders in policy analysis, can both support the use of accounts, further development of modelling approaches and creation of new models, all with the ultimate goal of informing policy decisions. This can happen through:

- Creation of new knowledge about ecosystems and how their extent and quality leads to ecosystem services that benefit communities and human wellbeing. This allows for the incorporation of ecosystems in social and economic assessments.
- Creation of coherent and harmonized accounts, allowing for the development of new models that can make use of such a data framework
- Promotion of the use of a systemic approach that assess (a) the impact of human activity on ecosystem and (b) models that determine the extent to which ecosystems influence human health and human activity.
- Improving the analysis performed with sectoral models, by introducing physical indicators on ecosystem extent, condition, services and hence generating a higher degree of realism.
- Generating knowledge on how existing models could be connected with one another to better represent the relations between society, economy and environment.

- Use of simulations, extending the analysis provided by SEEA, by forecasting or back-casting scenarios.
- Making explicit the importance of site-specific drivers of change, system responses and impacts, with the use of a spatially-explicit analysis that allows to determine the value of ecosystem services based on the location where these are used (i.e., more explicitly assess demand and supply).

Glossary

A

Abiotic flows are contributions to benefits from the environment that are not underpinned by ecological characteristics and processes.

Asset is a store of value representing a benefit or series of benefits accruing to an economic owner by holding or using the entity over a period of time. It is a means of carrying forward value from one accounting period to another. (SEEA Central Framework, 5.32)

B

Balance sheet is a statement, drawn up in respect of a particular point in time, of the values of assets owned and of the liabilities owed by an institutional unit or group of units. (2008 SNA, para. 13.2)

Basic spatial unit (BSU) is a geometrical construct representing a small spatial area.

Benefits are the goods and services that are ultimately used and enjoyed by people and society.

Biodiversity is 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 of ecosystems. (Convention on Biological Diversity, article 2, entitled "Use of Terms")

C

Catastrophic losses are reductions in assets due to catastrophic and exceptional events. (SEEA Central Framework, para. 5.49)

Cultural services are the experiential and non-material services related to the perceived or realized qualities of ecosystem assets whose existence and functioning contributes to a range of cultural benefits derived by individuals.

D

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

Discount rate is a rate of interest used to adjust the value of a stream of future flows of revenue, costs or income to account for time preferences and attitudes to risk. (SEEA Central Framework, para. 5.145)

E

Ecological integrity is defined as the system's capacity to maintain composition, structure, functioning and self-organization over time using processes and elements characteristic for its ecoregion and within a natural range of variability.

Economic owner is the institutional unit entitled to claim the benefits associated with the use of an asset in the course of an economic activity by virtue of accepting the associated risks. (2008 SNA, 10.5)

Ecosystem is "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity, article 2, entitled "Use of terms").

Ecosystem accounting area (EAA) is the geographical territory for which an ecosystem account is compiled.

Ecosystem assets (EAs) are contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions.

Ecosystem asset life is the time over which an ecosystem asset is expected to generate ecosystem services.

Ecosystem capacity is the ability of an ecosystem to generate an ecosystem service under current ecosystem condition, management and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem.

Ecosystem characteristics are the system properties of the ecosystem and its major abiotic and biotic components (water, soil, topography, vegetation, biomass, habitat and species) with examples of characteristics including vegetation type, water quality and soil type.

Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics.

Ecosystem condition indicators are rescaled versions of ecosystem condition variables.

Ecosystem condition indices are composite indices that are aggregated from the combination of individual ecosystem condition indicators recorded in the ecosystem condition indicator account

Ecosystem condition characteristics are those ecosystem characteristics that are relevant for the assessment of ecosystem condition.

Ecosystem condition typology (ECT) is a hierarchical typology for organizing data on ecosystem condition characteristics.

Ecosystem condition variables are quantitative metrics describing individual characteristics of an ecosystem asset.

Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services.

Ecosystem degradation is the decrease in the value of an ecosystem asset over an accounting period that is associated with a decline in the condition of an ecosystem asset.

Ecosystem disservices arise in contexts where the outcomes of interactions between economic units and ecosystem assets are negative from the perspective of the economic units.

Ecosystem enhancement is the increase in the value of an ecosystem asset over an accounting period that is associated with an improvement in the condition of the ecosystem asset.

Ecosystem extent is the size of an ecosystem asset in terms of spatial area.

Ecosystem functional groups (EFG), third level of the IUCN GET classification, which are functionally distinctive groups of ecosystems within a biome and are defined in a manner consistent with the CBD definition of ecosystems which underpins the SEEA EA concept of ecosystem assets. Ecosystem types within the same EFG share common ecological drivers which promote convergence of the biotic traits that characterize the group.

Ecosystem resilience is the ability of ecosystems to tolerate shocks and disturbance while maintaining the same level of functioning.

Ecosystem service measurement baseline is the level of service supply with which a regulating or maintenance service provided by an ecosystem is compared in order to quantify the service.

Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity.

Ecosystem services mapping is the discipline of allocating ecosystem services to locations.

Ecosystem type (ET) reflects a distinct set of abiotic and biotic components and their interactions.

Environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity (SEEA Central Framework, para. 2.17).

Exchange values are the values at which goods, services, labour or assets are in fact exchanged or else could be exchanged for cash (2008 SNA, 3.118).

Exclusive economic zone (EEZ) of a country is the area extending up to 200 nautical miles from a country's normal baselines as defined in the United Nations Convention on the Law of the Sea of 10 December 1982. (SEEA Central Framework, para. 5.248 and related footnote)

Externalities are impacts that arise when the actions of an individual, firm or community affects the welfare of other individuals, firms or communities and the agent responsible for the action does not take full account of the effect.

F

Final ecosystem services are those ecosystem services in which the user of the service is an economic unit – i.e., business, government or household.

G

Gross ecosystem product (GEP) is the aggregation of the monetary value, in exchange value terms, of the ecosystem services supplied by the ecosystem assets within an EAA less the imports of ecosystem services from ecosystem assets outside the EAA.

I

Intermediate services are those ecosystem services in which the user of the ecosystem services is an ecosystem asset and where there is a connection to the supply of final ecosystem services.

International Union for the Conservation of Nature Global Ecosystem Typology (IUCN GET) is a global typological framework that applies an ecosystem process-based approach to ecosystem classification for all ecosystems around the world. The SEEA ecosystem type reference classification reflects the IUCN GET.

L

Land cover refers to the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces. (SEEA Central Framework, para. 5.257)

Land management is the process of managing the use and development of land resources. The degree that areas of land and water are managed by humans may differ from intensively managed (e.g., build up areas, cropland) to not managed (e.g., polar regions, oceans).

Land ownership, encompassing ownership across all ecological realms, is a key characteristic that provides a direct link between ecosystems, their management and economic statistics.

Land use reflects both (a) the activities undertaken and (b) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions. (SEEA Central Framework, para. 5.246)

Legal owner is the institutional unit entitled in law and sustainable under the law to claim the benefits associated with the entities. (2008 SNA, para. 10.5)

M

Market prices are defined as amounts of money that willing buyers pay to acquire something from willing sellers (SNA2008, 3.119).

N

Natural resources include all natural biological resources (including timber and aquatic resources), mineral and energy resources, soil resources and water resources. (SEEA Central Framework, paras. 2.101, 5.18)

Net present value (NPV) is the value of an asset determined by estimating the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period. (SEEA Central Framework, para. 5.110)

Non-SNA benefits are goods and services that are not included in the production boundary of the SNA

O

Other changes in the volume of ecosystem assets refer to changes in the value of an ecosystem asset, other than those due to ecosystem enhancement, ecosystem degradation and ecosystem conversion, that are not solely the result of changes in unit prices of ecosystem services.

P

Provisioning services are those ecosystem services representing the material contributions to benefits supplied by ecosystems.

R

Reference condition is a point against which to compare past, present and future ecosystem condition for use as a standard and to measure relative change over time.

Reference level is the value of a variable at the reference condition and against which it is meaningful to compare past, present or future measured values of the variable.

Regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate and maintain climate, hydrological and biochemical cycles, and a variety of biological processes in ranges that benefit individuals and society.

Resource rent is the economic rent that accrues in relation to environmental assets, including natural resources. (SEEA Central Framework, para. 5.114)

Revaluations refer to changes in the value of ecosystem assets over an accounting period that are due solely to movements in the unit prices of ecosystem services.

S

SNA benefits are goods or services that are included in the production boundary of the SNA.

Supply and use tables are accounting tables structured to record the flow of goods and services from economic units or ecosystem assets to economic units and ecosystem assets. Entries can be made in physical and monetary terms.

W

Welfare values or total surplus, as understood in welfare economics, is equal to the area X + Y, i.e., the sum of the consumer surplus and producer surplus. It represents the total benefit accruing to consumers and suppliers in this one good market from exchanging the quantity of the good at price P.

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Chapter 2

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