DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
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System of Environmental-Economic Accounting—Ecosystem Accounting

Chapter 13 of the draft document submitted to the Global Consultation on the complete document

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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[1], 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.[2] 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

[1] See for example, (FAO, 2019).

[2] 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.[3] 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 <u>Development of Species Accounts.</u> 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

[3] 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 reappraisals										
Reductions										
Natural										
Managed										
Downward reappraisals										
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).

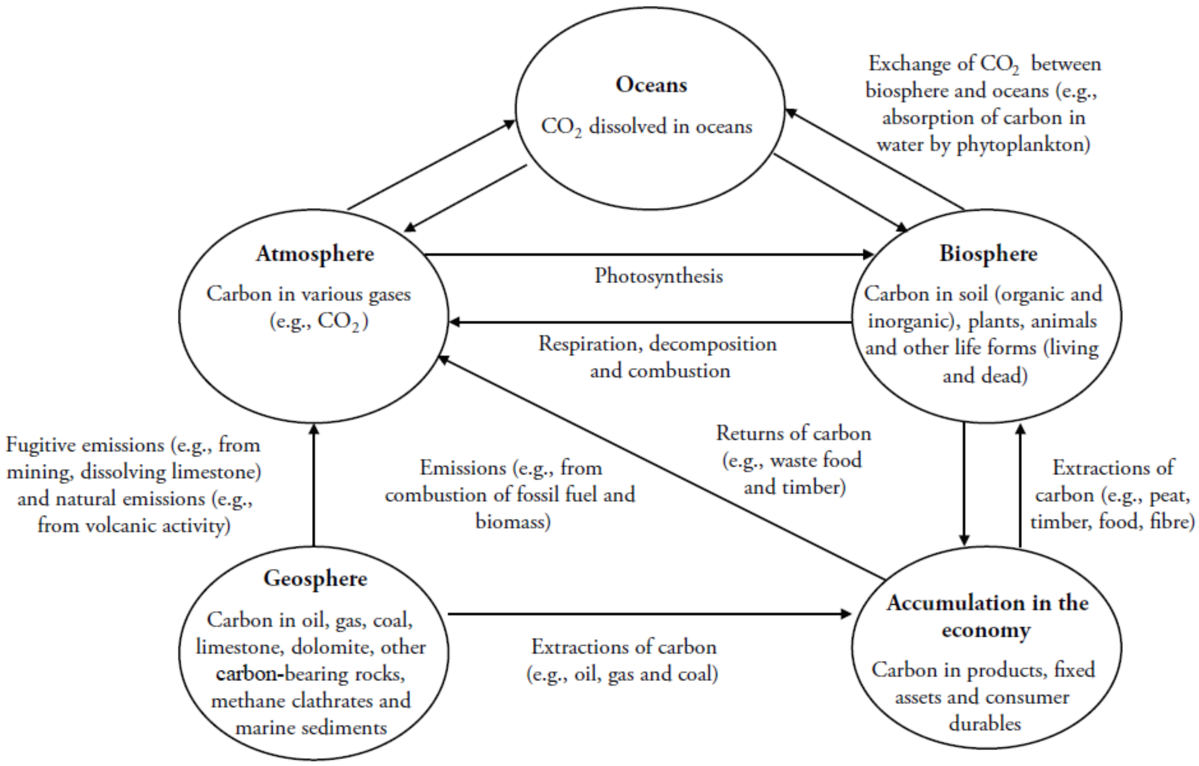
13.47 The measurement of stocks and flows of carbon can support discussion of many policy relevant issues. These issues include the analysis of greenhouse gas emissions, sources of energy, deforestation and land use change, loss of productivity and biomass, and sources and sinks of carbon emissions. 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 data.

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,[4] declared by the International Ocean Commission of UNESCO; UN Oceans is in the process of updating the First Global Ocean Assessment;[5] the OCED is continuing to support the assessment of the ocean economy;[6] the High Level Panel for a Sustainable Ocean Economy[7] 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".[8] 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 assets (e.g., mangroves, coral reefs); (2) ocean-related income and welfare for different

[4] https://en.unesco.org/ocean-decade
[5] https://www.unenvironment.org/resources/report/first-global-integrated-marine-assessment-world-ocean-assessment-i
[6] http://www.oecd.org/ocean/topics/ocean-economy/
[7] https://www.oceanpanel.org/about-the-panel
[8] "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

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.

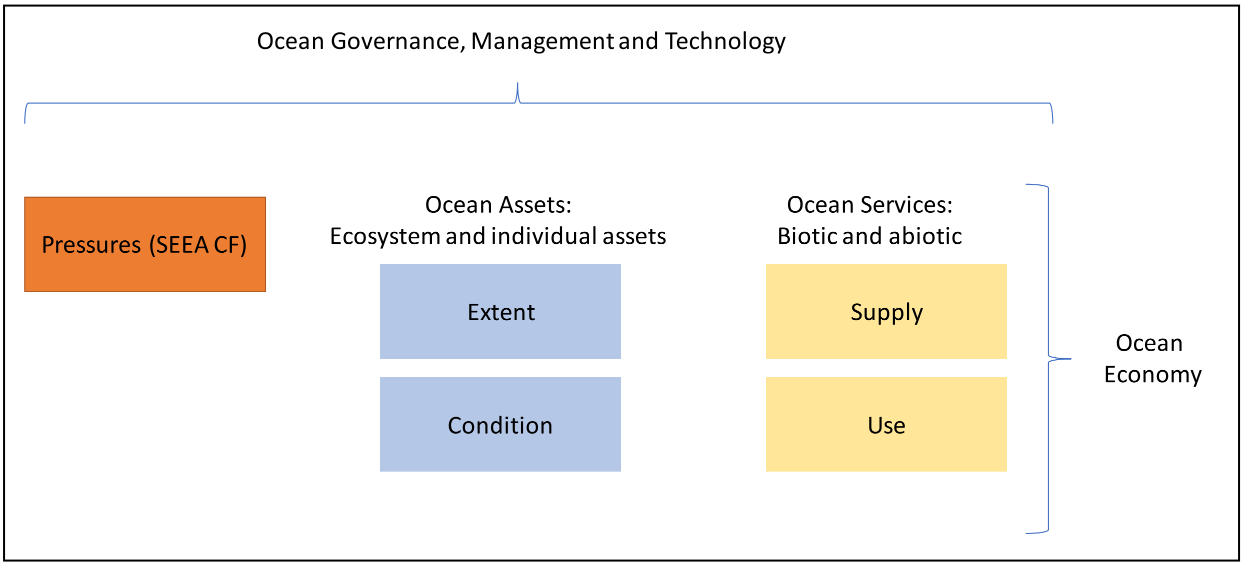
13.70 The Ocean Accounts Framework (Figure 13.2) builds on the components of the SEEA. Ocean accounts add the perspective of the ocean economy, governance, management and technology to the SNA and SEEA core accounts.

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[9] 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[10] 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.

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".

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[9] https://www.oceanaccounts.org/ and https://communities.unescap.org/environment-statistics/tools/regional-ocean-accounts-platform

[10] http://communities.unescap.org/system/files/global_ocean_data_inventory_v1.0_text_20191213_compressed.pdf

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>

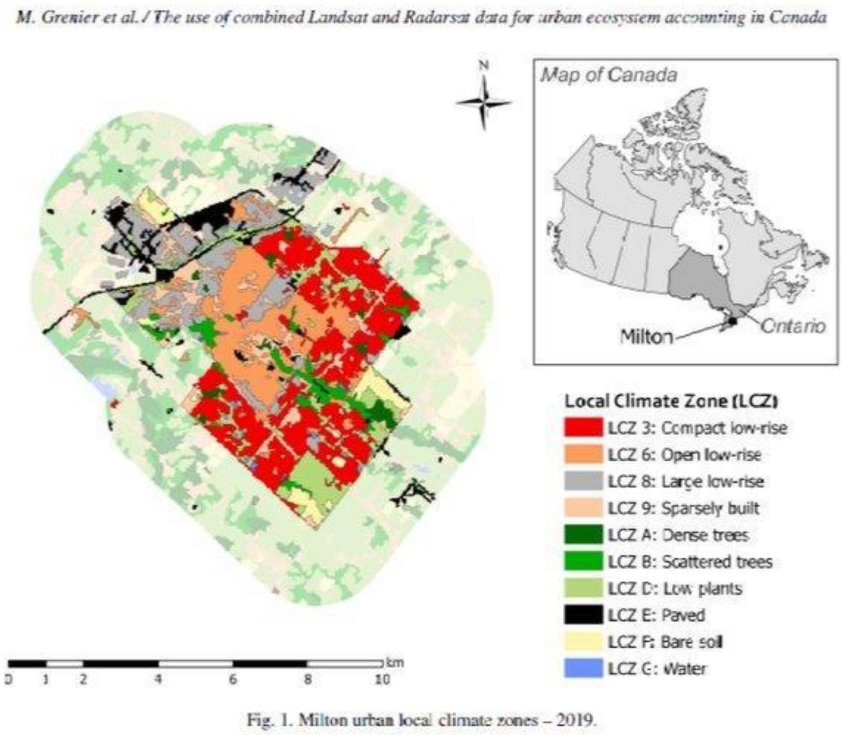
13.91 There are several approaches for defining the ecosystem accounting area for urban ecosystem accounts. Accounts can be compiled for cities based on administrative boundaries (i.e., local government boundary), functional boundaries (e.g., based on commuting flows as defined by census data), or morphological 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.

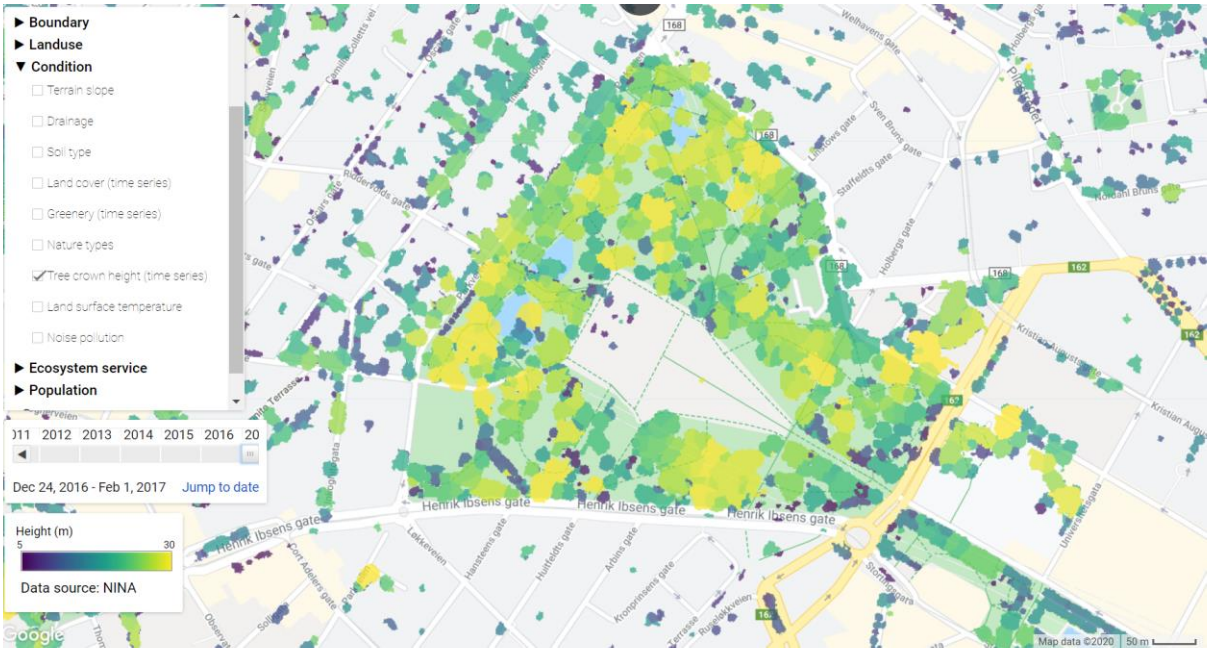
13.94 Individual asset approach: This approach tracks various individual asset types at as fine a scale as possible (e.g., lines of street trees, playgrounds, allotment gardens, green roofs, drainage and storage systems, airsheds, etc.) based on available very high resolution (10 m or less) satellite 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



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).

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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									
	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	All other (grey) areas	**Total EEZ**
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.[11] 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.[12] 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)[13] 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

[11] 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

[12] Soil is the layer of fine material covering the Earth's land surface influenced by and influencing plants and soil organisms.

[13] 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).