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Natural capital accounting in support of policymaking in Europe

A review based on EEA ecosystem accounting work

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Executive summary

Maintaining 'natural capital', i.e. ecosystems and the services they provide, is fundamental to human economic activity and well-being. The need to conserve and enhance natural capital is therefore an explicit policy target in the EU's Biodiversity Strategy to 2020 and its Seventh Environment Action Programme. Approaches to measuring the stocks of natural resources that yield benefits as natural capital have gained considerable traction in recent decades. By providing regular, objective data that are consistent with wider statistical data, natural capital accounting can provide the fundamental evidence base required for informing economic and environmental decision making that delivers on these ambitions for natural capital.

The System of Environmental-Economic Accounting (SEEA) is the statistical framework for compiling natural capital accounts. The SEEA Experimental Ecosystem Accounting (SEEA-EEA) is the part of the SEEA that provides the framework for ecosystem accounting. The European Environment Agency (EEA) has been a key contributor to developing the SEEA-EEA. The EEA is now working with Eurostat, the European Commission's Joint Research Centre and the European Commission Directorates General for the Environment (DG ENV) and Research and Innovation (DG RTD) to test the application of the SEEA-EEA in the EU (via the Knowledge innovation project on an integrated system for natural capital and ecosystem services accounting in the EU (KIP INCA)). This report presents the EEA's work on natural capital accounting, discusses the use of natural capital accounts in support of policymaking and reflects on the intrinsic value of biodiversity, which cannot only be measured in monetary terms.

Land and ecosystem extent accounts

The EEA calculates European land and ecosystem extent accounts on the basis of the land and ecosystem accounts database (LEAC) established by the EEA over 15 years ago. The accounts track changes in the stock of different Corine Land Cover (CLC) types and conversions between these types over time. They are developed using a flexible spatial grid and stable CLC accounting layers that allow land accounts to be compiled for different areas of interest. As part of KIP INCA, the EEA has applied this approach to generate accounts of ecosystem extent for 2000, 2006 and 2012. These accounts are based on the EU Mapping and Assessment of Ecosystems and their Services (MAES) ecosystem typology (tier I) and selected individual CLC classes (tier II).

In broad terms, the tier I ecosystem extent accounts reveal that urban ecosystems increased the most in relative extent (> 2 % between 2000 and 2006 and 2 % again between 2006 and 2012). They also reveal that ecosystem extent in Europe is generally stable, with approximately 99 % of the stock of ecosystems remaining unchanged over each accounting period.

The grid structure supporting the accounts allows ecosystem extent accounts to be compiled for various different administrative, environmental or geo-physically defined areas. These provide insights into the interactive effects of different land use and environmental characteristics on the extent of different ecosystems and how these correlate with different policy and management actions (e.g. Natura 2000 designation).

A key conclusion from the extent accounts to date is that the spatial and thematic detail of current data on ecosystem distribution should be further developed. The most important options in this regard include combining CLC data with other satellite data and developing spatially referenced biodiversity data.

Ecosystem condition accounts

Accounting for ecosystem condition is one of the least developed aspects of ecosystem accounting. To advance this, the EEA is testing a direct approach, by tracking trends in biodiversity and water quality, and an indirect approach, via the analysis of nutrient pressures.

Over the course of 2017, the EEA developed ecosystem condition accounts based on Nature Directive reporting data. This report presents pilot accounts compiled using data collected under Article 12 of the Birds

Directive. In broad terms, the Article 12-based accounts suggest a loss of condition in the cropland and grassland and improvement in forest and woodland ecosystems. Ongoing work on a more spatial approach is testing the use of data collected from national bird monitoring surveys.

During 2018, the data from the second Water Framework Directive (WFD) reporting cycle (for 2016) became available, providing an opportunity to build pilot water quality accounts. This has yielded a draft methodology for wider implementation. A workflow for compiling a nutrient pressures account was established for implementation during the course of 2019. The compilation of this account is grounded in combining spatial data on farm statistics, atmospheric nitrogen deposition and agricultural nutrient use.

The tests to date reveal the data foundation to be a critical limiting factor for the development of condition accounts for Europe, in particular the lack of spatially referenced biodiversity data.

Water quantity and fish biomass accounts

To better understand the use of water resources in Europe, the EEA has developed water quantity accounts. These accounts allow an assessment of the availability of renewable water resources and water use efficiency by economic sector. The headline indicator from the accounts is the Water Exploitation Index plus (WEI+) and it is available from 1990 to 2015. The accounts reveal that during the summer of 2015, around 30 % of the total European population was exposed to water scarcity conditions (WEI+ > 20 %). This corresponds to 19 % of Europe's territory. People living in densely populated European cities, agriculture-dominated areas of southern Europe and small Mediterranean islands were most affected.

The overall purpose of the marine fish biomass account is to understand the sustainability of the use of marine fish resources. The indicators of sustainable biomass use from the accounts reveal that, at the European level, landings correspond to or are just below surplus production during the period 1999-2013. However, regional differences emerge and the accounts reveal that landings are unsustainable in the Iceland Sea, Celtic Seas, Bay of Biscay and Iberian Peninsula, and Macaronesia over this period.

Further work is required to integrate these accounts with wider ecosystem accounting. For example, linkages between the marine fish biomass account and ecosystem capacity are proposed.

Reflections on policy applications and outlook for natural capital accounting in Europe

Natural capital accounting provides evidence on ecosystem trends in a structured and integrated manner that allows the analysis of environment-economy interactions. This evidence base will have various 'entry points' into different stages of policy cycles and policy analysis. This report identifies specific targets of the EU's Seventh Environment Action Programme as clear entry points for the natural capital accounts being developed at the EEA. However, further investment in the data foundation for natural capital accounting is necessary if this essential evidence base for informing actions towards attainment of these targets is to be realised. This investment is critical for building the knowledge base for a sustainable use of Europe's natural capital and maintaining its capacity to benefit future generations.

1 What is natural capital and why protect it?

1.1 Introduction

The need for preserving the environment and managing natural resources and ecosystems sustainably has been recognised for several decades (e.g. Meadows et al., 1972; MA, 2005). The fragility of the Earth systems that support our well-being is also underlined in the most recent EEA report on the state of the European environment (EEA, 2015b, 2015c) as well as in global analysis. This includes scientific studies on the likely impacts of climate change (IPCC, 2014), on planetary boundaries (Rockström et al., 2009) and on nature's contributions to people, which embody ecosystem services (IPBES, 2018). This has given traction to the proposal by environmental economists and ecologists that we should consider Earth's ecosystems as a kind of 'natural capital' that provides flows of ecosystem services for human benefit and that needs to be managed well to be able to provide sustainable flows of services in the future. Ecosystem accounting is a key analytical tool to provide insights for managing this shared natural capital.

The European Environment Agency (EEA) has supported the conceptual and methodological development of ecosystem accounting for more than 15 years by contributing to international discussions as well as the practical testing of land and ecosystem accounting approaches in Europe (e.g. EEA, 2006). In the last few years, global discussions on ecosystem accounting facilitated by the United Nations Statistical Division (UNSD) have produced practical methodological guidance, in particular the UN handbook on experimental ecosystem accounting (UN, et al., 2014b). The UNSD and others continue to develop ecosystem accounting methods with the help of independent experts and statistical offices in Europe and other continents and bodies such as the EEA (Weber, 2014; UNSD, 2017).

The concept of ecosystem accounting (under the term 'natural capital accounting') is also recognised in two key EU environmental policy documents: the EU Biodiversity Strategy to 2020 (EC, 2011) and the EU's Seventh Environment Action Programme (7th EAP) (EU, 2014). The following quotes illustrate well the longer term visions set out in EU policy documents with regard to natural capital and its links to economic development and human well-being.

*By 2050, European Union **biodiversity** and the **ecosystem services** it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided.*

Source: EC (2011).

*In 2050, **we live well, within the planet's ecological limits**. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a global safe and sustainable society.*

Source: EU (2014).

To build the knowledge base for achieving these objectives, a shared innovation project was set up at EU level in 2015 to develop an integrated system for natural capital and ecosystem services accounting: the Knowledge innovation project on an integrated system for natural capital and ecosystem services accounting (KIP INCA). KIP INCA is closely intertwined with, and supports, the EU Mapping and assessment of ecosystems and their services (MAES) process. The organisations taking KIP INCA forward are Eurostat, the European Commission's Joint Research Centre (JRC), the Directorate-General for Environment of the European Commission, the Directorate-General for Research and Innovation of the European Commission, and the EEA. The methodological starting point of KIP INCA is the United Nations (UN) System of Environmental-Economic Accounting Experimental Ecosystem Accounts (SEEA-EEA). KIP INCA aims to test the applicability of the different SEEA-EEA components to help establish a system that enables regular ecosystem accounting at EU level based on SEEA-EEA principles. This report combines outputs under KIP INCA as well as previous work of the EEA to review opportunities for using the results of ecosystem accounting for policymaking. Key KIP INCA outputs are available elsewhere, for example in La Notte et al. (2017) and European Commission (EC, forthcoming).

The idea of considering nature as 'capital' to be sustainably exploited has its origin in economics, and because of its conceptual basis it adopts a utilitarian perspective, i.e. natural capital is to be managed well to maintain the benefits that humankind derives from it. Adopting an economic perspective and defining nature as a kind of capital also means that in principle it can be traded like other types of capital. However, many proponents of the concept argue that there are limits to its tradability as different kinds of natural capital cannot be fully substituted with one another and that the intrinsic value of nature also needs to be considered.

The approach taken in this report includes the philosophical perspective that biodiversity and ecosystems need to be protected in their own right, i.e. for their intrinsic value. This needs to be combined with the recognition that ecosystems and the services they provide are an important resource that needs to be sustainably utilised to satisfy the needs of the growing world population and to enable the transition to a green economy. In this context, ecosystem accounting is an important knowledge framework that helps to manage natural capital better, for its own sake and as a resource for humankind.

1.2 What is natural capital?

Any methodological approach needs to have a clear analytical frame for the subject it wants to study. If natural capital accounting is a way of organising and presenting information about our natural capital, then an important first step is to be clear about the meaning of the term 'natural capital'. In this report the term is understood as representing ecosystems and their services, i.e. the core subject of ecosystem accounting as codified in the UN handbook on experimental ecosystem accounting. Natural capital and 'ecosystem capital' are therefore considered to be synonymous in this report.

The term 'natural capital' was proposed by David Pearce (Pearce et al., 1989) as a way to underline the role of nature in supporting the economy and human well-being. It is now recognised that human well-being depends on different types of resources or assets, which can be categorised in relation to four broad types of capital ([1]). Each of these types of capital supports the economy and human well-being (Pearce et al., 1989; Ekins and Max-Neef, 1992; ten Brink et al., 2012):

1. **Manufactured** or **man-made capital** — assets used to produce goods and services, such as machines, tools, buildings and infrastructure. Financial capital includes money and other financial assets, and is sometimes seen as a distinct additional category (Aronson et al., 2007).

2. **Human capital** — assets in the form of knowledge, education, motivation and work skills, and mental and physical health.

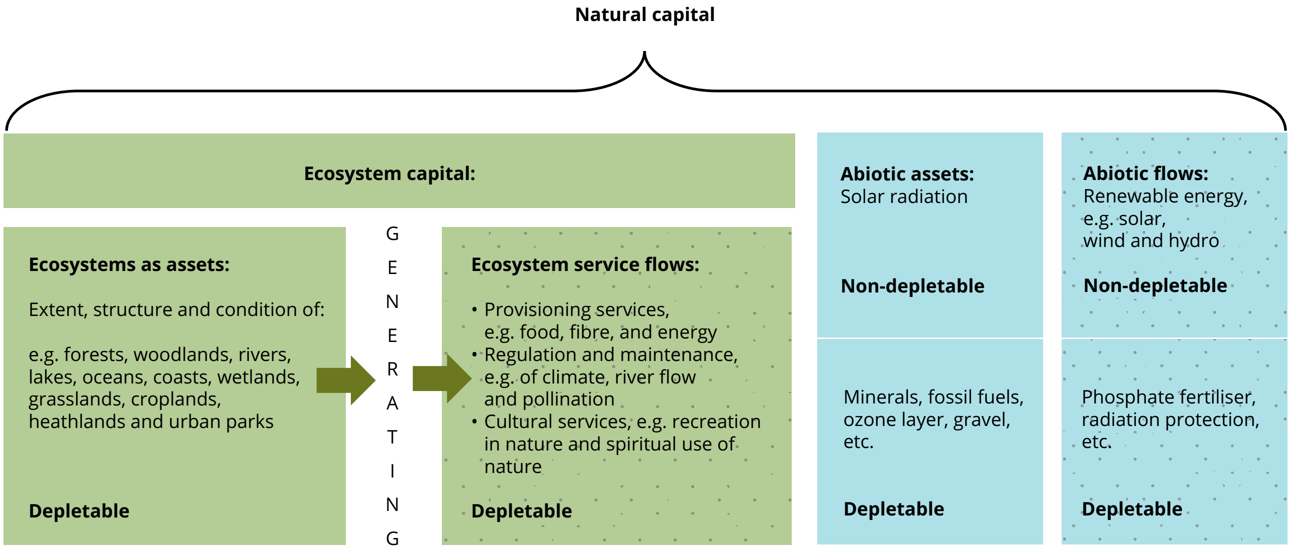
3. **Social capital** — includes social trust, norms and networks that facilitate social and intellectual interactions and solutions to common problems, e.g. neighbourhood associations, civic organisations and cooperatives, and the political and legal structures of a society.

4. **Natural capital** — comprises the ecosystems and abiotic assets of the planet that provide people with exploitable resources, e.g. solar radiation, fossil fuels and minerals, and that generate a flow of benefits via ecosystem services, e.g. food, climate regulation and recreation.

While all four types of capital are needed to support human well-being, natural capital is arguably the most important because it supports and underpins the other

([1]) Other authors add another type of capital: 'financial capital', which relates to the money flow and lending for investment and other purposes provided by the world financial system (public and private banks, stock markets, investment funds, etc.).

Figure 1.1 Components of natural capital



Note: Global solar radiation is constant above the atmosphere and hence considered a stable asset.

Source: Maes et al., 2013.

forms of capital. For example, minerals, metals, timber and fibres as well as energy are needed to build the components of manufactured capital. Human and social capitals are heavily dependent on the physical health of individuals who are dependent upon ecosystem services to maintain good health. These services range from the provisioning of food and freshwater, through regulating ecosystem services that support water purification, nutrient cycling and mitigation of floods to benefits from open landscapes and urban parks that support recreation and well-being.

The broad definition of natural capital proposed by David Pearce includes biotic and abiotic elements and comprises all natural resources that human society draws upon. This has been further developed by the EEA and others to formulate an approach that supports natural capital accounting. Figure 1.1 illustrates the main components of natural capital as currently understood; this is based on the natural capital figure in the first EU MAES report (Maes et al., 2013).

Figure 1.1 makes a distinction between ecosystem capital and abiotic resources. In reality, there is no clear-cut boundary between biotic and abiotic components. For example, soil is mainly composed of different minerals and water but only becomes an active substrate for plant growth due to the myriad of soil microorganisms that live in its pores and make its nutrients available for plants and fungi. However, this distinction helps to identify and classify different types of natural capital, which is important in the context of developing a natural capital accounting approach.

Another dimension in Figure 1.1 is the relationship between the concepts of 'assets' and 'flows'. According to standard economic theory, natural capital is the sum of the different physical assets of nature, e.g. mineral deposits or tonnes of biomass, and benefit flows are not really part of natural capital. However, for ecosystem capital in particular, the same natural processes govern ecosystem assets and ecosystem services, so it is often difficult to differentiate between the two. In addition, in the context of monetary accounting, the value of the asset stock is often derived from the flows it generates. Furthermore, in many less specialist discussions, flows are considered part of natural capital. For these reasons, Figure 1.1 shows ecosystem and abiotic assets and flows in the same colour but with different background shading.

The second key feature of assets and flows is their depletability. Some are, under current circumstances, unlimited, i.e. non-depletable — for example, sunlight and wind depend on the energy stock in solar radiation, which humans cannot influence. Most abiotic assets are, for obvious reasons, classified as depletable because they do not renew themselves and their stock is therefore reduced over time by exploitation, e.g. fossil fuels and minerals. Ecosystems and associated service flows are also depletable, as over-exploitation can lead to the extinction of species or depletion, e.g. fish stocks. Outright habitat destruction, e.g. the conversion of forests or grassland into urban areas, ultimately destroys ecosystems and the regulation and maintenance, or other services, they generate.

Ecosystem capital is particularly vulnerable because many species and habitats depend on specific conditions being maintained, and human society heavily exploits that capital via agriculture, forestry and other land uses. This part of natural capital can therefore be considered a component for which society has a particular 'duty of care' — it is fragile, and human actions have already had a negative impact on much of it. However, with suitable management and care, ecosystems are capable of delivering a sustainable flow of ecosystem services into the foreseeable future.

EU targets under the Biodiversity Strategy to 2020 and the 7th EAP relate primarily to the ecosystem capital component of Figure 1.1. Owing to the ecosystem focus of the SEEA-EEA and EU policy priorities, the discussion of natural capital accounting in this document therefore relates mainly to ecosystem capital.

1.3 The contribution of natural capital to human well-being and the economy

Society depends on ecosystems and the services they provide. The most recent EU state of the environment report (EEA, 2015b) describes natural capital as 'the most fundamental of the core forms of capital [...] since it provides the basic conditions for human existence'. Ecosystem services are the contribution of ecosystems to the multiple benefits that natural capital provides to humanity, and these depend directly on the good functioning of ecosystems, based inter alia on the diversity of species and their abundance and interactions.

Ecosystem services are divided into three main categories according to the Common International Classification of Ecosystem Services (CICES ([2]), 2017):

1. Provisioning services — these represent the products people obtain from ecosystems and include the provision of food, energy and materials.

2. Regulating and maintenance services — these result from the capacity of ecosystems to regulate climate, hydrological and biochemical cycles and include soil formation and retention, air and water filtration, climate regulation and protection against natural disasters such as flooding.

3. Cultural services — these are the benefits for the physical or mental well-being of people that we derive directly from being in a natural environment, whether that is an urban park or a rain forest, or indirectly from watching nature films, observing cultural practices linked to nature, or protecting species for their intrinsic value, etc.

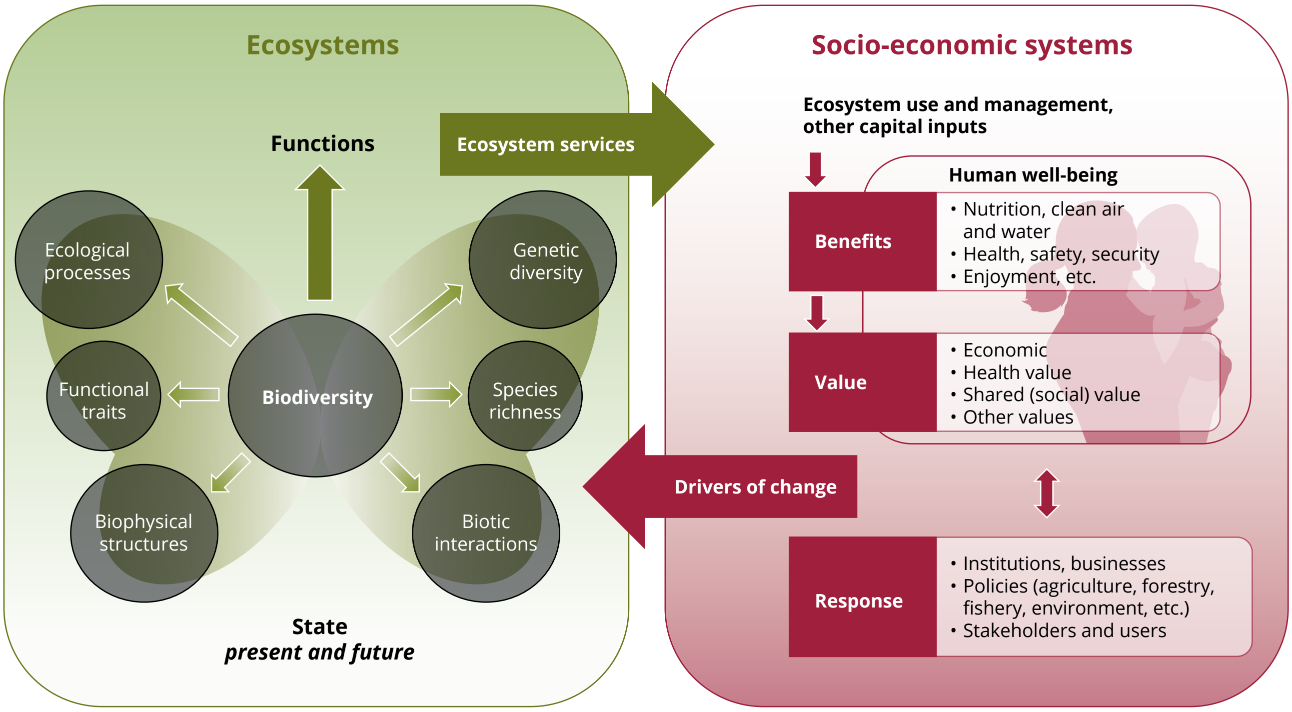
The World Bank-led Wealth Accounting and the Valuation of Ecosystem Services (WAVES) programme is an example of recognition of the importance of natural capital by international organisations. The WAVES web page ([3]) states that one 'major limitation of GDP is the limited representation of natural capital'. The full contribution of natural capital, including that of forests, wetlands and agricultural land, is not included in gross domestic product (GDP). Forestry is an example: timber resources are recorded in national accounts and its headline indicator (GDP). However, the other ecosystem services of forests, such as carbon sequestration and air filtration, are ignored in this system of national accounts. This has been fundamentally misleading to policymakers as it implies that many of the benefits that natural capital (forests in this example) provides are 'free' and can be ignored and/or degraded in the pursuit of economic growth. This assumption results in permanent losses in wealth as stocks of natural capital disappear or deteriorate. Partly as a result of this lack of policy attention, ecosystems are deteriorating worldwide, and with them their capacity to support human well-being and sustainable economic growth.

Natural capital is now recognised as a critical asset, especially for developing countries, for which it makes up a significant share of total wealth. An analytical approach built on this ecological perspective therefore needs to go beyond a focus on natural resources such as water, minerals or timber as separate commodities and has to aim for an integrated management of natural capital. There is clear recognition at international and European level that natural capital accounting can strengthen the evidence base for better informed socio-economic decision-making and also potentially help avoid environmental and related economic collapses in the future.

The business community has also organised itself to address the challenges of managing natural capital better. The Natural Capital Coalition ([4]) is a unique global multi-stakeholder collaboration that brings

([2]) Full documentation available at www.cices.eu
([3]) Full documentation available at https://www.wavespartnership.org
([4]) https://naturalcapitalcoalition.org

Figure 1.2 Conceptual framework for EU-wide ecosystem assessments



Source: Reproduced from Maes et al., 2013.

together leading initiatives and organisations to harmonise approaches to natural capital. It is made up of organisations from many areas: research, science, academia, business, advisory, membership, accountancy, reporting, standard setting, finance, investment, policy, government, conservation and civil society. These organisations have united under a common vision of a world where business conserves and enhances natural capital. They adopted the Natural Capital Protocol, a framework designed to help generate trusted, credible and actionable information to inform business managers' decisions.

In the EU, the analysis of the links between natural capital and human economy and well-being is supported by the MAES initiative under the EU Biodiversity Strategy to 2020. This initiative brings together EU bodies and Member State organisations to map and assess European ecosystems and their services on the basis of a conceptual framework for EU-wide ecosystem assessment. Figure 1.2 depicts this conceptual framework, which analyses the natural environment by looking at the state of biodiversity and ecosystems, and evaluates the level of ecosystem services provided to people. It shows the connections between the environment and the economy (economic sectors) by considering the ecosystems from which the services are derived and the different benefits to human society that are affected by changes in the supply of services (Maes et al., 2013).

The links between the economy, human well-being and our natural environment are also the core analytical target of the UN SEEA, which is being implemented in Europe as part of KIP INCA. The work of the EEA on describing core components of natural capital in Europe builds on the concepts developed under the EU MAES process and the methodological principles elaborated in the UN SEEA framework. Box 1.1 (next page) provides an overview of current EEA output related to the SEEA.

Box 1.1 Overview of EEA output with respect to ecosystem extent, condition and service accounting

Land accounts and ecosystem extent accounts

- Land accounts — analysing the flows between different land cover classes from 1990 to 2012, showing the change in European landscapes, the strong urbanisation trend around population centres and in coastal areas and the associated loss of productive land. Described in the SEEA Central Framework (SEEA-CF) (UN et al., 2014a), land accounts are also the methodological starting point for ecosystem extent accounting in Europe.

- Ecosystem extent accounts — showing changes in the extent and distribution of broad European ecosystem types and analysing these patterns in geographical focus areas (Natura 2000 areas, coastal areas, etc.). Together with the ecosystem condition accounts these implement the second part of the UN framework for environmental accounting (SEEA-EEA).

Ecosystem condition accounts

- Proposals and tests for ecosystem condition accounts — reviewing the important pressures on European ecosystems and illustrating options for using environmental reporting linked to EU legislation for understanding key trends in water quality and biodiversity.

Water accounts and marine fish biomass accounts

- Water quantity accounts — showing the volume of water available in different parts of Europe, its use by sector, and water basins where water resources are particularly heavily exploited. While this is a component of the SEEA-CF, water resources are an important component to integrate into a natural capital accounting framework.

- Marine fish biomass accounts — using ecosystem accounting to analyse the impact of fishing pressure on selected European fish stocks and reviewing how the sustainability of fisheries management can be analysed using ecosystem accounting principles. The harvesting of marine fish represents a very important marine ecosystem service to integrate into a natural capital accounting framework.

Both land and water accounts correspond to components of the SEEA-CF and are well-established approaches, whereas ecosystem extent and ecosystem condition accounts are part of the SEEA-EEA and are at different stages of development. While basic ecosystem extent accounts can now be produced, the EU approach to ecosystem condition accounting is in a test phase. The EEA developed a marine fish biomass account and a seafloor integrity account as test cases for bringing important marine ecosystems into the overall SEEA ecosystem accounting approach, which has been developed largely on the basis of terrestrial ecosystem data.

1.4 Structure and approach of this report

The field of natural capital accounting in both its conceptual foundation and its practical application is a very large one. Hence this report can only make a contribution to its development and aims to:

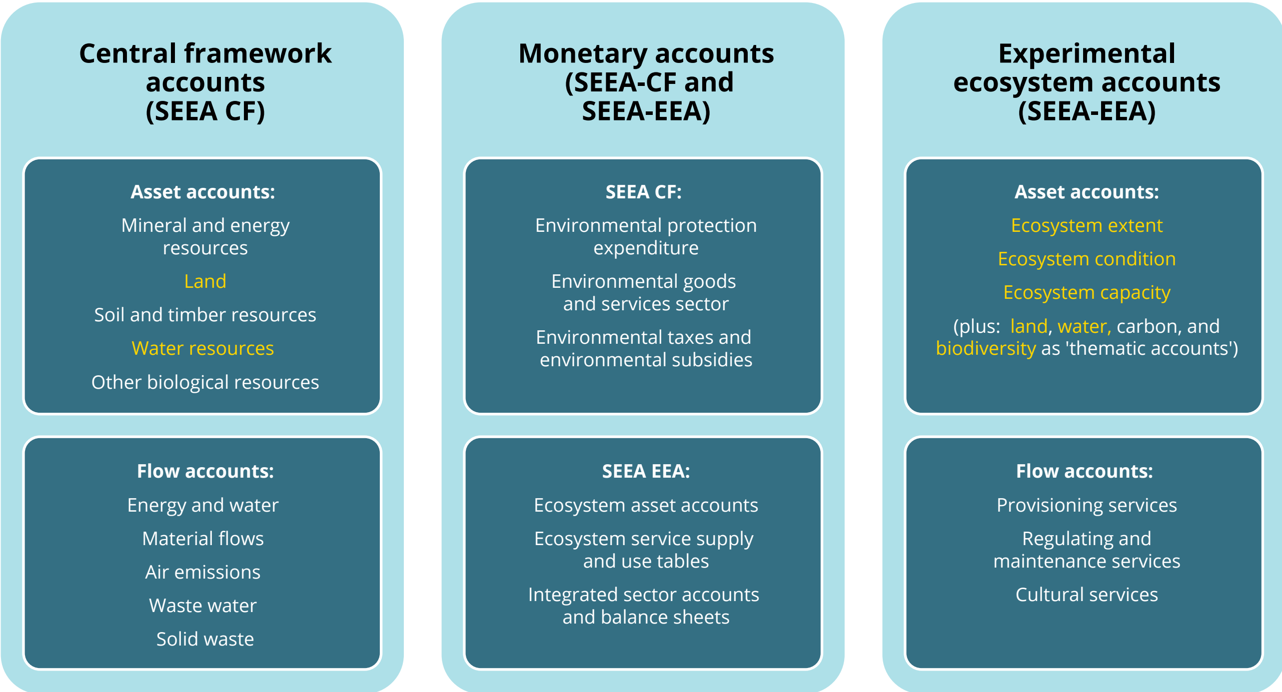
- present the conceptual frame of environmental-economic accounting, in particular with regard to accounting for natural capital and ecosystem services (see Chapters 1 and 2);

- describe the work of the EEA to develop environmental and ecosystem accounts (see Chapters 3, 4 and 5);

- show the analytical opportunities of ecosystem accounting in combination with other analytical methods and point to priorities for its further development to support better management of natural capital (see Chapters 6 and 7).

Natural capital accounting is still under development as a knowledge framework, with the UN handbook on experimental ecosystem accounting having been published only in 2014. This means that the work of the EEA and other EU bodies covers only some components of the UN SEEA in terms of practical implementation. Figure 1.3 shows in general terms which components of the UN SEEA framework are currently being implemented or developed via the work of the EEA (yellow text).

Figure 1.3 Components of the System of Environmental-Economic Accounting



Source: EEA, 2018.

The development of the SEEA has long been supported by the EU and its Member States, with Eurostat playing a leading role. It has particularly engaged in the development and implementation of central framework accounts. Furthermore, there has been longstanding cooperation between different EU bodies to develop environmental and ecosystem accounts, which is actively supported by KIP INCA. The JRC works foremost on ecosystem service and monetary accounts under SEEA-EEA. Eurostat and DG Environment also play a substantial role in testing SEEA-EEA accounts under KIP INCA.

2 The conceptual framework for ecosystem accounting and its uses

2.1 The System of Environmental-Economic Accounting

Accounting is an approach to structuring information that aims to provide an overview of income and expenses, for example, and gives complete and consistent results. This principle also underpins the System of National Accounts (SNA) that develops information on countries' GDP, which is a key figure for assessing economic progress and helps us to understand the economic wealth of a nation. However, the wealth of a nation and the well-being of its people not only depends on the state of the economy but also relies strongly on its natural resources and the services we derive from ecosystems (see Chapter 1). For this reason, statisticians, accountants and others have worked since the 1970s to create a complementary accounting system that covers natural assets and the benefits we derive from them — this is known as the System of Environmental-Economic Accounting.

Accounting for ecosystems has achieved significant traction since the early publications of Rapport, Daily and Costanza in the 1990s (Costanza et al., 2014), the first classification of ecosystem services by De Groot and Costanza (Costanza et al., 1997), the Millennium Ecosystem Assessment of 2005 (MA, 2005), 'The Economics of Ecosystems and Biodiversity' (TEEB) report (ten Brink et al., 2009) and applications such as the land and ecosystem accounts approach (LEAC) by the EEA (EEA, 2006). In this context, the UN Statistical Commission (UNSC) has accepted that experiments are required to further develop the SEEA framework with regard to ecosystem accounting, with noticeable actions steered by the UNSD, the UN Environment Programme (UNEP), the Convention on Biological Diversity (CBD), the World Bank or the Indian Ocean Commission (for a full review of the development of ecosystem accounting, please consult Weber, 2018).

The methodological development of the SEEA is being led by the UNSD, with support from the London Group on Environmental Accounting, which operates under the auspices of the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA). Conceptually, the SEEA provides a set of tables that are consistent and can be integrated with the SNA structure, classifications, definitions and accounting rules. In this way, an analysis of changes in the status of natural capital can be documented — with its contribution to the economy and the impacts of economic activities on natural capital recorded. The SEEA also provides detailed methodological guidance to prepare environmental-economic accounts on a wide range of issues.

The SEEA has been developed in a step-wise manner with its initial focus on work on environmental assets, such as land or water, which are more easily measured with standard accounting approaches. Over the last 10 years the main focus has been on developing accounting approaches for ecosystems and their services. The most recent revision of the SEEA is described in a three volume set, which consists of:

1. **SEEA Central Framework** (SEEA-CF). The environmental resource accounts that measure, in physical and monetary terms, the stock of natural resources and the flows that cross the boundary between economy and the environment, including natural inputs that circulate within the economy and the residuals that the economy returns to the environment.

   The SEEA-CF focuses on the abiotic components of natural capital, e.g. minerals and energy, although it also includes some biotic components of natural capital, e.g. timber. It also includes material flow accounts (MFAs) and waste, water and air emission accounts as well as environmental transfers, expenditures and environmental activities (see https://seea.un.org/sites/seea.un.org/files/seea_cf_final_en.pdf).

2. **SEEA-Experimental Ecosystem Accounting** (SEEA-EEA). At present, the SEEA-EEA is a methodological guidance document rather than a formal statistical standard. It aims to show how to measure ecosystem components of natural capital, in terms of the state of ecosystems and their capacity to provide ecosystem services, as well as organising the information required for estimating the costs of protecting or repairing damage. The aim is to develop accounts for important natural

capital stocks (ecosystem assets characterised by their extent and condition), thematic accounts (including land, carbon, water and biodiversity) and ecosystem service flow accounts, initially compiled using quantitative physical metrics. Over time, these accounts may be expressed in monetary terms, depending on methodological suitability. (The SEEA-EEA handbook can be found at: https://seea.un.org/sites/seea.un.org/files/websitedocs/eea_final_en.pdf).

3. **SEEA Applications and Extensions** (SEEA-AE). Among other things, this volume describes examples of analytical and policy uses of natural capital accounts (see http://unstats.un.org/unsd/envaccounting/ae_white_cover.pdf).

The concept of natural capital accounting as implemented in the EU is closest to the concept of ecosystem accounting described in SEEA-EEA. Figure 2.1 therefore illustrates the structure of the UN ecosystem accounting methodology by setting out the different core bio-physical accounting modules (green) and monetary accounting modules (blue) of the SEEA-EEA.

By way of further illustration, Table 2.1 provides an overview of the key accounting modules depicted in Figure 2.1 and gives a definition and example for each.

Important methodological aspects of the ecosystem accounting approach can be described as follows (adapted from UNSD, 2014b):

- The SEEA-EEA encompasses measurement in both bio-physical terms (e.g. hectares, tonnes) and in monetary terms, whereby flows of ecosystem services are ascribed monetary valuations through various market and non-market valuation techniques. The valuation of ecosystem services also supports the valuation of ecosystem assets.

- The SEEA-EEA is designed to facilitate comparison and integration with the economic data prepared following the SNA. This leads to the adoption of clear measurement boundaries and valuation concepts and facilitates the mainstreaming of ecosystem information with standard measures of income, production and wealth that are required for analysis of, for example, sustainability and green economy issues.

- The SEEA-EEA provides a broad, cross-cutting perspective on ecosystems at country or regional level. In principle, while many of the concepts can be applied at a detailed level, the intent is to provide a broad picture to enable integration with the broad picture of the economy from the national accounts.

- Ecosystem accounting outputs are generally produced both in maps and in tables — this allows aggregate physical or monetary information for administrative or physical units.

Figure 2.1 The structure of the SEEA EEA ecosystem accounts

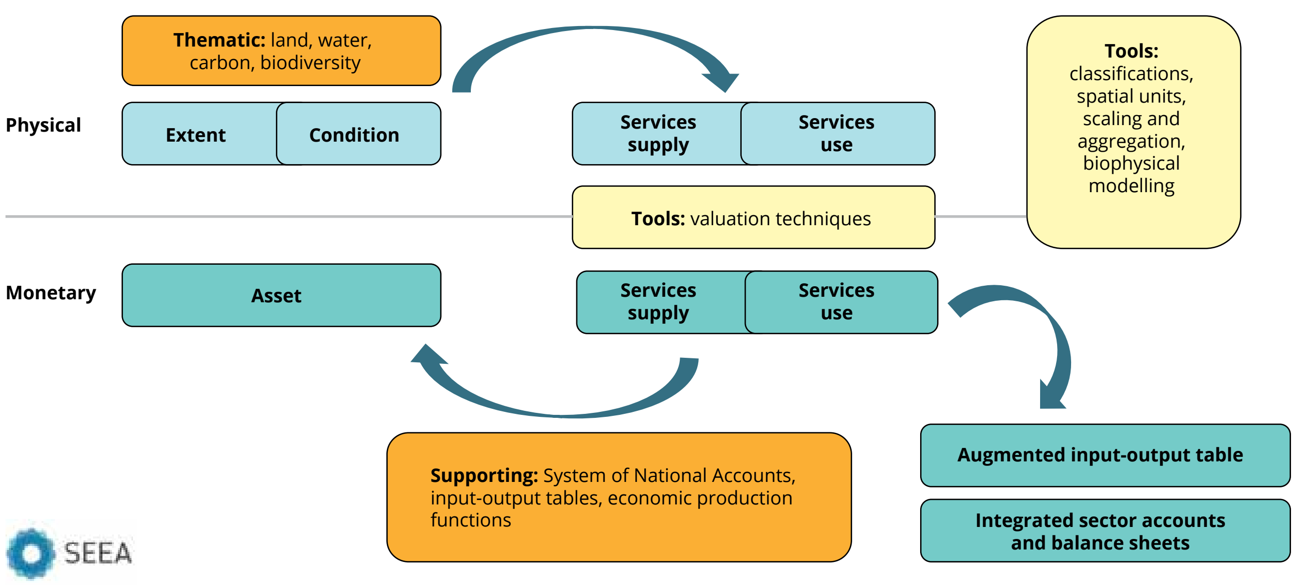
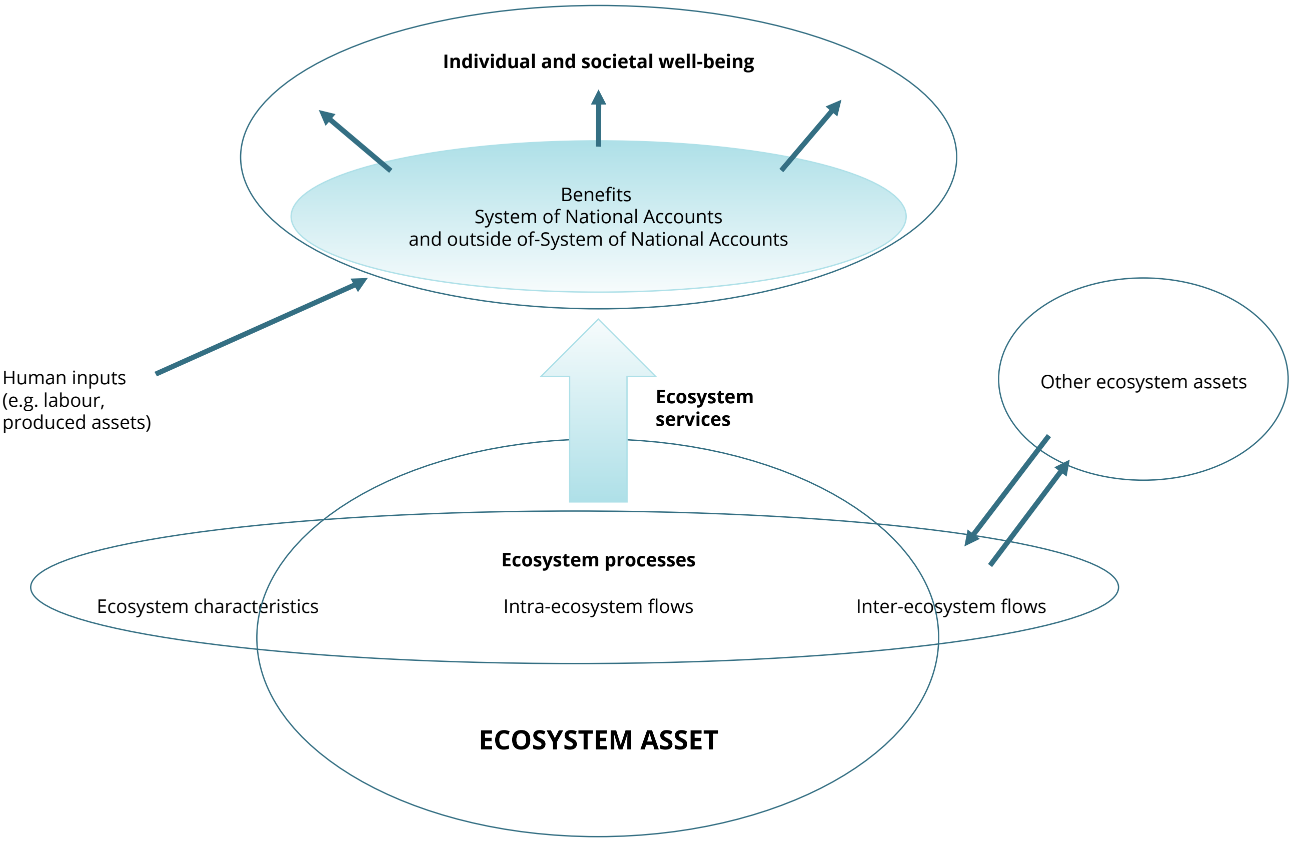


Table 2.1 Key accounting modules of the SEEA-EEA

Accounting module	Analytical Focus	Example
Ecosystem extent account	Records ecosystem types which are defined on the basis of aspects such as land cover, soils, and ecosystem use.	e.g. the extent of temperate beech forest
Ecosystem condition account	Reflects the state and functioning of ecosystems, as expressed in a range of indicators covering such aspects as vegetation, soils, hydrology, species diversity.	e.g. percentage organic matter in the topsoil, or level of fragmentation of forest ecosystems
Ecosystem services supply and use table — physical terms	Reflects the flow of ecosystem services, expressed in various physical units, during an accounting period, typically one year.	e.g. amount of timber produced in beech forests or amount of air pollutants filtered out of ambient air by forest vegetation.
Ecosystem services supply and use table — monetary terms	Reflects the flow of ecosystem services, expressed in euro, during an accounting period, typically one year.	e.g. the market value of the annual volume of carbon sequestration of forest ecosystems, calculated using EU carbon market prices and expressed in euro.
Ecosystem monetary asset account	Indicates the net present value (NPV) of the expected flow of ecosystem services over a discount period and for a given discount rate.	e.g. the NPV of the contribution of all ecosystem services of a specific ecosystem type to the economy in euro over the next 25 years.

Source: EEA, 2018.

Figure 2.2 A conceptual depiction of the SEEA-EEA



Source: Adapted from UNSD, 2017.

Figure 2.2 shows a key representation of the conceptual underpinning of the SEEA-EEA from the Technical Recommendations (SEEA-EEA-TR) document (UNSD, 2017): ecosystems (measured by extent and condition) are considered as assets that support a flow of ecosystem services that in combination with human inputs generate benefits for individuals and society. Some of these benefits are recorded in the national accounts (SNA), others are not — which is a key reason for developing ecosystem accounting.

Since 2014 a substantial amount of work has gone into the further development of methodological guidance for ecosystem accounting in the shape of 'Technical recommendations in support of the implementation of SEEA EEA' (UNSD, 2017). This provides the most up-to-date and detailed methodological guidance on developing a national ecosystem accounting approach and integrates experience gained from pilot work on developing ecosystem accounts in countries and at international level during recent years. A new revision process was launched by the UNSD in 2017 with the goal of preparing a revised SEEA ecosystem accounting handbook by December 2020 for submission to the meeting of the UNSC in March 2021.

Another useful reference document is the quick-start package on ecosystem natural capital accounts of the CBD (Weber, 2014), which provides concrete guidance for countries that would like to develop ecosystem natural capital accounts. As a CBD document, it aims to support the implementation of the Aichi Biodiversity Target 2 ([5]) on integration of biodiversity values in national accounting systems and builds on the UN handbook on experimental ecosystem accounting.

2.2 Environmental-economic accounting as an integrated analytical approach

The UN SEEA approach aims to follow national accounting principles and rules that emphasise the study of environment-economy links following standard economic techniques, such as using market ('exchange') values. This approach provides major new insights but is also likely to have certain limitations. The first limitation relates to representing the dynamic reality of ecosystem processes, which are characterised by feedback loops, non-linear resilience thresholds and multi-directional trade-offs. The complex interactions between ecosystems, human land use and the role of forests and other vegetation in slowing down climate change are an example. All of these are difficult to represent with an accounting approach that assumes more simple connections between the different accounting elements, which means that complementary analytical approaches are required (Oliver et al., 2015).

The second limitation relates to the territorial approach that underpins standard accounting approaches and does not allow an easy analysis of the transnational trading flows of economic goods or the global impact of national greenhouse gas emissions. For illustration, this means that the SEEA approach would not be able to provide a direct analysis of the indirect greenhouse gas effects of producing biofuels. The challenge of measuring flows between different countries is also discussed in the context of analysing the implementation of the international sustainable development goals (SDGs) by Ruijs et al. (2018).

Weber (2018) provides a review of two visions underlying the development of ecosystem accounting: extending the scope of the economy to improve recognition of ecosystems and their services; and multiple interacting (co-evolving) systems, in which maintaining the ecosystem's potential to deliver services is at the core.

In the first approach, degradation is understood as loss of services. As aggregation of physical ecosystem services is difficult because of their variety and the multiple units used for their measurement, valuation in money with market prices or shadow prices is seen as the only way to assess all services, to aggregate them and to calculate the wealth of the ecosystem.

In the second approach, degradation is the loss of functions and resilience. The aggregate relates to the ecosystem itself, measured according to the sustainability of its overall performance at delivering services, not to the services themselves. Therefore, services do not need to be recorded exhaustively and valued in money, and no valuation of ecosystem wealth is anticipated beside the value of economic natural assets presently recorded in the SNA. Valuation is anticipated only for the costs of restoring ecosystem functions.

In the context of these conceptual discussions, it seems worthwhile considering a wider ecosystem accounting perspective that also connects to other recent research areas exploring the carrying capacity of the Earth for human activity (e.g. the planetary boundaries proposed by Rockström et al. (2009)). Such an approach has been

([5]) CBD Aichi Biodiversity Targets: http://www.cbd.int/sp/targets developed in Australia that, using the SEEA-CF and SEEA-EEA as a foundation, seeks to build a more versatile framework that allows different perspectives to be taken into account in the analysis of environment-economy interactions (Bureau of Meteorology, 2013). This Joint Perspectives Model is depicted in Box 2.1.

The Joint Perspectives Model assumes that, while monetary accounts are useful, the development of physical accounts is more fundamental in the sense that it provides the foundation for the former. This approach is used to represent the core relationships between the economy, society and the environment. It envisages four nested systems: the physical Earth system, the living system, the human cultural system and the economic system; these collectively define the scope of any set of environmental accounts. The idea of nesting is used to emphasise the need to be able to use accounts to transfer value between places, times and entities and, especially, to show how physical accounts for the Earth and living systems are relevant to social and monetary accounts at the level of cultural and economic systems. It is envisaged that:

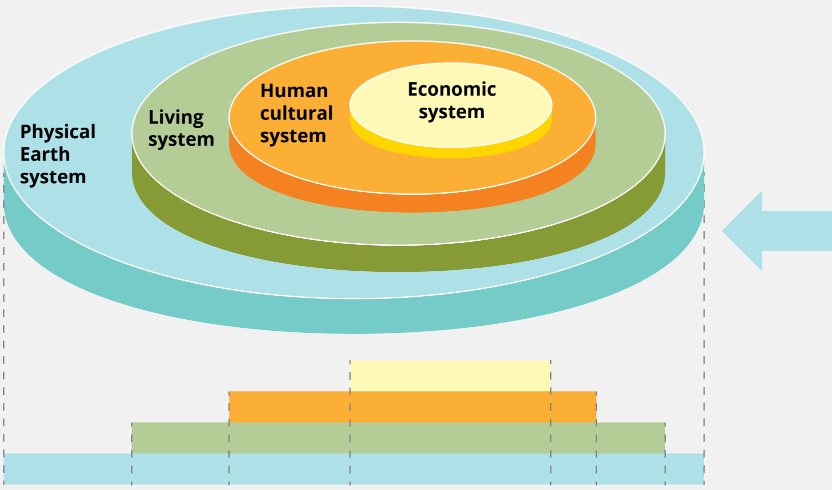
- **Physical and living systems** — accounts would be based on physical measures, and those for natural capital would document ecosystem assets and flows together with measures of their functions and processes, biodiversity, the bio-carbon cycle and the water cycle. The accounts would primarily be defined spatially using classifications of land cover, habitat, ecosystem or environmental asset.

- **Human cultural systems** — relevant accounts would include those for ecosystem services that would document the benefits flowing directly to human cultural systems that are outside the formal economy. The accounts would also use indices of human well-being, suffering and happiness, measured at the scales of individuals, groups, municipalities, communities, societies and nations.

- **Economic systems** — the use of ecosystem service accounts would also be a key part, but here they would be measured in market-based values and captured in the SNA, measured at the scale of individuals, households, businesses, enterprises and nations.

In this conceptual approach, the abiotic and ecosystem components of natural capital are represented in the blue and green layers. They are interconnected and provide the foundation for the human cultural and economic systems. As in the SEEA framework, this

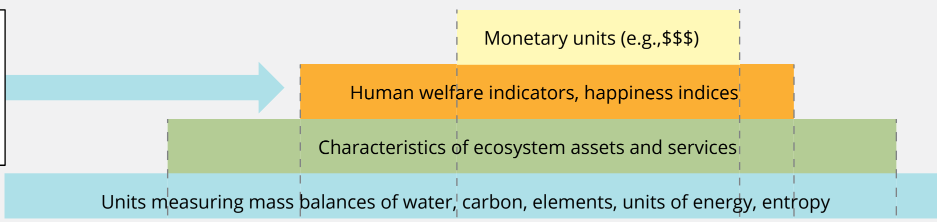
Box 2.1 The Joint Perspectives Model (after Bureau of Meteorology, 2013)



The Joint Perspectives Model is represented by a series of nested systems that include the physical earth system, the living system, the human cultural system and the economic system. These are represented in terms of the diagram left, and in the cross-sectional view, the vertical dotted lines delineate systems, while the coloured horizontal slices represent the different perspectives from which systems can be viewed.

Thus, while the economic system is generally viewed from the economic perspective, it can also be viewed from the physical Earth, living and human cultural system perspectives because it is, in turn, made of each of these systems. Similarly, the living system, which emerges from the physical Earth system, can also be understood from a physical perspective.

The nested system gives rise to the design of an integrated set of accounts linking physical and natural capital with human cultural and economic measures.



approach aims to offer an integration perspective, combining environmental and socio-economic analysis, but also a starting point that recognises more explicitly the bio-physical underpinning of the environment-economy relationship.

2.3 Environmental-economic accounting as a policy support tool

The SEEA is explicitly designed to help understand the interlinkages between the economy and the environment (both abiotic and biotic aspects), as its name implies. According to the UNSD (2015) the analytical use of SEEA results related to the environment-society interface can be divided into four themes:

1. improving access to services and resources linked to policies that ensure that households have access to appropriate, reliable and affordable resources, e.g. clean water, energy, food, land, materials and waste treatment;

2. addressing the allocation of endowments of natural resources to meet the needs of current and future generations by managing supply and demand;

3. improving the state of the environment and reducing impacts, recognising that economic activities may harm the environment, and including activities related to protecting and restoring natural capital for future generations;

4. mitigating risks and adapting to extreme events caused by extreme natural events and changing environmental patterns, referring to policies that aim to reduce harm to humans, ecosystems and the economy.

The four themes identified by the UNSD are helpful in the sense that they provide insight into the analytical objectives of the SEEA approach. To properly understand the policy utility of natural capital accounting, however, it is necessary to add analytical lenses that take the policy process as their starting point. There are two important aspects here: the use of natural capital accounts as indicators for different stages of the policy cycle (e.g. progress to targets and issue identification) and the role they play in supporting integrated and other analyses (e.g. using the drivers, pressures, state, impact, response (DPSIR) framework, an extension of the pressure-state-response (PSR) model developed by the OECD, and scenario analysis).

Vardon et al. (2017) proposed looking at five different stages of the policy cycle in the context of natural capital accounting, which are: (1) issue or problem identification; (2) policy response; (3) policy implementation; (4) policy monitoring; and (5) policy review.

European environmental accounting experts (Radermacher and Steurer, 2015) have argued in complementary work that it is essential to understand the stage or stages in the policy cycle where natural capital accounts would be used and they discuss the potential role of different natural capital accounting components in that regard.

Physical asset accounts provide information on the state, trends and distribution of different types of natural capital and such a monitoring function appears best suited to informing early stages of the policy cycle, i.e. identifying problems or opportunities and setting priorities (Vardon et al.'s stage 1). For example, specific types of natural capital that show strong decline or growth, or certain geographic areas that require particular attention in a natural capital perspective, can be highlighted.

Where accounting data include information on the ownership of natural capital assets, they can also provide useful input to identifying potential policy responses (i.e. stage 2), or improving programme delivery by giving insight into the structure and type of economic agents that need to be influenced for certain policy goals to be reached (i.e. stage 3).

The design of natural capital accounts influences their potential role in informing policymaking. This relates to spatial coverage, i.e. whether this covers an entire territory, certain regions or specific types of ecosystems or other ecological units, and spatial resolution, i.e. coarse or detailed. For example, evidence on the role of ecosystems in national greenhouse gas reporting must cover the entire territory of a country and all (important) types of bio-carbon in vegetation, animals and soils. However, detailed information on carbon trends and carbon management options in biomass carbon 'hotspots', e.g. peatlands, can also inform potential policy responses and the appraisal of policy options, e.g. regarding a development proposal that would affect a particular peatland area (i.e. stage 1 and/or 4).

Radermacher and Steurer (2015) consider that the requirements for natural capital accounts are likely to vary during different policy stages. Identifying these, and developing natural capital accounts with policy use in mind, will involve potential trade-offs between statistical measurability, scientific soundness and political relevance. This also has implications for key design requirements of natural capital accounts, such as their accuracy and update frequency. Further development and practical use of such accounts at national level will help improve our understanding of the most promising policy applications for accounting frameworks.

These considerations provide a good platform for understanding potential uses of natural capital accounting in different policy processes. However, environmental economic accounts are likely to be complemented with other analytical tools, just like general trends in GDP need to be dissected with the help of macro-economic models and sector-specific analysis to properly understand their implications for policymaking. The combination of natural capital accounts with other integrated analyses (e.g. DPSIR, scenario tools) could enhance their value for policymaking.

Overall, there is still substantial work to be done for natural capital accounting to achieve the policy influence it could have. This requires further development and a focused exploration of application options for natural capital accounts in policy debates and decisions. Such an exploration can be developed by identifying information needs relating to the management of natural capital by looking at related policy objectives. This issue is taken up again in the final chapters of this report.

3 Land accounts and ecosystem extent accounts

3.1 Introduction

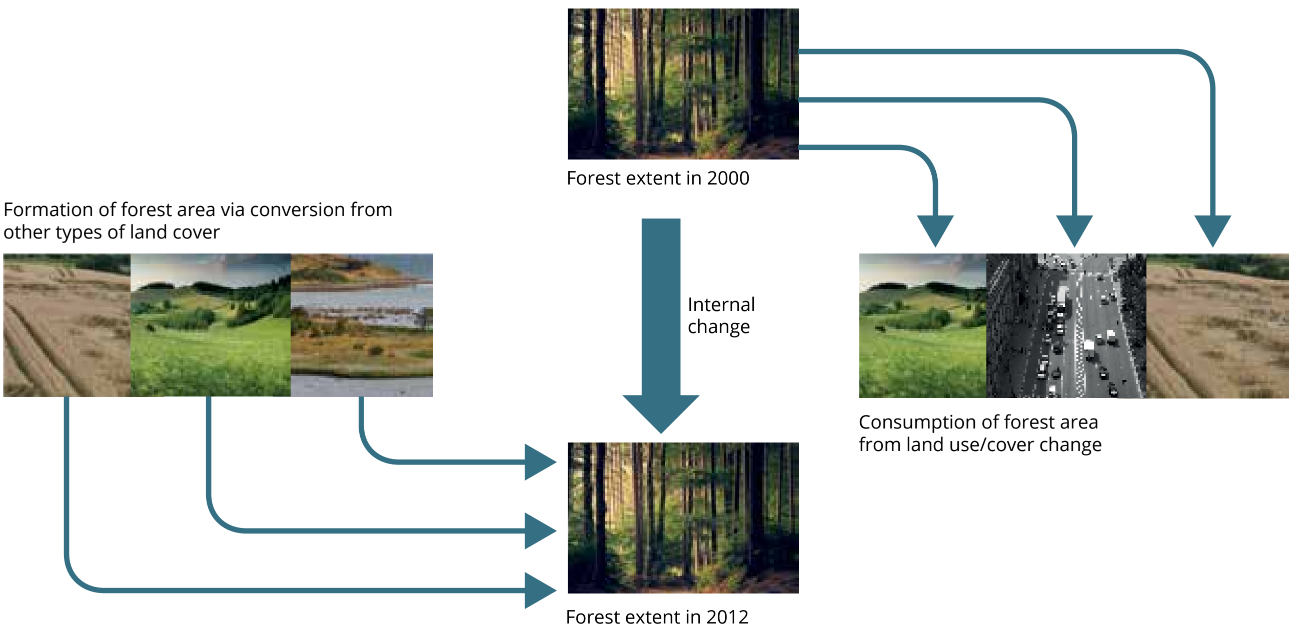
This chapter summarises the results of two accounting exercises that deal with terrestrial ecosystems and build on the LEAC database, initially developed by the EEA for accounting purposes (EEA, 2006). This was further developed as part of the Integrated Data Platform that the EEA has established to support integrated spatial analysis over recent years and now also facilitates accounts on ecosystem extent and condition. The European land accounts are a well-developed approach established over 15 years ago and are a component of the SEEA-CF. The summary presented here, therefore focuses on their use in an analytical context.

The European ecosystem extent accounts are partly completed and partly still under development as a key contribution of the EEA to KIP INCA. Section 3.3 presents selected results of tier I and tier II ecosystem extent accounts. Tier I extent accounts are close to land accounts in their current form, as they track broad ecosystem types developed under the EU MAES process, which align to a large degree with level 1 CLC categories. Tier II ecosystem extent accounts, however, allow a more differentiated analysis of ecosystem trends, which is highlighted in this chapter. Further detail on the methodology and results of the current ecosystem extent accounts is available in an EEA working report (EEA, forthcoming).

3.2 European land accounts

Land accounts track changes in the stock of different land cover types and analyse which land cover type conversions ('land cover flows') are the most important. Land accounts help us to understand the major trends that impact land and soil as key environmental resources. Figure 3.1 illustrates the principle of land accounts.

Figure 3.1 Illustration of the land accounting method



Source: EEA, 2018.

A recent EEA report summarises key outcomes of land account analysis for Europe in the period 1990 to 2012 (EEA, 2017b). The analysis presented in the report demonstrates the insight that can be gained for better management of land resources and terrestrial ecosystems by combining land accounting results with socio-economic and ecological analysis from other fields of research. Via this approach, the report provides an integrated perspective on the relationship between land cover/use and the environment. The following sections summarise key analytical outcomes of this recent EEA study.

3.2.1 The importance of land as an environmental resource

Land and the ecosystems that it supports are the foundation of our society and a source of economic growth. Land systems provide not only food, feed and fibre, but also building materials, bioenergy and, increasingly, a broad range of other products. Regulating ecosystem services such as flood regulation and carbon sequestration, ecosystem functioning, pollination and biocontrol of pests plays a crucial role in the functioning of land systems (Foley et al., 2005). Moreover, cultural ecosystem services are also closely connected to agricultural land use, which, for example, can facilitate as well as limit the benefits humans derive from our rural landscapes.

The use of land in Europe shows that accelerating rates of construction, changing demographics, technological changes and climate change are some of the key drivers influencing the use of Europe's vast landscapes. The continent's land use increasingly sees striking changes and conflicts over land demand, which will require reconciling place-based management and macro-policies to foster responsible land use. The increased covering up of fertile land with buildings, transport infrastructure and industry offers economic benefits but also highlights the need to maintain Europe's natural and landscape resources. Proactive and integrated policies on land planning, agriculture, recreation, tourism, transport, energy and other sectors can limit the negative effects of land take. In cities, smart and sustainable solutions for urban development — such as recycling old industrial land for new uses and creating more green spaces — will be needed.

Proper land management can lead to a wide diversity of land use between rural and urban settings. It can also protect fertile land for food and biomass production by ensuring effective means to promote soil functions, such as carbon storage, and prevent soil erosion. Therefore, managing the land resource well is essential for a wider societal transition to sustainability.

3.2.2 Main changes in European land cover 2000-2012

The most recent data on land cover change in Europe are derived from CLC 2012 and show that total land cover change increased from the period 2000-2006 to the period 2006-2012. There are indications that land use is changing even faster, e.g. through changes in agricultural practices, with a time lag of several years before the change is reflected and discernible in the land cover and landscape. Almost all trends in land cover change in Europe have shown a consistent direction throughout the period 1990-2012.

Land take for urban development, infrastructure and industrial purposes is the most important land cover flow and exceeds 1 000 km^2 per year in the EEA-39 (the 33 EEA member countries and six cooperating countries), which is an area three times the size of Malta. Several underlying causes of land take can be identified, driven by societal needs and shaped by regional, sectoral and environmental policies. Almost half of the land take was at the expense of arable farmland and permanent crops (EEA, 2017b).

Europe's agricultural land, often of good quality and in favourable locations, continues to decrease at an average rate of 1 000 km^2 per year (latest figures for 2006-2012 for the EEA-39). The fine-grained structure and associated biodiversity of traditional rural landscapes in Europe continue to be affected by land take, agricultural intensification and farmland abandonment.

The land area for forestry has largely stayed the same, gaining from a limited increase in forest area mostly because of farmland abandonment and afforestation. As expected, trends and figures differ between countries.

Other economic sectors require smaller land areas, but they can be locally dominating. Generally, energy generation by wind turbines and solar energy parks does not require much land. However, there can be other issues, such as public resistance to wind turbines due to their impact on landscape values or disturbance caused by noise. Flood protection also requires some space, e.g. by reserving certain areas for flood retention.

In some cases, land reclamation for coastal protection or harbour development can be substantial, with the latter generally considered under land take for urban, infrastructure and industrial purposes.

3.2.3 Impact of land cover change on biodiversity and ecosystems

The long history of land use in Europe has resulted in a specific interaction between human uses and biodiversity. This coevolution through time has created cultural landscapes that are valued for their ability to generate income as well as for their aesthetic, biodiversity and cultural values (Pedroli et al., 2007). Longstanding agriculture and forestry land use systems are generally the sources of the most valued landscapes and habitats in Europe (Hodge et al., 2015).

As farming and forestry systems became progressively more specialised and intensive, habitats and biodiversity came under increasing pressure. The threats to nature that result from such changes in land use systems have been acknowledged for decades now (Stanners and Bordeaux, 1995). However, land abandonment is also leading to the disappearance of former landscape patterns, or a change in their components, so that their associated biodiversity value is declining (Renwick et al., 2013).

Land use processes that act as the main drivers of changes in biodiversity are habitat loss, habitat deterioration and eutrophication, which are the result of land conversion, soil contamination or nutrient enrichment, and overharvesting of resources. All these factors can be exacerbated by other environmental drivers, such as climate change impacts and invasive alien species. In view of the second target of the EU Biodiversity Strategy to 2020 (EC, 2011) to restore at least 15 % of degraded ecosystems by 2020, close monitoring of the land-related drivers is crucial.

Examples of habitat loss can be found in almost all situations of land cover change, but they are associated in particular with urban sprawl and infrastructure developments or with land reclamation or consolidation for improved agricultural use. However, land abandonment, especially of extensively managed grazing land, can also lead to the loss of habitats for species characteristic of agricultural landscapes.

Spontaneous forest encroachment onto abandoned land is occurring in many areas across Europe, especially in the Mediterranean (Tomaz et al., 2013), but also in boreal semi-natural meadow systems, the existence of which depends on a well-defined sustainable grazing and mowing pressure (Berninger et al., 2015). Such encroachment can create extra habitat niches but in most cases it has negative effects on farming-related biodiversity that depends on extensive agricultural land use (Moreira and Russo, 2007).

3.2.4 Reflections on analysing land cover change in its socio-economic and policy context

The 2017 EEA report on landscapes in transition (EEA, 2017b) shows that the analysis of land cover change in Europe via land accounts can now build on a well-established methodology and tools. The report draws on this analysis and other studies for reviewing key economic and political factors that impact the use of land in Europe. The land report identifies that most scenarios for global economic and societal development show a strong territorial polarisation of land functions in Europe in the near future. Although multi-functional land use is widely seen as a promising solution for balancing the delivery of different types of ecosystem services (e.g. food provisioning with cultural services), there are not many proactive policy alternatives to set the boundaries for such use and at the same time address environmental management that invariably requires system and place-based adaptation (Buckwell et al., 2017). Various EU policies play an important role in achieving sustainable land management, in particular the EU Common Agricultural Policy, (bio-) energy policy and regional policy.

The EEA report identifies that urban sprawl, landscape fragmentation, soil degradation and the declining ecological quality of land are becoming better known and spatially localised. Therefore, increasing attention should be given to sound and efficient use of natural (land-related) resources, innovative approaches to sustainable rural and urban development and effective spatial planning methods based on shared territorial visions of the future. Natural capital accounting provides a measurement framework for integrated land use planning and policy that can support better management to deliver multi-functional landscapes in pursuit of this vision. However, the EEA report identifies crucial knowledge gaps for environmentally and societally sound land management in Europe. These include:

- **Monitoring and reporting data** — What data are needed for better land assessments? What can the EU Copernicus satellite programme contribute?
- **Land use and management** — How can the information on land cover change be better translated in terms of land use and management?
- **Scaling up** — How can the differences in national implementation be accounted for in developing EU policies for sustainable land management?

The above points need to be addressed in a coordinated way at national and European level to support the creation of a shared environmental knowledge base on land use, land cover and soil trends, and to enable better management of this crucial part of our natural capital (see Chapter 7 for additional analysis).

3.3 Ecosystem extent accounts

3.3.1 Introduction

Ecosystem extent accounts show the opening and closing stock of different ecosystem types in a spatially explicit manner (e.g. in ha or km^2). They follow a very similar approach to land accounts but aim to investigate land cover trends in a way that focuses on ecosystem stocks rather than land resources. Ecosystem extent accounts thus track the opening and closing stock of broad ecosystems and contain entries for additions and reductions to each ecosystem type, allowing a detailed analysis of the stock of ecosystems and changes over time. This section summarises recent work of the EEA in the context of KIP INCA to develop ecosystem extent accounts for Europe that follow the SEEA-EEA methodology.

3.3.2 Methodology for European ecosystem extent accounts

Calculating ecosystem extent accounts requires deciding on an appropriate typology for ecosystems within a given accounting area to allow the delineation of different ecosystem types. In this regard, the EEA proposes a three-tier approach to developing ecosystem extent accounts in Europe. Tier I comprises ecosystem extent accounts for 9 of the 12 broad ecosystem types developed in the MAES process ([6]) ('coastal', 'shelf' and 'open ocean' are excluded owing to data limitations for marine ecosystems). The extent of these ecosystems is determined based on aggregations of their constituent CLC classes (see Annex 1 for further detail). The tier I accounts are calculated using an updated version of the EEA LEAC.

The tier I ecosystem extent accounts cover the entire terrestrial area of the EEA-39 and the MAES typology (and constituent CLC classes) are non-overlapping. As such, the accounts satisfy the mutually exclusive and collectively exhaustive (MECE) principle required by the SEEA-EEA in a terrestrial context. Tier II comprises ecosystem extent accounts compiled using CLC level 3 classes that are considered to have a very good match to ecosystems of particular interest. Therefore, these do not provide the wall-to-wall coverage of the tier I ecosystem extent account, as only certain land cover classes match well to specific ecosystem types. Instead, tier II provides more detailed ecosystem extent accounts using the level 3 classes in the CLC system to analyse trends in the extent of MAES ecosystem sub-types.

Tier II ecosystem extent accounts focus on CLC classes that match ecosystems of high importance to biodiversity and ecosystem service provision. For example, the CLC class 244 ('Agro-forestry areas') matches well with a specific type of ecosystem mainly found on the Iberian Peninsula (called 'dehesa' or 'montado'), which has developed owing to a traditional land use that mixes the exploitation of oak trees with cropping and/or grazing. This ecosystem provides important habitat for species and habitats of European importance and delivers a variety of ecosystem services. The tier II ecosystem extent accounts are also calculated using updated LEAC cubes within the EEA Integrated Data Platform.

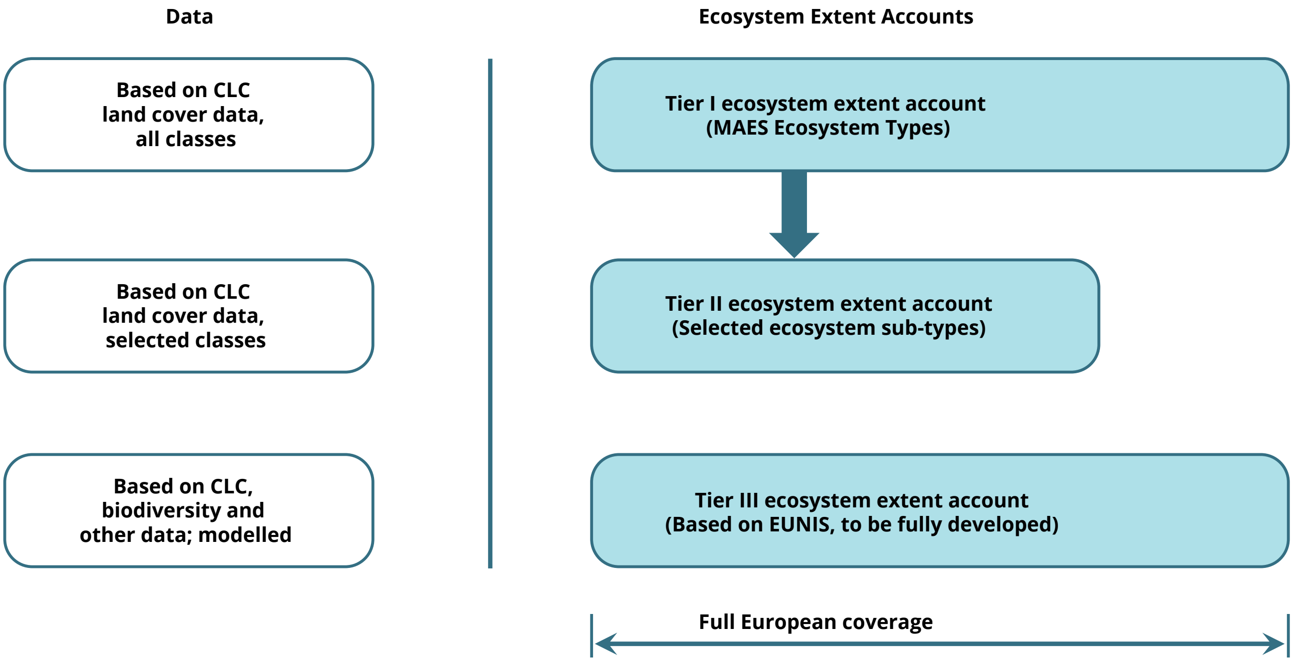
In future, the intention is to calculate tier III ecosystem extent accounts using a probability-based mapping approach for the distribution of EU ecosystems under the MAES process (based on combining satellite observation data sets and the EU Nature Information System (EUNIS) habitat classifications; see EEA, 2018b). This would allow a further differentiation of MAES ecosystem types into (groupings of) EUNIS habitat types. Figure 3.2 sets out the relationship between the CLC data and the three tiers of the ecosystem extent accounts proposed.

The UN handbook on experimental ecosystem accounting (UN et al., 2014b) discusses the need to define a reference situation as the baseline for calculating ecosystem extent and condition accounts. Several options exist for establishing such a baseline, which can refer back to a (hypothetical) natural state, an ecological target state or simply a certain starting year linked to availability of regular data for building accounts.

Environmental legislation in Europe often contains maintenance and restoration goals. For example,

([6]) The broad terrestrial ecosystem types in MAES include: urban, cropland, grassland, forest and woodland, heathland and shrub, sparsely vegetated land, and wetlands; freshwater ecosystems are rivers and lakes, plus marine inlets and transitional waters.

Figure 3.2 Structure for European ecosystem extent accounts



Source: EEA, 2018.

in developing the EU Water Framework Directive (EU, 2000) each country had to define a 'good ecological status of the watershed', which represents a target to be achieved in view of the current situation and the cost of measures. For ecosystem accounting, this could be represented by a societal goal of maintaining the capability of ecosystems at their current level as well as providing scope for dealing with future environmental pressures such as climate change.

In practice, this would be a very complex scientific exercise and the pragmatic choice under KIP INCA has been to settle for the most reliable starting year (which corresponds to the year 2000 for most component accounts). This approach was also adopted for the ecosystem extent accounts presented in this section, which start with CLC 2000 as the key input data layer for calculating opening stock. It needs to be acknowledged, however, that this choice of starting year means that the massive land cover change that occurred in Europe during the 20th century (and before) and the associated, often negative, environmental impacts are not recorded in the European ecosystem extent accounts presented below.

3.3.3 Results for tier I European ecosystem extent accounts (EEA-39)

This section presents the tier I ecosystem extent accounts calculated using the MAES typology at the European level (EEA-39). Tables 3.1 and 3.2 show the changes in ecosystem extent for the periods 2000-2006 and 2006-2012 across the EEA-39 countries collectively. The accounts show changes in ecosystem extent in absolute terms (km^2) and as a percentage of the initial ecosystem stock as well as reductions, additions, turnover (gross change, including internal transformations ([7])) and the extent of stable ecosystem stock (opening extent minus reductions). This information is presented in the rows of Tables 3.1 and 3.2. The data for each ecosystem type are organised in the columns and aggregated to a total in the final column of each table.

([7]) This includes change between CLC level 3 classes that are within the same, broader ecosystem type.

Table 3.1 Tier I ecosystem extent account, EEA-39, 2000-2006, in km²

Area in km²	MAES ECOSYSTEM TYPES									
	1 Urban	2 Cropland	3 Grassland	4 Forest and woodland	5 Heathland and shrub	6 Sparsely vegetated land	7 Inland wetlands	8 Rivers and lakes	9 Marine inlets and transitional waters	Total
Ecosystem extent 2000	**226 286**	**2 040 348**	**654 448**	**2 007 896**	**280 713**	**347 090**	**129 534**	**140 604**	**28 818**	**5 855 738**
Reductions to initial ecosystem extent	1 949	10 986	3 595	48 040	1 802	2 454	635	317	62	69 842
Additions to initial ecosystem extent	8 352	6 658	1 710	49 128	790	1 983	144	978	98	69 842
Net additions to ecosystem extent (additions – reductions)	+6 403	-4 328	-1 885	+1 088	-1 012	-471	-491	+661	+36	-
Net additions as % of initial extent	**2.8 %**	**-0.2 %**	**-0.3 %**	**0.1 %**	**-0.4 %**	**-0.1 %**	**-0.4 %**	**0.5 %**	**0.1 %**	**-**
Total turnover of ecosystem extent (reductions + additions)	10 301	17 644	5 305	97 168	2 592	4 437	779	1 295	160	139 684
Total turnover as % of initial extent	4.6 %	0.9 %	0.8 %	4.8 %	0.9 %	1.3 %	0.6 %	0.9 %	0.6 %	2.4 %
Extent of stable ecosystem stock	224 337	2 029 362	650 853	1 959 856	278 911	344 636	128 899	140 287	28 756	5 785 896
% of ecosystem stock	99.1 %	99.5 %	99.5 %	97.6 %	99.4 %	99.3 %	99.5 %	99.8 %	99.8 %	98.8 %
Ecosystem extent 2006	**232 689**	**2 036 020**	**652 563**	**2 008 984**	**279 701**	**346 619**	**129 043**	**141 265**	**28 854**	**5 855 738**

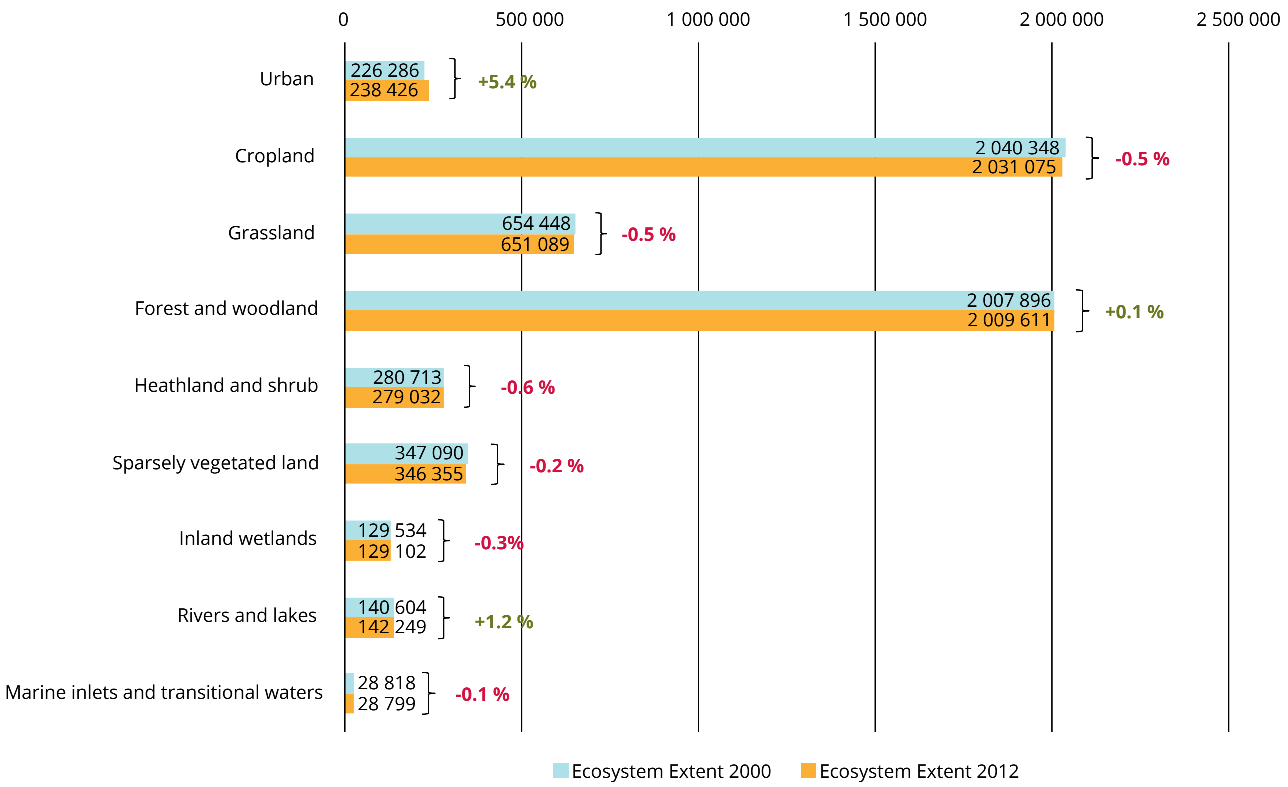
Source: EEA, CLC accounting layers 2000, 2006.

Table 3.2 Tier I ecosystem extent account, EEA-39, 2006-2012, in km²

Area in km²	MAES ECOSYSTEM TYPES									
	1 Urban	2 Cropland	3 Grassland	4 Forest and woodland	5 Heathland and shrub	6 Sparsely vegetated land	7 Inland wetlands	8 Rivers and lakes	9 Marine inlets and transitional waters	Total
Ecosystem extent 2006	**232 689**	**2 036 020**	**652 563**	**2 008 984**	**279 701**	**346 619**	**129 043**	**141 265**	**28 854**	**5 855 738**
Reductions to initial ecosystem extent	2 542	11 812	4 720	69 765	1 255	2 177	189	272	96	92 828
Additions to initial ecosystem extent	8 279	6 867	3 246	70 392	586	1 913	248	1 256	41	92 828
Net additions to ecosystem extent (additions – reductions)	+5 737	-4 945	-1 474	+627	-669	-264	+59	+984	-55	-
Net additions as % of initial extent	**2.5 %**	**-0.2 %**	**-0.2 %**	**0.0 %**	**-0.2 %**	**-0.1 %**	**0.0 %**	**0.7 %**	**-0.2 %**	**-**
Total turnover of ecosystem extent (reductions + additions)	10 821	18 679	7 966	140 157	1 841	4 090	437	1 528	137	185 656
Total Turnover as % of initial extent	4.7 %	0.9 %	1.2 %	7.0 %	0.7 %	1.2 %	0.3 %	1.1 %	0.5 %	3.2 %
Extent of stable ecosystem stock	230 147	2 024 208	647 843	1 939 219	278 446	344 442	128 854	140 993	28 758	5 762 910
% of ecosystem stock	98.9 %	99.4 %	99.3 %	96.5 %	99.6 %	99.4 %	99.9 %	99.8 %	99.7 %	98.4 %
Ecosystem extent 2012	**238 426**	**2 031 075**	**651 089**	**2 009 611**	**279 032**	**346 355**	**129 102**	**142 249**	**28 799**	**5 855 738**

Source: EEA, CLC accounting layers 2006, 2012.

Figure 3.3 **MAES ecosystem extent and relative change, EEA-39, 2000-2012, in km²**



A key observation from Tables 3.1 and 3.2 is that existing ecosystem stock tends to be quite stable in the EEA-39 (around 99 % or more of the ecosystem extent is stable between 2000 and 2006, and 2006 and 2012). The main exception is for forest and woodland, which also reveals relatively high levels of turnover (gross changes) of 5 % to 7 % over accounting periods.

A summary of the changes in ecosystem extent reported in Tables 3.1 and 3.2 is provided in Figure 3.3, which shows the extent of MAES ecosystem types in 2000 and 2012 (blue and orange bars, respectively) and the change in stock over this period as a percentage (red or green figures to the right of the bars). Figure 3.3 reveals that urban ecosystems show the highest relative increase in extent between 2000 and 2012 (5.4 % based on an opening extent of 226 286 km²). As shown in Tables 3.1 and 3.2, these increases represent the largest increases in absolute extent of any ecosystem type in the EEA-39.

Figure 3.3 also shows that the extent of the ecosystem type 'Rivers and lakes' increased between 2000 and 2012 (by 1.2 % based on an opening extent of 140 604 km²), the second largest increase after urban ecosystems. Figure 3.3 illustrates that the forest and woodland ecosystem type exhibits a small net increase between 2000 and 2006 (+0.1 %), although Table 3.1 reveals that forest and woodland ecosystems show the second largest net increases in extent in absolute terms between 2000 and 2006 (1 088 km²). However, given the minimal nature of the relative change, the extent of this ecosystem in the EEA-39 is considered to be stable over the accounting period 2000-2012.

Figure 3.3 reveals declines in the extent of heathland and shrub (-0.6 %) and grassland (-0.5 %). The decline in heathland and shrub may represent a greater environmental concern, given the relatively small opening stock of this ecosystem type in the EEA-39 (< 280 000 km²) compared with grassland (> 650 000 km²). Inspection of Tables 3.1 and 3.2 also reveals that, with the exception of cropland, these two ecosystems exhibit the largest reductions in extent in absolute terms between 2000 and 2006 (-1 885 km² and -1 012 km², respectively), and 2006 and 2012 (-1 474 km² and -669 km², respectively).

For cropland, Figure 3.3 reveals a decline in ecosystem extent of 0.5 % between 2000 and 2012 (equivalent to 9 273 km²). Figure 3.3 also shows that the extent of marine inlets and transitional waters remains essentially constant over the accounting period 2000-2012.

3.3.4 *Tier I ecosystem extent accounts by biogeographical region (EEA-39)*

The ecosystem extent accounts compiled at the European level depict a broad picture of the status of and changes in ecosystems in Europe. However, the spatial data set-up supporting the production of accounts at the EEA allows information on the changing composition of ecosystem types to be readily organised for different ecosystem accounting areas. In this regard, the biogeographical regions of Europe divide the European landscape into coherent areas, which exhibit common characteristics of habitats and species (Roekaerts, 2002). Therefore they represent key ecosystem accounting areas of environmental management concern.

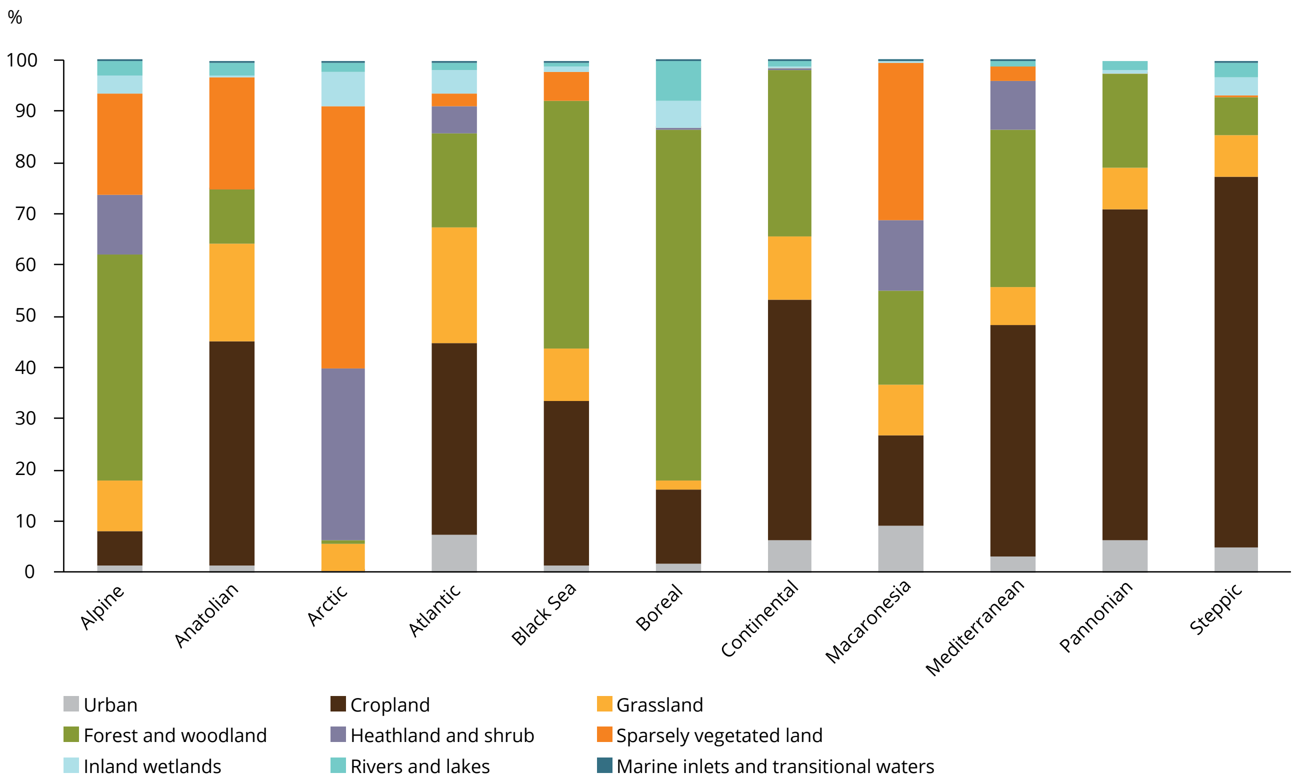
Consequently, calculating tier I ecosystem extent accounts by biogeographical region can directly support specific policy applications such as the objectives of the Habitats Directive (EC, 1992) or the Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention; Council of Europe, 1979). Figure 3.4 summarises the closing stocks of ecosystem extent presented in Table 3.2 for 2012 by biogeographical region as a percentage of the total area of the biogeographical region. This focuses attention on the biogeographical regions where particular ecosystem types may be a management concern (e.g. the dominance of cropland in the Steppic region). The tier I ecosystem extent accounts by biogeographical region can also identify where trends in ecosystem extent at the European level are manifesting. While not presented here, such analysis reveals that:

- Increases in the extent of the rivers and lakes ecosystem type observed in Tables 3.1 and 3.2 are driven by increases in the Mediterranean biogeographical region (possibly due to an increase in reservoirs and other artificial water bodies).
- Decreases in the extent of heathland are mainly driven by losses in the Mediterranean biogeographical region.
- Decreases in wetland extent are driven by losses in the Atlantic biogeographical region.

3.3.5 *Tier I ecosystem extent accounts by MAES ecosystem types of interest*

The tier I ecosystem extent accounts for the EEA-39 reveal that the largest relative and absolute changes in extent between 2000 and 2012 in Europe are associated with urban ecosystems. Urbanisation

Figure 3.4 Percentage of MAES ecosystem type per biogeographical region in 2012



also deserves specific attention, as urban land use activities and patterns have a particular impact on the environment, e.g. through fragmentation or soil sealing.

The versatile set-up of the ecosystem accounting tools developed within the EEA Integrated Data Platform for calculating tier I ecosystem extent accounts allows information on land cover flows for different geographical areas to be presented. Table 3.3 explores this further by presenting the ecosystem losses connected to urbanisation in the EEA-39 area between 2000 and 2012 by member country. It sheds light on the ecosystems most affected by urbanisation and how this varies across the various EEA-39 countries. In Table 3.3, columns 2 to 9 provide the area in hectares of that ecosystem converted to urban ecosystem between 2000 and 2012. The rows organise this by country and the EEA-39 (and 28 EU Member States, EU-28) areas as a whole. The final column aggregates the total area of non-urban ecosystems that were converted to urban during the period 2000-2012. It should be noted that these represent gross additions to the urban ecosystem stock at the MAES typology scale ([8]).

As revealed by Table 3.3, the ecosystem with the largest area converted to urban land use in the EEA-39 between 2000 and 2012 was cropland. In total, 829 231 ha of cropland was converted to urban ecosystem in the EEA-39 (equivalent to 62 % of the total ecosystem loss to urban sprawl). This was followed by both grassland, and forest and woodland, where the reduction in the extent of each of these ecosystems due to urbanisation accounted for approximately 15 % of urban expansion between 2000 and 2012 (comprising 209 825 ha and 195 345 ha, respectively). Comparing the reduction in grassland ecosystem extent due to urbanisation with the net changes in the extent of this ecosystem presented in Table 3.1 (1 885 km^2 between 2000 and 2006) and Table 3.2 (1 474 km^2 between 2006 and 2012) indicates that urban sprawl is likely to be a main driver of grassland ecosystem loss in Europe. Indeed it is likely that urbanisation accounts for more than half of the grassland ecosystem loss observed in Europe ([9]).

The extent of heathland and shrub lost to urbanisation (48 865 ha), sparsely vegetated land (approximately 21 688 ha) and inland wetlands (5 503 ha) in the EEA-39 was relatively low. A similar analysis as that conducted for grasslands suggests that urbanisation is unlikely to account for more than 15 % of the net loss of these ecosystem types between 2000 and 2012 in the EEA-39. However, there are likely to be regions or accounting areas where this is not the case.

3.3.6 Tier I ecosystem extent accounts by ecosystem accounting areas of policy interest

Delineating ecosystem accounting areas of interest on the basis of biogeographical region or country boundaries will be useful to inform European and national policy objectives. However, there are a manifold of geographical aggregations of potential policy interest. For example, understanding trends in ecosystem extent within areas of high Natura 2000 site coverage. Table 3.4 presents tier I ecosystem extent accounts for these areas in Europe (EU-28), specifically for 1 km grid cells in Europe where 80 % or more of the total area is Natura 2000 designated. This represents in excess of 80 % of the total Natura 2000 estate in Europe.

Table 3.4 identifies that forest and woodland ecosystems have the highest share in the total area of Natura 2000 sites. In addition, outside urban ecosystems, net changes in extent are relatively small, particularly for the other terrestrial ecosystems. Turnover (i.e. the gross changes as the sum of additions and reductions) are generally 1 % or less for terrestrial ecosystems, with the exception of urban, forest and sparsely vegetated land.

([8]) This means that these figures do not include any additions to non-urban ecosystem types from re-conversion of urban areas, for example to forest area.

([9]) Based on 209 825 ha of grassland lost to urban sprawl and a total reduction of 335 900 ha between 2000 and 2012 (1 885 km^2 between 2000 and 2006, and 1 474 km^2 between 2006 and 2012); 209 825 ÷ 335 900 x 100 = 60 %. It should be noted that the 335 900 ha of grassland lost to urban sprawl represents gross, not net, losses. Therefore, there may be some conversion of urban areas back to grassland between 2000 and 2012. However, given that additions to urban extent exceed reductions by a factor of four, this is not considered to change the assertion that urbanisation is the main driver of grassland loss in Europe.

Table 3.3 Urban ecosystem expansion by MAES type for the EEA-39, 2000-2012, in ha

Area in ha	Ecosystem change to urban 2000-2012 according to the ecosystem type of origin								
	2 Cropland	3 Grassland	4 Forest and woodland	5 Heathland and shrub	6 Sparsely vegetated land	7 Inland wetlands	8 Rivers and lakes	9 Marine inlets and transitional waters	Gross urban ecosystem additions 2000-2012
Albania	25 226	1 170	1 510	1 137	263	18	14	13	29 351
Austria	7 371	2 969	3 325	165	46	0	0	0	13 876
Belgium	4 568	709	625	972	0	29	204	19	7 126
Bosnia and Herzegovina	7 596	881	1 315	302	41	0	0	0	10 135
Bulgaria	5 024	2 202	1 360	68	23	0	46	27	8 750
Croatia	3 311	2 987	6 681	862	181	0	2	51	14 075
Cyprus	9 661	839	318	2 226	98	0	0	48	13 190
Czechia	17 922	4 750	2 002	0	0	0	10	0	24 684
Denmark	18 260	131	717	0	95	21	0	111	19 335
Estonia	2 394	1 528	4 487	25	32	605	0	194	9 265
Finland	3 238	78	17 548	0	37	626	89	248	21 864
France	118 018	27 830	17 115	2 306	152	80	39	316	165 856
Germany	74 645	16 293	12 654	309	651	102	371	667	105 692
Greece	23 166	4 361	2 011	4 702	215	46	0	135	34 636
Hungary	18 825	3 948	1 623	0	0	154	42	0	24 592
Iceland	0	1 114	187	4 672	165	418	0	116	6 672
Ireland	6 820	13 982	714	17	0	314	7	22	21 876
Italy	74 850	2 629	2 983	888	126	22	0	602	82 100
Kosovo	2 984	378	296	0	30	0	0	0	3 688
Latvia	1 350	1 187	1 094	0	0	146	33	6	3 816
Liechtenstein	16	0	0	0	0	0	0	0	16
Lithuania	5 526	705	587	0	0	0	0	10	6 828
Luxembourg	316	457	116	0	0	0	0	0	889
Macedonia	2 141	670	459	25	0	1	0	0	3 296
Malta	0	0	0	26	0	0	0	0	26
Montenegro	298	205	541	73	70	0	0	0	1 187
Netherlands	34 567	20 238	945	26	0	59	333	1 124	57 292
Norway	2 292	40	14 040	1 684	945	949	0	41	19 991
Poland	50 849	9 359	9 736	0	0	55	35	27	70 061
Portugal	14 472	1 876	19 657	1 881	643	0	183	129	38 841
Romania	15 655	3 422	1 214	0	90	35	0	0	20 416
Serbia	5 245	551	1 653	0	0	63	14	0	7 526
Slovakia	8 865	245	899	0	0	0	0	0	10 009
Slovenia	539	29	1 017	0	0	0	0	0	1 585
Spain	164 379	30 468	14 853	22 475	4 440	1	204	1 802	238 622
Sweden	9 582	950	17 891	15	82	482	96	50	29 148
Switzerland	1 327	105	257	0	0	0	0	0	1 689
Turkey	70 199	31 887	27 221	2 329	13 133	92	590	1 845	147 296
United Kingdom	17 734	18 652	5 694	1 680	130	1 185	78	115	45 268
EEA-39	**829 231**	**209 825**	**195 345**	**48 865**	**21 688**	**5 503**	**2 390**	**7 718**	**1 320 565**
EU-28	**711 907**	**172 824**	**147 866**	**38 643**	**7 041**	**3 962**	**1 772**	**5 703**	**1 089 718**

Source: EEA, CLC accounting layers 2000, 2012.

Table 3.4 Tier I ecosystem extent accounts for areas with a high Natura 2000 (N2k) coverage, 2000-2012

Area in km²	**MAES ECOSYSTEM TYPES**									
Cells with > 80 % of N2k	**1 Urban**	**2 Cropland**	**3 Grassland**	**4 Forest and woodland**	**5 Heathland and shrub**	**6 Sparsely vegetated land**	**7 Inland wetlands**	**8 Rivers and lakes**	**9 Marine inlets and transitional waters**	**Total**
Ecosystem extent 2000	**550 552**	**11 658 402**	**7 993 219**	**31 736 119**	**6 853 200**	**3 050 950**	**3 329 711**	**2 786 162**	**1 901 154**	**69 859 469**
Reductions to initial extent	7 922	63 222	37 702	441 558	50 774	53 425	12 134	2 033	968	669 738
Additions to initial extent	23 591	57 082	29 579	472 861	24 902	42 917	2 689	10 836	5 281	669 738
Turnover (additions + reductions)	31 513	120 304	67 281	914 419	75 676	96 342	14 823	12 869	6 249	1 339 476
(As % of initial extent)	5.7 %	1.0 %	0.8 %	2.9 %	1.1 %	3.2 %	0.4 %	0.5 %	0.3 %	1.9 %
Net change (additions – reductions)	15 669	-6 140	-8 123	31 303	-25 872	-10 508	-9 445	8 803	4 313	-
(As % of initial extent)	2.8 %	-0.1 %	-0.1 %	0.1 %	-0.4 %	-0.3 %	-0.3 %	0.3 %	0.2 %	0.0 %
Extent of stable ecosystem stock	542 630	11 595 180	7 955 517	31 294 561	6 802 426	2 997 525	3 317 577	2 784 129	1 900 186	69 189 731
Ecosystem extent 2006	**566 221**	**11 652 262**	**7 985 096**	**31 767 422**	**6 827 328**	**3 040 442**	**3 320 266**	**2 794 965**	**1 905 467**	**69 859 469**
Reductions to initial extent	7 809	67 209	37 406	447 824	26 801	40 139	919	1 736	2 940	632 783
Additions to initial extent	19 199	43 994	32 649	456 940	18 738	36 675	8 469	14 311	1 808	632 783
Turnover (additions + reductions)	27 008	111 203	70 055	904 764	45 539	76 814	9 388	16 047	4 748	1 265 566
(As % of initial extent)	4.8 %	1.0 %	0.9 %	2.8 %	0.7 %	2.5 %	0.3 %	0.6 %	0.2 %	1.8 %
Net change (additions – reductions)	11 390	-23 215	-4 757	9 116	-8 063	-3 464	7 550	12 575	-1 132	-
(As % of initial extent)	2.0 %	-0.2 %	-0.1 %	0.0 %	-0.1 %	-0.1 %	0.2 %	0.4 %	-0.1 %	0.0 %
Extent of stable ecosystem stock	558 412	11 585 053	7 947 690	31 319 598	6 800 527	3 000 303	3 319 347	2 793 229	1 902 527	69 226 686
Ecosystem extent 2012	**577 611**	**11 629 047**	**7 980 339**	**31 776 538**	**6 819 265**	**3 036 978**	**3 327 816**	**2 807 540**	**1 904 335**	**69 859 469**

Source: EEA , CLC accounting layers 2000, 2006, 2012.

From a policy perspective it is useful to compare ecosystem extent accounts for areas with a high proportion of Natura 2000 site coverage and areas where there are no Natura 2000 sites. This will identify if there are fundamental differences in ecosystem composition between these areas and if the Natura 2000 designations are associated with limited net changes (and turnovers) in ecosystem extent. Figure 3.5 summarises the information on relative changes in ecosystem extent between areas with < 80 % Natura 2000 coverage and the areas outside (i.e. the remainder of the EU-28 extent). Figure 3.5 clearly indicates that reductions in extent of cropland, grassland, heathland and shrub, sparsely vegetated land and inland wetland ecosystems are lower in areas with high Natura 2000 site coverage. Nonetheless, Figure 3.5 also reveals that the extent of all these ecosystems has still declined, accompanied by an increase in the extent of urban as well as river and lake ecosystems.

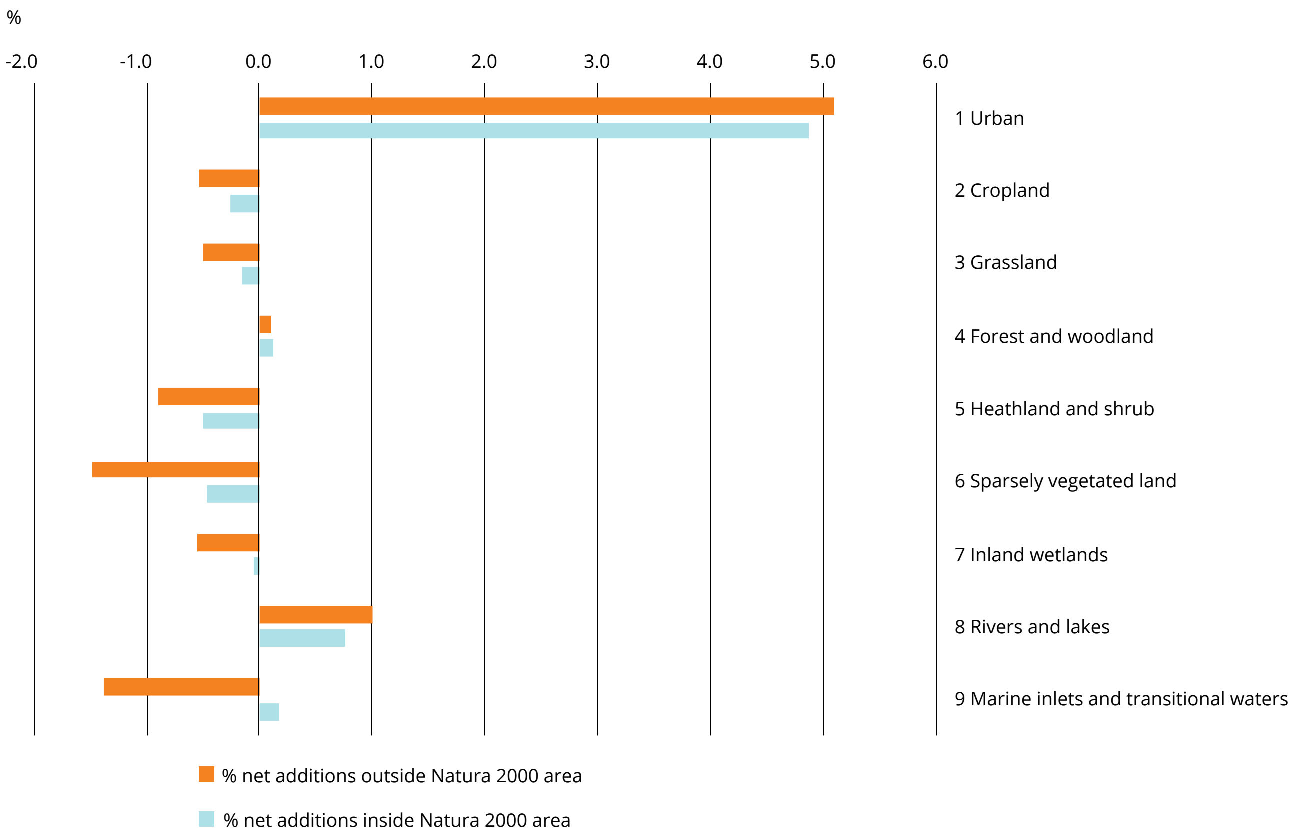
3.3.7 Results of tier II ecosystem extent accounts

Tier II provides an opportunity for producing more detailed ecosystem extent accounts using a more differentiated typology provided by the CLC system. This, in turn, improves the analytical power of the accounts and can support the tier I accounting results by compiling ecosystem extent accounts for CLC classes that are better aligned with specific ecosystem sub-types. In particular, more detailed insights are revealed by analysing trends at the CLC class level 3, which allows an aggregation to both the higher CLC levels and the terrestrial MAES ecosystem types themselves.

The tier II ecosystem extent accounts are not necessarily intended to provide the complete European coverage achieved via the tier I accounts but inform on ecosystems of specific policy and management interest. In this regard the following CLC level 3 classes are identified as being well matched to ecosystems of potential biodiversity importance and European conservation policy concerns (e.g. habitat protection), often providing a very distinct set of ecosystem services (e.g. coastal protection):

- CLC 244 Agro-forestry areas;
- CLC 331 Beaches, dunes and sands;
- CLC 411 Inland marshes;
- CLC 412 Peat bogs;
- CLC 421 Salt marshes.

Figure 3.5 Net ecosystem extent changes in areas of high and zero Natura 2000 cover, 2000-2012



Tier II ecosystem extent accounts for these ecosystems are provided in Table 3.5. As shown in Table 3.5, at the European level agro-forestry increased in extent by 14 307 ha between 2000 and 2006, followed by a decrease in extent of 5 482 ha between 2006 and 2012. Table 3.5 also illustrates the trends in ecosystem extent for beaches, dunes and sands; inland marshes; peat bogs; and salt marsh CLC classes, revealing that beaches, dunes and sand, and salt marsh ecosystems increased slightly in extent between 2000 and 2006 (1 566 ha and 2 349 ha, respectively), and 2006 and 2012 (6 950 ha and 745 ha, respectively). Peat bog decreased over both these periods in extent (-47 596 ha between 2000 and 2006, and -783 ha between 2006 and 2012). For inland marsh ecosystems, decreases in extent are observed between 2000 and 2006 (-1 526 ha), followed by increases in extent between 2006 and 2012 (6 708 ha).

3.3.8 Tier II ecosystem extent accounts for detailed agroforestry analysis

The detailed spatial data set that CLC provides is very flexible and allows for a range of different analyses (e.g. by disaggregating the accounts by country or other area of interest). The flows in land cover can also be assessed via land cover change matrices that describe the transitions between different land cover classes spatially and over time, thus revealing the influence of these flows on tier II ecosystem extent. Maps can be readily produced from the data underpinning the accounts to illustrate key features and support narratives of particular policy concern.

As an example of the more detailed analyses that can be achieved, Table 3.6 provides information on the extent of agro-ecosystems in the Nomenclature of Territorial Units for Statistics level 2 (NUTS2) class for Spain, Portugal and Italy. This level is aligned with the boundaries of autonomous communities and cities of Spain and regions of Italy and Portugal, and represents the basic regions for applying regional policies. As shown in Table 3.6 agro-forestry in Spain in 2012 is generally practised in Extremadura (1 122 839 ha), Andalucía (899 321 ha) and Castilla y León (308 924 ha), with fewer than 150 000 ha of agro-forestry located elsewhere in the country. For Portugal, the vast majority of agro-forestry is located in Alentejo (572 942 ha) and in Italy almost all agro-forestry is located in Sardegna (more commonly known as Sardinia) (167 635 ha). Therefore, these NUTS2 areas represent those European regions that need to be the centre of policy attention if maintaining the extent and condition of agro-forestry ecosystems is considered an important contribution to maintaining the biodiversity and natural capital stocks of the EU.

Table 3.5 Tier II ecosystem extent accounts for ecosystems of biodiversity importance, EEA-39, 2000-2012

	Agro-forestry	Beaches, dunes, sands	Inland marshes	Peat bogs	Salt marshes
Area in ha	**CLC244**	**CLC331**	**CLC411**	**CLC412**	**CLC421**
Ecosystem extent 2000	3 261 788	796 114	1 374 659	11 578 746	549 608
Consumption of Land Cover	25 323	23 015	8 654	54 822	849
Formation of Land Cover	39 630	24 581	7 128	7 226	3 198
Turnover (additions + reductions)	64 953	47 596	15 782	62 048	4 047
(As % of initial surface)	2 %	6 %	1 %	1 %	1 %
Net Change (additions – reductions)	14 307	1 566	-1 526	-47 596	2 349
(As % of initial surface)	0 %	0 %	0 %	0 %	0 %
Extent of stable ecosystem stock from 2000 to 2006	3 236 465	773 099	1 366 005	11 523 924	548 759
Ecosystem extent 2006	3 276 095	797 680	1 373 133	11 531 150	551 957
Consumption of Land Cover	9 352	19 595	6 604	12 245	664
Formation of Land Cover	3 870	26 545	13 312	11 462	1 409
Turnover (additions + reductions)	13 222	46 140	19 916	23 707	2 073
(As % of initial surface)	0 %	6 %	1 %	0 %	0 %
Net change (additions – reductions)	-5 482	6 950	6 708	-783	745
(As % of initial surface)	0 %	1 %	0 %	0 %	0 %
Extent of stable ecosystem stock from 2006 to 2012	3 266 743	778 085	1 366 529	11 518 905	551 293
Ecosystem extent 2012	3 270 613	804 630	1 379 841	11 530 367	552 702

Source: EEA, CLC accounting layers 2000, 2006, 2012.

Table 3.6 Extent of agro-forestry in NUTS2 areas (2012), surface area in ha

Country	NUTS2	Surface area (ha)	% in the country
Italy	ITG2 Sardinia	167 635	98.5
	Other location	2 559	1.5
	Total	**170 194**	**100**
Portugal	PT18 Alentejo	572 942	91.7
	Other location	51 609	8.3
	Total	**624 551**	**100**
Spain	ES43 Extremadura	1 122 839	45.4
	ES61 Andalucía	899 321	36.3
	ES41 Castilla y León	308 924	12.5
	Other location	143 875	5.8
	Total	**2 474 959**	**100**

Source: EEA, CLC accounting layers 2012.

Table 3.7 Agro-forestry extent by elevation (Italy, Portugal and Spain, 2012) , surface area in ha

	Italy		Portugal		Spain	
Elevation breakdown	**Surface area (ha)**	**%**	**Surface area (ha)**	**%**	**Surface area (ha)**	**%**
1 Low coast	1 142	0.6	6 694	1.1	1 830	0.1
2 High coast	11 353	6.7	1 894	0.3	7 801	0.3
3 Inlands	12 910	7.6	295 534	47.3	146 395	5.9
4 Uplands	117 926	69.3	320 122	51.3	2 053 925	83.0
5 Mountains	26 842	15.8	307	0.0	264 982	10.7
Total	**170 173**	**100.0**	**624 551**	**100.0**	**2 474 933**	**100.0**

Source: EEA, CLC accounting layers 2012.

Further analysis can be undertaken to understand some of the landscape characteristics and agronomic conditions that are associated with the spatial distributions of agro-forestry revealed in the tables above and identify where agro-forestry practices may be most successful and where conflict with other land uses is not so significant. As an example, Table 3.7 provides a summary of the extent of agro-forestry ecosystems in Italy, Portugal and Spain in 2012, disaggregated by elevation and distance from the coast. This very clearly identifies that agro-forestry is principally practised in upland areas (more than 50 % in Italy and Portugal, and 83 % in Spain) and also in mountainous areas in Italy and Spain (15.8 % and 10.7 %, respectively), and inland areas in Portugal (47.3 %). In relative terms, very little agro-forestry occurs in coastal areas.

Understanding which land uses are affecting agro-forestry and where conversion to agro-forestry land use is most common may also be of interest to decision-makers looking to conserve and encourage this ecosystem type. To this end, Table 3.8 provides a land cover change matrix for agro-forestry areas that details the ecosystems of origin for any additions to agro-forestry extent (prefixed by 'G') and the ecosystems of destination for any reduction in extent (prefixed by 'L'). Table 3.8 covers selected countries and the period 2000-2012. Table 3.8 provides some insight into the dynamics associated with the net changes via the detailed information on the additions and reductions from different ecosystem types. Notably, Table 3.8 reveals that a substantial proportion of the gross reduction in ecosystem extent in Portugal relates to conversion to transitional woodland and shrub (12 811 ha), whereas in Spain a substantial proportion of the gross additions relates to conversion from transitional woodland and shrub (20 777 ha). This suggests that the net changes observed could also be an outcome of the traditional management of agro-forestry areas in Portugal and Spain (e.g. cropping, grazing and/or mechanical clearing), and the spontaneous re-growth of small bushes and forbs that would lead to the classification of the affected

Table 3.8 Land cover change matrix for agro-forestry ecosystems in Italy, Portugal and Spain, 2000-2012

CLC244 Agro-Forestry	Italy	Portugal	Spain	Total
Ecosystem extent 2000	**170 574**	**636 914**	**2 453 382**	**3 260 870**
L1 conversion to Urban	66	488	2 467	3 021
L2 conversion to cropland	-	-	-	-
L21 conversion to arable land	-	292	1 795	2 087
L22 conversion to permanent crops	45	1 359	1 123	2 527
L23 conversion to heterogeneous agricultural areas	-	-	253	253
L3 conversion to grassland	-	-	790	790
L4 conversion to woodland	-	-	-	-
L41 conversion to forest	-	1 663	332	1 995
L42 conversion to transitional woodland shrub	-	12 811	3 236	16 047
L5 conversion to heathland and shrub	-	-	668	668
L6 conversion to sparsely vegetated land	-	-	210	210
L7 conversion to water areas	295	3 716	2 142	6 153
Total reductions	**406**	**20 329**	**13 016**	**33 751**
G1 conversion from urban	-	-	-	-
G2 conversion from cropland	-	-	-	-
G21 conversion from arable land	-	115	119	234
G22 conversion from permanent crops	-	32	2	34
G23 conversion from heterogeneous agricultural areas	5	152	87	244
G3 conversion from grassland	-	-	285	285
G4 conversion from woodland	-	-	-	-
G41 conversion from forest	16	5269	8311	13 596
G42 conversion from transitional woodland shrub	-	2130	20 777	22 907
G5 conversion from heathland and shrub	5	268	4 815	5 088
G6 conversion from sparsely vegetated land	-	-	197	197
G7 conversion from water areas	-	-	-	-
Total additions	**26**	**7 966**	**34 593**	**42 585**
Turnover (additions + reductions)	432	28 295	47 609	76 336
Turnover as % of initial ecosystem extent	0.25 %	4.44 %	1.94 %	2.34 %
Net change (additions - reductions)	-380	-12 363	+21 577	+8 834
Relative change as % of initial extent	-0.22 %	-1.94 %	0.88 %	0.27 %
Extent of stable ecosystem stock	170 168	616 585	2 440 366	3 227 119
Ecosystem extent 2012	**170 194**	**624 551**	**2 474 959**	**3 269 704**

Source: EEA, CLC accounting layers 2000, 2012.

parcel as transitional woodland shrub initially and as agro-forestry after traditional mechanical clearing of scrub between the oak trees.

3.3.9 Conclusions on European ecosystem extent accounting

This section presents the first set of ecosystem extent accounts for the EEA-39 for the accounting periods 2000-2006 and 2006-2012. The accounts have been compiled using both the MAES ecosystem typology (tier I) and selected individual CLC classes (tier II). These accounts allow analysis of ecosystem extent and trends at European level (via tier I), for example exploring the impacts of urbanisation. In addition, they support more detailed analysis of trends in ecosystem extent using the CLC classes that are better aligned with MAES ecosystem sub-types (via tier II).

Overall, the tier I ecosystem extent accounts reveal that urban ecosystems increased the most in relative extent: in excess of 2 % between 2000 and 2006, and by 2 % again in 2006 and 2012. The tier I ecosystem extent accounts also reveal that ecosystem extent in Europe is generally stable, with approximately 99 % of the stock of ecosystems remaining unchanged over each of the accounting periods 2000-2006 and 2006-2012. The notable exception was for forest and woodland ecosystems, where the highest rates of ecosystem turnover (gross changes as a percentage of opening stock) were observed, but this is likely to be associated with forestry harvesting cycles and the differences that emerge from observing land cover versus land use.

The ecosystem accounting approach implemented within the EEA Integrated Data Platform to support calculating the tier I and II extent accounts is demonstrated as a versatile tool that allows manifold spatial analyses. Some examples are demonstrated in this section with respect to administrative units (country boundaries, NUTS2), environmental policy-relevant areas (biogeographical regions, Natura 2000 sites) and geo-physical areas (by elevation). This allows the location and geo-physical context of ecosystems of key policy concern to be identified and the trends in their extent monitored over time. This, in turn, can provide insights into the interactive effects of different land use and environmental characteristics on the extent of different ecosystems and how these correlate with different policy/management actions (e.g. Natura 2000 designation). This will help those concerned with protecting key ecosystems to identify those for which the most attention for conservation is warranted.

Further results will become available in a dedicated working report from the EEA on ecosystem extent accounts for Europe (EEA, forthcoming). These will be based on CLC 2000 – 2018 data and include more detail on the ecosystem extent accounts presented in this chapter as well as additional analysis, including for the following themes:

- urbanisation in coastal zones;
- development of cropland;
- high nature value farmland.

4 Ecosystem condition accounts

4.1 Measuring ecosystem condition

The concept of ecosystem condition needs to be well defined to enable it to be measured. Ecosystem condition refers to the physical, chemical and biological condition or quality of an ecosystem at a particular point in time. This definition corresponds well with the definition published in the SEEA-EEA: ecosystem condition reflects the overall quality of an ecosystem asset in terms of its characteristics. Table 4.4 in the UN handbook on experimental ecosystem accounting (UN et al., 2014b), suggests five aspects of ecosystem condition that could be considered (vegetation, biodiversity, soil, water and carbon) in an example of a condition account for a single ecosystem unit.

Given the scope for experimentation provided by the SEEA-EEA and the need to develop an approach on ecosystem condition that is suited to the European ecological and land use context, the analytical frame developed under the MAES ecosystem assessment work becomes the starting point for developing ecosystem condition accounts in Europe. The third MAES report (*Mapping and assessing the condition of Europe's ecosystems: progress and challenges*) discusses the question of how to assess ecosystem condition (see Chapter 4 of Erhard et al., 2016). The MAES report suggests that ecosystem condition can be assessed via two approaches: indirectly via an analysis of pressures acting on ecosystems and directly by tracking habitat condition, biodiversity and environmental quality.

4.1.1 Identifying condition parameters per ecosystem type

The review of condition parameters provided in the third MAES report is helpful in pointing to candidate parameters to include in a draft account of ecosystem condition. It does not, however, discuss critical condition parameters by ecosystem type. EEA staff have therefore developed a proposal for identifying such critical parameters. The proposal sets out how different condition parameters could be allocated to the range of ecosystem types identified in the MAES analytical approach to support the development of EU ecosystem condition accounts. It has been developed on a number of premises:

- The condition parameters chosen should match critical pressures on, and fundamental changes in, ecosystem condition identified in recent MAES work.
- As far as feasible, condition parameters should be chosen that are applicable and comparable across all MAES ecosystem types, for example indicators related to biodiversity.
- Where appropriate or necessary, ecosystem-specific condition parameters were included.
- The overall number of condition parameters per ecosystem type should not be too high (e.g. in the range of three to five) to avoid complicating the construction and calculation of the overall account too much.
- The condition parameters finally chosen should ideally be underpinned by data sets that allow a reliable quantitative analysis of trends at suitable spatial and temporal scales.

Table 4.1 shows the allocation of condition parameters grouped into six different aspects of ecosystem condition across the nine different MAES ecosystem types plus three marine ecosystem types.

The condition parameters related to biodiversity and nutrient pressure are cross-cutting, whereas those relating to soil status, freshwater, marine and urban ecosystems are ecosystem specific. This is because biodiversity status and nutrient pressure are important condition parameters for all ecosystem types, whereas the other aspects are by their nature only relevant to those ecosystems that they relate to.

Table 4.1 Relevance of ecosystem condition aspects for MAES and marine ecosystem types

MAES ecosystems/ condition theme	Urban	Cropland	Grassland	Forest and woodland	Heathland and shrub	Sparsely vegetated land	Inland wetlands	Rivers and lakes	Marine inlets and transitional waters	Coastal area	Shelf	Open ocean
Biodiversity	(√)	√	√	√	√	√	√	√	√	√	√	√
Nutrient pressure	(√)	√	√	(√)	(√)	(√)	√	√	√	√	√	√
Soil status related	-	√	√	√	(√)	(√)	-	-	-	-	-	-
Freshwater related	-	-	-	-	-	-	(√)	√	(√)	-	-	-
Marine related	-	-	-	-	-	-	-	-	(√)	√	√	√
Urban related	√	-	-	-	-	-	-	-	-	-	-	-

Note: √ , high relevance; (√), partial relevance; ' – ', not applicable.

Source: EEA, 2018.

Using this proposal and other analysis, the MAES working group delivered a special report on ecosystem condition in 2018 (Maes et al., 2018). The report delivers a set of indicators for the mapping and assessment of ecosystem condition at the European level, and per ecosystem type. A core set with key indicators is available to support an integrated ecosystem assessment across ecosystem type. This fifth MAES report constitutes a useful starting point for the development of ecosystem condition accounts. In essence, a condition account tracks the values of indicators over at least two points in time, and for each ecosystem type included in the analysis.

Indicators of ecosystem condition may reflect aspects such as the occurrence of species, soil characteristics, water quality or ecological processes. In turn, the indicators should be relevant for policy- and decision-making, for instance, because they reflect policy priorities (e.g. preservation of native habitat), pressures on ecosystems (e.g. deposition levels of acidifying compounds versus critical loads for such compounds), ecosystem functioning or processes (e.g. net primary production) or the capacity of ecosystems to generate one or more services (e.g. attractive landscape features supporting tourism). Generally, in a fully spatial approach, different ecosystem types require different indicators.

The fifth MAES report presents explicit lists of condition indicators per MAES ecosystem type in a clear analytical framework and also sets out the link between ecosystem condition and the flow of services on the basis of a number of examples. Box 4.1 shows the analytical framework used in the report to illustrate the link between ecosystem condition and ecosystem service flow.

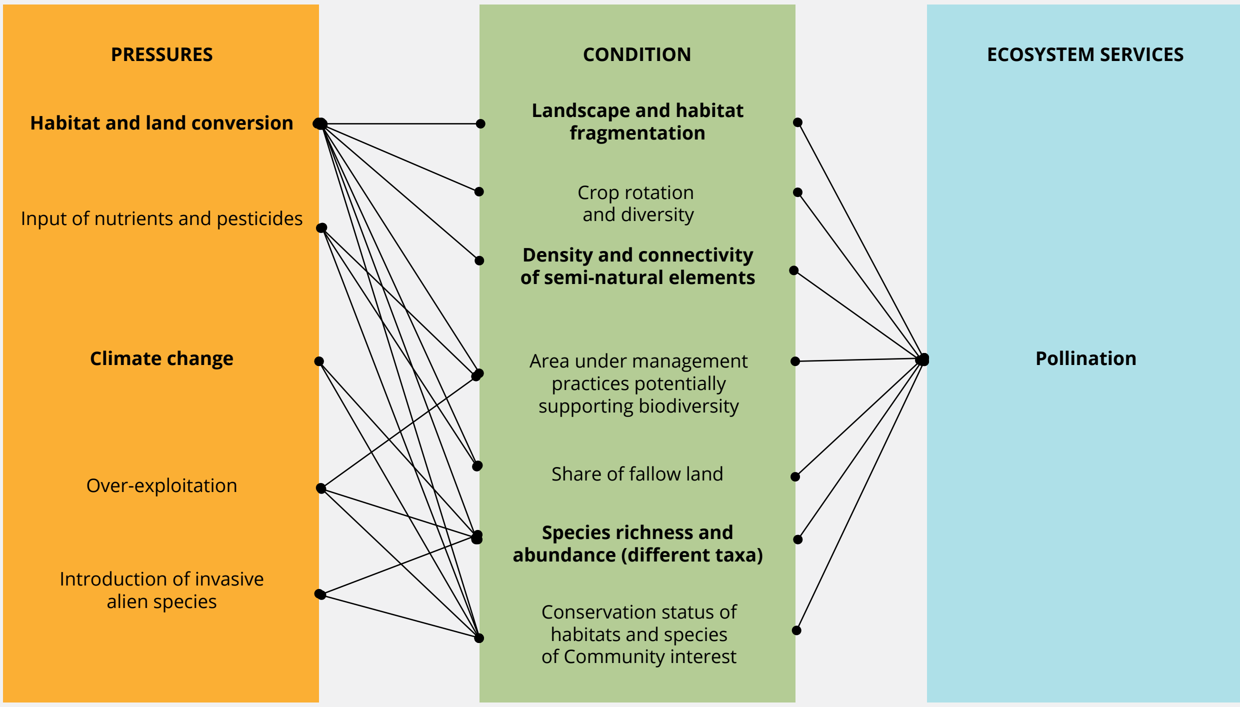
Box 4.1 Linking ecosystem condition to the capacity of ecosystems to deliver ecosystem services

There is an increasing body of scientific literature demonstrating the close relationship between biodiversity, good ecosystem condition and long-term delivery of multiple ecosystem services. The work under the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has substantially contributed to that.

International platforms such as IPBES have also inspired the main pressure categories identified in MAES as causing ecosystem change — these comprise habitat change, climate change, 'over-exploitation' (unsustainable land or water use or management), invasive alien species, and pollution and nutrient enrichment.

Figure 4.1, taken from the fifth MAES report on ecosystem condition (Maes et al. 2018), depicts the different pathways that link the main categories of pressures to a subset of indicators proposed to measure the condition of agro-ecosystems. In turn, these condition indicators are important for quantifying the levels of pollination that an ecosystem can supply. So while, for example, the density of semi-natural elements and species richness (of pollinator species) increase the pollination potential of ecosystems, habitat fragmentation (e.g. by roads) will decrease this potential. In turn, increasing or decreasing pressures will impact pollination through the effects they have on ecosystem condition.

Figure 4.1 Relations between pressure, condition, and pollination in an agro-ecosystem (adapted from EC, 2018)



Note: For pressures, the main categories are presented, whereas for condition a selection of indicators is included. The indicators in bold are directly or indirectly used in the model of pollination accounts. (For full details, see Maes et al. (2018).

The following sections present work overseen by the EEA on developing pilot accounts relevant to ecosystem condition in Europe. These specifically comprise biodiversity, nutrient pressure and freshwater condition parameters, as highlighted in Table 4.1. This work focuses on selected ecosystem condition parameters identified under the MAES process as test cases for developing ecosystem condition accounts. Complementary work is ongoing in the MAES context to develop as many of the MAES condition indicators as possible by the end of 2019.

4.2 Using Nature Directives reporting to account for ecosystem condition in Europe

Biodiversity is identified as a cross-cutting indicator of ecosystem condition in Table 4.1. Within Europe, Member States' obligations for conserving and improving biodiversity are set out in the Nature Directives; this includes provisions for regularly reporting on the status of aspects of biodiversity of European Community interest. Specifically, Article 17 of the EU Habitats Directive requires Member States to prepare and submit reports on the conservation status of habitats and species of European Community interest to the European Commission every 6 years. Article 12 of the Birds Directive (EC, 2009) now requires that Member States provide the European Commission with reporting data on the actual state of and trends in bird populations.

Under phase II of KIP INCA, methodological approaches to develop thematic accounts for biodiversity using data reported by Member States under the Habitats and Birds Directives have been tested. This included an assessment of their potential to provide information on ecosystem condition at the European level. This work contributes to operationalising a direct approach to assessing condition via tracking the status of biodiversity, as discussed in the third MAES report and subsequent work.

4.2.1 Pilot bird species abundance accounts for the EU

Article 12 data are available in tabular and spatial format for the reporting period 2008-2012 from the EEA website (EEA, 2015a). The tabular data include population sizes, ranges and trends (short- and long-term) for breeding and wintering populations as part of a Microsoft Access database. The spatial data provide coarse-scale information on bird species distribution. A distinct benefit of the new Article 12 reporting format for the period 2008-12 is that it provides numerical abundance data. This potentially provides a more sensitive measure of biodiversity than species richness or conservation status alone (i.e. statistics on population abundances and evenness). An important associated database has been developed by the EEA (2015a) to link species and habitat types to MAES ecosystems.

In combination, the Article 12 data and information on birds' ecosystem preferences allow accounts to be constructed from a MAES perspective. Using these data, Table 4.2 presents a species abundance account for the EU using all breeding bird species records, disaggregated according to the bird species MAES ecosystem type preferences. In total, the account summarises information on 454 breeding bird species in Europe. It reveals that forest and woodland ecosystems represent the most populated ecosystem for birds in the EU (total abundance, 470 million). The forest and woodland ecosystem type also has the highest Shannon's Index value (3.66), which implies the highest species diversity based on species richness and evenness ([10]). Interestingly, the second highest abundance measure is associated with the urban ecosystem type (309 million). However, the Shannon's Index for urban ecosystems (2.92) is lower than that for five other ecosystem types, indicating that the high abundance is not indicative of high diversity (a notion supported by the species richness of 49 within this ecosystem and often observed by dominance of species associated with urban areas). It also identifies that Article 12 data are limited in species numbers for open ocean (7) and shelf ecosystems (13) but reasonable elsewhere (36 in coastal and higher elsewhere).

To overcome the current lack of a time series of data reported under the new Article 12 reporting format, use has been made of the short- (12 years prior to reporting) and long-term (from circa 1980) trends reported for bird species by Member States. These trends are reported by Member States as stable, increasing, declining or unknown. As detailed in Table 4.2, these trend data have been combined to provide 'prevailing trend' and 'overall trend' indicators for bird species in each MAES ecosystem type. It should be noted that these trend indicators are proposed as an interim approach, until the 2012-2018 Article 12 reporting data become available.

([10]) The Shannon Index varies between zero (when just one species is present in a data set) and the natural log of the number of species in the data set (when all the species are equally abundant, with one species being a particular case).

The prevailing trends and overall trends generally provide stable results by ecosystem type, meaning that no significant upward or downward trend can be observed. The exceptions are sparsely vegetated ecosystems, where the prevailing trend is slightly positive (5.62) and the overall trend slightly negative (-3.32). This consistency is also reflected in the values for these trends for the EU as a whole (i.e. in the final column of Table 4.2). The overall trend suggests small improvements in bird species populations across the EU for coastal (2.78), rivers and lakes (5.81), urban (2.04), wetlands (0.68) and forest and woodland (12.64) ecosystems. Conversely, the overall trend indicates that populations are declining in cropland (-20.48), grassland (-22.22), heathland and shrub (-16.96) and marine inlet (-13.16) ecosystems. These trend indicators can be broadly interpreted as indicators of the condition of ecosystems with respect to their capability to support biodiversity.

One key limitation of these accounts is their ability to support detailed spatial analysis at sub-national scales. To move to a more concrete spatial accounting approach, the EEA is working with geo-referenced data from national bird monitoring surveys provided by the British Trust for Ornithology (BTO) and the Czech Society for Ornithology (CSO). This work is exploring how these data can be integrated with information on MAES ecosystem extent and aggregated to inform ecosystem condition accounting at different spatial scales. The methodological approach for compiling these accounts is presented and discussed in King and Petersen (2018). By working with data in which annual production is well assured, the ongoing work in 2018 also aims to establish a roadmap for implementing an EU-wide approach. The roadmap will draw on the lessons learned from working with the BTO and CSO data to propose methods to move to a spatially explicit ecosystem condition accounting based on integrating species diversity metrics with the EEA's 1 km accounting grid.

4.2.2 Integration of Article 17 and Article 12 reporting data

While not presented here, related KIP INCA analysis has also calculated pilot species accounts that track changes in species conservation status over time, using Article 17 data reported in 2006 and 2012 under the Habitats Directive. The Article 17 and Article 12 accounts are considered complementary, given that the Article 12 data relate purely to birds, whereas the Article 17 data relate to the other species groups. It is to be expected that these different species groups may respond differently to various ecosystem pressures. Therefore, bird species statistics should not be expected to always provide the same signals as other species, and there is clear analytical advantage in maintaining statistics across as large a range of species groups as possible. For example, understanding what is happening to fish species is likely to be of primary importance for understanding conditions in the rivers and lakes ecosystem type.

4.3 Spatial nutrient accounts

Nutrient enrichment is a key pressure indicator for ecosystem condition, as all terrestrial and aquatic ecosystems are potentially affected by it. Consequently, work has been ongoing to capture agricultural (and other) nutrient pressures on the environment in different contexts (e.g. as an agri-environment indicator at country level, and in a more spatially differentiated analysis in previous MAES reports; see Erhard et al., 2016). However, these previous approaches all have different limitations. Further work is therefore ongoing to prepare a European spatial nutrient balance as part of EU ecosystem condition accounts.

A pilot account is under development, utilising a number of different input data sets, e.g. gridded farm statistics provided by Eurostat, atmospheric nitrogen deposition data from air monitoring programmes and data on agricultural nutrient use generated by the Common Agricultural Policy Regionalised Impact (CAPRI) agro-economic model. The CAPRI model approach includes providing supported stable releases (updates) to ensure accessibility for the scientific and user community. The results, intended for use in the spatial EU nutrient accounts, will be provided based on current stable release patterns. While the CAPRI model provides unrivalled spatial and agronomic detail, a remaining challenge is to develop stable and comparable time series for the spatial data sets that will allow a regular updating of EU ecosystem accounts in the future.

Figure 4.2 shows the workflow developed for combining different data sources in close cooperation with different KIP INCA partners to develop spatially explicit pilot nutrient accounts. Figure 4.2 illustrates that a substantial number of input data sets need to be brought together to derive an output data set on nutrient balance that can be deployed for understanding nutrient pressures on different ecosystem types or analytical units. While these accounts require complex data processing and multiple input data, this results in a high level of ecological representation at a high spatial resolution (1 km) that can support flexible, detailed analytical applications (e.g. water basin-scale analyses). However, this is possible only if the different data sets can be efficiently combined in one shared spatial reference frame.

Table 4.2 Pilot species account — all birds for the EU

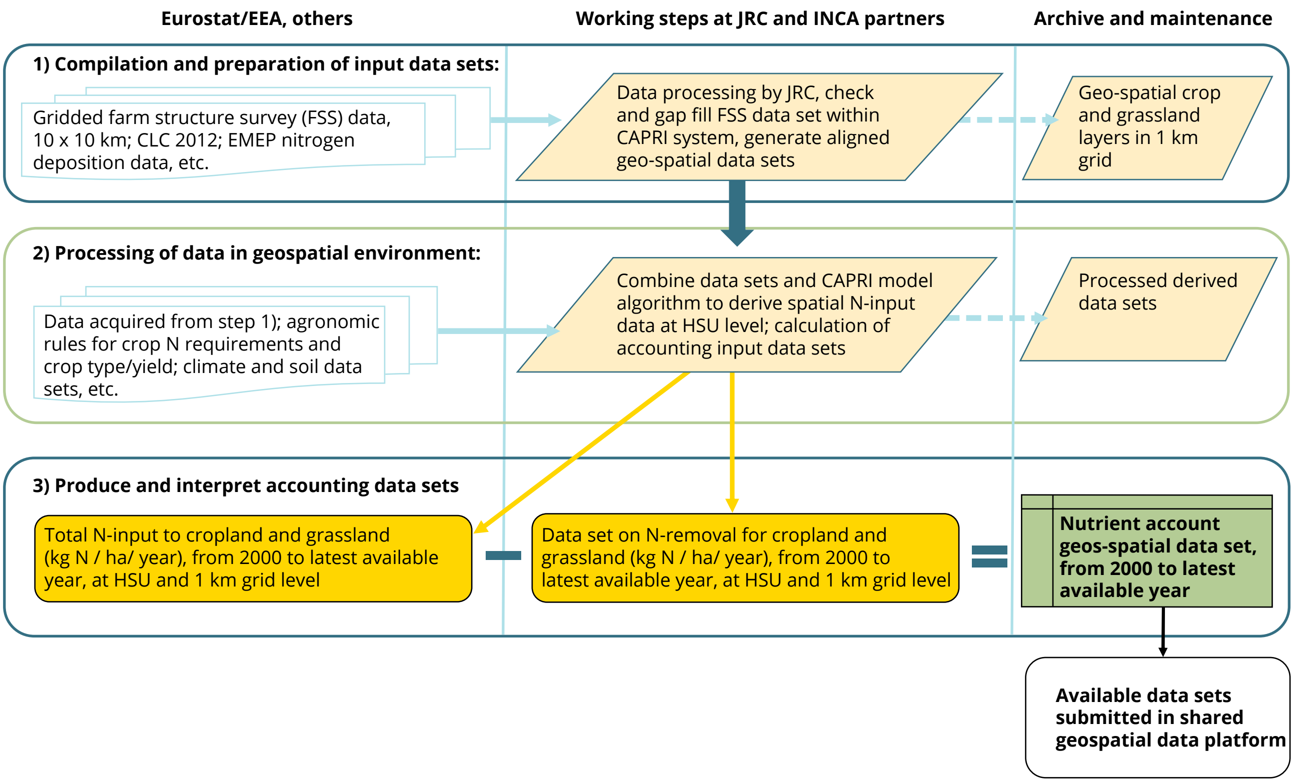
MAES ecosystem type	Coastal	Cropland	Grassland	Heathland and shrub	Marine inlets	Rivers and lakes	Sparsely vegetated land	Urban	Inland wetlands	Forest and woodland	Shelf	Open ocean	All ecosystems
Trends in status 2008-2012 (based on short and long-term population trends submitted by Member States for the reporting period 2008-2012, Article 12, Birds Directive)													
Prevailing trends ([1])	2.78	-7.23	-14.81	-5.36	-7.89	18.06	5.62	16.33	12.24	25.86	15.38	0.00	10.57
Overall trend ([2])	2.78	-20.48	-22.22	-16.96	-13.16	5.81	-3.37	2.04	0.68	12.64	15.38	0.00	-1.32
Intensity of change	86.11	71.08	79.01	70.54	81.58	71.61	73.03	75.51	70.07	66.67	92.31	85.71	27.81
Coverage of trends	86.11	84.34	86.42	82.14	86.84	83.87	82.02	89.80	81.63	79.89	92.31	85.71	81.06
Situation 2008-2012 (based on data submitted by Member States for the reporting period 2008-2012, Article 12, Birds Directive)													
Total abundance (No. individuals)	1.52E+06	2.63E+08	9.58E+07	9.73E+07	2.02E+06	2.68E+07	4.15E+07	3.09E+08	2.42E+07	4.70E+08	1.34E+06	6.35E+05	1.33E+09
Number of species	36	83	81	112	38	155	178	49	147	174	13	7	454
Shannon's Index	2.76	2.93	2.32	3.13	2.46	3.12	3.14	2.92	3.22	3.66	1.35	1.36	4.18

Notes: ([1]) Calculated as: (stable + increasing - declining) / (No. of all species including unknowns) * 100

([2]) Calculated as: (increasing - declining) / (No. of all species, including unknowns and stable) * 100

Source: EEA, 2018.

Figure 4.2 Workflow for pilot spatial nutrient accounts



Notes: CLC, Corine Land Cover; N, nitrogen; JRC, Joint Research Centre; CAPRI, Common Agricultural Policy Regional Impact Analysis; EMEP, European Monitoring and Evaluation Programme (on air emissions); HSU, Homogeneous Soil Unit.

4.4 Using Water Framework Directive reporting for ecosystem condition accounting

Water quality represents a key condition indicator for lake, river and coastal ecosystems and their ability to deliver ecosystem services. The assessment of freshwater ecosystem condition (or state) and the impacts of condition trends on the flow of freshwater ecosystem services has been an area of substantial focus under MAES (including the integrated assessment framework presented by Grizzetti et al. (2016), described in Section 6.3). Within the EU, the Water Framework Directive (WFD) (EU, 2000) establishes the legal requirement for achieving good status (or condition) of water bodies for Member States. The directive has a 6-year water quality monitoring and reporting cycle, which provides a rich data set to support the assessment of freshwater ecosystem condition in the EU. Under the WFD, water bodies are classified according to whether their status is high, good, moderate, poor or bad. This status is derived by combining different assessments relating to ecological, chemical and biological status.

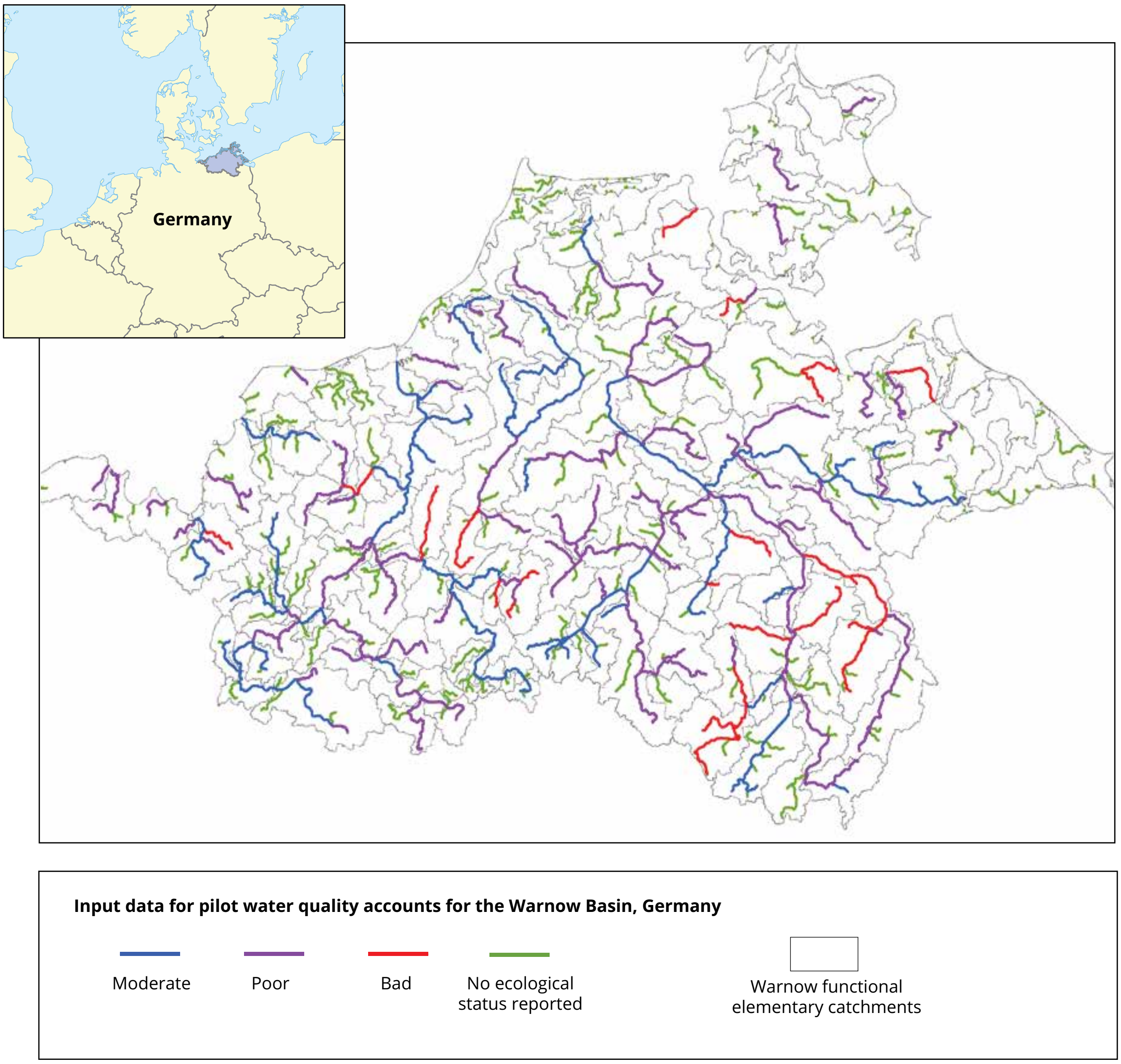
The information collated via WFD reporting processes on water quality has the potential to be organised in a spatial accounting framework to provide information on the condition of freshwater ecosystems. There are a number of dimensions by which these data can be organised and reported, including by river segment, river flow volume, river length and catchments. All of these spatial arrangements can be supported by the information reported under the WFD and the spatial data system underpinning the European Catchments and Rivers Network System (ECRINS) maintained by the EEA.

To explore the potential for WFD reporting to inform ecosystem accounting, the EEA has implemented a project to test different accounting applications using WFD reporting data. This was supported by the European Topic Centre on Urban, Land and Soil Systems (ETC/ULS) and the European Topic Centre on Inland, Coastal and Marine Waters (ETC/ICM). As a first step, a methodological test was carried out to compile pilot accounts of water quality for the Warnow Basin, Germany. This methodological approach was based on integrating information on the ecological status and flow values reported for rivers under the WFD, and the spatial representation provided by ECRINS. The ECRINS database provides sub-divisions of the river network as river length segments and sub-catchments (functional elementary catchments, FECs). Figure 4.3 provides a representation of the input data used by river segment, showing the ecological status reported under the WFD for the Warnow Basin. It should be noted that Figure 4.3 reveals that among the overall river segments in the Warnow Basin (786 in total, as characterised by ECRINS) there is a significant proportion for which water quality data are not available (ecological status is only reported for 415 river segments under the WFD).

Based on the test case developed in 2017 and subsequent work, the EEA has produced a draft methodology for water quality accounts based on WFD reporting in a second step. The main principles set out in that proposal are summarised below.

The data basis for the stock and change tables is the data submitted under the WFD. The basic spatial unit

Figure 4.3 Input data for pilot water quality accounts for the Warnow Basin, Germany



Source: EEA, 2018.

(BSU) in the WFD is the water body (WB), and the countries are supposed to report information for all WBs in their country. The WBs are assigned to different water categories: lake, river, transitional and coastal WBs as well as groundwater bodies. For the purpose of this exercise, the focus is on the fresh surface water, i.e. ecosystem type rivers and lakes.

- The parameter chosen to represent water quality is the ecological status. This is a compound indicator, based on a range of quality elements (QEs), related to different groups of organisms indicating biological status. Ecological status and biological QE status are expressed in five status classes: high, good, moderate, poor and bad. The ecological status is set for each WB based on the biological QE that has the poorest status, and it can be further downgraded if any of the other QEs are in less than good status. The ecological status thus reflects the overall conditions of the water basin from an ecosystem perspective. It is not a measure of other qualities of the water, e.g. suitability as drinking water source.

- The information at water basin level is aggregated into the stock and change tables. Here certain principles have been chosen:

  - So far, there have been two rounds of reporting under the WFD: the first river basin management plans (RBMPs) (in 2010) and the second RBMPs (in 2016). The stock is given for each reporting and the change is presented as reporting in the second minus reporting in the first RBMPs.

  - The tables are given for selected river basin districts (RBDs) or sub-units (SUs) of these RBDs (where there were SUs in the RBDs). This was desirable, as part of the purpose is to transfer the information to maps. The information is aggregated separately for rivers and lakes to be able to evaluate the water categories separately and because the spatial representation is different for lake and river WBs.

  - Two different types of stock units are used: the number of individual WBs (count) and the sum of the length (for river WBs) or area (for lake WBs) of the individual WBs. There are arguments for and against both ways of aggregation, and by providing results for both units the outcomes can be compared. Briefly, aggregating by a spatial unit (length/area) is closer to representing the extent of the water. However, as the quality is the same for the whole WB, this means that large lake WBs and long river WBs will be given more weight.

The above methodological proposal is currently being tested on selected water basins. This will use both approaches to be able to evaluate which best fits the purpose. The resulting pilot account for freshwater ecosystem condition is expected to be finalised by the end of 2019.

4.5 Conclusions on initial results in developing pilot condition accounts in Europe

4.5.1 Conclusions on use of Nature Directives reporting for natural capital accounting

Using the data collected under the Nature Directives for ecosystem condition accounting will be of direct relevance to informing on condition with respect to biodiversity. This provides a means to integrate information on species-level biodiversity with a wider set of data on ecosystems, including the way they are used, and the economy. This can greatly assist in planning to meet objectives for biodiversity in a holistic manner. However, further testing of both the Article 12- and the Article 17-based approaches is required. This should include testing the integration of these accounts with wider ecosystem accounts, for example ecosystem extent. It may also be possible to align these biodiversity-based accounts with some specific ecosystem services, including cultural ecosystem services and experiential interactions (e.g. bird watching or hunting). However, other links between condition and services are likely to be more implicit, for example wetlands with higher bird species abundance or diversity are likely to be healthier and able to deliver various regulating services. Therefore, establishing a clear link between information on ecosystem condition derived from reporting under the Nature Directives and wider ecosystem services may be difficult. This is well noted in the wider biodiversity and ecosystem assessment literature (e.g. Harrison et al., 2014).

From a spatial accounting perspective, the aggregated nature of data reported under the Nature Directives is a constraint. Access to spatially referenced micro-data under national biodiversity monitoring schemes (including that collected to inform the Pan-European Common Bird Monitoring Scheme) may provide an opportunity to inform a more concrete spatial accounting approach. This is identified as a priority for future testing to inform ecosystem condition accounting in Europe. To further develop a spatial and integrated accounting approach, additional work is necessary to test approaches using geo-referenced data on bird species observations.

4.5.2 *Conclusions on use of Water Framework Directive reporting data for natural capital accounting*

As reported in Section 4.4, the EEA has tested the methodology for water quality accounts during 2017. The approach for water quality reporting under the WFD, based on carefully selected parameters to evaluate chemical, hydrological and ecological status, is a very good foundation for freshwater accounts that focus on ecological status.

During 2018, the data from the second WFD reporting cycle (for 2016) became available and provided an opportunity to calculate pilot water quality accounts that relate to the RBD or sub-basin (SB) level. The methodology developed enables the calculation of spatially explicit condition accounts for freshwater quality although the reported data do not cover all water bodies in either reporting cycle.

A further goal in developing water quality accounts will be their integration or combination with water quantity and water emission accounts (as discussed in Section 5.2). This requires further research and testing, but there is clear potential to achieve a harmonised presentation using the common spatial data frame that ECRINS provides. This would allow further assessment of the relationship between water quality and water provision, including the role of water quality in providing this service and the impact of water abstraction on water quality. It would also be useful to test how spatial information on freshwater ecosystems provided by ECRINS can be integrated with the ecosystem extent accounts presented in Section 3.3 (i.e. for rivers and lakes).

4.5.3 *Overall conclusions*

Ecosystem condition is a complex concept and measuring it is no easy undertaking. However, work under the EU MAES process and complementary reflections on calculating condition accounts by the EEA have led to clear proposals for priority condition indicators (see Section 4.1). As reported above, first pilot condition accounts have been developed or are under testing. These cover only two state indicators and one pressure indicator but include species diversity and nutrient pressure (for terrestrial ecosystems), which are key condition parameters for all ecosystem types. However, only the reporting under the WFD results in an ecosystem-specific condition account and further work needs to be invested into developing ecosystem-specific condition accounts. It is expected that the work being undertaken under the EU MAES process will provide a very useful foundation in that regard (see Maes et al., 2018).

Initial reflections have gone into how to combine different indicators into a potential ecosystem condition index but its practical implementation and ecological interpretation still encounter a number of challenges. In this regard Erhard et al. (2016) points out that:

- Indicators for the 'health' (i.e. condition) of ecosystems do not always fully address the multi-functionality of ecosystems.
- Habitat quality indicates condition for species but not necessarily for other ecosystem functions.
- Structural components of ecosystems can be useful indirect indicators of ecosystem condition, e.g. tree age class distribution or amount of dead wood in forests.
- Chemical condition of freshwater and marine ecosystems and the physical condition of river and sea beds are important indicators for habitat quality and biodiversity, and also address other important ecosystem functions (e.g. carbon sequestration).

Overall, it is clear that accounting for ecosystem condition is one of the least developed aspects of ecosystem accounting and that we are just at the beginning of a challenging endeavour. Developing a suitable data foundation and understanding the link between ecosystem condition and ecosystem service flow seem critical tasks in providing a convincing overall approach. Opportunities for establishing targeted ecosystem condition accounts should be harvested but it is also necessary to invest in targeted ecosystem monitoring and research that can fill critical gaps in the developing ecosystem condition accounts.

5 Accounts for water quantity and fish biomass

5.1 Introduction

This chapter presents accounting outputs that correspond to the SEEA-CF and SEEA for Water (SEEA-W) as well as the SEEA-EEA. One is well established, the other is a methodological test. What they have in common is that they provide a good insight into the connection between the natural capital resource and its economic use — a core objective of the UN SEEA. The accounts comprise:

- Water quantity accounts — showing the volume of water available in different parts of Europe, its use by different sectors, and water basins where water resources are particularly strongly exploited. These accounts are derived from the SEEA-W.
- Marine fish biomass accounts — using ecosystem accounting to analyse the impact of fishing pressure on selected European fish stocks, and reviewing how the sustainability of fisheries management can be analysed using ecosystem accounting principles. These accounts aim to build on SEEA-EEA principles.

5.2 Water quantity accounts

5.2.1 Introduction

The availability of water in Europe varies substantially because of climatic and other environmental factors as well as resource demand. High water demand from different economic sectors and the need to satisfy societal needs for health and sanitation put pressures on water resources, in particular where the availability of water resources fluctuates between seasons or years. Water scarcity has therefore become a major issue in some parts of Europe, particularly in the south and around metropolitan areas.

The EU WFD requires potential conflicts between different sectors to be resolved and to commit all users in a river basin to focus on the achievement of healthy water bodies with good ecological status (EEA, 2010).

In 2012, water directors agreed to regularly carry out an indicator-based assessment of water scarcity conditions and droughts (Faergemann, 2012). Such an assessment requires an understanding of the relations between water availability in the environment and water use by the economic sectors.

To support a better understanding of the use of water resources in Europe, the EEA has developed water quantity accounts. These are designed to provide information on the state of renewable water resources, water scarcity and related policy goals, such as resource efficiency. The EEA water quantity accounts are based on the conceptual framework of the UN SEEA-W, which focuses on quantifying assets accounts and exchange of water resources between the environment and the economy, and constitutes a sub-system of the SEEA-CF. The information derived from water quantity accounting is very useful for assessing the availability of renewable water resources and the water use efficiency by economic units. Such information can support the establishment of water efficiency targets at the sectoral level and help establish better management of water resources.

5.2.2 Hydrological cycle

Renewable freshwater resources are generated from precipitation at the global level. A portion of precipitation is then returned back to the atmosphere via evaporation and transpiration (evapotranspiration). The remaining precipitation is known as effective precipitation, which defines the total renewable freshwater corresponding to the maximum theoretical yearly amount of water available for a given area (FAO, 2016).

In terms of renewable water resources, water availability and exploitable water are often used interchangeably. However, there are technical differences. Exploitable water is the volume of water that is feasible to store for economic and environmental purposes (FAO, 2003), whereas water availability is about the hydrological capacity of a water source (surface water or groundwater body) to sustain additional water demands after considering other current water uses and water conditions. As for renewable water resources, effective precipitation (precipitation minus actual evapotranspiration) defines the volume of renewable water resources, while external inflow has to be factored in at the local level. External inflow is the water coming in from upstream territories. In a European context, water storage in reservoirs is also included in the quantification of renewable water resources (Faergemann, 2012).

5.2.3 Methodology of European water accounts

The water quantity (asset) accounts comprise two main components: inland water systems and the economy that makes use of the latter (as shown in Figure 5.1). The main transactions and interconnections between these two systems have their own internal structure, following natural processes, such as the hydrological cycle and the economic system that exploits the water resource (stocks and renewable). The water accounting system takes into account all these processes, mechanisms and particularities that comprise the unique conditions defining the hydrological regions in different parts of Europe. The stepwise approach followed by the SEEA-W is:

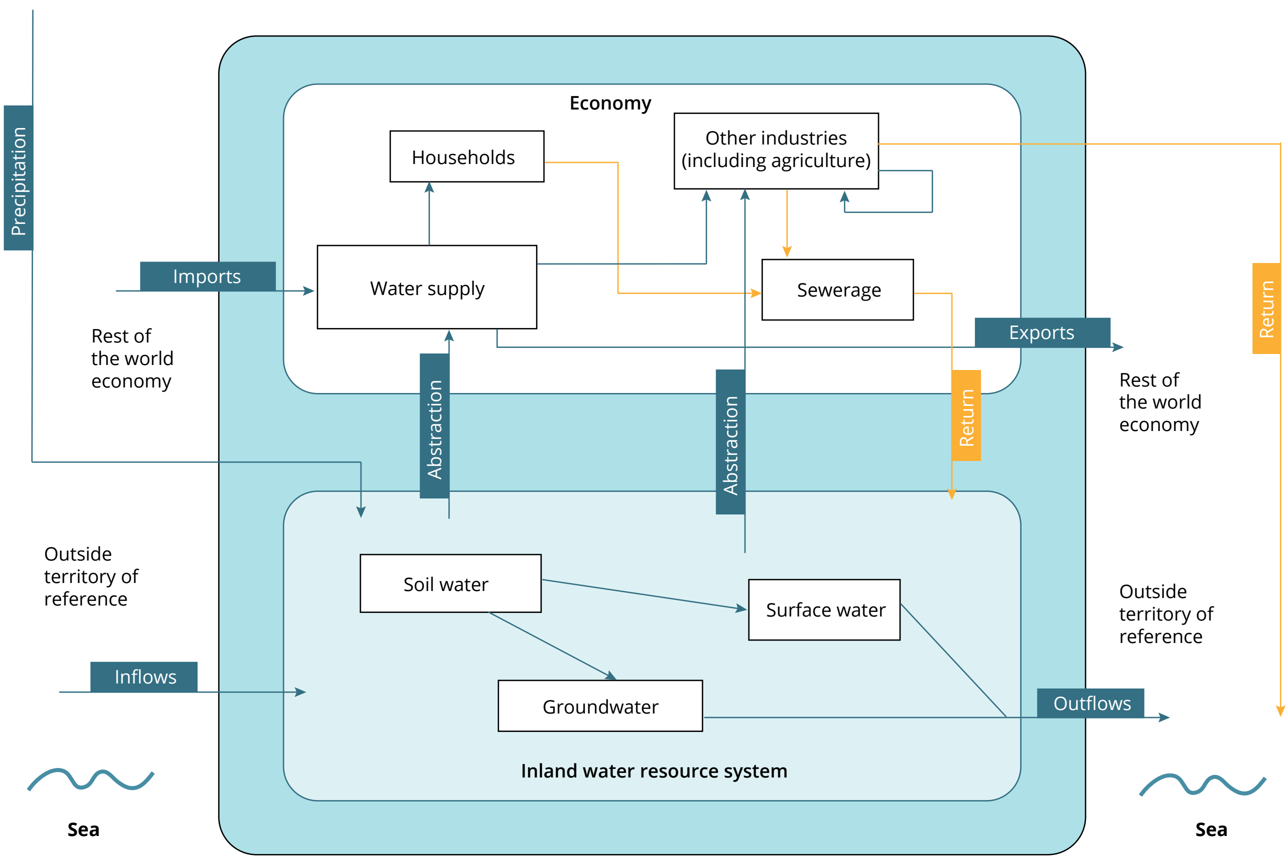
1. Define natural input and the stock of the water assets.

2. Estimate the use of water by the economy to support production processes.

3. Quantify the residuals that are returned back from the economy.

The SEEA-W accounts for the variation in water stocks (broken down into assets of surface, ground and soil waters) occurring either in the same area or between two neighbouring areas (upstream-downstream relationship) due to natural conditions or socio-economic needs. The main interaction processes between the water system and the economy are those of water abstractions and returns. The latter create the water flows and by consequence the variations in

Figure 5.1 Flows between the economy and the environment



Source: Rohd-Thomsen, 2015.

natural or artificial water stocks. External exchanges of water between the water system and/or the economy also need to be taken into account (e.g. imports, exports and outflow to the sea).

Information derived from water quantity accounting allows an assessment of the availability of renewable water resources and water use efficiency by economic sector. Using this information, the EEA calculates an indicator that communicates the use of freshwater resources known also as the Water Exploitation Index plus (WEI+). The WEI+ compares water use with the renewable water resources in a given territory and time. A WEI+ of above 20 % implies that a water unit is under stress, while a WEI+ of over 40 % indicates severe stress and clearly unsustainable resource use (see Raskin et al., 1997: water stress categories described on pp. 27-29).

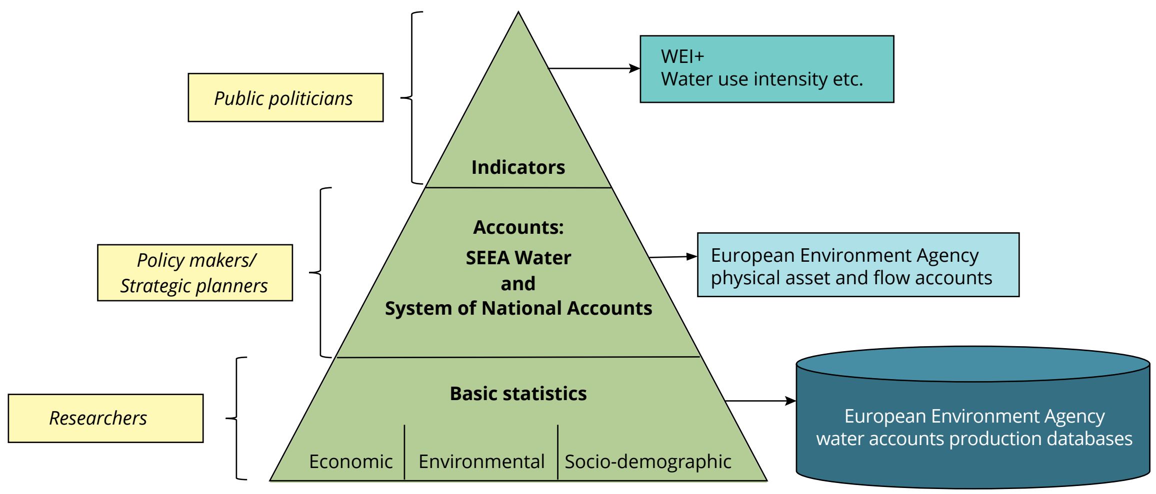
The WEI+ is now one of the core set of indicators (CSI) regularly updated by the EEA, with the purpose of informing policymakers about water scarcity conditions across Europe. Figure 5.2 illustrates the production chain, from data collection on water quantity accounting to developing the WEI+ for assessing the water scarcity conditions in Europe.

5.2.4 *Data for European water accounts*

In terms of data needs, the water accounting methods require many data to be collected, analysed and processed in such a way as to allow calculation of standardised physical supply and use tables. This is also supported by geo-spatial information systems for input data sets (for delineation of the hydrological regions and surface water bodies) as well as socio-economic data collected or estimated by international and European institutions (the Food and Agriculture Organization of the United Nations (FAO), Organisation for Economic Cooperation and Development (OECD), Eurostat, EEA). The time resolution of the input data varies depending on the parameters, but the minimum input that could be used after compiling the water accounts tables is the monthly resolution.

The BSUs that are used in the water scarcity assessment are sub-basin and functional river basin

Figure 5.2 Information pyramid from data to the implementation of WEI+



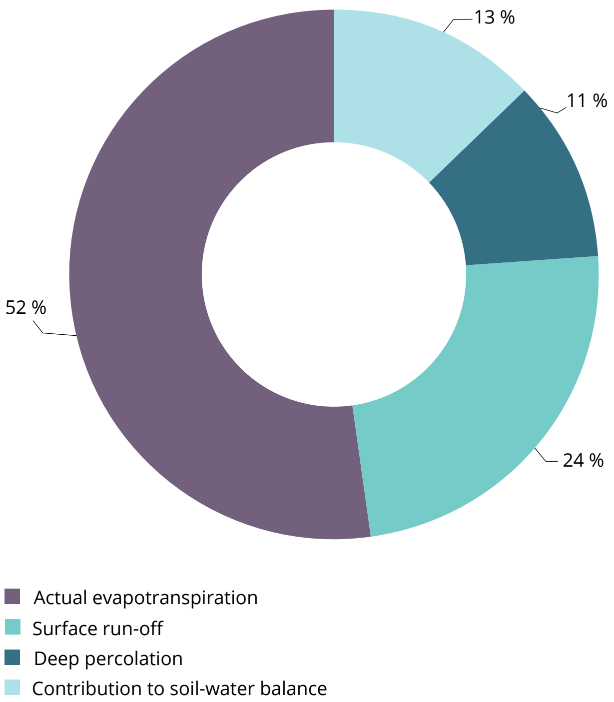
Source: Mazza et al., 2013.

district (FRBD) level as defined by ECRINS (EEA, 2012), while the temporal resolution is monthly for computation and seasonal for assessing the results. As water scarcity assessment is dependent on large-scale data, intensive data integration and assimilation have to be implemented before running the computation of the accounts.

5.2.5 Results from European water accounts

Europe receives around 4 000 km³ of water from precipitation annually, which corresponds to 4.1 % of precipitation globally (FAO, 2014). More than half of the precipitation (52 %) is returned to the atmosphere via evapotranspiration. About 13 % of water is either used by ecosystems or contributes to the soil-water balance. Around 11 % of water goes into soil (deep percolation) and feeds groundwater aquifers. The remaining water (24 %) feeds surface run-off and stream flow and meets the immediate water demands of ecosystems (Figure 5.3).

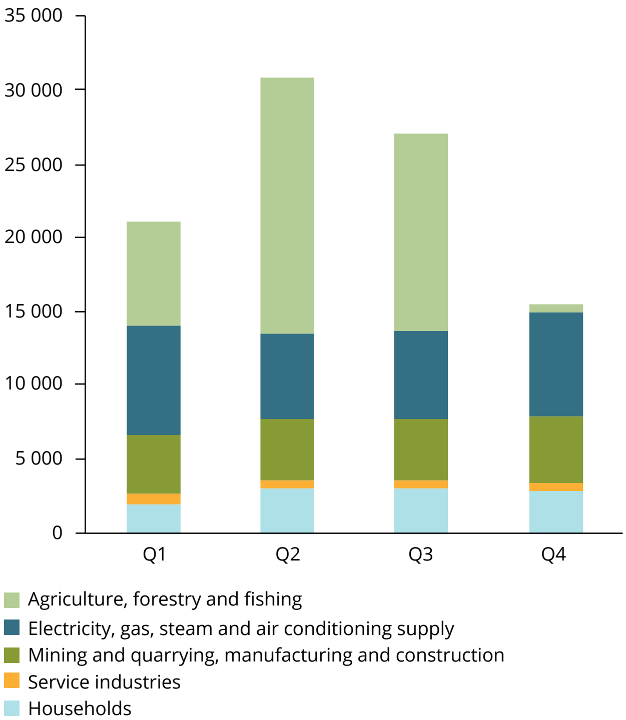
Figure 5.3 Natural water balance of Europe, 2002-2012



Source: EEA water accounts production database, based on Burek et al., 2013, and Haylock et al., 2008.

Figure 5.3 shows the overall renewable water resource in Europe and the respective shares of different compartments of the water cycle. Via further analysis it is possible to understand the size of the overall water resource that is potentially available for human use, which economic sectors represent the highest share of use and whether or not there are (temporal) water scarcity issues that may be connected to seasonal water cycles or socio-economic demand peaks. Analyses on water use by economic sector has revealed that agriculture and the water collection, treatment and supply sectors continue to be the major pressure on renewable water resources compared with other sectors, as shown in Figure 5.4.

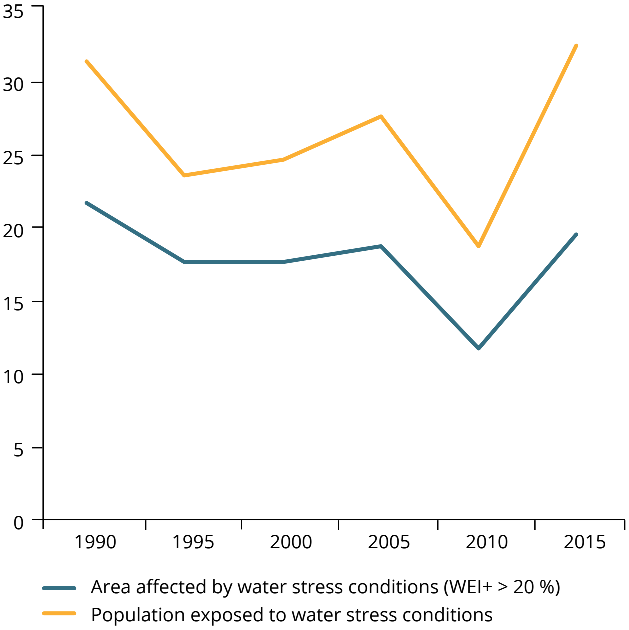
Figure 5.4 Seasonal water use by economic sectors, 2015



Source: EEA, 2018a.

The available time series for WEI+ covers 25 years (1990-2015). As shown in Figure 5.5, during the summer of 2015 one third (33 %) of the total European population was exposed to water scarcity conditions (defined as WEI+ values greater than 20 %). This contrasts with 20 % of the European population experiencing water scarcity conditions in 2014. As

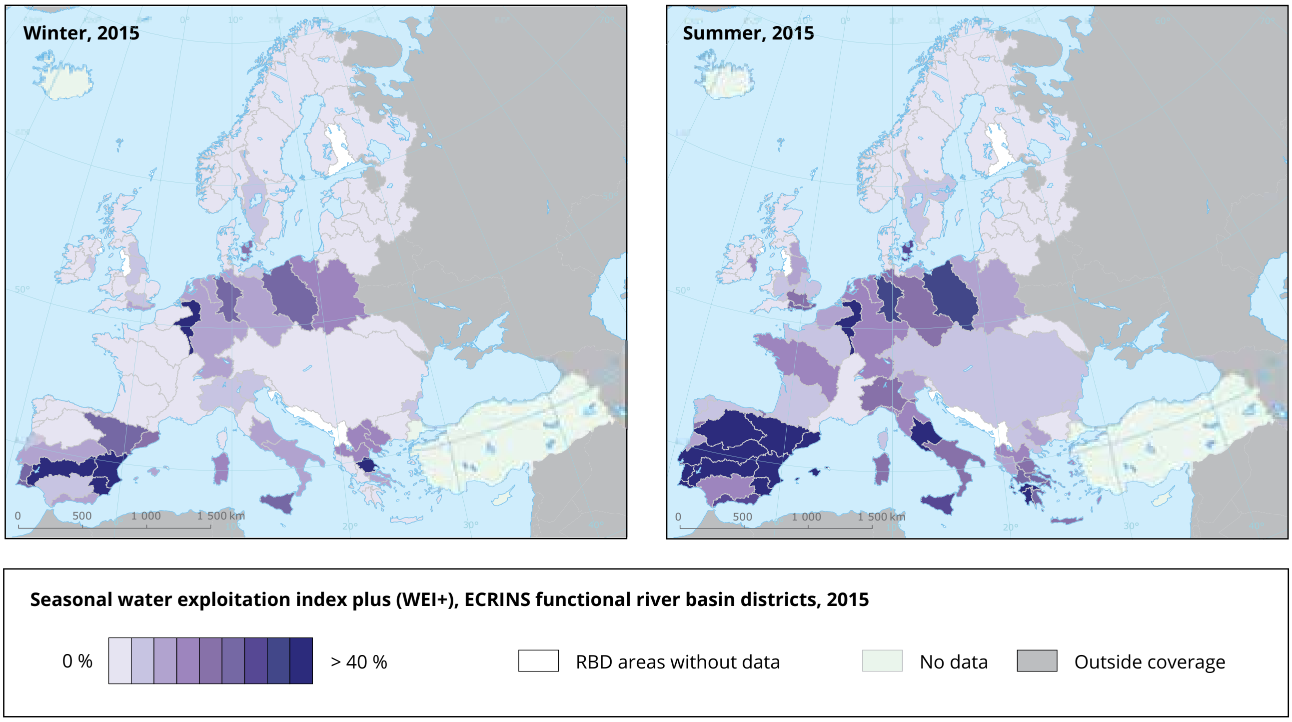
Figure 5.5 European area and population affected by water scarcity conditions, 1990-2015



also shown in Figure 5.6, the area affected by water scarcity conditions corresponded to 20 % of the extent of Europe's territory.

The spatial nature of the EEA water accounts allows those regions and water basins in Europe where water scarcity issues occur most often to be identified. Figure 5.6 presents this spatial information on water scarcity for Europe at the river basin scale for summer and winter 2015. During 2015, a total of 36 RBDs experienced water stress, i.e. a WEI+ higher than 20 % (compared with 12 RBDs in 2014). As shown in Figure 5.6, water stress is a widespread issue on the Iberian Peninsula and especially during the summer.

Figure 5.6 Seasonal WEI+, ECRINS river basin districts, 2015



Source: Zal et al., 2017.

Figure 5.7 presents the distribution of areas experiencing WEI+ > 20 % at the river SB scale, for all seasons in 2015. The greater spatial data provided in Figure 5.7 reveal that those most affected were people living in densely populated areas (e.g. lowland countries in the north-west coastal region of Europe), agriculture-dominated areas of southern Europe and small Mediterranean islands. This indicates that water scarcity is generally driven by climate conditions and population pressures. Figure 5.7 provides the spatial detail necessary to identify where measures need to be taken to reduce the water consumption by economic sectors and the human population, e.g. by improving the efficiency of water use.

Water scarcity conditions are most extensive during summer seasons, as would be expected and as is confirmed in Figure 5.7. However, Figure 5.7 also reveals that there are several areas that continually suffered from water scarcity throughout 2015. This included areas of south-east Spain, the lowland countries and parts of Germany and Poland.

5.2.6 Conclusions for water quantity accounting

Analytical results

This section has shown how European water accounts developed by the EEA allow a regionally and seasonally differentiated assessment of available water resources in Europe and underpin the EEA CSI water scarcity indicator (Zal et al., 2017). The EEA water accounts also enable an assessment of water use by all key economic sectors, i.e. agriculture (irrigation), water collection treatment and supply (households and tourism), the energy sector, construction and manufacturing, and the mining and quarrying industries.

Water abstraction and use by the economic sectors are described in seasonal resolution to emphasise the variability of water uses, mainly for agricultural and water collection treatment and supply sectors. This indicates the geographic areas and the economic sectors where measures are most urgently needed to improve the management of the regionally scarce water resources in Europe.

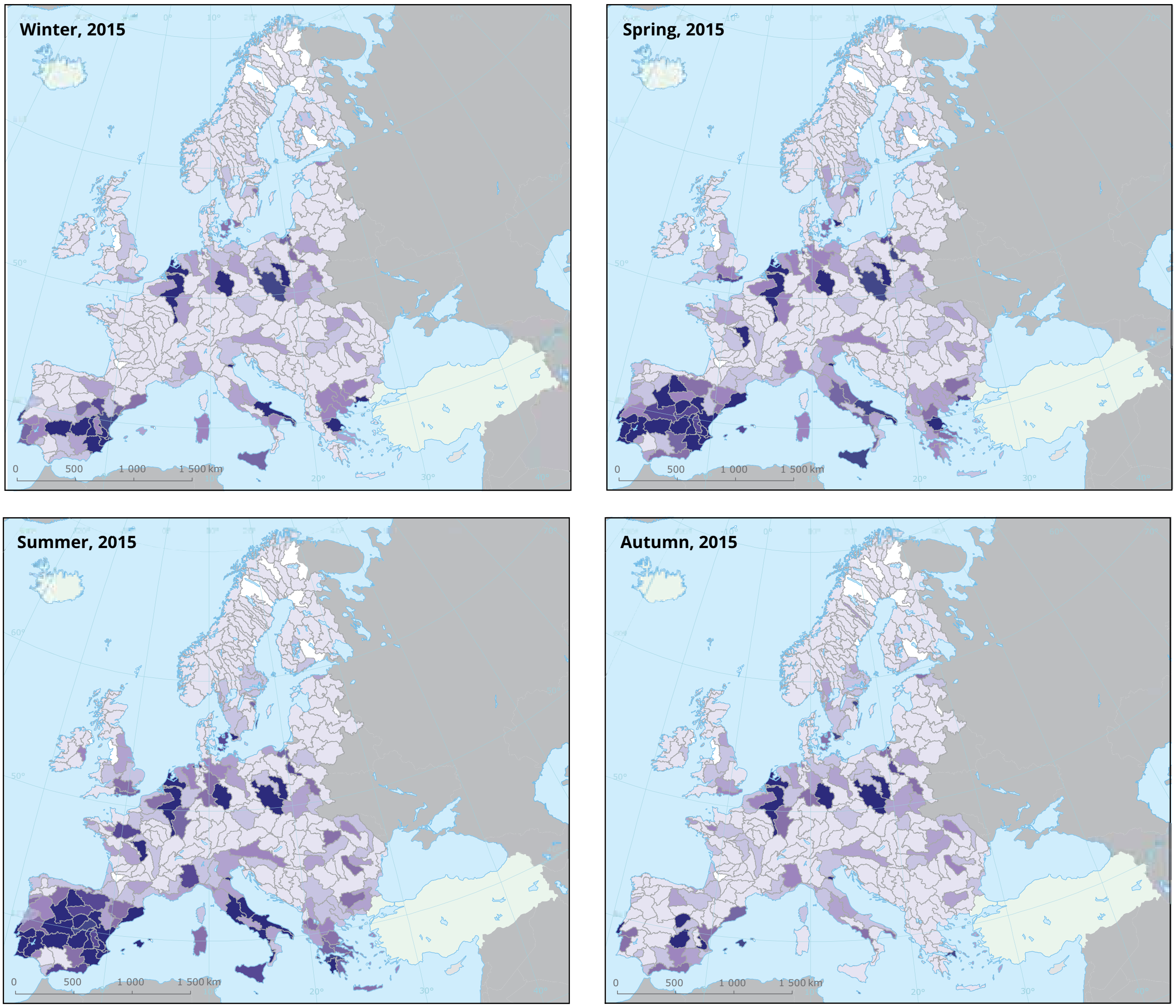
Development opportunities

The current water accounts would benefit from maintaining and expanding the time series of water accounts while increasing their integration with other environmental assessments in the water quantity area. Furthermore, it would be very useful in the future to combine the water quantity accounts with the pilot water quality accounts and water emission accounts (both of which are under development) to enable an integrated analysis of trade-offs.

Data foundation and analysis

Building spatially explicit water accounts requires the compilation, assimilation and integration of a substantial number of data sets from the economy and environment at various spatial and temporal levels. While river basins seem an appropriate spatial scale to undertake data integration from various sources in developing water quantity accounts, it is important to have monthly data available for producing water scarcity assessments from the accounts. This requires a substantial investment in data compilation, curation, analysis and associated computing power.

Figure 5.7 Seasonal WEI+, sub-basin scale, 2015



Seasonal water exploitation index plus (WEI+), sub river basin district scale

0 % > 40 %

RBD areas without data

No data

Outside coverage

Source: Zal et al., 2017.

5.3 Marine fish biomass accounts — a pilot account for marine ecosystems

5.3.1 Introduction

The European seas are an important part of Europe's natural capital and provide many essential ecosystem services (EEA, 2015). Therefore, they should ideally be included in a comprehensive natural capital accounting approach. This section describes an example of the development and application of the natural capital accounting framework for European marine ecosystems at a regional sea and European level. It summarises a pilot study of ecosystem asset and service accounts for commercial (wild) fish stocks as one component of marine ecosystem capital (Piet et al., 2017). The work presented here was initially inspired by the approach put forward in 'Ecosystem natural capital accounts: a quick start package' (ENCA-QSP) (Weber, 2014) and then adjusted to the conceptual framework presented in the SEEA-EEA (UN, et al., 2014b). The method developed can be considered a potential satellite account to inform on the sustainability of using marine fish resources as a source of the wild seafood provisioning service, and it is meant as a contribution to KIP INCA on building an EU ecosystem accounting system. As a pilot study it covers only a limited time period and does not include the most recent available data on fish catches.

The resulting marine commercial (wild) fish ([11]) asset and service accounts were tested by applying them in most of the European marine sub-regions, resulting in a consolidated European assessment and compilation of relevant metrics. These different SEEA-EEA-related components were combined in one integrated marine fish account (IMFA), which includes a measure of the sustainability of the use of fish stocks by commercial fisheries. This integration allows a link to EU policy by analysing how the accounting metrics relate to the implementation of relevant EU marine and fisheries policy frameworks.

5.3.2 Integrated marine fish account methodology

The overall purpose of developing an IMFA is to better understand the sustainability of marine fish resources as a source of the wild seafood provisioning service. This can be done by combining standard fisheries management knowledge with ecosystem accounting concepts, and it results in the potential implementation of bio-physical capacity accounts, as proposed in the roadmap for KIP INCA (EC and EEA, 2016). The use of fisheries management data implies that the IMFA organises information on the characteristics of a semi-discrete group of fish with some definable attributes, which are of interest to fisheries managers. This group of fish thus represents the marine fish community in terms of its wild seafood provisioning capacity and consists of all commercial fish species (i.e. fish populations, some of which consist of several fish stocks) for which the appropriate data are available.

Figure 5.8 illustrates how the population dynamics processes underpin the development of the fish asset (consisting of several fish stocks). When these fish stocks are harvested, they generate an ecosystem service flow ('wild fish harvested'), which is represented by fish landings. This process can be described by three separate IMFA components:

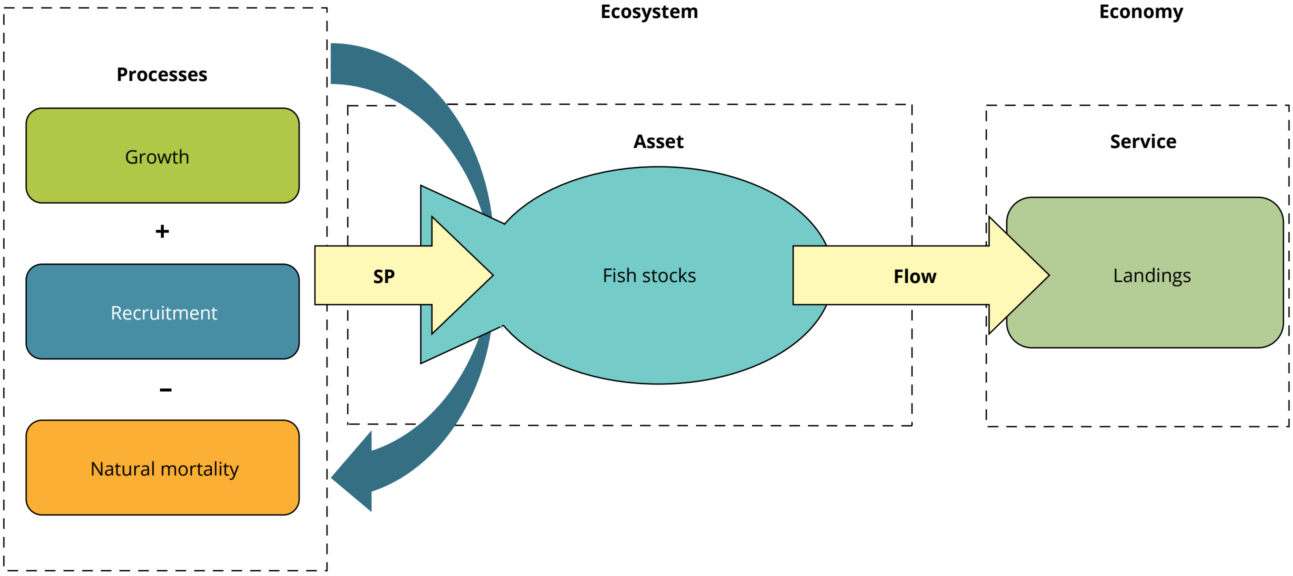
- **Processes** — 'recruitment', 'body growth' and 'natural mortality' representing net production due to natural processes, equivalent to the total inflow into the asset.
- **Asset** — aggregated commercial fish stock biomass
- **Service (flow)** — 'catch' represents the impact of the fishery as removals from the asset, equivalent to the total use of (commercial fish) biomass. In practice, the data usually represent the landings (which is catch without the discards).

The fish stocks are considered closed units (i.e. no emigration or immigration), which are usually attributed to one marine region. If this was not possible because one stock occurs in several regions, the stock biomass was divided between those regions according to the ratio of the landings. Figure 5.8 illustrates how the basic fish stock dynamics and the harvesting chain relate to ecosystem accounting concepts.

From a fisheries management perspective, the two processes through which harvestable biomass is generated (recruitment and growth) provide sensible indicators of the capacity of fisheries to deliver fish catches. The recruitment potential is reflected in one of two indicators commonly used to report the status of commercial fish species, i.e. spawning stock biomass (SSB). SSB represents the amount of biomass of a fish stock above a certain age/size that is considered

([11]) Beyond actual fish species, commercial fish stocks include mollusc (e.g. squid) and crustacean (e.g. lobster) species.

Figure 5.8 Basic fish stock dynamics and their link to ecosystem accounting concepts



Source: EEA, 2018.

Note: SP = surplus production.

mature and, thus, contributes to recruitment. However, an ideal indicator for the wild seafood provisioning service (WSPS) should represent the potential fish biomass that can be sustainably harvested (and hence allow a sustained supply of the service).

The term 'surplus production' is a well-established concept in fisheries science and is considered to represent this concept best (Piet et al., 2017). Therefore, it is proposed as the preferred metric for the capacity of the marine fish community to sustain the WSPS, as defined below. However, it is a fish community metric, i.e. an aggregate, relating to the supply of a service, which should complement, rather than replace, the existing fish stock indicators, i.e. SSB and fishing mortality, used in fisheries management.

- **Surplus production** is the net result of several biological processes — growth, recruitment and natural mortality — that determine species-specific surplus production, which is then aggregated into a fish community metric (see Figure 5.8). Surplus production reflects the capacity of the marine fish community to sustain the WSPS.

In addition, there are two other concepts that are relevant to surplus production: ecosystem productivity and the sustainability of exploiting fisheries. These concepts are translated into relevant metrics to place the IMFA in such a context as follows:

- **Productivity** is calculated as surplus production/total (commercial) fish biomass, and it reflects the amount of surplus production produced per unit of biomass. This is an ecosystem-specific metric of the capacity of the fish community (as represented by the selected fish stocks) to produce surplus production that implicitly links surplus production to the characteristics of an ecosystem, such as primary and secondary production. This is considered a robust parameter as long as the subset of marine fish stocks is sufficiently representative of the targeted regional marine fish community. In the event that regional selections are made, this metric allows comparison between marine regions.

- **Sustainability of biomass use (SBU)** is calculated as surplus production/catch. A value of 1 or greater, therefore, implies that the fish community is being harvested sustainably from the point of view of ensuring that the WSPS is maintained. This is (also) an ecosystem-specific metric showing how sustainable the fisheries' exploitation of a marine fish community is. More specifically, it reflects the level of human exploitation in relation to the WSPS capacity of the marine fish community. In the event that regional selections are made, this metric allows comparison between marine regions.

Box 5.1 ENCA-QSP (Weber, 2014) and how this relates to the IMFA metrics

Table I. Ecosystem fish biomass balance
- C1 Opening fish stocks
- C2 Total inflow (SP)
- C7 Total outflow (catch)
- C9 Closing fish stocks

Table II. Accessible resource surplus
- C2 Total inflow of fish biomass (SP)
- C2/C1 Capability of the stock to generate the accessible resource surplus (productivity = SP/stock)

Table III. Total uses of ecosystem fish biomass
- C5 Total use of ecosystem fish biomass (fish landings ([a]))

Table IV. Table of indexes of intensity of use and ecosystem health
- C2/C5 Sustainability of (fish) biomass use (SBU = SP/fish landings)

Note: This accounting table for fish biomass accounts has been developed from a proposed carbon biomass accounting table in Weber (2014).

([a]) Discards and recreational catches are considered negligible.

5.3.3 Building an integrated marine fish (biomass) account

To date, ecosystem accounting concepts have largely been developed with a focus on terrestrial ecosystems. It is important, therefore, to explore integrating marine ecosystems and their services into ecosystem accounting approaches. The initial inspiration to develop and calculate the IMFA came from the methodology proposed in the ENCA-QSP (Weber, 2014) with regard to establishing accounts for carbon biomass. To produce the basic account in accordance with the ENCA-QSP requires building Tables I, II, III and IV proposed in Section 5.1 of the ENCA-QSP document. The data items presented in these accounting tables, as adapted for the IMFA, are presented in Box 5.1.

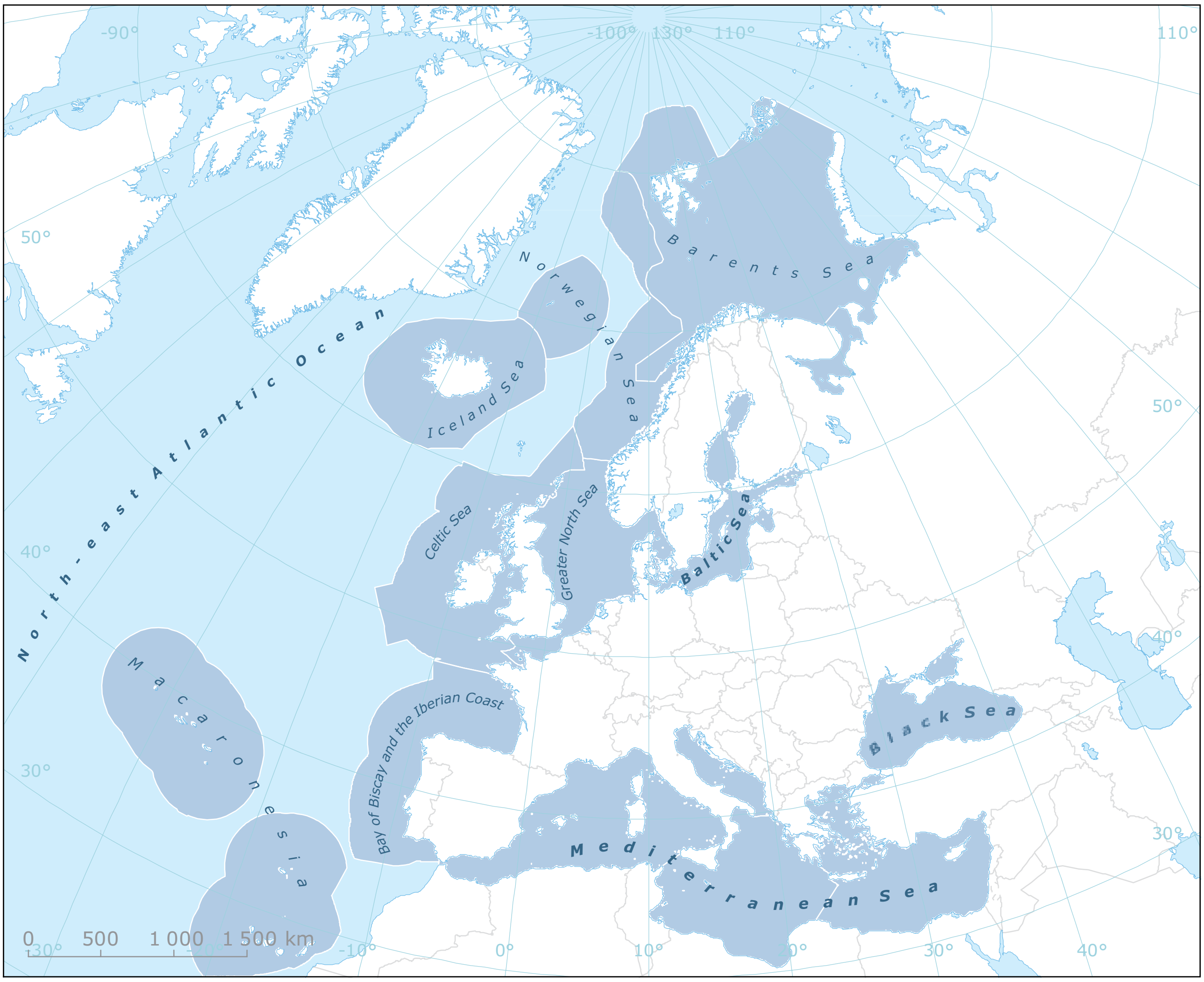
5.3.4 Data and results

Available data on the implementation of the relevant requirements of the common fisheries policy (CFP) allowed IMFAs to be calculated for most of the European marine sub-regions (see Figure 5.9). For the European IMFA, data requirements meant that it could be calculated only for the fish stocks covered by the International Council for the Exploration of the Seas (ICES), i.e. those in the North-East Atlantic and Baltic Sea. This was due to lack of comparability (of the length of the time series) with the other European regional seas, i.e. the Mediterranean and Black Seas. However, even though the European account covers only the North-East Atlantic and Baltic Sea, it represents most of the European landings: approximately 75 %. Therefore, this account is considered reasonably representative of the European capacity for the WSPS.

The availability of data was determined by checking, species by species, whether sufficiently long time-series of annual stock assessments reporting on total stock biomass were recorded in official databases. This resulted in a selection of 54 commercial fish stocks available through a dedicated website — the ICES Stock Database — covering several European marine sub-regions except for those in the Mediterranean and Black Seas.

The regional sea IMFAs were calculated for fixed periods, for which the selection of the period was determined by the availability of data between 1999 and 2013. In this fixed period, the composition of the marine fish species in the database was consistent, which avoided bias through differences in data availability. The IMFAs were then compiled using the aggregated marine fish stock biomass across all species/stocks for which the required data are available, which implies being able to select only commercial fish species subject to quantitative stock assessments and for which total biomass is reported.

Figure 5.9 Marine regions and sub-regions according to the Marine Strategy Framework Directive, as well as additional sub-regions in the North-east Atlantic considered by ICES (Iceland, Norwegian and Barents Seas)



Source: European Marine regions.

Table 5.1 Marine fish biomass basic balance (in tonnes), opening in 1999 and closing in 2013

	Barents and Norwegian Seas	Iceland Sea	North Sea	Baltic Sea	Celtic Seas	Bay of Biscay and Iberian Coast	Macaronesia
Opening	9 548 987	4 986 668	12 700 253	3 652 996	7 197 915	953 184	141 588
Additions	28 270 224	11 984 640	25 621 016	9 463 830	15 911 355	2 947 891	328 985
Reductions	26 839 872	12 435 507	25 935 299	8 905 842	17 078 395	3 131 925	365 161
Closing	10 979 339	4 535 801	12 385 970	4 210 984	6 030 876	769 150	105 412

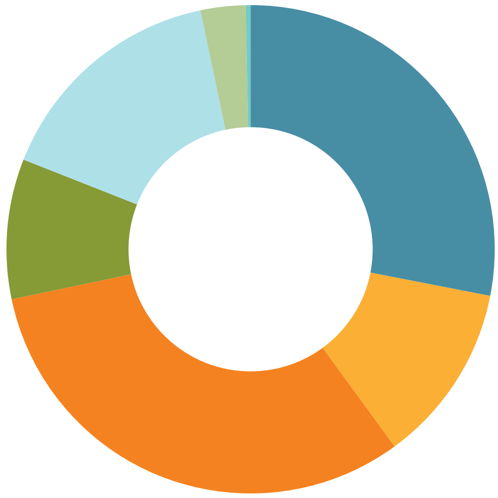
Source: EEA, 2018.

Table 5.2 Productivity (%) of the marine fish community per European marine sub-region covered in this study over the period 1999-2013

Region	Productivity (%)
Barents and Norwegian Seas	19
Iceland Sea	18
North Sea	18
Baltic Sea	17
Celtic Seas	17
Bay of Biscay and Iberian Coast	24
Macaronesia	18

Source: EEA, 2018.

Figure 5.10 Share in annual surplus production for each European marine sub-region covered in this study over the longest possible consistent period, i.e. 1999-2013



Source: EEA, 2018.

When combining the regional total biomass data with the landings data, the study aimed to use only the part of the landings that can be attributed to the stock in each region. If this was not possible, the total amount of landings was used, which may cause an overestimation of the regional surplus production for that stock. However, this did not concern any of the main stocks, nor did it affect the European IMFA.

The marine fish biomass balance over the period 1999-2013 shows that, for Europe as a whole, in- and outflow are fairly balanced but with marked regional differences (Table 5.1). The biggest decrease in fish biomass is observed in the Azores, with approximately a 25 % decline, while the Baltic Sea and the Barents and Norwegian Seas show a 15 % increase.

Accessible resource surplus

This part of the biomass account records changes in the surplus production and productivity of marine fish, which is an indicator of the capability of the standing stock to generate this surplus production. Annual surplus production for each of the European marine sub-regions covered is given in Figure 5.10. This shows considerable differences between the marine sub-regions, or at least between the stocks as attributed to different marine sub-regions.

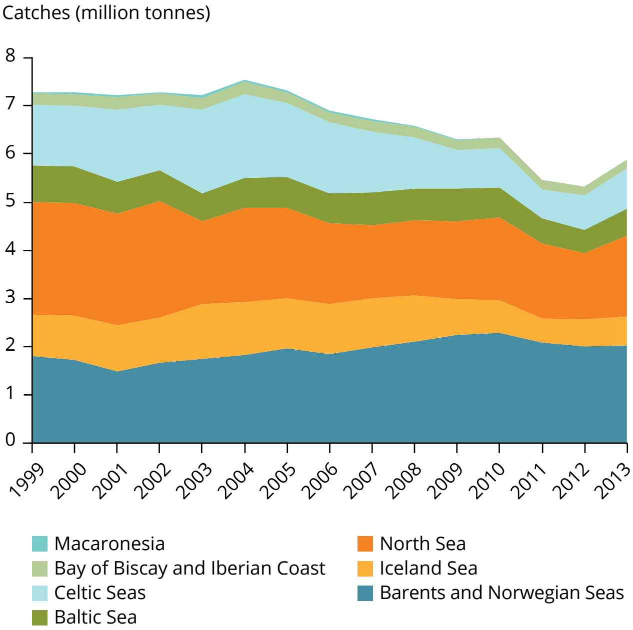
The sub-regions contributing most to the surplus production are the North Sea (32 %) and the Barents and Norwegian Seas (28 %).

Information on productivity by region is presented in Table 5.2. The most productive marine sub-region (i.e. the one producing the highest surplus production per unit of fish biomass stock) is the Bay of Biscay and Iberian Coast (24 %). Productivity in the remaining marine sub-regions was reasonably consistent, varying between 17 % and 19 %.

Total uses of ecosystem fish biomass

This part of the biomass account presents the total use of marine fish biomass in each European marine sub-region (i.e. total fish landings). Figure 5.11 illustrates that the North Sea, and Barents and Norwegian Seas represent a majority of the fish biomass landings accounted for, with this share increasing in recent years (both approximately 2 million tonnes in 2013).

Figure 5.11 Fisheries landing over time per European marine sub-region covered in this study



Source: EEA, 2018.

Indexes of intensity of use

This part of the IMFA shows the degree to which the intensity of biomass use is sustainable, calculated from the accessible resource surplus/total use. In the IMFA, this is represented by the SBU (surplus production/total fish landings). Table 5.3 presents the calculated SBU over time by European marine sub-region as well as for the whole of Europe. For Europe as a whole, nearly all surplus production is landed (SBU 1.05). Accordingly, at this aggregate level, fisheries' exploitation of the WSPS can be considered sustainable. However, regional differences emerge; in several sub-regions fish landings exceed surplus production (i.e. SBU < 1). This will therefore lead to a decrease in total fish biomass over time.

While not presented here, a more detailed analysis reveals that all sub-regions show a large variation in SBU over time. This is attributed to variations in surplus production driven by changes in the stock of specific small pelagic species, which dominate the biomass in that particular sub-region (i.e. sandeel in the North Sea, herring in the Bay of Biscay and Iberian Coast, sprat in the Baltic Sea). These fairly minor deviations from 1 may therefore be caused by the selection of the time period and are not representative of the true long-term regional SBU.

Table 5.3 Sustainability of biomass use per European marine sub-region covered in this study over the period 1999-2013

European marine sub-region	SBU
Barents and Norwegian Sea	1.03
Iceland Sea	0.97
North Sea	1.22
Baltic Sea	1.04
Celtic Seas	0.93
Bay of Biscay and Iberian Coast	0.95
Macaronesia	0.89
European aggregation	1.05

Source: EEA, 2018.

5.3.5 Discussion and policy relevance of the IMFA

The IMFA is based on surplus production, a well-established concept in fisheries science, to represent the capacity of marine ecosystems to provide the 'Wild Seafood' Provisioning Service (WSPS). However, the IMFA is not supposed to represent the status of the commercial fish stocks, which is usually assessed using two typical fisheries management indicators, i.e. fishing mortality and SSB relative to the maximum sustainable yield (MSY) level enshrined in both the Marine Strategy Framework Directive (EC, 2008, MSFD) and the CFP. In fact Piet, et al. (2017) who compared the performance of surplus production with that of these two indicators in relation to the WSPS, found that surplus production is probably a better indicator of the performance of fisheries management in terms of sustaining the supply of the WSPS than aggregates of the fisheries management indicators, such as the proportion of stocks in 'good environmental status' (MSFD) or 'within safe biological limits' (CFP).

Overall, the IMFA is well aligned to these indicators, as it is based on similar information from the same subset of commercial fish species. Nevertheless, the IMFA is supposed to complement the fisheries management indicators rather than replace them. Thus, it can provide a broader and more holistic picture of the state of the fish community by specifically providing information on its capacity to sustain the WSPS. It can, therefore, be used as a 'surveillance' tool to inform policy by providing warning signals on the sustainability of such capacity. For example, the study by Piet et al. (2017) shows that, whereas the performance of fisheries management in terms of the proportion of fish stocks in 'good environmental status' (MSFD) or 'within safe biological limits' (CFP) was increasing, the capacity of these fish stocks to sustain the WSPS was decreasing.

The fact that the IMFA is calculated on a subset of the whole (wild) marine fish community, i.e. commercial fish, implies a systematic underestimation of the total fish biomass. Therefore, the account could be criticised for misrepresenting the total capacity of marine fish to contribute to the WSPS. However, while this subset only makes up a relatively small component in terms of its contribution to the biomass present in the marine ecosystem, it makes up a key component in terms of its contribution to the actual marine ecosystem WSPS. It thus reveals relevant information on the biomass fluxes on which the WSPS depends, showing how the natural production (i.e. surplus production) varies over time and how this is related to resource use (fish landings), which together represent the flow that determines the stocks of the fishery asset (i.e. total commercial fish stock biomass).

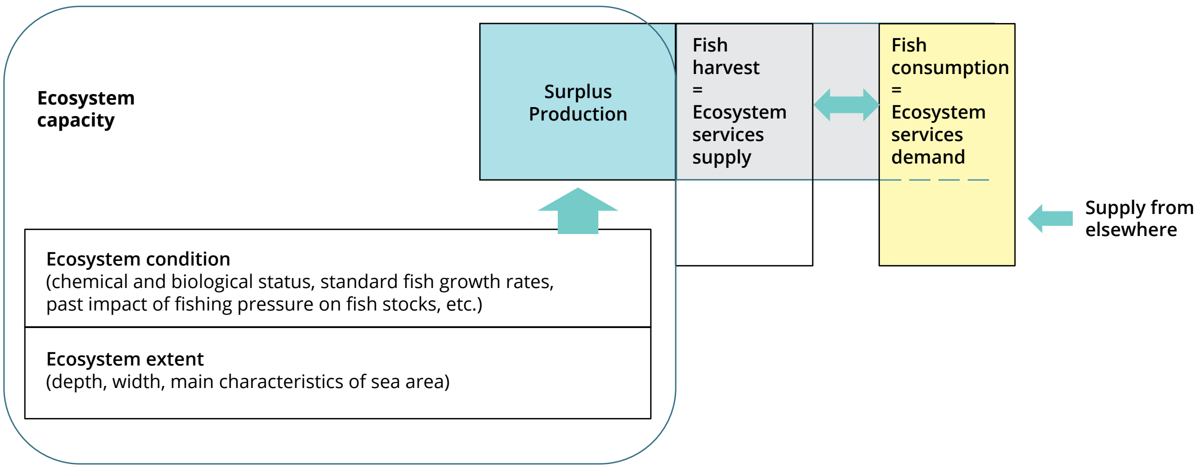
The IMFA is based on analyses at a highly aggregated level, i.e. European or regional, but over a relatively long period (1999-2013, i.e. 14 years). As information is disaggregated, or the time period shortened, the meaningful patterns observed are likely to disappear due to the high variability in the ecosystem. Thus, the requirement for relatively long periods may need to be balanced against the limitations in terms of data availability and/or a potential requirement for selecting specific periods in which a specific management regime occurred (e.g. revisions of the CFP). The question 'What can be considered an appropriate period for obtaining meaningful results from the calculation of these accounts?' needs to be further explored. In doing this, it is again important to distinguish between the fisheries management indicators, which are usually calculated and applied on an annual basis to underpin specific management actions, and the IMFA. As noted, the latter is supposed to act as a surveillance tool and thus needs to operate over longer time scales.

5.3.6 Final reflections — potential for integrating the IMFA with the SEEA-EEA

The EEA developed marine fish biomass accounts as a test case for bringing the important marine ecosystems into the overall SEEA ecosystem accounting approach, which has been developed largely on the basis of terrestrial ecosystem data. The review of methodology and results in this section shows that the important services of the marine biome can be included in natural capital accounting. At the same time, it provides a useful reflection on whether and how ecosystem accounting approaches can provide additional insights into the management of natural resources compared with already established resource management concepts. This study also provides a foundation to reflect on the concept of ecosystem capacity.

The concept of ecosystem capacity is discussed in the SEEA-EEA, where the focus is on integrating the monetary values of current and future ecosystem services into national accounts. While this emphasis is different compared with the ENCA-QSP, the concept of capacity accounts that elaborate on the sustainable management of (human activities on) ecosystems is also discussed in the SEEA-EEA-TR (SEEA, 2017) as an area of ongoing research. Related work is

Figure 5.12 Schematic representation of links between accounts for ecosystem extent and condition, ecosystem capacity and ecosystem services in the context of the IMFA

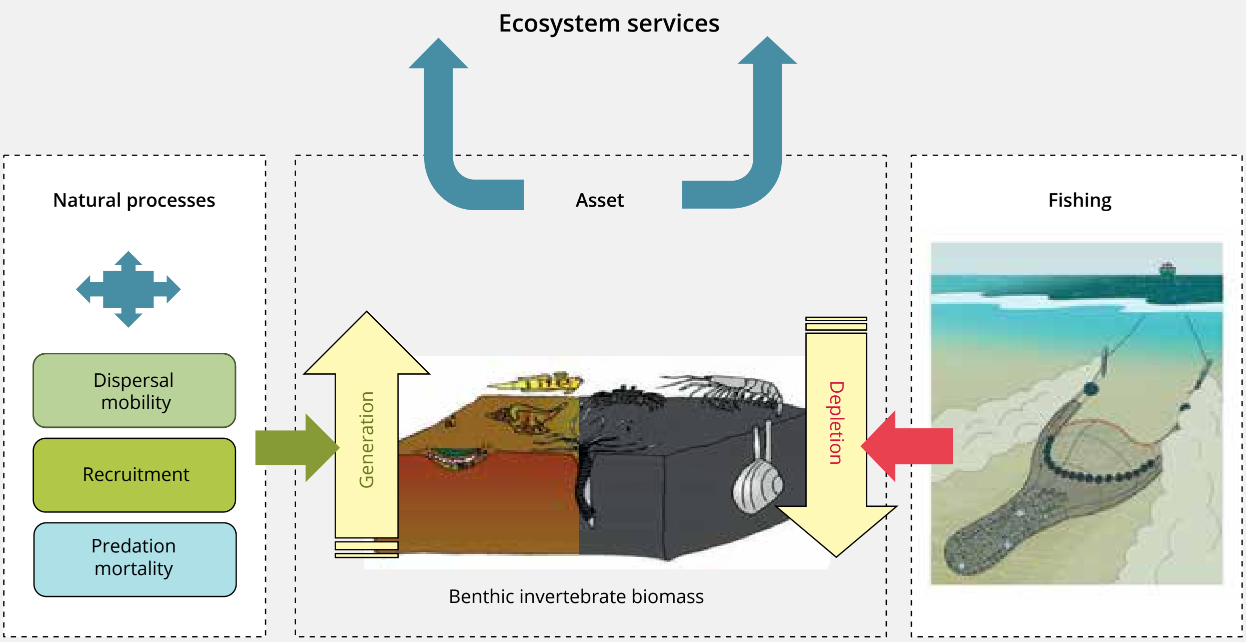


Box 5.2 Pilot European seafloor integrity account

The EEA and its ETC/ICM have developed a concept and method for a pilot European seafloor integrity account (SIA) to help assess the condition of marine ecosystems. The pilot SIA has been tested in the North Sea and aims to assess the impact of fishing-induced physical disturbance on seabed habitats, specifically on the animal species living on the seabed (i.e. the benthic invertebrate community).

The population density and species richness of the benthic invertebrate community determine its contribution to the capacity of seabed habitats to supply regulation and maintenance, and cultural ecosystem services. Using the fish and shellfish provisioning ecosystem service requires bottom trawling but this damages seabed habitats and hence reduces their capacity to supply those other ecosystem services. The pilot SIA can, therefore, inform policy decisions on the need to maintain good ecosystem condition and ecosystem service supply capacity in relation to fishing-induced physical disturbance of seabed habitats. Figure 5.13 shows the conceptual logic of the pilot account.

Figure 5.13 Concept of the pilot European seafloor integrity account



Source: ETC/ICM (2019, in prep.)

Note: Figure 5.13 illustrates the basic processes determining the condition of the ecosystem asset in the focus of the pilot SIA (the biomass of benthic invertebrates in the seabed). The condition of this asset is improved via natural growth processes (generation), which increase the asset, and declines due to impacts from fishing-induced physical disturbance (depletion). If fishing pressure leads to the degradation of the condition of the ecosystem, its capacity to supply ecosystem services is reduced.

Relevant EU policy (i.e. the Marine Strategy Framework Directive) considers seabed habitats impacted by physical loss (i.e. complete destruction) separately from those impacted by physical disturbance, as only the latter can recover within a policy-relevant time-period. This is why the development and calculation of the pilot SIA focuses on the physical disturbance of seabed habitats. In addition, the account focuses on one human activity causing physical disturbance: commercial fishing, which is because: 1) this is the main cause of physical disturbance pressure on Europe's seas (ETC/ICM, 2015) and 2) data on fishing activity and methods to estimate its impact are available on an annual basis, at least for some EU marine (sub) regions. It should be noted that the account calculates the biomass of a subset of the benthic community — the benthic invertebrate community (in a certain range of soft-substrate seabed habitats), i.e. excluding plants and algae, relative to an undisturbed situation.

The concept and method to calculate the SIA and its calculation for the North Sea will be published as an ETC/ICM Technical Report entitled 'Development of a pilot 'European seafloor integrity account' to assess the state of seabed habitats from fishing pressure' during 2019, which should be made available at this site: https://icm.eionet.europa.eu/ETC_Reports.

ongoing within the frame of KIP INCA in the context of developing ecosystem service accounts (see La Notte et al., 2017).

One particular dimension that is important to consider in this context is exploring the links between accounts for ecosystem extent and condition with ecosystem capacity and the (sustainability of) connected flows of ecosystem services. Figure 5.12 provides a first proposal for how the IMFA metrics could be integrated with extent, condition and ecosystem service supply and use accounts as well as accounting items relevant to ecosystem capacity.

In this proposal, ecosystem capacity is seen as encompassing the accounts for ecosystem extent and ecosystem condition, both of which underpin surplus production. Fish harvest is assumed to be limited by the surplus production, as 'ecosystem capacity' for marine fish communities is defined as the ability to generate the wild seafood (biomass) provisioning ecosystem service at rates that do not exceed such production. In Figure 5.12, fish demand is depicted as greater than (sustainable) supply but the gap is assumed to be closed by fish supply from elsewhere (which is the case in many real-life situations, as it is in most European countries).

This brief exploration of how to link ecosystem accounting concepts with knowledge derived from fisheries management methodology is proposed as a first contribution to the field of ecosystem accounting in terms of including marine ecosystems in natural capital accounting as well as reflecting on how European fish supply chains are actually operating. This shows again the importance of reflecting on how to deal with imports of biomass and other ecosystem services from non-Member States or other continents in the SEEA-EEA context. Furthermore, integrating the marine biome into ecosystem accounting remains an important challenge that requires more attention in the future.

6 Use of ecosystem accounting results as support to policy analysis — initial reflections

6.1 Introduction

Since the publication of the Brundtland report (Brundtland, 1987), it has been argued that sustainable development requires the integration of economic, environmental and social goals. The system of environmental-economic accounting is explicitly designed to help understand the interlinkages between the economy and the environment (both abiotic and biotic aspects). Section 2.3 reviewed the potential analytical contributions of the SEEA-EEA framework by stage of policy cycle. The MAES report on natural capital accounting (EC, forthcoming) also includes an exploration of the potential analytical use of natural capital accounting to support policymaking.

As set out in Section 2.3, Radermacher and Steurer (2015) consider that the requirements for natural capital accounts to contribute to policy decisions are likely to vary during different policy stages. Identifying these, and developing natural capital accounts with policy use in mind, will involve potential trade-offs between statistical measurability, scientific soundness and political relevance. This also has implications for key design requirements of natural capital accounts, such as their accuracy and update frequency. Further development and practical use of such accounts at national level will help to improve our understanding of the most promising policy applications for accounting frameworks.

To properly understand the policy utility of natural capital accounting it is therefore necessary to add analytical lenses that take the policy process as their starting point. Two approaches are explored in the following section with a view to understanding which are the most important contributions that ecosystem accounting can make for better management of natural capital. The first approach aims to identify concrete information needs for managing natural capital by looking at policy targets in the 7th EAP as a key EU policy document. A subsequent section explores the use of information from environmental and ecosystem accounting in the practical case of freshwater resources and ecosystems.

As background to this analysis, it is useful to recall for which components of the SEEA-EEA and for which European ecosystems actual accounting results are available so far. The following points provide a short summary of the material presented in previous chapters.

Land accounts and ecosystem extent accounts

- EEA land accounts focus on analysing the flows between different land cover classes from 1990 to 2012, showing the change in European landscapes. Notable results include the strong urbanisation trend around population centres and in coastal areas and the associated loss of productive land and/or natural areas. The analysis in the 2017 EEA land report also shows the advantage of combining accounting results with other analytical approaches in an integrated analysis of land use trends.

- Ecosystem extent accounts show general changes in the extent and distribution of broad European ecosystem types between 2000 and 2012 and analyse these patterns in so-called geographical focus areas (e.g. inside and outside Natura 2000 areas). This geographical focus provides an important complement to country-level trends. This provides a useful analysis but the spatial and thematic detail of current data on ecosystem distribution should ideally be further developed by combining CLC with other satellite data sets and spatially referenced biodiversity data.

Ecosystem condition accounts

- Chapter 4 reviewed the conceptual background for measuring ecosystem condition and presented experimental approaches for developing ecosystem condition accounts based on environmental reporting linked to EU legislation to analyse key trends in water quality and biodiversity. In addition, spatial nutrient accounts are being developed by combining a range of statistical and other data sources. A key conclusion from current tests is that the data foundation, in particular the lack of spatially referenced biodiversity data sets at EU level, is a critical limiting factor for developing ecosystem condition accounts for Europe.

Water accounts and marine fish biomass accounts

- Chapter 5 presented water quantity accounts, which analyse the volume of water available in different parts of Europe, its use by different sectors and the basins where water resources are particularly heavily exploited. The water quantity accounts are a very good illustration of the analytical power of environmental accounting for understanding environment-economy interactions when data on the economic use of the (water) resource are integrated into the underpinning data foundation.
- Marine fish biomass accounts track the impact of fishing pressure on selected European fish stocks and review how the sustainability of fisheries management can be analysed using ecosystem accounting principles. This experimental account showed the feasibility of rolling out natural capital accounting to marine ecosystems. At the same time it also illustrates that existing monitoring and analytical frameworks within the fisheries realm provide similar and sometimes more targeted information for the management of the European fish stocks.

The analytical work of the EEA is complemented by substantial efforts at the JRC to produce ecosystem service accounts within KIP INCA. Figure 6.1 provides an overview of completed and ongoing work in that regard.

As previously illustrated by Figure 1.3, the above review shows that the current set of natural capital accounts for Europe is far from comprehensive or complete. Nevertheless, it is a useful first foundation for reviewing the potential uses of natural capital accounting in different policy processes. This analysis should be repeated in a few years' time, once the set of bio-physical ecosystem accounts is more complete.

6.2 Review of natural capital accounting outputs in relation to EU policy objectives

This section explores concrete application options for natural capital accounts in EU policy decisions by identifying information needs relating to the management of natural capital by looking at related EU policy objectives. The EU's 7th EAP provides a very good starting point for developing a detailed list of information needs as the programme sets out detailed objectives for 'protecting, conserving and enhancing the EU's natural capital' (EU, 2014, paragraph 28). These consist of the following targets to be achieved by 2020:

a) 'The loss of biodiversity and the degradation of ecosystem services, including pollination, are halted, ecosystems and their services are maintained and at least 15 % of degraded ecosystems have been restored;

Figure 6.1 EU ecosystem service accounts under the responsibility of the JRC

		Urban	Cropland	Grassland	Heathland/ shrub	Woodland/ forest	Sparsely vegetated land	Wetland	Rivers and lakes
2018	Crop provision		Euro						
2018	Timber provision					Euro			
2017	Crop pollination		Euro						
2019	Water purification								Euro
2018	Global climate regulation	Euro		Euro	Euro	Euro			
2018	Flood regulation		Euro	Euro	Euro	Euro	Euro	Euro	
2017	Outdoor recreation	Euro	Euro	Euro	Euro	Euro	Euro	Euro	Euro

Σ Monetary value ecosystem asset

Source: EEA, 2018.

b) The impact of pressures on transitional, coastal and fresh waters (including surface and ground waters) is significantly reduced to achieve, maintain or enhance good status, as defined by the Water Framework Directive;

c) The impact of pressures on marine waters is reduced to achieve or maintain good environmental status, as required by the Marine Strategy Framework Directive, and coastal zones are managed sustainably;

d) Air pollution and its impacts on ecosystems and biodiversity are further reduced with the long-term aim of not exceeding critical loads and levels;

e) Land is managed sustainably in the Union, soil is adequately protected and the remediation of contaminated sites is well under way;

f) The nutrient cycle (nitrogen and phosphorus) is managed in a more sustainable and resource-efficient way;

g) Forest management is sustainable, and forests, their biodiversity and the services they provide are protected and, as far as feasible, enhanced, and the resilience of forests to climate change, fires, storms, pests and diseases is improved.'

Additional objectives that link to marine natural capital under points 2 and 3 above are listed in other sections of the 7th EAP:

- urgently increase efforts to ensure that healthy fish stocks are achieved;
- combat pollution and establish an EU-wide quantitative reduction headline target for marine litter supported by source-based measures;
- complete the Natura 2000 network of marine protected areas;
- ensure that coastal zones are managed sustainably.

This review delivers a substantial list of concrete policy objectives for conserving and enhancing natural capital in the EU. The list shows that actions are required in a wide range of economic sectors (such as agriculture, forestry and fisheries) as well as in changing production and consumption patterns (e.g. regarding air pollution or marine litter) to achieve the protection and better management of natural capital, as defined in the 7th EAP.

The detailed objectives of the 7th EAP can be used to review the potential and actual contributions of natural capital accounting to the knowledge base required for achieving them. The standard ecosystem accounting framework is the SEEA-EEA. Table 6.1 provides a comparison of 7th EAP objectives with SEEA-EEA components and complements that with a review of the actual contribution from completed or ongoing EEA work in the natural capital accounting domain.

The long list of objectives above shows that generating a knowledge base that allows well-informed and focused development and implementation of policies to better protect and manage the EU's natural capital is a substantial task. A second observation is that achieving many of the natural capital-related objectives of the 7th EAP requires integrated analysis and actions at various levels. Natural capital accounts offer important information in this context but this needs to be complemented with other sources of knowledge, for example with regard to resilience thresholds.

The current accounting output of the EEA covers only part of all natural capital-related objectives in the 7th EAP. This observation would also hold if the work of EU partners in KIP INCA (see above) is included. However, that is to be expected, as the development of natural capital accounts is only beginning and various gaps will be filled over the coming years.

Even when assuming a much better coverage of ecosystem extent, condition and services through future natural capital accounts, it needs to be noted that many 7th EAP targets either require a change in sectoral management of natural capital or relate to general environmental concepts, such as resource efficiency, sustainability and ecosystem resilience. These depend on analytical approaches, e.g. life cycle analysis, and bio-physical knowledge, e.g. on planetary boundaries, that natural capital accounts cannot provide by themselves. Hence, a combination of the SEEA approach with other analytical tools is required to fully track success in achieving 7th EAP targets.

A fair number of the issues listed in Table 6.1 above relate to questions that ecosystem assessment aims to analyse, which shows that a combination of natural capital accounts with knowledge generated in the EU MAES process on the mapping and assessment of ecosystems and their services would be very useful. The following section aims to analyse how an accounting approach can be combined with such additional analysis via the example of freshwater ecosystems.

Table 6.1 Comparing 7th EAP objectives with the SEEA-EEA and current EEA output

7th EAP objective (general summary)	SEEA EEA component	EEA accounting outputs	Review of further work required:
Protect and restore biodiversity and ecosystems	Ecosystem extent and condition accounts	Ecosystem extent accounts, *Species accounts*	Both need further development, input data a key issue
Reduce pressures on coastal, transitional and fresh waters	Ecosystem extent and condition accounts	Land accounts, *Nutrient and water quality accounts*	Last two accounts need further development; spatialisation of land use data required
Good status of marine waters, fish stocks and coastal zones	Ecosystem extent, condition and service accounts	Integrated Marine fish accounts, *Pilot sea floor integrity account*, *Nutrient accounts*	The elements covered so far mainly relate to pressures rather than state
Reduce air pollution impacts on ecosystems	Ecosystem condition accounts	*Species accounts, Nutrient accounts*	Need further development, input data a key issue
Land and soil protected and well-managed	Ecosystem extent and condition accounts	Land accounts	Soil protection depends on management — these parameters are not well covered in accounts
Nutrient cycle is sustainable and resource-efficient	Ecosystem extent and condition accounts	*Nutrient and water quality accounts*	'Sustainability' and 'resource efficiency' need to be determined by other analytical tools
Forests and their biodiversity are well-managed and resilient	Ecosystem extent, condition and service accounts	Ecosystem extent accounts, *Species accounts*	Accounts need further development; 'resilience' needs to be determined by other analytical tools

Note: Accounts listed in italics are currently at an experimental or pilot stage only.

Source: EEA, 2018.

6.3 Analysing environment-economy interactions for freshwater ecosystems

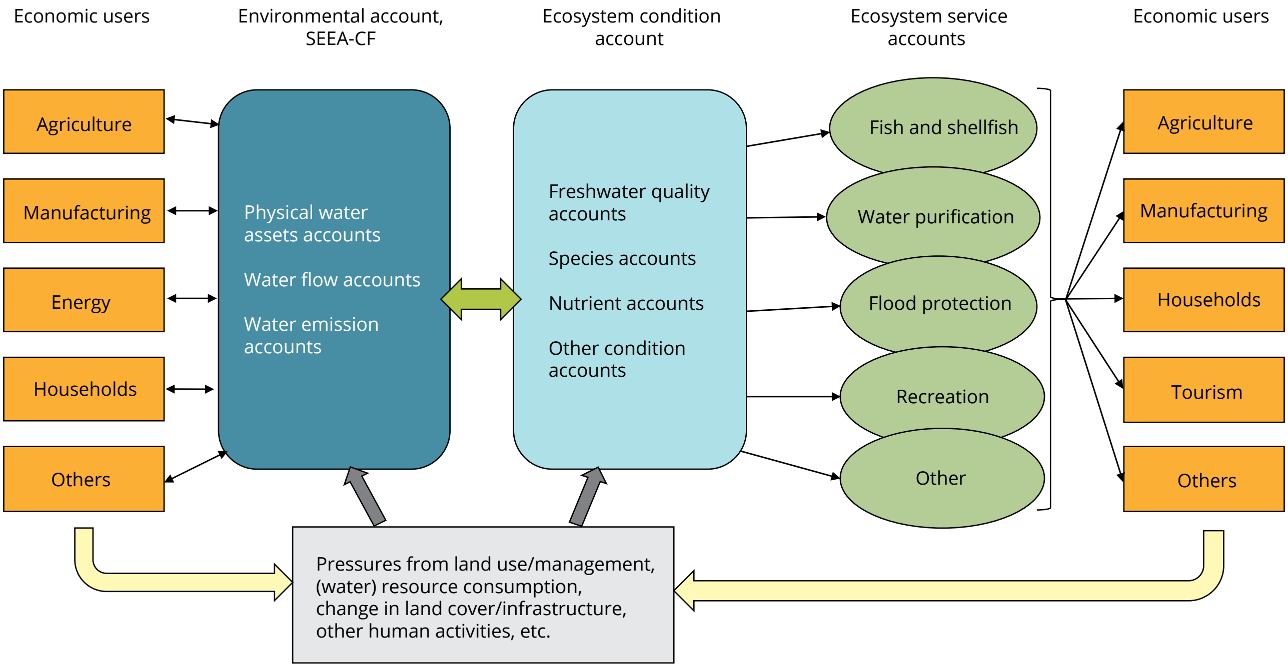
Freshwater ecosystems (rivers, lakes, groundwater) support the delivery of crucial ecosystem services, such as fish production, water provisioning and recreation. Key ecosystem services are also connected to the hydrological cycle in the river basin, for example water purification, water retention and climate regulation. Most of these water-related ecosystem services can be directly appreciated by people and quantified, but some, especially regulation and maintenance services, are less evident. The sustainable use and management of water resources also has important implications for protecting the species and habitats connected to freshwater ecosystems.

The management of EU freshwater ecosystems is governed via several pieces of EU (and national) legislation, in particular the WFD. The WFD aims to achieve the integrated management of EU water bodies via the development of RBMPs. The WFD has also established a comprehensive monitoring programme for tracking the environmental status of water bodies that covers their biological, chemical and hydrological status.

A study by Grizzetti et al. (2017) has analysed the use of condition indicators from the WFD to provide information on the ability of freshwater ecosystems to deliver services. Outputs from the work indicate that regulating (e.g. water purification, sediment mitigation, flood protection, coastal protection) and recreational freshwater ecosystem services are mostly positively correlated with the ecological status of European water bodies (as reported under the WFD). However, water provisioning, which strongly depends on the climatic and hydrographic characteristics of river basins, was found to be negatively correlated with water quality (Grizzetti et al., 2017). This suggests that water quantity provisioning services represent a pressure for freshwater ecosystems. Drawing on these results, the study identifies a need to develop water quality and quantity accounts and further test the potential for integration or combined presentation to present a coherent picture of freshwater ecosystem services. Figure 6.2 below aims to show how a combination of different accounts supports the analysis of the links between sectoral uses of freshwater resources, the environmental status of water bodies and the flow of related services.

Figure 6.2 shows the importance of connecting water quantity accounts under the SEEA-CF with components

Figure 6.2 Analysing environment-economy interactions for freshwater ecosystems



Source: EEA, 2018.

of ecosystem accounting to arrive at an integrated picture of environment-economy interactions for freshwater ecosystems. As Chapter 5 has shown, the water quantity accounts allow us to understand the sectoral uses of freshwater resources in Europe. Water flow or volume throughout the year is an important component of the condition of freshwater ecosystems, which makes it an important part of understanding the condition of freshwater ecosystems in a conservation perspective and for identifying the potential flow of ecosystem services. Ecosystem service accounts provide another important bridge for identifying links between freshwater ecosystems and human economy and well-being.

Figure 6.2 also illustrates that pressures on freshwater ecosystems are generated not only from direct uses of water resources but also from other activities, such as the use of fertilisers, urbanisation, etc. These also need to be monitored and analysed to be able to properly understand the source and volume of pressures and to do trade-off analysis between them and with the flow of different ecosystem services. Two accounts that are under development by the EEA and its partners (spatial nutrient accounts and water emission accounts) are likely to be helpful in that regard. What Figure 6.2 does not cover is the analysis and design of policy responses, which require actions at many different levels, as already identified in the WFD and related legislation. Additional analytical tools are required to generate that kind of knowledge.

The study by Grizzetti et al. (2017) sets out an in-depth methodological framework for assessing and valuing ecosystem services relevant for water resource management, considering the links between pressures, ecological status and ecosystem services. The focus of the analysis was on inland waters and the spatial scale of interest ranges from the water body to the catchment/river basin and the European scale. While for water bodies the main focus is on specific ecosystem functions that support ecosystem services, and their alteration under different stressors, the catchment is the appropriate scale to observe and quantify processes related to the water cycle, and to implement monitoring and management plans to reduce multiple pressures. The assessment and valuation of ecosystem services at the European scale allows us to address regional trends, identify hot spots in the delivery or degradation of services, test the effectiveness of regional policies (such as EU directives) and conduct scenario analysis at the large scale.

To support the analysis of these linkages, the study team developed a conceptual framework for the integrated assessment of water-related services (presented in Figure 6.3). The framework comprises four main elements: (1) water quantity (including seasonality); (2) water quality; (3) biological quality elements (QE); and (4) hydro-morphological and physical structure. The study includes in the analysis biological and hydro-morphological aspects and aims to make the link to the WFD elements explicit (so that the relationship to ecological status should be very clear in principle). For each attribute the study selected a number of representative indicators (as examples) and identified some possible relationships with the ecosystem services analysed.

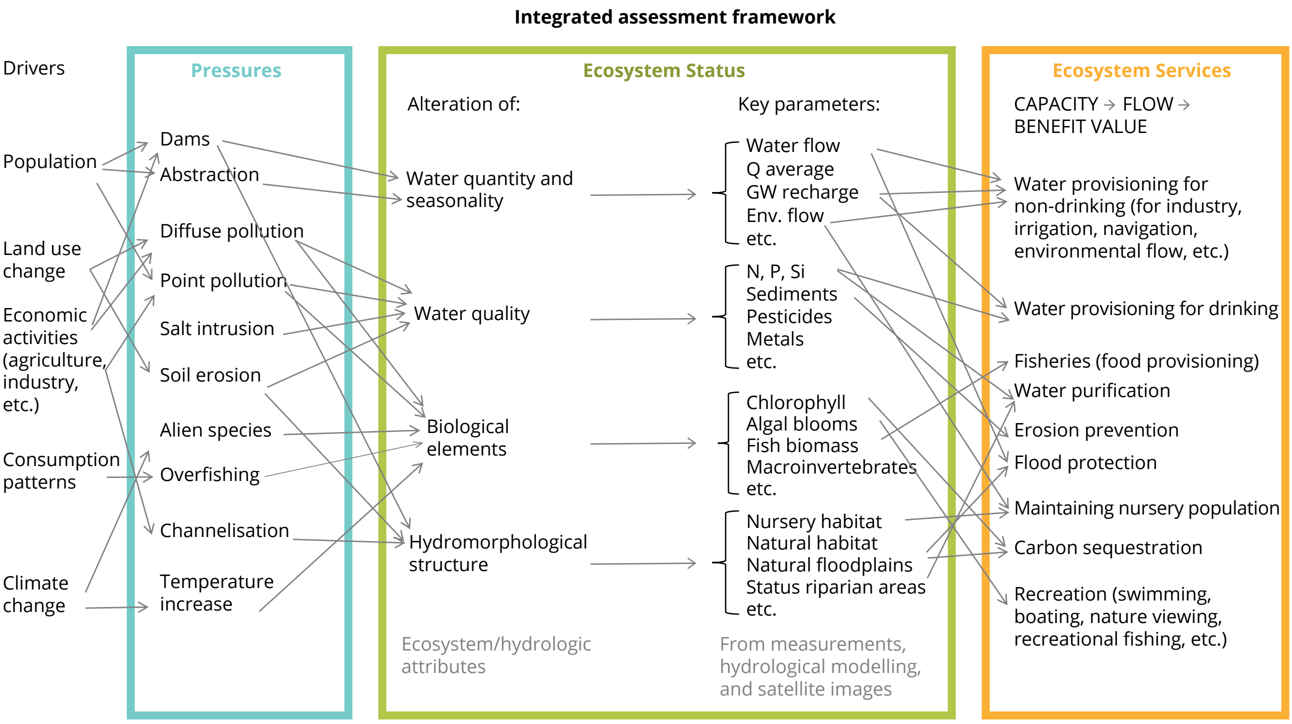
The study concludes that to address current sustainability challenges it is necessary to recognise the dependency of human well-being on natural capital (Guerry et al., 2015). Integrative frameworks such as the ecosystem service approach allow incorporation of natural components in the system analysis (Liu et al., 2015). However, economic models to value ecosystem services related to water quality are often poorly integrated with the bio-physical models describing the underpinning natural processes (Keeler et al., 2012).

By adopting the ecosystem services approach, there are opportunities to capture and integrate all the effects (economic, environmental and social) associated with new water plans and investments. Performing bio-physical assessment and economic valuation collaboratively could boost awareness and inclusion of the interdependence of nature and people for a sustainable management of water resources. The authors conclude that the integration of bio-physical and economic approaches and data remains one of the main challenges and key aspects of such an integrative approach.

6.4 Analytical benefits and limitations of natural capital accounting

The previous sections have reviewed the ecosystem accounting outputs by the EEA and other KIP INCA partners at EU level against natural capital-related targets in the 7th EAP and summarised a study on the links between the state of water resources and ecosystem service capacity. This has provided some

Figure 6.3 Link between the status of freshwater habitats, pressures and ecosystem services



The list of pressures and the arrows describing the relationships are not exhaustive, the users are invited to develop the specific relationships at stake in their case study

Note: N, nitrogen; P, phosphorus; Si, silicon.

Source: Grizzetti et al., 2017.

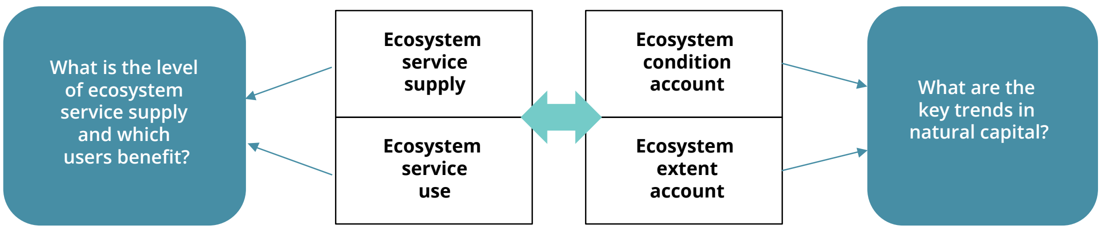
initial insight into the potential use of natural capital accounting as input to policy process. It needs to be acknowledged that the output from natural capital accounting will become more comprehensive in thematic and geographic coverage, so this is an initial analysis only. It will nevertheless be useful to reflect on the analytical strengths and limitations of natural capital accounts to be able to identify those elements of the approach that provide most added value. This section aims to provide input to the discussion on the analytical power and limits of natural capital accounting in relation to key policy questions. It does so by using diagrams that compare the (potential) outputs from ecosystem accounting with key questions that relate to the state and management of natural capital.

Figure 6.4 shows the key questions that can be answered by physical ecosystem asset and service accounts. These relate to essential knowledge that society needs to have about its natural capital resource base as well as the supply of ecosystem services.

Putting these accounts in place already provides key input to policies that aim to protect natural capital and allows basic economic analysis in relation to benefits that different economic sectors and other users derive from ecosystem services.

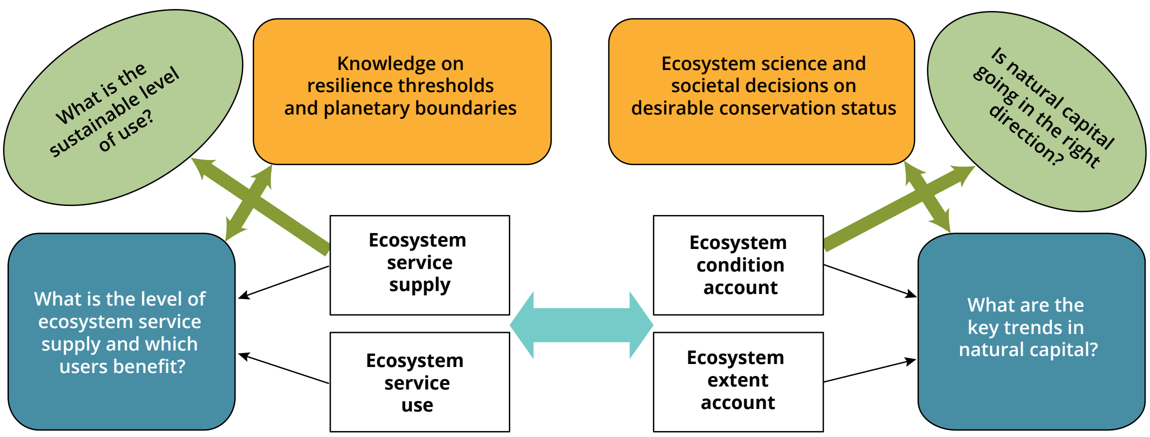
Figure 6.5 shows additional questions (in green) and the knowledge components that are required to understand fully whether ecosystems and their services are likely to be under sustainable use and will remain resilient in the future. In this set-up, natural capital accounts are combined with additional knowledge components and different analytical tools to understand the bio-physical sustainability of society-ecosystem interactions more comprehensively, for example regarding the bio-physical thresholds of planetary boundaries. However, it can be argued that further additional analytical tools are needed on the socio-economic side to be able to develop a better understanding of economic drivers and potential policy responses for managing natural capital better (see Figure 6.6).

Figure 6.4 Information to be gained from physical ecosystem asset and service accounts



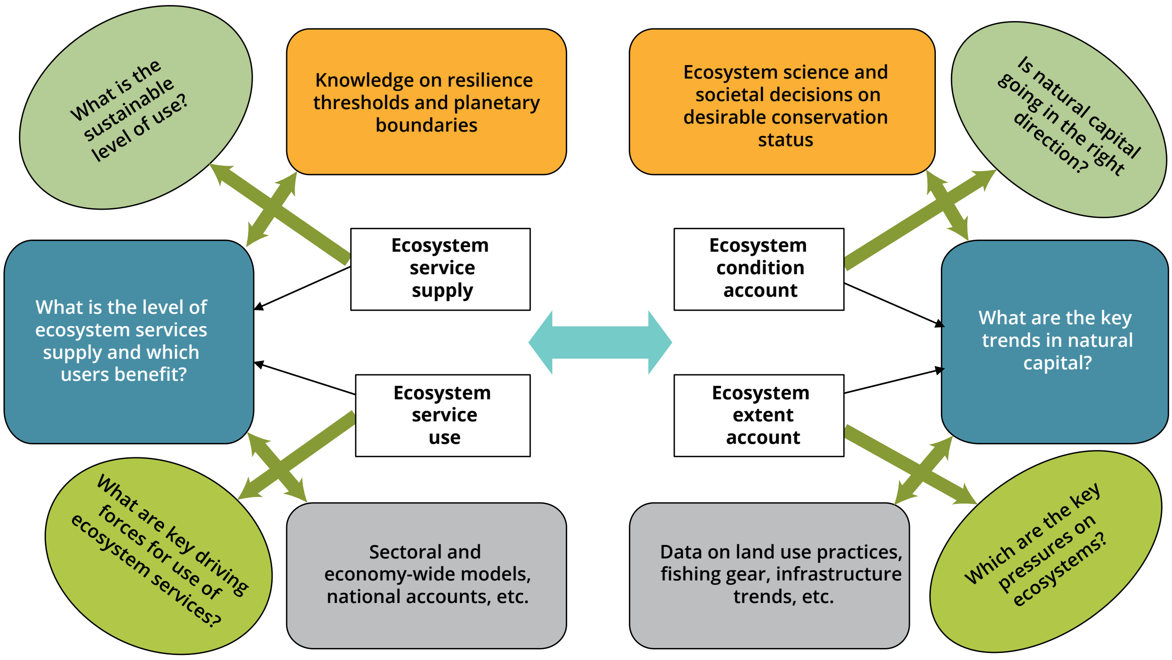
Source: EEA, 2018.

Figure 6.5 Analysing the bio-physical sustainability of ecosystem assets and their services



Source: EEA, 2018.

Figure 6.6 A comprehensive knowledge framework for the management of natural capital



Source: EEA, 2018.

Figure 6.6 illustrates that various analytical tools need to be combined to enable the different analytical angles required to manage natural capital in an integrated perspective via a range of policy instruments. In such a setting the accounts are combined with bio-physical models that describe ecological limits as well as socio-economic and sectoral models and data sets that allow exploring the suitability and efficiency of different policy measures, for example. Natural capital accounts remain central to the overall analytical approach but are complemented by other knowledge sources.

6.5 Conclusions on ecosystem accounting and policy analysis

This chapter aimed to review the potential for using the results of ecosystem accounting to support policymaking via practical and theoretical analysis. That yielded initial results only because natural capital accounts are still in a development phase in Europe. Nevertheless, useful insight was gained into how to establish natural capital accounting as a new knowledge frame and to generate meaningful inputs to policymaking processes.

Comparing natural capital-related targets of the 7th EAP with the SEEA ecosystem accounting framework and current KIP INCA outputs showed that ecosystem accounting can in principle provide many of the knowledge needs of the 7th EAP with regard to managing natural capital. The currently established ecosystem accounting modules in Europe are useful in this context but clearly not yet sufficient.

The review of the work by Grizzetti et al. (2016) showed the benefits of an integrated analysis of the link between the condition of freshwater bodies using ecosystem accounting and ecosystem service concepts. The approach taken in that study went beyond the strict SEEA ecosystem accounting methodology, however, which shows the benefits of combining ecosystem accounting with other knowledge frames. This is also considered a key result of the analysis presented in Section 6.4 — the more complex the analytical question the more advantageous it is to combine different analytical tools.

The following points bring out some key conclusions on the benefits from, and development challenges for, natural capital accounting.

The benefits of developing ecosystem accounting are:

- It provides better information on the status of and trends in ecosystems.
- It is the most thorough approach to describing and measuring ecosystem services.
- It supports a more integrated perspective in understanding our links with natural capital.
- It underpins the analysis of environment-economy links.
- It helps to bring ecosystem considerations into economic policymaking.

The key challenge for further developing it is that ecosystem accounting and its outputs are only as effective as:

- our ecological and modelling knowledge of ecosystem processes;
- actual *in situ* biodiversity monitoring data and statistical and other data input;
- related analytical tools and economic data that help to translate it into policy decisions.

7 Outlook and reflections

7.1 Introduction

The European environment state and outlook report 2015 states that 'natural capital is the most fundamental of the core forms of capital (i.e. manufactured, human, social and natural) since it provides the basic conditions for human existence' (EEA, 2015c). That is a very clear statement of the importance of natural capital to our society, which also finds expression in the targets of the EU Biodiversity Strategy to 2020 as well as the 7th EAP, which lists 'protecting, conserving and enhancing natural capital' as its 'priority objective 1'.

The importance of understanding human impacts on natural capital and how we could manage it better is therefore fully recognised. However, human society and the environmental systems that we rely on are very complex and there is a multitude of interactions between the economy and natural capital. It is essential, therefore, that we develop analytical approaches that help us identify the correct steps for managing natural capital well. This report has argued that natural capital accounting plays an essential role in this regard but will probably not suffice on its own.

Chapters 3 to 5 presented current natural capital accounting outputs that the EEA has produced. Chapter 6 discussed the potential use of these as input to policymaking and reviewed some development challenges. This chapter includes a discussion of two aspects of building natural capital accounting as a knowledge framework to support policymaking:

1. key steps that are required to improve the data foundation for natural capital accounting to strengthen its potential input to policy decisions;

2. how natural capital accounts can be combined with other analytical approaches to cover all aspects of managing natural capital sustainably.

This analysis is meant to contribute to the efficient further development of ecosystem accounting in Europe. As ecosystem accounts are in the early stages of their development, we need to identify what their particular analytical strengths and weaknesses are and how to develop a data foundation that allows an efficient and spatially targeted calculation of accounts.

7.2 Current data foundation and critical investment needs

The output of any analytical tool is only as good as the input data that are available to run it. This also holds for the analytical instruments and knowledge frames that can be used for analysing trends in the state and management of natural capital. A review of current accounting results in previous chapters shows that input data sets are often a limiting factor for developing natural capital accounts. Reviewing the required data foundation for managing natural capital is a very broad task. The first report on KIP INCA looked into the requirements for developing a spatial data architecture for natural capital accounting in the EU — part of that analysis is summarised below.

Regarding the choice of data sources and their spatial resolution, it is necessary to first define the analytical objectives of the anticipated ecosystem accounting system. The following steps represent a simplified approach to establishing a data platform for ecosystem accounting (for a more detailed review, see Petersen and Steurer, 2015):

- Identify the essential ecosystem and other parameters for analysing natural capital trends (e.g. via an analysis of key policy targets on natural capital, as listed in the 7th EAP).

- Decide on the primary (or main) ecosystem accounting units on which the different ecosystem component accounts are based and/or which form the main analytical and reporting units.

- Develop a comprehensive and efficient geo-referenced sampling system for these variables.

- Review which are the currently available statistical, geo-spatial and other data sets relevant for monitoring the parameters, identified under step 1 and to what degree they match the analytical structure and sampling frame under steps 2 and 3.

The sequence of steps above helps identify the data sets and other knowledge elements that are required for developing natural capital accounts in Europe. A first review of ecosystem parameters under step 1 has been completed to support KIP INCA and the MAES project. This shows that there are many different variables that are required to describe trends in the extent and condition of European ecosystems and the associated service flows. Completing step 2 will build on work under the EU MAES process regarding the definition of ecosystem types and the EEA's work on a shared ecosystem accounting grid. Step 3 represents a key challenge at EU level to be able to connect many different data sets in a common spatial reference frame; this is illustrated by Figures 7.1 and 7.2. Figure 7.1 shows the many different types of data that need to be brought together in one common spatial frame, ranging from biodiversity monitoring data to agricultural statistics.

Substantial further investment is required, even in Europe, for developing geo-referenced data sets and a shared data architecture for ecosystem accounting. Figure 7.2 (next page) illustrates the approach developed by the EEA (as part of the EEA Integrated Data Platform) of combining many different input data layers for ecosystem accounting in a shared spatial grid as an essential foundation for successful ecosystem accounting.

A review of data sets suggested in 2018 as input to MAES and KIP INCA ecosystem condition analysis shows that the data sets currently available in Europe do not properly match the requirements of ecosystem accounting — see Table 7.1. This shows that many of the data sets (~ 50 %) underpinning ecosystem condition indicators are not suitable for regularly updated assessments. Furthermore, data sets that relate to pressures on ecosystems are generally easier to measure than parameters that show the inherent conditions of ecosystems per se.

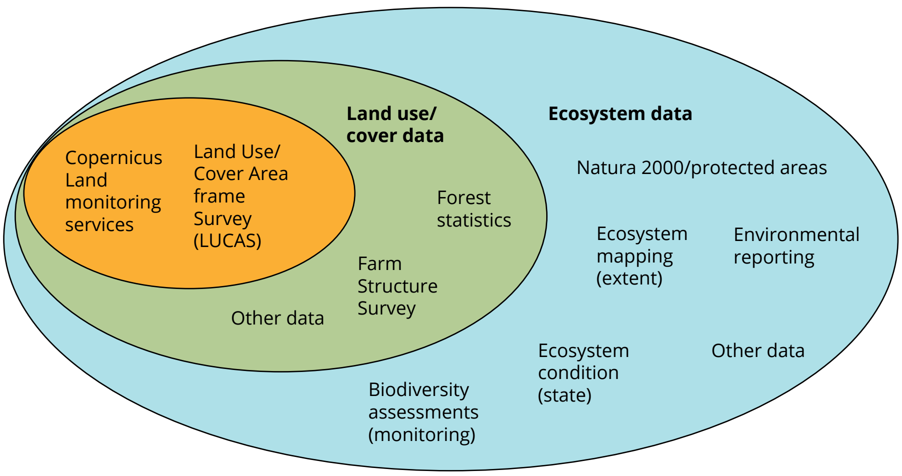
This is no major surprise, as existing statistical data collection systems or environmental monitoring were not designed for monitoring trends in ecosystem extent and condition. Where ecosystem-related variables are being collected, the spatial referencing of existing reporting systems, e.g. under Natura 2000 reporting, is only adequate to report on national-level trends in many cases. This makes it very difficult, if not impossible, to develop biodiversity data sets at the scale of ecosystem accounting units.

A key aspect of implementing the EU's activities on natural capital accounting therefore focuses on improving the usefulness of existing source data and extending the source data available. Developing ecosystem accounts at European level successfully will require substantial investment in direct or indirect

Figure 7.1 Bringing diverse EU-level data sets into one common reference frame

Improving the data foundation — steps to take

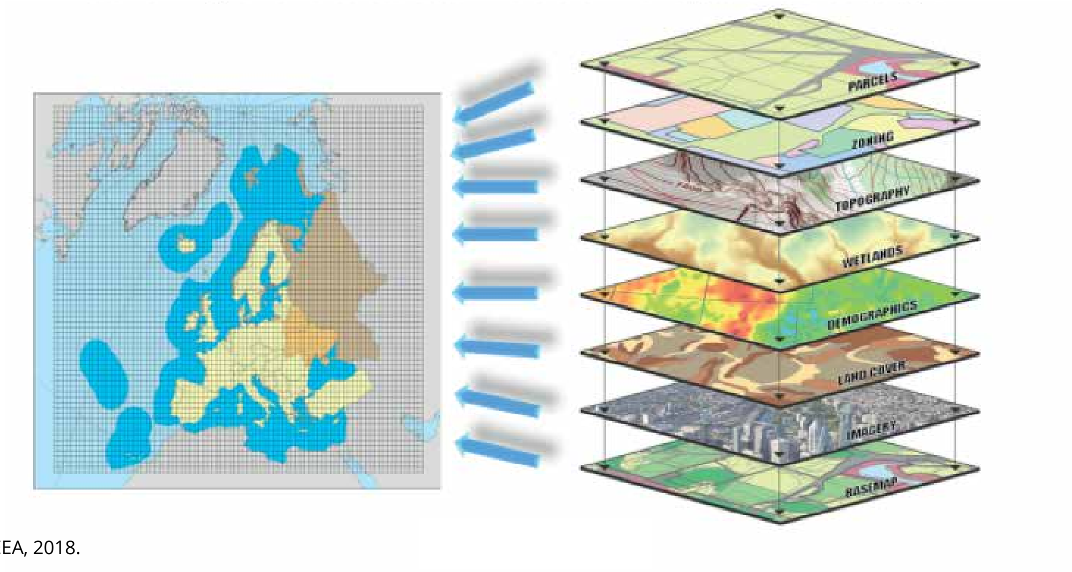
- A system of datasets within *a common spatial reference framework*;
- Integration of existing initiatives – assessment of ecosystems, modelling of ecosystem services, etc.;
- Use of models to transfer data into accounts and fill data gaps.



Source: EEA, 2018.

Figure 7.2 Aligning diverse input data sets on one common ecosystem accounting grid

Combining different data sets in one common spatial reference grid



Source: EEA, 2018.

Table 7.1 Regularity of data sets for five MAES ecosystem pilots (status 2018)

	Data series — frequent and regular?			
Ecosystem type, category of data set	**Yes**	**No**	**Partial**	**Grand Total**
Cropland	**15**	**16**	**11**	**42**
Pressures	9	2	5	16
Environmental quality		2		2
Structural ecosystem attributes	6	9	5	20
Functional ecosystem attributes		3	1	4
Grassland	**15**	**15**	**13**	**43**
Pressures	9	2	5	16
Environmental quality		2		2
Structural ecosystem attributes	6	8	7	21
Functional ecosystem attributes		3	1	4
Rivers and lakes	**14**	**10**	**4**	**28**
Pressures	8	3		11
Environmental quality	3	2	3	8
Structural ecosystem attributes	3	5	1	9
Forest	**45**	**38**	**7**	**90**
Pressures	17	9	4	30
Environmental quality	4			4
Structural ecosystem attributes	21	22	1	44
Functional ecosystem attributes	3	7	2	12
Marine	**18**	**19**		**37**
Pressures	8	4		12
Environmental quality	5	5		10
Structural ecosystem attributes	5	10		15
Grand Total	**107**	**98**	**35**	**240**

Source: EEA, 2018.

data on ecosystem parameters to support better management of natural capital. Some efforts are already ongoing, for example in revising the EU Land Use/Cover Area Frame Statistical Survey (LUCAS) or in implementing the EU Copernicus programme on Earth observation, but an area that needs substantial further investment is the development of *in situ* biodiversity monitoring programmes that are designed for good spatial referencing of the source data.

In summary, creating information about natural systems requires a combination of various data sets: statistics, biodiversity and environmental monitoring data, land use and land cover information, other *in situ* observations and the analysis of satellite images. At the same time, all these data sets need to be referenced at a spatial scale that corresponds to the ecosystem processes and units that are to be analysed. This means that the data-processing and analytical tools (whether for accounting or other tasks) need to be capable of handling detailed geo-spatial data.

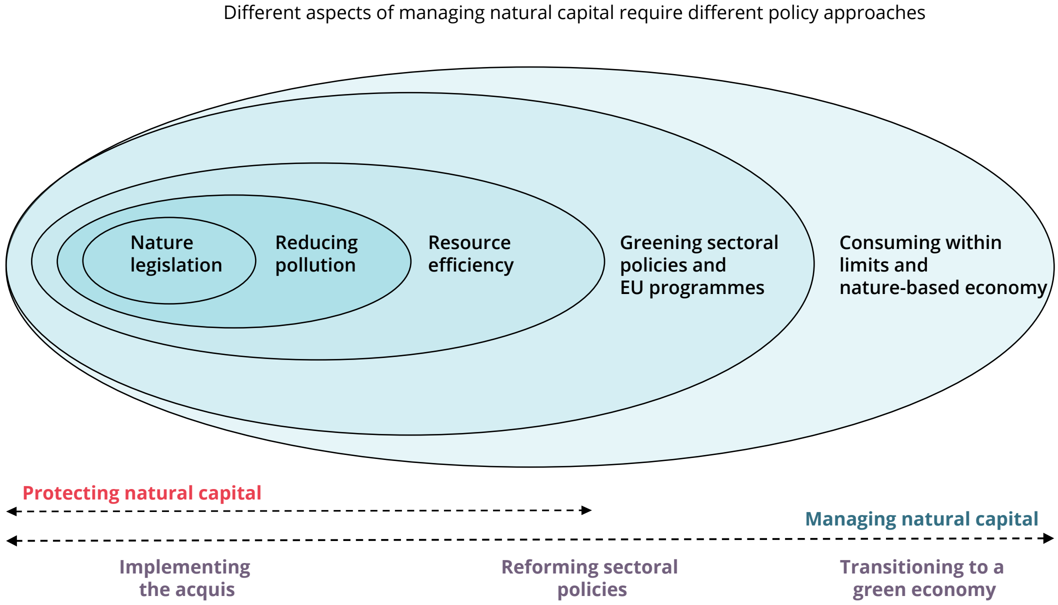
7.3 Ecosystem accounting and managing natural capital

This report has shown that natural capital accounting can provide important input into policy decisions, in particular via its ability to show environment-economy interlinkages. It offers a well-organised frame for structuring information relating to a range of environmental and economic domains that are required for an integrated analysis of the links between the state of ecosystems and their services and their exploitation by human society and sectoral users.

There has been substantial progress in developing the concept and methodology of natural capital accounting. Comprehensive methodological guidance is available via the work coordinated by the UNSD in the form of the UN handbook on experimental ecosystem accounting, and technical recommendations to support the implementation of the SEEA-EEA developed at UN level. This provides a solid theoretical basis for ecosystem accounting as a tool for managing natural capital better. In addition, practical experience at country and EU level is now becoming available (see, for example, EC, forthcoming). The EEA has contributed substantially to the knowledge base by engaging in developing methodological guidance at UN and EU level and by producing different environment and ecosystem accounts, as described in earlier chapters of this report.

However, the substantial list of individual objectives for conserving and enhancing natural capital in the 7th EAP shows that actions are required in a wide range of economic sectors (e.g. agriculture, forestry and fisheries) as well as in changing production and consumption patterns (e.g. regarding air pollution or marine litter) to achieve the protection and better management of natural capital. Figure 7.3 below aims

Figure 7.3 Managing natural capital in different policy domains



Source: EEA, 2018.

to show the wide range of policies that are relevant in this context. It has been developed with the view that two perspectives need to be combined: the need for preserving and improving the remaining natural capital (represented on the left side of the figure) and a vision for a transformation of society and economy that achieves a sustainable use of the planet's natural capital (on the right side).

Maintaining natural capital while transitioning to a green economy in Europe (and worldwide) requires actions in a number of diverse policy fields and at different levels. This includes global climate negotiations and macro-economic policy, which set an important overall frame and direction. It requires action in sectoral policies, such as agriculture, transport, energy and industry, to achieve the transition to more nature-based solutions and an economy and society that operate within the limits of the planet. At the same time, it is important to maintain and improve environmental and nature conservation policy instruments because of their crucial role in protecting and conserving natural capital.

While not the only source of evidence for policymaking, natural capital accounts will offer crucial information in this context. What they offer as added value, over other information sources, together with existing environmental data sets and indicators, is the potential for an integrated framework of environmental and economic data. If structured appropriately, such a framework allows cross-linkages to be made between different uses and components of natural capital and consideration of trade-offs in managing and exploiting this capital and the service flows it provides.

Sections 6.2 and 6.3 have shown how natural capital accounts can contribute to different stages of the policy cycle and how they could be applied to freshwater ecosystems. Comparing 7th EAP objectives in relation to natural capital with the current and potential application of the SEEA framework in Europe, however, also illustrates that different knowledge frames need to be combined for managing natural capital well. In particular, natural capital accounts need to be complemented with scientific reference values on thresholds that prevent ecosystem collapse due to over-use, pollution or other factors (Petersen, 2017). 'Living within the limits of the planet' means that we need to combine Earth system science, ecology and (environmental) economics to develop a green economy that respects planetary boundaries and exploits natural capital sustainably.

Finally, Section 7.2 demonstrates that the data foundation for natural capital accounting is an important factor for the success of this analytical framework. Progress has been made in developing shared spatial data and establishing analytical tools that allow efficient calculation of EU ecosystem accounts. However, for natural capital accounting to become as useful an input to policymaking as it could be, further significant investment is required, as for any new system. This investment would ideally cover three connected areas:

- strengthening or establishing monitoring programmes that generate ecosystem-related data sets of good spatial and thematic resolution;
- further developing accounting methodology, in particular with regard to the necessary combination with complementary analytical tools;
- establishing sufficient analytical capacity at EU and country levels to be able to fully exploit the opportunities that natural capital accounting provides.

Building on current and future investment will allow natural capital accounting to become an important analytical tool for understanding the success of reaching the objectives of the 7th EAP, in particular with regard to natural capital. The 'natural capital tree' is still a small sapling, but with sufficient care and nurturing it can grow into a big tree that provides shade and other services for many, so that natural capital accounts can reach their full potential as an essential knowledge framework for society's decisions on a more sustainable management of our shared natural capital.

Glossary of terms (adopted from the SEEA-EEA)

Term	Definition
Basic spatial unit	According to the SEEA-EEA definition, basic spatial units (BSUs) support the delineation of ecosystem units and the integration of multiple data sets. For ecosystem accounting, BSUs are assumed to be internally homogeneous in terms of their bio-physical properties. BSUs may be delineated through the formation of a spatial grid covering the extent of a country. A BSU is a small spatial area that is a geometrical construct. The purpose of delineating BSUs is to provide a fine-level frame to which a range of different information can be attributed. Once different data have been integrated to the same spatial scale then many aggregation and integration possibilities emerge. The most common approach to delineating BSUs is to form a grid of appropriate coverage and cell size (ideally < 100 m) that is overlaid on a large area or country. This forms a reference grid. In this context, a BSU corresponds to a grid cell in geo-information disciplines and a grain in landscape ecology.
Biodiversity	'Biodiversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and ecosystems.' (Convention on Biological Diversity, 2003, Article 2, Use of Terms). Generally, in SEEA Experimental Ecosystem Accounting, the measurement of biodiversity is focused on the assessment of diversity of species, although changes in the diversity of ecosystems are also an important output from measuring changes in ecosystem extent and condition.
Ecosystems	'Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.' (Convention on Biological Diversity, 2003, Article 2, Use of Terms). Ecosystems may be identified at different spatial scales and are commonly nested and overlapped. Consequently, for accounting purposes, ecosystem assets are defined by the delineation of specific and mutually exclusive spatial areas.
Ecosystem accounts	Ecosystem accounts are national accounts that contain statistics on ecosystems. According to the SEEA-EEA Technical Recommendations, there are three main types of ecosystem accounts that describe the ecosystems in accounting terms: accounts for ecosystem assets, accounts for ecosystem services and integrated accounts that present ecosystem accounting information with standard economic and national accounts data. For each of the accounts, there will be an opening stock, additions and reductions in stock and a closing stock. Ideally, changes in stock over an accounting period would be separated into those that are naturally driven and those due to human activities.
Ecosystem assets	Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together. Depending on the analysis being conducted, an ecosystem asset may be defined as containing a specific combination of ecosystem characteristics, e.g. a large area of tropical rain forest, or it may combine areas that contain a variety of combinations of ecosystem characteristics, e.g. a river basin containing wetlands, agriculture and settlements. Ecosystem assets should be distinguished from: • the various individual components, e.g. plants, animals, soil and water bodies, that are contained within a spatial area; • other ecosystem characteristics, e.g. biodiversity and resilience. In different contexts and discussions, each of these components and other characteristics may be considered assets in their own right. For example, in the SEEA Central Framework (SEEA-CF) many individual components are considered individual environmental assets. However, for ecosystem accounting purposes, the focus is on the functioning system as the asset. The term 'ecosystem assets', rather than 'ecosystem capital' has been adopted, as the word 'assets' is more aligned with the terminology employed by the System of National Accounts (SNA) and also conveys better the intention for ecosystem accounting to encompass measurement in both monetary and physical terms. In general, however, the terms 'ecosystem assets' and 'ecosystem capital' may be considered synonymous.
Ecosystem or ecological capital	Ecosystem or ecological capital is not explicitly defined in SEEA Experimental Ecosystem Accounting. Instead, the term 'ecosystem assets' is employed to refer to the individual spatial areas that are the focus of measurement. In many discussions, the term 'ecosystem capital' may be considered to relate to a broader concept of the stock that provides a foundation for future well-being, together with human capital, produced/man-made capital and social capital. These various types of capital are regularly brought together in models of sustainable development and wealth accounting. While there is no difference between the application of the terms 'capital' and 'assets' in SEEA Experimental Ecosystem Accounting and their use in other contexts, e.g. wealth accounting, some care is needed to understand the potentially different measurement scopes of these types of capital/asset. Specific considerations concern the treatment of mineral and energy resources and the distinction between natural and cultivated biological resources.
Ecosystem capacity	The concept of ecosystem capacity is not defined from a measurement perspective in SEEA Experimental Ecosystem Accounting, but it is linked to the general model of ecosystem assets and ecosystem services that is described. In general terms, the concept of ecosystem capacity refers to the ability of a given ecosystem asset to generate a set of ecosystem services in a sustainable way into the future. While this general concept is very relevant to ecosystem assessment, definitive measurement of ecosystem capacity requires the selection of a particular 'basket' of ecosystem services, and in this regard measures of ecosystem capacity are more likely to relate to consideration of a range of alternative ecosystem use scenarios than to a single basket of ecosystem services.

Term	Definition
Ecosystem characteristics	Ecosystem characteristics relate to the ongoing operation of the ecosystem and its location. Key characteristics of the operation of an ecosystem are its structure, composition, processes and functions. Key characteristics of the location of an ecosystem are its extent, configuration, landscape forms, and climate and associated seasonal patterns. Ecosystem characteristics also relate strongly to biodiversity at a number of levels. There is no classification of ecosystem characteristics since, while each characteristic may be distinct, they are commonly overlapping. In some situations, the use of the generic term 'characteristics' may seem to be more usefully replaced with terms such as 'components or 'aspects'. However, in describing the broader concept of an ecosystem, the use of the term characteristics is intended to be able to encompass all of the various perspectives taken to describe an ecosystem.
Ecosystem condition	Ecosystem condition reflects the overall quality of an ecosystem asset, in terms of its characteristics. Measures of ecosystem condition are generally combined with measures of ecosystem extent to provide an overall measure of the state of an ecosystem asset. Ecosystem condition also underpins the capacity of an ecosystem asset to generate ecosystem services and hence changes in ecosystem condition will impact on expected ecosystem service flows.
Ecosystem (or environmental) flow	In the SEEA Central Framework, environmental stocks and flows are considered holistically. From the perspective of environmental flows, the environment is the source of all natural inputs to the economy, including natural resource inputs (minerals, timber, fish, water, etc.) and other natural inputs absorbed by the economy, for example energy from solar and wind sources and the air used in combustion processes.
Ecosystem (or environmental) stock	In the SEEA Central Framework, environmental stocks and flows are considered holistically. From a stock perspective, the environment includes all living and non-living components that constitute the bio-physical environment, including all types of natural resources and the ecosystems within which they are located.
Ecosystem units	Conceptually, ecosystem assets are represented by ecosystem units. Ecosystem units are contiguous spatial areas of different types distinguished according to different characteristics including vegetation, climate, soil type, hydrology and use. They form the conceptual base for accounting and the integration of relevant statistics.
Environmental assets	Environmental assets are the naturally occurring living and non-living components of the Earth and they constitute the bio-physical environment that may provide benefits to humanity. This definition of environmental assets is intended to be broad and encompassing. As explained in the SEEA Central Framework, the measurement of environmental assets can be considered from two perspectives. First, from the perspective of individual components, i.e. individual environmental assets that provide materials and space to all economic activities, e.g. land, soil, water, timber, aquatic, mineral and energy resources. Second, environmental assets can be considered from the perspective of ecosystems. However, the scope of environmental assets is not the same as ecosystem assets, as it includes mineral and energy resources, which are excluded from the scope of ecosystem assets. Also, the scope of environmental assets is broader than natural resources, as it includes produced assets such as cultivated crops and plants, including timber and orchards, livestock and fish in aquaculture facilities. In the SEEA Central Framework, the measurement scope of environmental assets is broader in physical terms than in monetary terms as the boundary, in monetary terms, is limited to those assets that have an economic value in monetary terms following the market valuation principles of the SNA.
Expected ecosystem service flow	Expected ecosystem service flow is an aggregate measure of future ecosystem service flows from an ecosystem asset for a given basket of ecosystem services. In general terms, the measure of expected ecosystem service flows is an assessment of the capacity of an ecosystem asset to generate ecosystem services in the future. However, the focus is on the generation of specific, expected combinations of ecosystem services, which may not be produced on a sustainable basis. The measure does not necessarily reflect sustainable or optimal scenarios of future ecosystem asset use. At the same time, the expectations of future ecosystem service flows must be informed by likely changes in ecosystem condition, noting that the relationship between condition and ecosystem service flow is likely to be complex and non-linear.
Inter-ecosystem flows	Inter-ecosystem flows are flows between ecosystem assets that reflect ongoing ecosystem processes. An example is the flow of water between ecosystem assets via rivers. These flows may relate directly or indirectly to flows of ecosystem services. Most commonly, inter-ecosystem flows relate to the flows considered as supporting or intermediate services.
Intra-ecosystem flows	Intra-ecosystem flows are flows within ecosystem assets that reflect ongoing ecosystem processes, e.g. nutrient cycling. These flows may relate directly or indirectly to flows of ecosystem services. Most commonly, intra-ecosystem flows relate to the flows considered supporting or intermediate services.
Natural capital	Natural capital is described as the elements of nature that directly, or indirectly, produce value for people, including ecosystems, species, freshwater, land, minerals, air and oceans, as well as natural processes and functions. The term natural capital is not defined in SEEA experimental ecosystem accounting. Commonly, natural capital is used to refer to all types of environmental assets as defined in the SEEA Central Framework. Used in this way, natural capital has a broader scope than ecosystem assets as defined in SEEA experimental ecosystem accounting, as it includes mineral and energy resources. Generally, natural capital incorporates broad notions of the set of services from ecosystems in line with the accounting for ecosystem assets described in SEEA experimental ecosystem accounting. In this regard, although aligned in bio-physical terms, natural capital may be considered a broader measure than the measures of environmental assets that are described in the SEEA Central Framework which are limited to consideration of material/SNA benefits.
Natural resources	Natural resources include all natural biological resources, including timber and aquatic, mineral and energy, and soil and water resources. In the SEEA, unlike the SNA, natural resources exclude land, which is considered a distinct type of environmental asset. Following the SNA, natural resources are defined in the SEEA to include only non-produced environmental assets, i.e. they are not considered to have come into existence as outputs of processes that fall within the production boundary of the SNA. A distinction is thus made between 'natural' and 'cultivated' environmental assets.

References

Aronson, J., et al. (eds), 2007, *Restoring natural capital: science, business and practice*, Island Press, Washington DC.

Berninger, F., et al., 2015, 'Management and site effects on carbon balances of European mountain meadows and rangelands', *Boreal Environment Research* 20(6), pp. 748-760.

Brundtland, G. H., 1987, *Our common future: report of the World Commission on Environment and Development*, United Nations, New York (http://www.un-documents.net/our-common-future.pdf) accessed 10 October 2018.

Buckwell, A., et al., 2017, CAP-thinking out of the box: further modernisation of the CAP — why, what and how?, RISE Foundation, Brussels.

Bureau of Meteorology, 2013, *Guide to environmental accounting in Australia*, Environmental Information Programme Publication Series no 3, Bureau of Meteorology, Canberra, Australia (http://www.cbd.int/financial/values/australia-accountingguide.pdf) accessed 27 November 2014.

Burek, P., et al., 2013, *LISFLOOD — distributed water balance and flood simulation model*, Joint Research Centre, European Commission, Brussels.

CBD (Convention of Biological Diversity), 2003, 'Article 2, Use of Terms' (https://bch.cbd.int/protocol/nkl/article2) accessed 3 December 2018.

Costanza, et al., 1997. The value of the world's ecosystem services and natural capital. Nature, 387(6630), p. 253.

Costanza, R., et al., 2014, 'Changes in the global value of ecosystem services', *Global Environmental Change* 26, pp. 152-158 (http://dx.doi.org/10.1016/j.gloenvcha.2014.04.002) accessed 05 October 2016.

Council of Europe, 1979. Convention on the Conservation of European Wildlife and Natural Heritage. Bern, Switzerland (http://conventions.coe.int/Treaty/EN/Treaties/Html/104.htm.) accessed 3 December 2018.

EC, 1992, 'Habitats Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora' (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043) accessed 13 January 2016.

EC, 2008, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (MSFD) (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1549635484429&uri=CELEX:32008L0056) accessed 15 February 2017.

EC, 2009, 'Birds Directive: Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds' (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147) accessed 13 January 2016.

EC, 2011, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'Our life insurance, our natural capital: EU biodiversity strategy to 2020' (COM (2011) 0244 final) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52011DC0244) accessed 15 February 2017.

EC, 2015, Guidance document on the application of water balances for supporting the implementation of the WFD. Technical Report - 2015 – 090, Luxembourg. ISBN 978-92-79-52021-1, doi: 10.2779/352735.(https://publications.europa.eu/en/publication-detail/-/publication/7d148604-faf0-11e5-b713-01aa75ed71a1/language-en) accessed 15 November 2018.

EC, forthcoming, Natural capital accounting: overview and progress in the European Union – MAES INCA Report 2019, European Commission, Brussels.

EC and EEA, 2016, Report on phase 1 of the knowledge innovation project on an integrated system of natural capital and ecosystem services accounting in the EU (KIP-INCA Phase 1 report), European Commission and European Environment Agency (http://ec.europa.eu/environment/nature/capital_accounting/pdf/KIP_INCA_final_report_phase-1.pdf) accessed 15 November 2018.

EEA, 2006, *Land accounts for Europe 1990-2000 — toward integrated land and ecosystem accounting*, EEA Report No 11/2006, European Environment Agency.

EEA, 2010, *The European environment: state and outlook. Water resources: quantity and flows*, European Environment Agency (https://www.eea.europa.eu/soer/europe/water-resources-quantity-and-flows) accessed 29 November 2018.

EEA, 2012, *EEA Catchments and rivers network system v1.1*, EEA Technical Report 7/201, European Environment Agency.

EEA, 2015a, 'Linkages of species and habitat types to MAES ecosystems', European Environment Agency (https://www.eea.europa.eu/data-and-maps/data/linkages-of-species-and-habitat) accessed 24 November 2017.

EEA, 2015b, *The European environment — state and outlook 2015: synthesis report*, European Environment Agency.

EEA, 2015c, *The European environment — state and outlook 2015: assessment of global megatrends*, European Environment Agency.

EEA, 2015d, *State of Europe's seas,* EEA report No 2/2015, European Environment Agency (https://www.eea.europa.eu/publications/state-of-europes-seas) accessed 30 October 2017.

EEA, 2016, *Environmental indicator report 2016 — in support to the monitoring of the 7th Environment Action Programme*, EEA Report No 30/2016, European Environment Agency (https://www.eea.europa.eu/publications/environmental-indicator-report-2016) accessed 20 October 2017.

EEA, 2017, *Landscapes in transition — an account of 25 years of land cover change in Europe*, EEA report No 10/2017, European Environment Agency (https://www.eea.europa.eu/publications/landscapes-in-transition) accessed 4 December 2018.

EEA, 2018a, 'Use of freshwater resources, CSI 018', European Environment Agency (https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-2/assessment-3) accessed 4 December 2018.

EEA, 2018b, *Mapping Europe's ecosystems*, European Environment Agency.

Ekins, P. and Max-Neef, M. (eds), 1992, 'A four-capital model of wealth creation', in: *Real-life economics: understanding wealth creation*, Routledge, London, pp. 147-155.

Erhard, M. et al., 2016, Mapping and assessment of ecosystems and their services — mapping and assessing the condition of Europe's ecosystems: progress and challenges, Third report — final, March 2016, Technical Report No 2016/095, European Commission (http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/3rdMAESReport_Condition.pdf) accessed 10 October 2018.

ETC/ICM (2015) Initial Assessment of European Seas based on Marine Strategy Framework Directive Article 8 reporting – Summary report, ETC/ICM Technical Report 1/2015, Magdeburg: European Topic Centre on Inland, Coastal and Marine Waters, p. 80.

EU, 2000, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (http://www.waterframeworkdirective.wdd.moa.gov.cy/docs/pdf/wfd.pdf) accessed 4 December 2018.

EU, 2014, Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN) accessed 27 November 2014.

Faergemann, H., 2012, Update on water scarcity and droughts indicator development, European Commission, Brussels.

FAO, 2003, *Review of world water resources by country*, Food and Agriculture Organization of the United Nations, Rome.

FAO, 2014, 'Freshwater availability — precipitation and internal renewable water resources (IRWR), AQUASTAT', Food and Agriculture Organization of the United Nations, (http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en) accessed 27 November 2017.

FAO, 2016, 'AQUASTAT database', Food and Agriculture Organization of the United Nations (http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en) accessed 8 September 2018.

Feranec, J., et al. (eds), 2016, *European landscape dynamics: CORINE land cover data*, CRC Press, Florida, United States.

Foley, J. A., et al., 2005, 'Global consequences of land use', *Science* 309(5734), pp. 570-574.

Grizzetti, B., et al., 2016, 'Assessing water ecosystem services for water resource management', *Environmental Science & Policy* 61, pp. 194-203 (http://dx.doi.org/10.1016/j.envsci.2016.04.008) accessed on 12 February 2017.

Grizzetti B., et al., 2017, 'D5.1-3: impact of multi-stressors on ecosystem services and their monetary value' in: *Five reports on stressor classification and effects at the European scale*, EU FP7 project MARS Contract No 603378 (http://www.mars-project.eu/files/download/deliverables/MARS_D5.1_five_reports_on_stressor_classification_and_effects_at_the_european_scale.pdf) accessed 8 September 2018.

Guerry, A. D., et al., 2015, 'Natural capital and ecosystem services informing decisions: from promise to practice', *Proceedings of the National Academy of Sciences* 112(24), pp. 7348-7355.

Haines-Young, R. and Potschin, M., 2013, Common classification of ecosystem services (CICES): consultation on version 4, August-December 2012, Report to the European Environment Agency (https://cices.eu/content/uploads/sites/8/2012/07/CICES-V43_Revised-Final_Report_29012013.pdf) accessed 12 February 2017.

Harrison, P. A., et al., 2014, 'Linkages between biodiversity attributes and ecosystem services: a systematic review', *Ecosystem Services* 9, pp.191-203.

Haylock, M. R., et al., 2008, 'A European daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006', *Journal of Geophysical Research* 113(D20), D20119 (http://doi.wiley.com/10.1029/2008JD010201) accessed 12 September 2018.

Hodge, I., et al., 2015, 'The alignment of agricultural and nature conservation policies in the European Union', *Conservation Biology* 29(4), pp. 996-1005.

IPBES, 2018, The regional assessment report on biodiversity and ecosystem services for Europe and Central Asia — summary for policymakers, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.

IPCC, 2014, *Climate change 2014 synthesis report — summary for policymakers*, Intergovernmental Panel on Climate Change (https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf) accessed 12 September 2018.

King, S., and Petersen, J. E., 2018, 'Testing the development of Species Accounts for measuring ecosystem condition in the EU', London Group on Environmental Accounting, 24th Meeting from 1-4 October 2018.

La Notte, A., et al., 2017, Implementing an EU system of accounting for ecosystems and their services: initial proposals for the implementation of ecosystem services accounts, JRC Technical Reports EUR 28681 EN, Publications Office of the European Union, Luxembourg (https://doi.org/10.2760/214137) accessed 15 November 2018.

Liu, J., et al., 2015, 'Systems integration for global sustainability', *Science* 347(6225), 1258832.

MA, 2005, 'Millennium Ecosystem Assessment (https://www.millenniumassessment.org/en/index.html).

Maes, J., et al., 2013, Mapping and assessment of ecosystems and their services. An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020, Discussion paper (http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf) accessed 15 November 2018.

Maes, J., et al., 2018, Mapping and assessment of ecosystems and their services. An analytical framework for ecosystem condition in the EU, Discussion paper — final, Publications Office of the European Union, Luxembourg.

Mazza, L., et al., 2013, *Natural capital in a Nordic context*, Nordic Council of Ministers, Copenhagen.

Meadows, D.H., et al., 1972, *The limits to growth*, Universe Books, New York (http://www.donellameadows.org/wp-content/userfiles/Limits-to-Growth-digital-scan-version.pdf) accessed 15 November 2018.

Moreira, F. and Russo, D., 2007, 'Modelling the impact of agricultural abandonment and wildfires on vertebrate diversity in Mediterranean Europe', *Landscape Ecology* 22(10), pp. 1461-1476.

Oliver, T. H., et al., 2015, 'Biodiversity and resilience of ecosystem functions', *Trends in Ecology & Evolution* 30, pp. 673-684.

Pearce, D. W., et al., 1989, *Blueprint for a green economy*, Earthscan, London.

Pedroli, B. et al. (eds), 2007, Europe's living landscapes: essays exploring our identity in the countryside, KNNV Publishing, Zeist, Netherlands.

Petersen, J.-E. and Steurer, A., 2015, *Geo-spatial data and statistics to support the knowledge base for monitoring natural capital*, Paper submitted to the conference on New Techniques and Technologies for Statistics (NTTS) 2015, Brussels, Published in the NTTS 2015 Proceedings (https://ec.europa.eu/eurostat/cros/system/files/NTTS2015%20proceedings.pdf) accessed 10 November 2018.

Petersen, J.-E., 2017, Developing a knowledge frame for managing natural capital – what do we need to know? In: Paracchini M.L., Zingari P.C., Blasi C (Eds.) 2017. *Reconnecting Natural and Cultural Capital. Contributions from Science and Policy*. Publications Office of the European Union, Luxembourg. doi:10.2788/09303

Piet, G. J., et al., 2017, 'Indicators of the "wild seafood" provisioning ecosystem service based on the surplus production of commercial fish stocks', *Ecological indicators* 72, pp. 194-202.

Radermacher, W., and Steurer, A., 2015, 'Do we need natural capital accounts for measuring the performance of societies towards sustainable development, and if so, which ones'. Eurostat Review on National Accounts and Macroeconomic Indicators, 2015, 1. (https://ec.europa.eu/eurostat/cros/content/do-we-need-natural-capital-accounts-measuring-performance-societies-towards-sustainable_en) accessed 10 October 2018.

Raskin, P., et al., 1997, *Comprehensive assessment of the freshwater resources of the world*, Document prepared for UN Commission for Sustainable Development 5th Session 1997, Stockholm Environmental Institute, Sweden.

Renwick, A., et al., 2013, 'Policy reform and agricultural land abandonment in the EU', *Land Use Policy* 30, pp. 446-457.

Roekaerts, M., 2002, The biogeographical regions map of Europe. Basic principles of its creation and overview of its development, European Environmental Agency (https://www.researchgate.net/publication/224840052_The_Biogeographical_Regions_Map_of_Europe_Basic_principles_of_its_creation_and_overview_of_its_development) accessed 5 October 2017.

Rockström, J., et al., 2009, 'A safe operating space for humanity', *Nature* 461, pp. 472-475.

Rohd-Thomsen, L., 2015. Water accounts and Statistics for Sustainable Development Goal 6, Workshop on capacity development in advancing water and sustainable development, 24-25 February 2015, New York. (https://sustainabledevelopment.un.org/content/documents/130885.2%20UNSD%20presentation_v1.pdf) accessed 3 December 2018.

Ruijs, A., et al., 2018, Natural capital accounting for the sustainable development goals. Current and potential uses and steps forward, PBL Netherlands Environmental Assessment Agency, The Hague.

Russi, D., et al., 2013, *The economics of ecosystems and biodiversity for water and wetlands*, Institute of European Environmental Policy and Ramsar Secretariat, London.

SEEA, 2017, *SEEA experimental ecosystems accounting: technical recommendations*, Consultation draft V4.1: 6 March 2017, System of Environmental Economic Accounting, United Nations (https://unstats.un.org/unsd/envaccounting/eea_project/TR_consultation/SEEA_EEA_Tech_Rec_Consultation_Draft_II_v4.1_March2017.pdf) accessed 15 October 2018.

Stanners, D. and Bordeaux, P. (eds), 1995, *Europe's environment: the Dobris assessment*, European Environment Agency, Publications Office of the European Union, Luxembourg.

ten Brink, P., et al., 2009, TEEB — The economics of ecosystems and biodiversity for national and international policy makers. https://www.researchgate.net/publication/279755510_TEEB_-_The_Economics_of_Ecosystems_and_Biodiversity_for_National_and_International_Policy_Makers_-_Summary_Responding_to_the_Value_of_Nature accessed 20 November 2016.

ten Brink, P., 2015, 'Natural capital — an old concept with a new life', in: Monnoyer-Smith, L. and Perrissin Fabert, B. (eds.), *Nature and the wealth of nations*, Collection (Études et documents) of the Department for the Economics, Assessment and Integration of Sustainable Development (Service de l'Économie, de l'Évaluation et de l'Intégration du Développement Durable, SEEIDD) in the Department of the Commissioner-General for Sustainable Development (Commissariat Général au Développement Durable, CGDD), Paris (http://temis.documentation.developpement-durable.gouv.fr/docs/Temis/0083/Temis-0083488/22322_ENG.pdf accessed 20 November 2016.

Tomaz, C., et al., 2013, 'Land cover change and afforestation of marginal and abandoned agricultural land: a 10 year analysis in a Mediterranean region', *Forest Ecology and Management* 308, pp. 40-49.

UNSD, 2012, *System of Environmental-Economic Accounting for Water*, United Nations Statistics Division, New York, (https://unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf) accessed 20 November 2016.

UNSD, 2015, *System of Environmental-Economic Accounting 'SEEA'*, United Nations Statistics Division, New York.

UNSD, 2017, *Technical recommendations in support of the System of Environmental-Economic Accounting*, United Nations Statistics Division, New York (https://seea.un.org/sites/seea.un.org/files/technical_recommendations_in_support_of_the_seea_eea_final_white_cover.pdf) accessed 20 November 2018.

UN, et al., 2014a, *System of Environmental-Economic Accounting 2012— Central Framework*, United Nations, New York (http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf) accessed 27 November 2014.

UN, et al., 2014b, *System of Environmental Economic Accounting 2012 — Experimental Ecosystem Accounting*, United Nations, New York (http://unstats.un.org/unsd/envaccounting/seeaRev/eea_final_en.pdf) accessed 15 October 2017.

Vardon, M. et al., 2017, 'The Aichi targets and biodiversity conservation — the role of natural capital accounting', in: Vardon, M., et al. (eds), *Forum on natural capital accounting for better policy decisions: taking stock and moving forward*, WAVES, Washington DC (https://www.wavespartnership.org/en/knowledge-center/forum-natural-capital-accounting-better-policy-decisions-taking-stock-and-moving) accessed 15 October 2018.

Weber, J. L., 2014, 'Ecosystem natural capital accounts: a quick start package', *CBD Technical Series* No 77, p. 248.

Weber, J. L., 2018, 'Ecosystem accounting – a short account', in: *Oxford research encyclopedia — environmental science, environmental accounting*, Oxford University Press, Oxford.

Zal, N., et al., 2017, Use of Freshwater Resources in Europe — An assessment based on water quantity accounts, ed. Künitzer, A., ETC/ICM Technical Report 1/2017, Magdeburg: European Topic Centre on inland, coastal and marine waters, p. 75 (https://icm.eionet.europa.eu/ETC_Reports/UseOfFreshwaterResourcesInEurope_2002-2014/Water_Accounts_Report_2016_final_for_publication.pdf) accessed 3 December 2018.

Abbreviations

BTO	British Trust for Ornithology
BSU	Basic spatial unit
CAPRI	Common Agricultural Policy Regionalised Impact (model)
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
CLC	Corine Land Cover
CSI	Core set of indicators
CSO	Czech Society for Ornithology
DPSIR	Drivers, pressures, state, impact, response
EAP	Environment Action Programme
EC	European Commission
ECRINS	European Catchments and Rivers Network System
EEA	European Environment Agency
EEA-39	All 33 EEA member countries and six cooperating countries
ENCA-QSP	Ecosystem natural capital accounts: a quick start package
ETC/BD	European Topic Centre on Biological Diversity
ETC/ICM	European Topic Centre on Inland, Coastal and Marine Waters
ETC/ULS	European Topic Centre on Urban, Land and Soil Systems
EU	European Union
EU-28	All 28 European Union Member States
EUNIS	European Union Nature Information System
FAO	Food and Agriculture Organization of the United Nations
FEC	Functional elementary catchment

FRBD	Functional river basin district
GDP	Gross domestic product
ICES	International Council for the Exploration of the Seas
IMFA	Integrated marine fish account
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
JRC	Joint Research Centre
KIP INCA	Knowledge innovation project on an integrated system for natural capital and ecosystem services accounting
LEAC	Land and ecosystem accounts database
LUCAS	Land Use/Cover Area Frame Statistical Survey
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MECE	Mutually exclusive and collectively exhaustive
MFA	Material flow accounts
MSFD	Marine Strategy Framework Directive
MSY	Maximum sustainable yield
NUTS2	Nomenclature of Territorial Units for Statistics level 2
OECD	Organisation for Economic Co-operation and Development
PSR	Pressure-state-response
QE	Quality element
RBD	River basin district
RBMP	River basin management plan
SB	Sub-basin
SBU	Sustainability of biomass use
SEEA	System of Environmental-Economic Accounting
SEEA-AE	System of Environmental-Economic Accounting — Applications and Extensions
SEEA-CF	System of Environmental-Economic Accounting — Central Framework
SEEA-EEA	System of Environmental Economic Accounting — Experimental Ecosystem Accounting
SEEA-EEA-TR	System of Environmental Economic Accounting — Experimental Ecosystem Accounting — Technical Recommendations

SEEA-W	System of Environmental Economic Accounting for Water
SNA	System of National Accounts
SP	Surplus production
SSB	Spawning stock biomass
SU	Sub-unit
UN	United Nations
UNCEEA	United Nations Committee of Experts on Environmental-Economic Accounting
UNEP	United Nations Environment Programme
UNSC	United Nations Statistical Commission
UNSD	United Nations Statistical Division
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WB	Water body
WCMC	World Conservation Monitoring Centre
WEI+	Water Exploitation Index plus
WFD	Water Framework Directive
WSPS	Wild seafood provisioning service

Annex 1 Methodology for European ecosystem extent accounts

Tier I ecosystem extent accounts

Tier I comprises ecosystem extent accounts for the broad terrestrial, freshwater and marine transitional ecosystem types established by the MAES process. In tier I, nine MAES ecosystem types are delineated, comprising: urban, cropland, grassland, forest and woodland, heathland and shrub, sparsely vegetated land, inland wetlands, rivers and lakes, and marine inlets and transitional waters (as described in Box A1.1). These nine ecosystem types are based on aggregations of the 44 CLC level 3 classes. Table A1.1 illustrates this correspondence between MAES ecosystem types and CLC classes. The first column to the left lists the nine MAES ecosystem types considered in the tier I ecosystem extent accounts; the column to the far right shows the correspondence with CLC classes.

The MAES ecosystem types coastal, shelf and open ocean are not included in the tier I extent accounts. This reflects the current lack of marine spatial data suitable for developing accounts for ecosystem or

Box A1.1 MAES typology of ecosystems considered in tier I ecosystem extent accounts (EC, 2013)

Urban ecosystems are areas where most of the human population lives and it is also a class significantly affecting other ecosystem types. Urban areas represent mainly human habitats, but they usually include significant areas for synanthropic species, which are associated with urban habitats. This class includes urban, industrial, commercial and transport areas, urban green areas, mines, and dumping and construction sites.

Cropland is the main food production area including both intensively managed ecosystems and multi-functional areas supporting many semi-natural and natural species along with food production (lower intensity management). It includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics).

Grassland covers areas dominated by grassy vegetation (including tall forbs, mosses and lichens) of two kinds: managed pastures and (semi-) natural (extensively managed) grasslands.

Forest and woodland are areas dominated by woody vegetation of various ages or they have succession climax vegetation types on most of the area supporting many ecosystem services.

Heathland and shrub are areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable natural conditions. They include moors, heathland and sclerophyllous vegetation.

Sparsely or unvegetated land is all unvegetated or sparsely vegetated habitats (naturally unvegetated areas). Often these ecosystems have extreme natural conditions that might support particular species. They include bare rocks, glaciers, and dunes, beaches and sand plains.

Inland wetlands are predominantly water-logged areas with specific plant and animal communities, located inland, that support water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens as well as peat extraction sites.

Rivers and lakes are inland surface waters, including water courses, bodies and coastal lakes without a permanent connection to the sea.

Marine inlets and transitional waters are ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5 %. They include coastal wetlands, lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments.

condition. Nonetheless, the tier I ecosystem extent accounts cover the entire terrestrial area of the EEA-39 and the typology is non-overlapping. They fulfill, therefore, the mutually exclusive collectively exhaustive (MECE) principle required by the SEEA-EEA in a terrestrial context.

Tier II ecosystem extent accounts

The tier II ecosystem extent accounts are calculated on the basis of CLC level 3 classes, which have a good match with clearly defined and/or vulnerable European ecosystems of conservation or management interest that cannot be attained using the broad MAES typology alone. For example, the CLC class 244 ('Agro-forestry areas') matches well with a specific type of ecosystem mainly found on the Iberian Peninsula (called 'dehesa' or 'montado'), which has developed as a result of a traditional land use that mixes the exploitation of oak trees with cropping and/or grazing. The CLC level 3 classes therefore support more refined analysis in the context of both the tier II and the tier I ecosystem extent accounts as they nest under both these aggregations.

Tier III ecosystem extent accounts

An outstanding step is the development of tier III ecosystem extent accounts using a probability-based mapping approach for the distribution of European ecosystems under the MAES process (on the basis of combining the CLC and EUNIS habitat classifications). This would allow a further differentiation of MAES ecosystem types into EUNIS habitat types. The EUNIS system lists 233 major habitat types, which could be aggregated to specific ecosystem sub-types. In addition to these data input layers, data from reporting under the Nature Directives will be used for refinements, where geo-referencing and comparability between Member States is of a sufficient consistency and quality. The tier III ecosystem extent accounts may also be further enhanced by data from vegetation surveys, spatial biodiversity data and data on environmental pressures, such as nutrient loads. This will produce a more refined and ecologically representative delineation of ecosystems in Europe, rather than relying on CLC classes. However, the final approach that will inform the tier III ecosystem extent accounts remains subject to confirmation.

Data foundation and organisation

The tier I and II ecosystem extent accounts are built on the basis of CLC data derived from satellite images. CLC represents a unique Europe-wide approach to land monitoring, supported by 39 countries. CLC specifications, including nomenclature, were formulated in the 1980s with regard to initial user needs, input data availability, spatial resolution and methodology. The nomenclature includes 44 classes, organised in a three-level hierarchical system, with five main categories: artificial surfaces, agricultural areas, forests and seminatural areas, wetlands, and water bodies. Harmonised production of the data set is aided by very detailed, illustrated nomenclature guidelines as well as well-established technical coordination (guidelines, training, quality control) provided by the EEA's CLC technical team. Although the list of classes has remained unchanged since the beginning, class descriptions have undergone significant refinement in response to methodological developments. For further description of the CLC programme, see Feranec et al. (2016).

The organisation of data for calculating ecosystem extent accounts is based on the system developed by the EEA for calculating land accounts: the LEAC database (EEA, 2006). The LEAC database is a system of spatial grids, which are based on the 100 m × 100 m CLC raster files and can be used to support spatial analysis at 100 m × 100 m, 1 km × 1 km, 5 km × 5 km and 10 km × 10 km resolutions (cf. EEA, 2017).

CLC data are stored in the LEAC database at a resolution of 100 m^2 as raster files. To facilitate the use of the CLC data for ecosystem accounting purposes, a 1 km × 1 km accounting grid is superimposed on the CLC land cover map. The statistical information on the distribution of the land cover types (% of each land cover type per 1 km × 1 km grid cell) is based on the 100 m resolution of CLC and retained and stored in the LEAC database. For calculating the ecosystem extent accounts the 1 km^2 grid was employed.

Consequently, the basic spatial data infrastructure for Europe-wide ecosystem extent accounting is based on the LEAC approach, which allows analytical assessments for a wide variety of ecosystem accounting areas. At the largest scale, this comprises overall analysis of trends in ecosystem extent for the EEA-39 and EU-28 areas. However, ecosystem extent accounts can readily be calculated to assess trends by Member State, biogeographical region or water basin, or for examining ecosystem loss due to urbanisation. The single accounting grid facilitates the combination of different data layers as well as the production of different types of tabular, graphical and map views. It also provides the essential spatial foundation for integrating and compiling ecosystem condition and services accounts, when available.

Table A1.1 Correspondence of MAES classification with Corine Land Cover classes

MAES ecosystem types	CLC classes	CLC labels
1 — Urban	111	Continuous urban fabric
	112	Discontinuous urban fabric
	121	Industrial or commercial units
	122	Road and rail networks and associated land
	123	Port areas
	124	Airports
	131	Mineral extraction sites
	132	Dump sites
	133	Construction sites
	141	Green urban areas
	142	Sport and leisure facilities
2 — Cropland	211	Non-irrigated arable land
	212	Permanent irrigated arable land
	213	Rice fields
	221	Vineyards
	222	Fruit trees and berry plantations
	223	Olive trees
	241	Annual crops associated with permanent crops
	242	Complex cultivation patterns
	243	Agriculture land with significant areas of natural vegetation
	244	Agro-forestry areas
3 — Grassland	231	Pastures
	321	Natural grassland
4 — Forest and woodland	311	Broad-leaved forest
	312	Coniferous forest
	313	Mixed forest
	324	Transitional woodland shrub
5 — Heathland and shrub	322	Moors and heathland
	323	Sclerophyllous vegetation
6 — Sparsely vegetated land	333	Sparsely vegetated areas
	331	Beaches, dunes and sand plains
	332	Bare rock
	334	Burnt areas
	335	Glaciers and perpetual snow
7 — Inland wetlands	411	Inland marshes
	412	Peatbogs
8 — Rivers and lakes	511	Water courses
	512	Water bodies
9 — Marine inlets and transitional waters	421	Salt marshes
	422	Salines
	423	Intertidal flats
	521	Coastal lagoons
	522	Estuaries
	523	Sea and ocean

Additional LEAC measurements

In addition to recording the opening and closing stocks and associated additions and reductions, three further measurement items have been included in the ecosystem extent accounts to improve the analytical insights they can provide. These correspond to concepts already introduced with the original LEAC approach (EEA, 2006) and comprise:

- **Internal transformations**. Level 1 and 2 CLC classes and MAES ecosystem types are aggregated from underlying CLC level 3 class types. Transfers in extent between the level 3 classes within the same higher level class or MAES ecosystem are defined as internal transformations. They are included in the calculations of the additions and reductions and the accounting variable 'turnover' (see below). This can lead to high turnover rates in internally dynamic land cover types and MAES ecosystem types, such as the urban and forest and woodland types.

- **Turnover of ecosystem extent**. This is the gross change in ecosystem extent, the sum of the additions and reductions for an ecosystem type over the accounting period (this includes internal transformations).

- **Stable ecosystem stock**. This is the stock of the original ecosystem type that remains unchanged over the accounting period, the opening stock of a given ecosystem type minus the reductions over the accounting period (EEA, 2006).

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