Natural Capital Accounting: Overview and Progress in the European Union
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1. INTRODUCTION

1.1 Context

The growing human population and our ever more resource-intensive behaviours are increasingly placing demands on global ecosystems and biodiversity. Depleting and degrading these reserves may irreversibly reduce the availability of benefits to future generations, and many ecosystems may be so degraded that future generations are unable to benefit from them at all. Furthermore, many people are today still not aware of nature’s full ‘worth’ or ‘value’, i.e. the great number of services that nature provides. Thus there is growing political pressure to find ways to account for natural resources and their benefits in a clear and systematic fashion that can be embedded into the range of decisions that affect our well-being today and our common future.

Ecosystem services provide a range of benefits, and can be separated into three main categories: provisioning services, which include food provision or timber production; regulating services, which include air and water filtration, pollination and climate regulation and protection against natural disasters such as flooding; and cultural ecosystem services, which include recreation and leisure, education, aesthetic and spiritual benefits. These services can be considered flows, derived from stocks of ecosystem assets. Such stocks are referred to as Natural Capital, a term which describes Earth’s natural assets, including soil, air, water, and living things, existing as complex ecosystems – as well as the related ecosystem services that human societies need in order to survive and thrive.

There are many definitions of natural capital in literature. The definition provided in the European Commission’s 7th Environment Action Programme (EAP) defines natural capital as: "biodiversity, including ecosystems that provide essential goods and services, from fertile soil and multi-functional forests, to productive land and seas, from good quality fresh water and clean air to pollination and climate regulation and protection against natural disasters." As highlighted in the 1st objective of the 7th EAP, the European Union’s economic prosperity and well-being is underpinned by its natural capital.

A sound analysis of ecosystem processes, combined with the general principles of environmental accounting, is the foundation for developing a natural capital accounting approach. Figure 1.1 illustrates the main components of natural capital as currently understood – this has been developed from the natural capital figure in the first EU MAES report on the ‘Mapping and Assessment of Ecosystems and their Services’ (European Commission, 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.

Natural capital accounting (NCA) offers a way to create a register of the natural ‘assets’ — soil, water, air, and all living things — along with the range of services provided. One of the objectives of natural capital accounting is to help integrate natural capital, and in particular, ecosystems into socio-economic decision-making. This report focuses more specifically on the ecosystem accounting component of NCA.

Even though a broad range of economic activities are dependent upon ecosystems, national accounts currently do not fully take their contribution into consideration. The objective is to enable governments, businesses, and individuals to sufficiently value ecosystems and take
responsibility for maintaining and monitoring their health. Also, by including an analysis of the health of the ‘assets’ and their ability to function, it is hoped that better decisions can be made to improve them, protect them, and use them more wisely so they can continue to support future generations.

Accounting is a core element of socio-economic decision-making at EU, national, and business levels. For many countries, national accounts have been regularly compiled for the last 50 years. National accounts, as we know them today, emerged during the Great Depression of the 1930s. At that time there was no clear measure of overall economic activity, and instead policymakers had to make their choices based on a mixture of information on variables such as foreign trade, manufacturing orders, and employment data.

The first international standard for national accounts, the System of National Accounts (SNA), was introduced by the United Nations in 1953. Since then, the ongoing refinement and development of comparable economic data around the world has underpinned a large number of economic and other related policies, at national and international level.

The incorporation of ecosystems into standard accounting frameworks can help mainstream nature and biodiversity in decision-making, and to promote more resource efficient and sustainable choices. NCA can measure the changes in the stock and condition of natural capital at a variety of scales, and integrates the use value (i.e. not non-use such as existence or bequest or altruistic values of nature) of ecosystem services into accounting and reporting systems. By conducting NCA, one can also develop macro-indicators that provide relevant environment-related information alongside Gross Domestic Product (GDP) and employment.

To conclude, NCA can help mainstream biodiversity and ecosystems in economic decision-making and ensure that natural capital continues delivering ecosystem services to our economy and society in the long-term. Overall, it can contribute to the better management of the European Union’s natural capital.

### 1.2 INCA and MAES

Establishing a sound method for NCA, with a strong focus on ecosystems and their services, is a key objective of the 7th EAP and of the EU Biodiversity Strategy to 2020. However, significant work is required in order to develop full natural capital accounts for the EU.

Action 5 of the EU Biodiversity Strategy to 2020 foresees that Member States will, with the assistance of the European Commission (EC), map and assess the state of ecosystems and their services (MAES) in their national territories, value them, and integrate these values into accounting and reporting frameworks. The Integrated system of Natural Capital and ecosystem services Accounting in the EU (INCA) project contributes to MAES by developing an EU approach for ecosystem accounting. It is therefore working closely with the overall MAES work.
INCA aims to design and implement an integrated accounting system for ecosystems and their services in the EU. The project was established in 2015 in the context of the European Knowledge community, a platform in the European Commission with the aim of working jointly to improve the generation and sharing of knowledge. The INCA partners are Eurostat, DG Environment (ENV), DG Research and Innovation (RTD), DG Joint Research Centre (JRC), and the European Environment Agency (EEA).

The INCA project also aims to connect relevant existing projects and data collection exercises to develop a shared platform of geo-referenced information on ecosystems and their services. It builds on the biophysical work undertaken in the first phase of the EU MAES initiative, and contributes to its second phase by developing an accounting system for ecosystems and their services at the EU level. Primarily this will use EU-wide data sources to support a wider range of Member States in developing ecosystem accounts at the national or sub-national level.

The INCA accounting framework requires an operational geospatial data infrastructure that pulls together geospatial information about ecosystems from various sources. INCA could help to make these data sources consistent in terms of update cycles, spatial resolution, thematic scope, and data policies.

The INCA accounting approach is aligned with UN standards on environmental economic accounting. The UN System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA) provides a framework for testing ecosystem accounting at different levels, and the INCA project uses this framework as working guidance to develop EU pilot ecosystem accounts. The INCA partners have been closely involved in the development of the experimental ecosystem accounting framework since its inception. The outcomes from INCA are expected to support the SEEA EEA revision process, which aims to achieve an internationally agreed statistical standard for ecosystem accounting by 2020.

Whilst INCA mainly uses EU-wide data sources, finer-scale data available at national or local levels could be linked to this EU layer for more detailed analysis. Biophysical and economic data related to the extent and condition of ecosystems should ideally be integrated in a systematic way, so that they can be aggregated and disaggregated at the required scale, including at national level, to complement figures of economic performance.

The project aims to explicitly account for a wide range of ecosystem services, and demonstrate in monetary terms the benefits of investing in nature and the sustainable management of resources. Macro-indicators will also be developed to assess the economic importance and value of ecosystems and their services, alongside GDP. The outputs of INCA should be able to:

- Present a comprehensive overview of the stock of ecosystem assets and related ecosystem service flows
• Show the interdependencies between natural capital and economic activities
• Enable measurement of the changes in these elements over time
• Present information at different scales: e.g. at the scale of ecosystem units, river basins, and bio-geographic regions, but also the regional, national or EU level, and enable the aggregation/disaggregation of data
• Provide a range of policy-relevant examples worked out in detail
• Provide a reliable basis for decision-making on the use of natural resources

1.3 Purpose of the Report
The aim of this report is to describe the status of work being undertaken by INCA in order to provide information on Natural Capital Accounting for EU Member States and other actors working in this area. It aims, in particular, to serve as a reference document on ecosystem services to the EC guidance document on integrating ecosystems and their services into decision-making. The document provides a brief overview of natural capital accounting, and more specifically, ecosystem accounting. It also reports on the progress of INCA, and showcases NCA work in practice in EU Member States and at EU-level, illustrating its use for various types of decision-making.
2. POLICY CONTEXT OF NCA

2.1 The use of NCA in various policy contexts

NCA and ecosystem accounting can be applied to a broad range of policy contexts for supporting decision-making at the national (Member State) and regional (EU) levels.

2.1.1 SECTORAL POLICIES

NCA can support sectoral policies by better quantifying the contribution of ecosystems to different sectors, and assessing synergies and trade-offs between different measures. These are of particular relevance in the areas of land-use management and planning, agriculture and forestry, coastal and marine planning, and the integration of nature with tourism and other economic activities.

For example, ecosystem accounting can support the following policies:

- **Forest policy**: by providing tangible and systematic information that better reflects the true value of forest ecosystem services beyond timber production alone (e.g. by including other services such as carbon sequestration, water filtration, air purification, soil retention, flood control, and recreation). This information can also be useful for assessing new agreements through 'Payment for Ecosystem Services' (PES) schemes.

- **Agricultural policy**: by providing input to reviews of the Common Agricultural Policy. For example, accounts can help to assess the benefits of investing in more sustainable forms of farming, connecting landscapes, and increasing opportunities for biodiversity, as well as by providing quantitative estimates of the risks to agricultural production from environmental degradation and associated reductions in ecosystem services (e.g. pollination).

- **Marine policy**: by quantifying the contributions of marine ecosystem services, such as provisioning services (including food supply), regulating services (including coastal resilience and protection and climate regulation), and cultural services (such as recreation). Accounts can also support better planning in marine areas, for example, targeting the design of marine protected areas, restoration measures, and the implementation of blue and green infrastructure.

- **Infrastructure policy**: by identifying synergies and trade-offs between different ecosystem services to inform the implementation of green infrastructure approaches for regional development. Accounts can also help to better target investment in projects by including a wider range of values related to ecosystems and their services.
Benefits realised through the supply of ecosystem services can cut across several sectoral policies, or provide co-benefits from one policy area to another (e.g. peri-urban forests, in addition to providing air and water purification services, also contribute to climate change mitigation and adaptation). Ecosystem accounting can help identify these synergies, as well as potential trade-offs within and between ecosystem services across time and space. An example of this is the distribution of costs and benefits of ecosystem services, and the challenges and opportunities of designing Payments for Ecosystem Services (PES) schemes.

Importantly, ecosystem accounting can also provide an indication of the level of sustainable use of ecosystems. For example, accounts of ecosystem condition or ecosystem capacity provide essential information to aid the assessment of the sustainable use of ecological assets. This is particularly relevant for the EU Bioeconomy Strategy.

### 2.1.2 Environmental Policies

Ecosystem accounts explicitly articulate a range of ecosystem services and demonstrate, in both physical and value terms, the benefits of improving the condition of ecosystems, and the sustainable management of resources. Therefore, ecosystem accounts can be useful for assessing the benefits of a range of environmental policies.

Ecosystem accounting can contribute to the better understanding, articulation, and accounting of the range of services that ecosystems provide (e.g. provisioning, regulating and cultural services) in specific sectoral policies. These services need to be explicitly taken into consideration alongside those typically accounted for, such as the provision of timber or food (e.g. in forestry and agricultural policies).

Ecosystem accounting can also provide a common reference point or baseline to help assess progress towards targets related to ecosystem restoration, for example, the EU 2020 Biodiversity Strategy target to restore 15% of degraded ecosystems, and to support a strategic approach to financing green infrastructure throughout Europe. Ecosystem accounts can also contribute additional information to reporting on EU legislation, in particular for the Birds and Habitats Directive, the Water Framework Directive, and the Marine Strategic Framework Directive.

### 2.1.3 Macro-Economic Policies, Indicators, and Corporate Accounting

Ecosystem accounting makes the contributions of natural capital to economic development explicit, alongside produced/manufactured capital and human capital. In this way, ecosystem accounting provides important input to macro-level decision-making, and can help estimate the contribution of ecosystems to the economy.

NCA can highlight the economic values of natural capital, e.g. monetary values of the goods and services related to ecosystems that are produced in a specific year or in a specific sector, alongside other economic information. It can help identify opportunities and trade-offs
between economic, social and environmental priorities, and can evaluate investment and policy options in a way that explicitly takes into account externalities, better reflecting the true costs of ecosystem degradation.

NCA can also be used to support the systematic development of aggregated physical and economic indicators that are consistent with National Accounts and thus could complement GDP.

In the corporate sector, natural capital accounting can provide a concrete framework for business performance reporting, helping to measure impacts and dependencies on natural resources, in both physical and monetary terms. There is an opportunity to build synergies between public level accounting and corporate accounting.

### 2.1.4 GLOBAL LEVEL

Accounting in EU policy contexts provides useful input for further development of international guidelines, such as the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA) (UN, 2014 a). This, in turn, can provide a consistent basis for measuring progress at the international level, and provide opportunities for synergies for reporting under the 2030 sustainable development agenda.

Examples of how NCA has been used to help policies both in the EU and internationally have focused on the regional and national level, and some of these are described later in the document.

The ambition of INCA is to develop ecosystem accounts that can serve a variety of purposes, at different levels, and for different users.

### 2.2 Using NCA to guide decisions

NCA is an important tool in a "tool box" designed to aid making decisions on natural capital in particular in relation to social and economic considerations. Later sections in this report outline some examples of the accounts being developed and can be used to provide relevant information and guide decisions, both at EU level and as part of national development work within EU Member States.

Examples include:

- Systematic and periodic information about land cover change (EEA; section 4.2.2) and also to guide regional decisions (Limburg).
- Crop Pollination and recreation (JRC; section 4.4)
- Maritime spatial planning (section 5.3, Italy)
- Contributions to the economy (UK)
A number of these approaches are still in an experimental phase and should be seen in that context. There are still many open issues, for example relating to choices as to how to define ecosystem condition, clarity about various forms of values that are being represented, and the degree of spatial accuracy and disaggregation. Nonetheless, all of these examples do indicate the potential use of natural capital to support practical decisions.

Clearly, a decision-making context will require a broader set of inputs and considerations beyond accounting alone. A Guidance document on integrating ecosystem and their services into decision-making is being prepared by the European Commission in this respect, and this document will be referenced in the Guidance.
3. FRAMEWORK OF NCA

The SEEA is a statistical system that integrates information from different domains into one common framework, based on internationally agreed standard concepts, definitions, classifications, and accounting rules and tables, for producing comparable accounts on the environment and its relationship with the economy (UNSD, 2018). The SEEA framework follows a similar accounting structure to the System of National Accounts (SNA), which is the global standard to produce statistics on economic production and consumption, and for balance sheets that show capital assets. GDP is among the indicators that are derived from national accounts. The alignment of the SEEA framework with the SNA facilitates the integration of environmental and economic statistics. This allows understanding of the economic implications of changes in the environment using an internationally comparable measurement framework.

The SEEA sets out a framework to facilitate organising and combining spatial, environmental, and economic data into accounts. These can then be used to derive coherent indicators and descriptive statistics for monitoring the interactions between the economy and the environment, and the state of the environment. In so doing, this enables better informed decision-making (UNSD, 2018). At present, the SEEA consists of three parts:

1. The Central Framework (SEEA CF), which was adopted by the UN Statistical Commission in 2012 as the first international standard for environmental-economic accounting;

2. The Experimental Ecosystem Accounting (SEEA EEA) officially completed in 2012 and published in 2014, offering a synthesis of current knowledge in ecosystem accounting; and

3. Applications and Extensions of the SEEA, published in 2017, illustrating how the information derived from ecosystem accounting can be used in decision-making, policy review and formulation, and analysis and research.

Moreover, sub-systems of the SEEA framework elaborate on specific resources or sectors (e.g. energy, water, fisheries, land and ecosystems, and agriculture). These sub-systems are fully consistent with the over-arching SEEA, but provide further details on specific topics, and try to build bridges between the accounting community and the community of experts in each subject area.

Ecosystem accounting is a coherent and integrated approach to the measurement of ecosystem assets and the flows of services from these ecosystems into economic and other human activity (UN et al., 2015). Ecosystem accounting complements the accounting for environmental assets as described in the SEEA CF, where environmental assets are accounted for as individual resources (e.g. timber, soil, and water). In the SEEA EEA, the ecosystem accounting approach recognises that these individual resources function in combination within a broader system, and includes a set of indicators on ecosystem state and functioning. Furthermore, ecosystem accounting also includes regulating and cultural services, which are not explicitly considered in
the SEEA CF. Conversely, the SEEA CF also includes non-renewable assets, such as oil and gas, and mineral resources, as well as data on economic activities in the environment sector including environmental expenditure.

The alignment with the national accounts, as described in the SNA, distinguishes ecosystem accounting from various ecosystem valuation approaches that build on the Millennium Ecosystem Assessment. These include processes such as The Economics of Ecosystems and Biodiversity (TEEB) and more recently the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES) frameworks. Advantages of such alignment include a consistent set of definitions for key concepts. In addition, it facilitates the application of a coherent valuation approach and avoids double counting, and allows the comparison of outputs from the ecosystem accounts with economic statistics measured in the national accounts. However, this also means that ecosystem accounts typically do not consider welfare values and are not designed to support social cost-benefit analyses which would normally be based on a broader set of values. Ecosystem accounting builds upon the broad range of literature in the field of ecosystem services and ecosystem monitoring, recent insights in spatial modelling and the increasing availability of spatial data, and the advances made with natural capital accounting in the statistical and environmental economic communities – including earlier work by the European Environment Agency (EEA, 2011).

The ecosystem accounting approach described in the UN SEEA EEA framework (UN et al., 2014) has been tested and advanced in the recent white cover publication ‘Technical Recommendations in support of the System of Environmental-Economic Accounting 2012-Experimental Ecosystem Accounting (UN, 2017). It has been applied in a range of case studies in various countries including Australia (ABS, 2015) and the Netherlands (Remme et al., 2014, 2015; CBS/WUR, 2016). It has also been used in support of the UK National Ecosystem Assessment. In recent years, more and more European Member States, including France, Germany, Italy, Spain, and Ireland, have initiated their own ecosystem accounting initiatives to test and advance ecosystem accounting work.

A formal review process commenced in 2017; this seeks to update the SEEA EEA by 2020. It takes into account all relevant conceptual and practical developments of recent years, and intends to set up the first international statistical standard for ecosystem accounting. This process is undertaken with the support of the statistical, research, and academic communities involved in ecosystem-related measurement and analysis work (UNSD, 2018).

3.1 Description of the different accounts and links between them

The main distinguishing features of the ecosystem accounting approach are the following (as adapted from UN et al., 2015):

- The SEEA EEA includes accounting for the changes in ecosystem condition (including changes in biodiversity) and the flows of ecosystem services. Often, measurement of these two aspects of ecosystems is undertaken in separate fields of research.
The SEEA EEA encompasses measurement in both biophysical terms (e.g. hectares, tonnes) and in monetary terms, where flows of ecosystem services are ascribed monetary valuations through various market and non-market valuation techniques. The valuation of ecosystem services also supports the valuation of ecosystem assets.

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

The SEEA EEA provides a broad, cross-cutting perspective on ecosystems at a 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, in order to enable integration with the economic overview obtained from the national accounts.

The SEEA EEA approach consists of five core accounts, four thematic accounts, and four integrated accounts (see Table 3.1 for an overview of the core accounts). Typically, information is produced both in maps and in tables, where physical or monetary information may be aggregated for administrative or physical units.

**Table 3.1: Overview of SEEA EEA core accounts**

<table>
<thead>
<tr>
<th>Account</th>
<th>Definition</th>
<th>Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem asset accounts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecosystem extent account</td>
<td>Records ecosystem types which are defined on the basis of aspects such as land cover, soils, hydrology and ecosystem use.</td>
<td>The extent of temperate deciduous forest</td>
</tr>
<tr>
<td>Ecosystem condition account</td>
<td>Reflects the state and functioning of ecosystems, as expressed in a range of indicators covering aspects such as vegetation, soils and hydrology.</td>
<td>Percentage organic matter in topsoil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level of fragmentation of forest ecosystems</td>
</tr>
<tr>
<td>Ecosystem monetary asset account</td>
<td>Indicates the net present value of the expected flow of ecosystem services over a discount period and for a given discount rate.</td>
<td>The Net Present Value (NPV) of the contribution of all ecosystem services of a specific ecosystem type to the economy</td>
</tr>
</tbody>
</table>
### Ecosystem service accounts

| Supply and use table | Physical terms                                                                 | Reflects the flow of ecosystem services, expressed in various physical units, during an accounting period (typically one year). | Amount of timber produced in Boreal coniferous forests  
Amount of air pollutants filtered out of ambient air by vegetation |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem service supply and use table – in physical terms</td>
<td>Reflects the flow of ecosystem services, expressed in various physical units, during an accounting period (typically one year).</td>
<td>Water purification services valued using replacement costs</td>
<td></td>
</tr>
<tr>
<td>Ecosystem service supply and use table – in monetary terms</td>
<td>Water purification services valued using replacement costs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thematic accounts complement the core system of accounts within the overall SEEA EEA framework. They provide specific information on land (cover, use, land-cover change and/or ownership), carbon (stocks and flows, including sequestration in vegetation and soils, and emissions from ecosystems), biodiversity (species relevant for biodiversity conservation and/or for ecosystem functioning), and water (stocks, flows and uses, in line with the SEEA Water Framework). The issue-specific focus of these accounts corresponds to the approach set out in the SEEA CF and facilitates their development.

These integrated accounts combine information from the core accounts and the various other accounts of the SNA in order to provide an integrated picture of ecosystem-economy interactions. Typically, they do not require new data to be collected. However, they do require data to be integrated from diverse sources with models from different scientific disciplines. Integrated accounts feature:

1. **Combined presentations** which bring together information on ecosystems and the economy without requiring the estimation of ecosystem services and assets in monetary terms
2. **Extended supply and use table** which supports the analysis of extended supply chains and the integration of ecosystem services to form extended economic production functions
3. **Institutional sector accounts** which provide the means by which standard aggregates of income and production can be adjusted for ecosystem degradation
4. **National and sector balance sheets** which provide the framework for extended measures of wealth, incorporating the value of a complete range of ecosystem services embodied in ecosystem assets (UN, 2017)
4. INCA work – Achievement and work in progress

4.1 INCA approach to natural capital accounts

INCA works in line with the UN SEEA EEA (see Figure 4.1), and proposes how the approaches to accounting can be improved, based on experience from within the EU. The Technical Recommendations of SEEA EEA put forward proposals on how to develop accounting tables of ecosystem extent, condition, and service supply and use. Associated to these accounts are thematic accounts of land, water, carbon, and biodiversity.

INCA is currently developing and testing pilot accounts for ecosystem extent and ecosystem services, and will also include ecosystem condition.

*Figure 4.1 Connections between ecosystem and related accounts and concepts (UN 2017). The accounts on which INCA has focused during the first phase are indicated with a red circle.*
4.2 Ecosystem extent accounts

Ecosystem extent accounts are a core component of the SEEA EEA; they are used to track the spatial distribution and trends in ecosystems. They show the stock of different ecosystem types at the opening and closing of the account in a spatially explicit manner (e.g. in ha or km²). Calculating the accounts requires that an appropriate typology for ecosystems within a given territory to be used, in order to allow the delineation of different ecosystem types. In INCA, the selection of land cover classes was adapted to reflect the MAES ecosystem typology, and the accounts themselves were calculated on the basis of CORINE (Co-ORDinated INformation on the Environment) Land Cover (abbreviated as CLC). The following sub-sections present the methodology and key results for the ecosystem extent accounts. Further results are available in a dedicated working report of the European Environment Agency (EEA, forthcoming).

4.2.1 METHODOLOGY FOR EUROPEAN ECOSYSTEM EXTENT ACCOUNTS

INCA proposes a three-tier approach to the development and compilation of ecosystem extent accounts in Europe. The Tier I Ecosystem Extent Accounts are calculated using CLC groupings that correspond to the MAES ecosystem typology. Tier II is calculated on the basis of individual CLC classes that have a particular environmental interest. 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. These nine ecosystem types are based on aggregations of the 44 CLC Level 3 classes.

The Tier II ecosystem extent accounts are compiled in a way that they can be matched to ecosystems of special policy or management interest (e.g. those of iconic status or conservation focus). These accounts are intended to provide an improved understanding of trends in broadly similar ecosystem types. For example, in the management of natural areas, there may be interest in understanding what is happening to forests and semi-natural areas as a group (CLC Level 1), or forests specifically (CLC 2), within certain accounting areas of interest.

The disaggregated Tier II ecosystem extent accounts are calculated on the basis of CLC level 3 classes, which may 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 2.4.4 (‘Agro-forestry areas’) matches well with a specific type of ecosystem mainly found on the Iberian Peninsula (called ‘Dehesa’ or ‘Montado’), which has developed due to a traditional land use that mixes the exploitation of oak trees with cropping and/or grazing.

In the coming years, 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 (on the basis of combining the CLC & EU Nature Information System (EUNIS) habitat classifications). This would allow a further differentiation of MAES ecosystem types into EUNIS...
habitat types. Figure 4.2 sets out the relationship between the CLC data and the three tiers of the ecosystem extent accounts proposed.

**Figure 4.2: Structure for European ecosystem extent accounts**

### 4.2.2 RESULTS FOR TIER I EUROPEAN ECOSYSTEM EXTENT ACCOUNTS

This section presents the Tier I ecosystem extent accounts, calculated using the MAES typology at the European scale (EEA-39). Table 4.1 and Table 4.2 show the changes in ecosystem extent for the periods 2000 to 2006, and 2006 to 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, and the extent that is stable (opening extent minus reductions). This information is presented in the rows of Table 4.1 and Table 4.2. The data for each ecosystem type is organised in the columns, and is aggregated to a total in the final column of Table 4.1 and Table 4.2. The total extent stays the same for both opening and closing periods for 2000, 2006, and 2012 (5,857,028 km$^2$). Although not unexpected, this demonstrates that the accounts are internally consistent, with the extent of different ecosystem types consistently aggregating to the same EEA-39 accounting area.

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1 EEA-39 consists of the members of the European Environment Agency (EU-28, Iceland, Liechtenstein, Norway, Switzerland and Turkey), as well as, six collaborating countries: Albania, Bosnia and Herzegovina, Kosovo, the Republic of North Macedonia, Montenegro and Serbia.
TABLE 4.1: TIER I ECOSYSTEM EXTENT ACCOUNT, EEA-39 COUNTRIES, 2000-2006

<table>
<thead>
<tr>
<th>MAES ECOSYSTEM TYPES</th>
<th>1 Urban</th>
<th>2 Cropland</th>
<th>3 Grassland</th>
<th>4 Forest</th>
<th>5 Heathland and shrub</th>
<th>6 Sparsely vegetated land</th>
<th>7 Inland wetlands</th>
<th>8 Rivers and lakes</th>
<th>9 Marine inlets and transitional waters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem extent 2000</td>
<td>226,332</td>
<td>2,040,801</td>
<td>654,756</td>
<td>2,009,111</td>
<td>380,712</td>
<td>347,227</td>
<td>129,640</td>
<td>140,842</td>
<td>21,962</td>
<td>5,858,028</td>
</tr>
<tr>
<td>Reductions to initial ecosystem extent</td>
<td>1,952</td>
<td>10,991</td>
<td>3,395</td>
<td>48,096</td>
<td>2,803</td>
<td>2,458</td>
<td>635</td>
<td>318</td>
<td>73</td>
<td>69,872</td>
</tr>
<tr>
<td>Additions to initial ecosystem extent</td>
<td>8,359</td>
<td>6,601</td>
<td>1,713</td>
<td>49,134</td>
<td>790</td>
<td>1,094</td>
<td>144</td>
<td>978</td>
<td>110</td>
<td>69,872</td>
</tr>
<tr>
<td>Net additions to ecosystem extent (additions - reductions)</td>
<td>6,407</td>
<td>-3,430</td>
<td>-1,383</td>
<td>41,088</td>
<td>-1,013</td>
<td>-474</td>
<td>-691</td>
<td>660</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>Net additions as % of initial extent</td>
<td>+2.8</td>
<td>0.2</td>
<td>-0.3</td>
<td>+0.1</td>
<td>-0.4</td>
<td>-0.1</td>
<td>-0.1</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Total turnover of ecosystem extent (reductions + additions)</td>
<td>10,311</td>
<td>7,652</td>
<td>5,309</td>
<td>97,180</td>
<td>2,593</td>
<td>4,442</td>
<td>779</td>
<td>1,296</td>
<td>183</td>
<td>139,744</td>
</tr>
<tr>
<td>Total turnover as % of initial extent</td>
<td>6.6</td>
<td>0.9</td>
<td>0.8</td>
<td>8.8</td>
<td>0.9</td>
<td>8.8</td>
<td>1.3</td>
<td>0.6</td>
<td>0.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Stable ecosystem stock</td>
<td>224,180</td>
<td>2,097,811</td>
<td>651,160</td>
<td>1,961,005</td>
<td>278,909</td>
<td>344,814</td>
<td>129,005</td>
<td>140,524</td>
<td>28,489</td>
<td>5,765,231</td>
</tr>
<tr>
<td>Suf ecosystem stock</td>
<td>99.1</td>
<td>99.5</td>
<td>99.5</td>
<td>97.6</td>
<td>99.4</td>
<td>99.3</td>
<td>99.5</td>
<td>99.8</td>
<td>99.7</td>
<td>99.4</td>
</tr>
</tbody>
</table>

A summary of the results reported in Table 4.1 and Table 4.2 is provided in Figure 4.3, 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 and green figures to the right of the bars). Figure 4.3 reveals that urban ecosystems show the highest relative increase in extent between 2000 and 2012 (5.1 % based on an opening extent in the year 2000 of 226,332 km²). These increases represent the largest increases in absolute extent of any ecosystem type in the EEA-39.
Figure 4.3: MAES Ecosystem extent and relative change, EEA-39, 2000-2012

Figure 4.3 also shows the extent of river and lake ecosystem increases between 2000 and 2012 (1.2% based on an opening extent of 140,842 km²). The increase in the extent of rivers and lakes between 2006 and 2012 (+984 km²) observed in Table 4.2 also represents the second largest net increase in any ecosystem extent over this period. Figure 4.3 shows that forest and woodlands exhibit a small net increase between 2000 and 2006 (+0.1%), although Table 4.1 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 2000 to 2012 accounting period.

Figure 4.3 reveals declines in extent for 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 to grassland (>650,000 km²). Inspection of Table 4.1 and Table 4.2 also reveals that, with the exception of cropland, these two ecosystems exhibit the largest reductions in extent in absolute terms between 2000 and 2006 (-1,883 km² and -1,013 km², respectively), and 2006 and 2012 (-1,476 km² and -668 km², respectively).

For cropland, Figure 4.3 reveals a decline in ecosystem extent of 0.5% between 2000 and 2012 (equivalent to 9,277 km²). However, the opening and closing stocks of this ecosystem remain substantial and in excess of 2 million km². Figure 4.3 also shows that the extent of marine inlets and transitional waters remains, essentially, constant over the 2000 to 2012 accounting period.

4.2.3 Results for Tier I ecosystem extent accounts in and outside of Natura 2000 areas

The ecosystem extent accounts compiled at the European scale provide a broad picture of the status and changes of ecosystems in Europe. The European Environment Agency’s integrated data platform, and associated tools to support the calculation of ecosystem extent accounts in
Europe, allows the calculation of extent accounts for a manifold of geographical aggregations of interest that can inform policy or management objectives. To illustrate, this section presents Tier 1 Ecosystem Extent Accounts for Natura 2000 sites across Europe.

Information on the spatial distribution of Natura 2000 sites was derived from the spatial data submitted by Member States and validated by the European Environment Agency². These data are available and downloadable in GIS format at a resolution of 1ha x 1ha. This information was aggregated to 1km x 1km in order to merge with the Land and Ecosystem Accounting (LEAC) database. These data processing activities allow the potential of Natura 2000 coverage to be presented as hectares per 1km². As shown in Figure 4.4, the distribution and size of Natura 2000 sites are varied, with Spain, northern Scandinavia, and eastern European Member States displaying larger and more connected Natura 2000 sites than central European countries. This is particularly noticeable in Germany, where there are many small, scattered Natura 2000 sites.

![Potential N2k sites by cells of 1 km²](https://www.eea.europa.eu/data-and-maps/data/natura-8#tab-gis-data)

**Figure 4.4: Percentage share of Natura 2000 sites per 1 km² grid cell in 2012**

In order to analyse ecosystem trends within the Natura 2000 network, an ecosystem accounting area was defined based on 1 km² grid cells with a very high presence of Natura 2000 sites (i.e. 81 to 100 ha per km²). Table 4.3 presents a Tier 1 Ecosystem Extent Account for this area, covering the period 2000 to 2012.

**Table 4.3: Tier I ecosystem extent accounts for areas with very high Natura 2000 coverage, 2000-2012**

<table>
<thead>
<tr>
<th>Ecosystem extent 2000</th>
<th>1 Urban</th>
<th>2 Cropland</th>
<th>3 Grassland</th>
<th>4 Forest</th>
<th>5 Heathland and shrub</th>
<th>6 Sparser vegetation</th>
<th>7 Inland waters</th>
<th>8 Rivers and lakes</th>
<th>9 Marine Inlets and transitional waters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>97,532</td>
<td>62,759</td>
<td>30,659</td>
<td>1,602</td>
<td>910,213</td>
<td>3,345,553</td>
<td>1,508,961</td>
<td>3,219,454</td>
<td>20,232,734</td>
<td>21,906,196</td>
</tr>
<tr>
<td>Reductions to initial extent</td>
<td>8,204</td>
<td>63,843</td>
<td>37,746</td>
<td>442,099</td>
<td>50,934</td>
<td>53,806</td>
<td>12,134</td>
<td>2,031</td>
<td>1,175</td>
<td>671,972</td>
</tr>
<tr>
<td>Additions to initial extent</td>
<td>24,849</td>
<td>57,170</td>
<td>29,602</td>
<td>473,242</td>
<td>24,809</td>
<td>43,110</td>
<td>2,867</td>
<td>10,841</td>
<td>5,006</td>
<td>671,972</td>
</tr>
<tr>
<td>Turnover (Additions + Reductions)</td>
<td>33,053</td>
<td>121,013</td>
<td>67,408</td>
<td>513,341</td>
<td>75,743</td>
<td>56,916</td>
<td>14,821</td>
<td>12,872</td>
<td>1,720</td>
<td>1,343,944</td>
</tr>
<tr>
<td>as % of initial surface</td>
<td>+5.5</td>
<td>+1.0</td>
<td>+0.8</td>
<td>+2.9</td>
<td>+1.1</td>
<td>+3.1</td>
<td>+0.4</td>
<td>+0.5</td>
<td>+0.8</td>
<td>+1.9</td>
</tr>
<tr>
<td>Net change (additions - reductions)</td>
<td>16,645</td>
<td>-6,673</td>
<td>-8,084</td>
<td>13,143</td>
<td>-26,125</td>
<td>-10,696</td>
<td>-9,447</td>
<td>8,810</td>
<td>-1,470</td>
<td></td>
</tr>
<tr>
<td>as % of initial surface</td>
<td>+2.8</td>
<td>-0.1</td>
<td>-0.1</td>
<td>+0.1</td>
<td>-0.4</td>
<td>-0.3</td>
<td>-0.3</td>
<td>+0.3</td>
<td>-0.5</td>
<td>+0.0</td>
</tr>
</tbody>
</table>

Table 4.3 clearly identifies that forest and woodland ecosystems contain the highest area of Natura 2000 sites. From a policy perspective, it is useful to compare ecosystem extent accounts for areas of high Natura 2000 site density, and areas where there are no Natura 2000 sites. This will identify if there are fundamental differences in ecosystem condition between these areas, and if the Natura 2000 designations are associated with limited net changes and turnovers in ecosystem extent. To this end, Table 4.4 presents a Tier 1 Ecosystem Extent Account for the area containing zero Natura 2000 sites (comprising 314,441,385 ha) for the period 2000 to 2012.

**Table 4.4: Tier I ecosystem extent accounts for areas with zero Natura 2000 coverage, 2000-2012**

<table>
<thead>
<tr>
<th>Ecosystem extent 2000</th>
<th>1 Urban</th>
<th>2 Cropland</th>
<th>3 Grassland</th>
<th>4 Forest</th>
<th>5 Heathland and shrub</th>
<th>6 Sparser vegetation</th>
<th>7 Inland waters</th>
<th>8 Rivers and lakes</th>
<th>9 Marine Inlets and transitional waters</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>624,149</td>
<td>11,604,819</td>
<td>8,042,627</td>
<td>31,381,585</td>
<td>8,669,698</td>
<td>3,072,127</td>
<td>3,341,280</td>
<td>2,799,411</td>
<td>1,911,944</td>
<td>70,189,649</td>
</tr>
</tbody>
</table>

Source: EEA – CEC2012 accounting layers
Table 4.4 reveals that cropland ecosystems are the most common ecosystems in areas with no Natura 2000 sites. It would be expected that areas with high concentrations of Natura 2000 sites would exhibit lower net changes in ecosystem extent. Figure 4.5: Net changes in ecosystem extent in areas of high and zero Natura 2000 coverage, 2000-2012 summarises the information on relative changes in ecosystem extent provided in Table 4.3 and Table 4.4. Figure 4.5: Net changes in ecosystem extent in areas of high and zero Natura 2000 coverage, 2000-2012 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 4.5: Net changes in ecosystem extent in areas of high and zero Natura 2000 coverage, 2000-2012 still reveals that the extent of all these ecosystems has nevertheless declined, accompanied by an increase in the extent of urban, and river and lake ecosystems.

![Net changes in ecosystem extent in areas of high and zero Natura 2000 coverage, 2000-2012](image)

**Figure 4.5: Net changes in ecosystem extent in areas of high and zero Natura 2000 coverage, 2000-2012**

### 4.3 Ecosystem condition accounts

Most work on ecosystem condition at the EU level has been developed under the MAES process in an ecosystem assessment context. For the purpose of the MAES work, ecosystem condition is usually used as a synonym for ‘ecosystem state’ (MAES, 2018). It embraces legal concepts (e.g. conservation status under the Birds and Habitats Directives, ecological status under the Water Framework Directive, and environmental status under the Marine Strategy Framework Directive) as well as other proxy descriptors related to state, pressures, and biodiversity. Therefore, ecosystem condition is an important concept that should be used to assess trends and set targets related to the improvement of environmental health.
The third MAES report (‘Mapping and assessing the condition of Europe’s ecosystems: progress and challenges’, Erhard et al., 2016) discussed the question of how to assess ecosystem condition. This report suggests that ecosystem condition can be assessed through two approaches: indirectly via an analysis of pressures acting on ecosystems; and directly by tracking habitat condition, biodiversity, and environmental quality.

Building on the above, the MAES working group delivered a special report on ecosystem condition in 2018 (Maes et al., 2018). 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 technical recommendations: “ecosystem condition reflects the overall quality of an ecosystem asset in terms of its characteristics”. Indicators of ecosystem condition may therefore 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, because they reflect, for example: 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. attractiveness of the landscape for tourism). Generally, in a fully spatial approach, different ecosystem types require different indicators.

Taking into account the SEEA EEA technical recommendations, and based on an inclusive approach led by the European Commission involving the consultation of experts, policymakers, and stakeholders, 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 5th 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 time, and across each ecosystem type. It is anticipated that the MAES indicator framework for ecosystem condition will be applied using real data in 2018-19, with a view to deliver an integrated assessment of the state of ecosystems and their services in the EU in 2019.

The challenge in the INCA context is to provide a bridge from the comprehensive analysis of important ecosystem condition indicators per ecosystem type, to the operational condition accounts that will, at least initially, focus on a selection of the indicators identified in the MAES process.

**Box 4.1 Thematic ecosystem condition accounts**

**Species accounts:** The first thematic accounts for biodiversity, which can support ecosystem condition accounting in the EU, were developed in 2017. These used data supplied by Member States under the reporting obligations of the EU Habitats and Birds Directives (collectively the Nature Directives). A number of different accounting constructs were developed and tested using this data. For example,
comparing the indicators derived from the accounts using all data, focusing on species groups (e.g. Common Birds) and disaggregating data to the ecosystem typology developed under MAES. These accounts were found to provide a useful foundation for informing on policy objectives in the EU. Most importantly, they support an integrated approach to ecosystems management in order to achieve the goals of the EU Biodiversity Strategy for habitats and birds in the context of other land use concerns (UNEP-WCMC, 2017).

One key limitation for these accounts is their ability to support detailed spatial analysis at sub-national scales. Further experimentation with data reported under the Birds Directive, identified that information on distribution could be used to support accounting for suitable habitat condition. However, spatial disaggregation of statistics on bird and species status derived from the Nature Directives was not possible beyond national or biogeographical scales.

To further develop a spatial and integrated accounting approach, work is ongoing during 2018 to test approaches using geo-referenced data on bird species observations.

**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) (Erhard et al., 2016). These previous approaches all have different limitations however, hence work is ongoing to prepare a European spatial nutrient balance as part of EU ecosystem condition accounts.

A pilot account is foreseen to be developed by the end of 2018, utilising a number of different input datasets, 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 CAPRI agro-economic model. The CAPRI model approach includes the provision of supported stable releases (updates) to ensure accessibility for the scientific and user community. The results, intended for use in the spatial EU nutrient balances, 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 datasets that will allow a regular update of EU ecosystem accounts in the future.

**Water quality:** Water quality represents a key condition indicator for lakes, rivers, and coastal ecosystems and their ability to deliver ecosystem services. The assessment of freshwater ecosystem condition, and the impacts of trends in condition on freshwater ecosystem services, has been an area of substantial focus in the MAES work on ecosystem condition, and other work, such as that of Grizzetti et al. (2016), for example.

Within the EU, achieving good status (or condition) of water bodies is a legal requirement for Member States under the Water Framework Directive (WFD). This includes rivers, streams, lakes, estuaries, coastal waters, and groundwater. The directive has a six-year water quality monitoring and reporting cycle, where water bodies are classified according to whether their status is: high; good; moderate; poor; or bad. This classification relates to ecological, chemical, and biological status, and provides a rich dataset for informing water quality accounting in the EU.
The information collated via the WFD reporting processes on water quality has the potential to be organised in a spatial accounting framework to help inform on the condition of rivers. There are a number of dimensions over which this data can be organised and reported, including by river segment, Strahler stream order (a numbering system which assigns a hierarchy to river segments from source to final stretches), river flow, river length, and by catchments. All of these spatial arrangements can be supported by the information reported on under the WFD, and by the wider spatial data infrastructure for the European Catchment and Rivers Network System (ECRINS), maintained by the European Environment Agency. In order to explore the potential for the WFD to inform ecosystem accounting, the European Environment Agency has implemented a project to test different accounting applications using WFD reporting data.

4.4 Ecosystem Service Accounts

The general approach of the INCA ecosystem service accounts is to quantify supply and use tables for ecosystem services and link these to the different tables for the benefits (La Notte et al. 2017b). illustrates the relationship between ecosystem units and the benefits they provide through the flow of ecosystem services. Different drivers have different levels of potential to bring about ecosystem change, such as extent and condition. For example, land-cover changes and environmental management practices can instigate change, which can be good or bad, and, in turn, this can change the potential of ecosystems to supply services.

Supply and use tables report the actual use of ecosystem services in physical or monetary terms. Supply tables describe how much of a service is generated by different ecosystem types. And use tables assign these quantities to different economic sectors. The Common International Classification of Ecosystem Services (CICES) is used as classification system for ecosystem services within the work of the INCA.

**Drivers of change**
- Land cover flows: main flows of LC changes
- Land management practices: main use of ecosystems and their services

**Ecosystem unit**
- ecosystem types which provide the service (following the MAES ecosystem typology)

**Ecosystem service**
- **Potential**: total amount of ES that can be provided or used in a sustainable way
- **Use**: actual flow of the service which is used

**Benefit**
- what society receives from the service

**Beneficiaries**
- actors who receive the benefit

**Human inputs that process/act on the product**
The INCA approach to populate the accounting tables is based on the mapping of ecosystem services. In essence, both ecosystem service potential and demand are mapped, and the intersection between both maps is used to estimate the actual use of the service. Taking pollination as an example, a map of pollination potential (e.g. Zulian et al. 2013) is used to depict where in the landscape is suitable to support pollinating insects, providing conditions for them to thrive. Additionally, a map of pollination demand is used to show where farmers have planted crops (e.g. rape seed), fruit and vegetables which are dependent upon pollinators. The overlay between both of these maps can then be used to reveal where pollination as a service is realised, and therefore provides a benefit for farmers. The service provided can be expressed in several possible units, but usually it is expressed as the share of the total yield (e.g. tonnes/ha) derived from insect pollination activities. In turn, this quantity can be used to estimate the monetary value of pollination, and it can be reported in the supply use tables.

It is important to realise that spatial models are used to estimate ecosystem service potential, demand, and use at large spatial scales. Ideally, sampling or monitoring data of pollinating insects should be used to estimate total population sizes. This would enable analysis of the effectiveness of pollination activities, and to locate where agricultural crops are situated in relation to populations of pollinators. The Land Use and Land Cover Survey (LUCAS) is an example of such a sampling programme at a large spatial scale, but it does not include a component on bee monitoring. Hence, there is reliance upon models to estimate how much pollination service is provided. Using models in this way always involves uncertainty, so it is important to acknowledge this fully.

An advantage of using maps and models is that we can also assess different indicators, such as ecosystem service potential, which relates to the amount of service that can theoretically be supplied from an ecosystem. Supply and use tables can provide information on how much of a service is used by which economic sector, but they cannot reveal if an ecosystem service is used at a rate which exceeds the natural capacity of the source ecosystem to generate it. Or in case of services such as air filtration and water purification, emissions of pollutants should not exceed the capacity of ecosystems to assimilate or remove them. Comparing ecosystem service potential with use, in particular if there is a risk of overusing an ecosystem service, is essential to provide information on the sustainable use of natural resources. However, such an assessment necessitates the application of models.

To date, INCA has developed three pilot ecosystem service accounts at the EU level: water purification, pollination, and outdoor recreation. These are described below.

An experimental account for water purification is fully described by La Notte et al. (2017a). For this account, nitrogen is used as an indicator. A pan-European model has been used to estimate how much nitrogen is in freshwater ecosystems, as reducing nitrogen concentrations in rivers and lakes improves water quality and reduces coastal eutrophication. Next, using replacement costs, the physical flow was converted to a monetary estimate. Households, industry, traffic, and agriculture are important emitters of different forms of nitrogen pollution.
Experimental accounts for crop pollination and recreation at the EU level have been developed by Vallecillo et al. (2018). A conceptual approach to crop pollination is explained above and has been used to calculate pollination potential, demand, and use. Accounting for cultural services, such as recreation also involves mapping ecosystem service potential and demand (Figure 4.7). In this context, maps of ecosystem service potential are used to show where ecosystems with a high potential to accommodate different recreational activities are situated in the landscape and how close they are to populations of likely beneficiaries. If it is assumed that across Europe a certain fraction of people enjoy outdoor recreation, then a map of demand for recreation can simply be approximated against population maps. Assessing both service potential and demand is a first step to assessing the use of the service, but this alone is not sufficient. An understanding of the proximity of areas for recreation is also required. For example, an offshore, unpopulated island could be considered as having high potential for recreation, but given its inaccessible nature, there are few beneficiaries that will ever realise this potential, and as such, in reality this service is limited. Importantly, the demand for outdoor recreation has different forms. People need nearby ecosystems such as urban green spaces, forests, or nature reserves for daily activities such as jogging, walking, or cycling. But there is also an important demand for outdoor recreation which requires long distance travelling; for instance, visits to national parks, or hiking in the mountains. Assessing and valuing outdoor recreation has to consider these different types of recreation because the valuation techniques for long and short distance recreation may differ. Moreover, the possible policy uses of short and long distance recreation accounts differ as well. For example, offering citizens’ recreation opportunities in nearby urban and rural green space requires an availability of dense, well-connected and high quality natural areas, managed at municipal or regional level. In contrast, the provision and management of long-distance outdoor recreation sites requires coordination at higher governance level. Currently, INCA has developed a short-distance recreation account, which estimates the value of ecosystems with a high recreation potential for daily use.
Two studies (La Notte et al., 2017a and Vallecillo et al., 2018) were used to populate a supply and use table at the EU level. It is important to stress that the table is an experimental account and that the numbers reported in this table are conditional on the specific methods used and described in the original studies. The table is thus subject to further refinement. Furthermore, it will be progressively updated with data for other ecosystem services once they become available during the course of the INCA project.

**Table 4.5: Experimental ecosystem service accounts: supply and use tables for three ecosystem services at the EU level for the year 2000.**

<table>
<thead>
<tr>
<th>Ecosystem services</th>
<th>Economic sectors</th>
<th>Ecosystem types</th>
<th>Supply (billion €, year=2000)</th>
<th>Use (billion € year=2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop pollination</td>
<td></td>
<td>Urban</td>
<td>2.67</td>
<td>2.67</td>
</tr>
<tr>
<td>Water purification</td>
<td></td>
<td>Cropland</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grassland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor recreation</td>
<td></td>
<td>Heathland and shrub</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Woodland and forest</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sparsely vegetated land</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wetlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rivers and lakes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coastal areas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* For simplicity, this supply use table does not contain a products section.

The supply and use table (Table 4.5) presents the flows of ecosystem services from 9 (out of the 12) MAES ecosystem types (Maes et al., 2013) to a number of aggregated economic sectors. The table can easily be extended for more ecosystem services and can host a more detailed description of the economy by breaking the current classes down over more detailed sectors.

Table 4.5 reports flows in monetary units, but these data are based on a biophysical assessment. Similar tables can be made using physical data, such as the total yield derived from crop pollination, the total amount of nitrogen which has been removed, or the number of visits to areas for recreation. The advantage of monetary units is that they can be summed to
assess total values across ecosystem types\(^3\). However, it should be noted that ecosystem services have other values which are often not captured in the accounting tables.

For pollination and water purification, the supply use table can be read in a simple way. Freshwater ecosystems (rivers and lakes) provide water purification services worth 13.8 billion Euros (for the year 2000). In the supply section of the table, this value is assigned to the tertiary sector (in this case, water companies). A similar reading for pollination suggests cropland utilises pollination services with a total value of 2.67 billion Euros which is used by the primary sector. Clearly some more detail is needed here to provide more nuance and context to these numbers. Pollination services are supported by habitats adjacent to croplands, which provide pollinator populations with foraging and breeding habitats, such as forest edges, hedgerows, scrub, field margins. In addition, the model used to assess pollination potential also includes information about the distribution of certain pollinator species. Such information is lost during aggregation. In addition, the use table contains an aggregated number, but data are available to break down the benefits to more specific sub-sectors within the broader agricultural sector. The estimate for water purification also contains considerable simplifications. Most importantly, in addition to nitrogen, there are several further important pollutants, the removal of which also has a value, which is not included in this figure. Furthermore, several other ecosystem types, most importantly wetlands also have a significant contribution to the maintenance of freshwater quality. The allocation of the aggregated figure to each contributing ecosystem type is, nevertheless, similarly difficult as in the case of pollination.

The supply section of Table 4.5 for outdoor recreation contains more details than for the other services as it provides separate estimates per ecosystem type. Woodland and forest is the ecosystem type which contributes most to short-distance daily recreation. The aggregated use of this supply is assigned to households, but, again, more detailed statistics can be made available, such as the share of the population which has access to nearby ecosystems for daily recreation.

Whilst there is little doubt about which ecosystem produces which service, a proper assignment of values in the use table is still the subject of debate. Considering water purification, ecological processes such as nitrogen uptake by algae, and denitrification by bacteria in the anoxic layers of the sediment are well known and contribute to the water purification service of freshwater ecosystems. But who is benefitting from the service? In Table 4.5 the use of water purification is assigned to the tertiary sector (drinking water companies). The argument is that they realise important savings in their operating costs incurred to produce safe drinking water, and thus benefit from the service. Part of the pollution associated to the use of nitrogen is simply cleaned up by rivers and lakes. Therefore, it is important to indeed experiment with these

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\(^3\) Assessment methodologies may change over time; as such, assessments from different years may not be readily comparable, and any changes that affect comparability should be acknowledged. Equally, different assessments conducted for the same year using different methodologies may produce different results.
accounts and see what the impact of assigning use values is when integrating natural capital accounts in the system of national accounts (La Notte and Marques, 2017).

These accounts can also be produced for extended timeframes, for example over several years, so that, in principle, trends on the supply and use of ecosystem services can be derived. However, the timeliness of input data still presents a major bottleneck to produce and update ecosystem service accounts. The CORINE land cover land use dataset is a key resource for the experimental ecosystem service accounts presented in Table 4.5. These data are updated only once every six years. But the accounts are also dependent on several other data layers (including nitrogen data, population, species distributions, linear landscape elements, or hydrological data), and the production of these layers is not necessarily aligned with the CORINE data cycle. Clearly this puts a constraint on the regular production of accounts.

4.5 Links between condition and services

The MAES conceptual model (Figure 4.8) shows in a simple way how ecosystem condition and ecosystem services are connected⁴. Ecosystems need to be in good condition to provide a set of essential services which, in turn, deliver benefits and increase well-being. Drivers of change can have a positive (e.g. conservation) or negative (pressures) impact on ecosystem condition.

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⁴ Figure 4.8 is a simplified MAES conceptual model and is based on Grizzetti et al. (2016). The full conceptual model is presented in the first MAES report (Maes et al., 2013) and highlights the underpinning role of biodiversity. The simplified version of Figure 4.8 has been used to guide the 5th MAES report on ecosystem condition (Maes et al. 2018).
important to estimate how many different ecosystem services, and at which levels, it can deliver. Keeping everything else constant, a wetland of 100 ha has the potential to remove more pollutants from the water, store more carbon, and provide more habitat for waterfowl than a wetland ten times smaller. But wetland condition is important as well. A wetland which possesses its full functionality provides more ecosystem services per unit area than a wetland in a degraded state. So both ecosystem quantity and quality determine the variety and levels of ecosystem service delivery. Pressures on wetlands which either decrease the extent, such as land take, or which degrade the water quality, such as pollution, therefore have an impact on ecosystem services through ecosystem extent and ecosystem condition.

In the following example, these relationships are made more explicit, and it is discussed how they will eventually appear in ecosystem accounts. The example, pollination, is based on the pollination account published by Vallecillo et al. (2018). Pollination of crops, such as fruits and vegetables, is an essential ecosystem service to ensure food production in farmland. Pollination is predominantly delivered by pollinating insects, such as bees and butterflies. Flower-rich grasslands and forest edges are typical habitats inside farmland-dominated landscapes which host these insects. Keeping agro-ecosystems in good condition is thus important to maintain pollination services.

Figure 4.9, taken from the 5th 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 which are proposed to measure the condition of agro-ecosystems. In turn, these condition indicators are important for the quantification of the levels of pollination which 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 bring about upon ecosystem condition.
Natural Capital Accounting: Overview and Progress in the European Union

**Figure 4.9: Relations between Pressure, Condition, and Pollination in an Agro-ecosystem** (adapted from Maes et al., 2018). 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 all details see Maes et al., 2018.

Now consider the pollination model which has been used by Vallecillo et al. (2018) to make a pollination account (Figure 4.10). As a first step, Vallecillo et al. (2018) calculated pollination potential by mapping the total area of ecosystem that is available to supply pollination services at a low, medium, or high level. This map was then overlaid with a map of demand for pollination, set by different crop types, to assess the actual use of pollination and to fill the supply and use table of the pollination account.

**Figure 4.10: Data used in the pollinator potential model for mapping purposes** (Vallecillo et al. 2018).

Here the focus of interest turns to how pollination potential is mapped, so as to help understand how ecosystem condition can influence the delivery of pollination services. Figure 4.10 explains the data used in the mapping of pollination potential. In brief, the account is based on different thematic maps of land cover and land use, as well as climatic data.

Five indicators which are proposed to assess the condition of agro-ecosystems (printed in bold in Figure 4.9), are also used in the model to calculate pollination potential (Figure 4.10): land conversion, climate change, fragmentation, semi-natural areas, and species richness. These indicators influence directly or indirectly the pollination potential of ecosystems, and thus the final supply and use of the service recorded in the accounts.

**Land conversion** is considered whenever land-cover and land-use data are used in the pollination potential model. Any impact of land-use change between two years has a direct impact on the service delivery and is therefore, reflected in the accounts. It follows that there is a direct link between the ecosystem extent account and the supply and use tables of the ecosystem service account.
Climate change is considered indirectly, as the pollination potential model uses temperature and precipitation (and to a lesser extent, solar irradiance) to model bee activity, and to model the distribution and species richness of bumblebee species.

Species richness itself is also a condition indicator which is used in the pollination model. Higher species richness is assumed to increase the pollination potential of an ecosystem.

Fragmentation is indirectly included in the model through the road network. Traffic on major roads causes insect mortality. Roads are thus assumed to have a negative impact on pollinating insects.

Finally, semi-natural areas are used in the model as their presence or proximity are known to enhance populations of pollinators.

Some indicators for pressure and ecosystem condition are not (yet) used in the pollination potential model. For instance, the use of pesticides which are harmful for pollinating insects reduces pollination potential. However, the absence of spatially-resolved data of pesticide use, the unavailability of temporal data (which is a crucial requirement for accounting), or difficulties in upscaling results of local case studies, currently limit the inclusion of pesticides in the model for pollination potential. Therefore, in this case, the presumed link between the pressure, condition and service is not made explicit in the model and will not yet be reflected in the current accounting framework.

Nonetheless, the pollination example makes clear that the three physical ecosystem accounts (extent, condition, and services) are coupled, even if all of the links are not yet included. Changes in the extent of ecosystem types which support pollinating insects, or in ecosystem condition, will result in changes in pollination potential, and hence, a change in the use of the service. This approach ensures that the accounts are internally consistent and that changes in one account are propagated in the downstream accounts.

4.6 Reporting system and data architecture

4.6.1 INTRODUCTION

KIP-INCA aims to test and implement an integrated accounting system for ecosystems and their services in the EU. One necessary activity in that regard is to connect relevant existing projects and data collection exercises to build up a shared platform of geo-referenced information on ecosystems and their services. The KIP INCA roadmap expresses that aim as follows (EC, 2016):

‘Ecosystem accounting depends on the availability of geospatial data that accurately describe the distribution and condition of ecosystems with sufficient resolution to capture small ecosystems. This means that a further investment is required at EU level to develop a shared data platform for the integration of ecosystem-related data at large spatial scale (<1:100 000) than currently feasible for a number of data sets. Such a shared data platform would be a key building block for operational EU ecosystem accounts but would also provide substantial value-added for other analytical purposes.'
The SEEA EEA handbook (UN et al., 2014) describes how to produce regular ecosystem accounts grounded in a spatially explicit and time series approach. As such, ecosystem accounting depends on the availability of geospatial reference data that accurately describe the distribution and condition of ecosystems and the services they deliver with sufficient resolution to capture both large and small ecosystems.

4.6.2 NATURAL CAPITAL REFERENCE DATA - STATE OF THE ART AND REQUIREMENTS FOR A REGULAR PRODUCTION OF ECOSYSTEM ACCOUNTING:

Reviews of available data sets on natural capital at EU level show that most statistical data collection exercises or environmental monitoring programmes do not focus on the ecosystem and biodiversity variables needed for ecosystem and ecosystem services accounting. In this context, it needs to be acknowledged that (based on Petersen and Steurer, 2016):

a) The current data foundation derived from statistical, environmental, earth observation and other sources was not developed for ecosystem accounting purposes and hence needs to be further developed to fit its requirements.

b) As a characteristic of ecosystems is their complex and often fine-grained geographic distribution any new or revised data gathering exercise needs to be built on geo-referencing of the data to be collected that is commensurate with the scale of the observation units.

c) Geographic information systems and a common geo-spatial reference frame will therefore play an important role in developing monitoring and accounting systems for natural capital.

d) Experience from other areas of statistics, such as demography, can be fruitfully harvested for developing a cost-effective and analytically powerful sampling frame for building a good knowledge base on natural capital.

e) Ecosystem service mapping is often based on modelling exercises, with different levels of complexity, that require a broad range of input data, mainly related to ecosystem extents and condition, but also with other relevant factors key for each specific service.

Furthermore, EU level experience on ecosystem accounting over the last 10 years indicates some key tenets in ecosystem accounting design that help steer the identification of the most promising data products and services for calculating the core bio-physical ecosystem accounts (relating to ecosystem extent, condition and services). In particular, ecosystem accounting reference data should ideally meet the following requirements:

- Provide regular temporal updates to properly detect signals of change;
- Be relevant to ecosystem typologies used in Europe (e.g., the MAES Typology and EUNIS system);
- Match key indicators on ecosystem condition identified in recent MAES work;
- Be comparable across all MAES ecosystem types to which they are applicable;
- Support an analysis of the link between ecosystem condition and service delivery;
- Be able to organise information at the scale of functional ecological units (water basins, mountain ranges, ecosystem types, etc.), e.g. by linking to the 1km grid used by the EEA as core accounting grid;
• Be harmonised, geo-referenced and quality assured;
• Updated on a regular basis & fully documented in published metadata files.

The analytical requirements listed above can be connected to concrete statistical criteria which are listed in Table 4.6 below.
TABLE 4.6: STATISTICAL CRITERIA FOR ECOSYSTEM ASSESSMENT AND ACCOUNTING REFERENCE DATA (ADAPTED FROM STATISTICAL CRITERIA FOR THE EU SDG INDICATORS)

<table>
<thead>
<tr>
<th>Criteria for EU level assessments</th>
<th>Preferred quality</th>
<th>Minimum quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of data production</td>
<td>Annual – every 3 years</td>
<td>Regular</td>
</tr>
<tr>
<td>Timeliness</td>
<td>T-1 year</td>
<td>T-3 years</td>
</tr>
<tr>
<td>Geographical coverage</td>
<td>Data available for all Member States</td>
<td>Member State data represent at least 50% of EU total</td>
</tr>
<tr>
<td>Comparability between countries</td>
<td>Data for all countries are comparable</td>
<td>Data comparable for Member States representing at least 50% of EU total</td>
</tr>
<tr>
<td>Comparability over time</td>
<td>At least 5 data points without methodological break</td>
<td>At least 2 data points without methodological break</td>
</tr>
<tr>
<td>Length of time series</td>
<td>&gt; 10 years</td>
<td>2 – 5 years</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>1 km² grid</td>
<td>10 km² grid</td>
</tr>
</tbody>
</table>

4.6.3 NATURAL CAPITAL DATA CHALLENGES ACROSS DIFFERENT EU LEVEL ACCOUNTING AND MONITORING EXERCISES

‘Natural capital’ is quite a broad concept that stretches across many different environmental themes. At the same time, many EU level environmental monitoring, assessment and accounting exercises are based on similar indicators relying on the same reference data sets. Hence it is important to cross-compare the input data sets required for different reporting and analytical purposes. Recent experience within MAES (MAES et al., 2018) and the monitoring of EU progress towards the SDGs (EC, 2017) have shown that many existing environmental indicators are not fit for purpose when it comes to supporting a regular monitoring and accounting and that there is a need for strengthening the existing environmental data foundation in order to being able to provide a more complete and sustained picture of the trend and state of ecosystems, their condition and the services they provide. Often currently available environmental indicators fail to meet several of the statistical criteria presented in table 1. The following areas show particular data insufficiencies that should be addressed:

- Distribution and condition of European terrestrial and marine ecosystems over a sufficiently long time period;
- Distribution and population trends of species, in particular for insects and plants over a sufficiently long time period;
- Intensity and distribution of key economic land uses, in particular agriculture and forestry over a sufficiently long time period;
- The spatial distribution and trends of key pressures on ecosystems (such as nutrient input, invasive alien species, chemical pollution, soil erosion) over a sufficiently long time period;
- For European marine ecosystems in general very little information is available on their condition, intensity of use and trends of key pressures;

4.6.4 OUTLOOK

While the current foundation for developing natural capital accounts at EU level as well as for environmental monitoring in general is not ideal there are opportunities for making progress by combining data in a spatial modelling environment, by improving the spatial referencing of statistical and other data sets. In addition, there are a number of instruments that could help improve the data foundation for natural capital accounting and environmental monitoring. These include: environmental reporting under EU Directives or national legislation, the EU Copernicus programme, strengthening of Citizen Science initiatives to record the presence and trends of certain species groups (such as for birds or butterflies), statistical surveys of economic sectors, information recorded during the implementation of the EU Common Agricultural Policy, the evolution of the LUCAS etc.

The second avenue for creating a better data foundation is to make the sharing of, and access to, data at different EU data producers more efficient. That is a key purpose of the proposed spatial data platform for KIP INCA. In the context of this objective, the KIP INCA partners have to agree on what elements of such a data platform should be developed and how far these elements should be shared. A key element is a shared structured approach that enables harmonized, quality controlled and quality assured storage, access and sharing of spatial data while allowing targeted search by environmental topics. Further elements of a spatial data architecture could address, among others, automation of workflows related to geo-processing scripts and models, servers, publishing and data integration, editing environments, and semantic inventories.

Box 4.2: Key objectives for developing a shared spatial data platform under KIP INCA:

- Aim is to develop a shared platform that is stable, ‘institutional’ and achieves full integration of systems and sharing data sets (as far as appropriate)
- Develop accounts underpinned by harmonised, geo-referenced and QA/QCd datasets
- Develop a semantic inventory of spatial datasets placing data in their context.
- Serve as common spatial reference framework; with a 1km grid as the core accounting grid
- Ensure transparency, traceability and accountability of the datasets and models used to compute the accounts
- Facilitate greater efficiency in sharing of spatial data and related joint analysis, thus enabling a pooling of resources between KIP INCA partners and synergies
- Achieve this making best use of the present capacity and resources
More and more attention is being directed towards tackling the existing natural capital data challenges and limitations. At EU-level the Commission has initiated an inter-service initiative to addressing the issue of building and improving a common data base for different assessments and monitoring exercises. It focuses on collating priority spatial data sets for the environmental sphere as well as for other domains such as regional policy and agriculture. A first list of environmental priority datasets has been established and will be reviewed during 2018.

By improving EU natural capital reference data under KIP INCA other EU level environmental assessment and monitoring exercises will benefit substantially as many data sets can be used for different analytical purposes. This will contribute to building a stronger data foundation for analysing ecosystem trends in Europe and managing ecosystems and their services better.

4.7 Still many issues to solve!
Natural capital accounting is a very technical and complex matter, although interest in it, and the community as a whole, is growing. The Technical Recommendations of the SEEA EEA (UN, 2017) represent an important source for organisations, countries, or businesses that want to keep track of the state and trends of the ecosystems they manage, impact, or depend on.

INCA is testing these recommendations and guidelines by developing EU-wide accounts on ecosystem extent, condition, and ecosystem services. By doing so, INCA is gaining the expertise to help find practical solutions to the many issues and technical difficulties that come with accounting.

Different ecosystem types are considered as the assets which provide essential services to the economy. However, they are mostly approximated by using land-cover and land-use datasets. An advantage of LULC datasets is that they are regularly updated, and thus are useful for accounting purposes, provided that uncertainty is well addressed when comparing maps over different points in time (La Notte et al. 2017b). A drawback, however, is that LULC data do not entirely capture the dynamics of ecosystems. For instance, species, which are the building blocks of an ecosystem, are not represented in land-cover maps. So more efforts are needed to create ecosystem maps (e.g. the map of ecosystem types in Europe\(^5\), or the ecosystem map of Italy (Blasi et al. 2017) with 43 different types), and also to regularly update them.

The 5\(^{th}\) MAES report on ecosystem condition has delivered a set of indicators which can now be quantified and presented in accounting tables (Maes et al. 2018). However, the report did not define reference conditions against which the past, present, or future condition of ecosystems can be evaluated. Previous studies which have assessed ecosystem integrity have compared the actual integrity against a reference value based on a pristine or historic reference situation. In cases where neither pristine conditions nor a historical reference could be found, statistical approaches and expert judgement have been used to set a reference. However, in many cases ‘natural’ reference conditions are difficult to define, and proposals result in substantial

scientific debate. It is particularly difficult to define a reference condition in social-ecological (or semi-natural) systems where people and ecosystems have been closely interacting for several thousand years to shape and co-produce ecosystems from which services are supplied. For example, agricultural ecosystems would not exist in Europe without human management. For that reason, the 5th MAES report opted to simply use a recent historic baseline as a pragmatic choice for a reference condition, and to evaluate condition against this baseline situation.

In addition, the development and testing of ecosystem service accounts is raising a number of issues, as summarised by La Notte et al. (2017b).

- As noted earlier in this chapter, actual flows of ecosystem services do not allow inferences to be made about the sustainable use of ecosystems. Ecosystems are often overexploited and this often cannot be observed based on the actual use of ecosystem services. Further work is needed to test how condition and capacity accounts can record the sustainable use of ecosystem services.
- The complementarity with the SEEA Central Framework should be tested. The SEEA EEA records provisioning services, such as timber and water, which are also recorded in the Central Framework. More clarity is needed too, in terms of reporting which data under which accounts (e.g. Central Framework versus EEA).
- The difference between SNA and non-SNA benefits need to be clarified (e.g. public goods from regulating and cultural services).
- Separating ecosystem services from benefits might require the definition of different categories of users. Specifically, in the case of sink-related services (e.g. mediation of wastes or toxic substances of anthropogenic origin), the actual flow of ecosystem services is determined by the enabling actors. Identification of these enabling actors allows the establishment of the causality nexus between the economic activities that modify the flow, and the changes in the flow of service.
5. SELECTION OF CASE STUDIES FROM MEMBER STATES

This chapter contains a set of highlights from a selection of Member States (MS), illustrating different approaches for establishing ecosystem accounts and the progress made to realising them. To further support Member States in the development of national ecosystem accounting, grants have been made available to national statistical offices, as well as through a support contract issued through DG Research and Innovation.

Seven Member States (BG, DE, FI, HR, IT, NL, UK) applied for the 2017 ESTAT Grant. The proposed MS projects (see Table 5.1) cover the working areas predefined by ESTAT: testing of monetary and physical ecosystem service accounts, pilot test ecosystem extent and condition accounts, improve and extend source data, build capacity and a community of practice and conduct conceptual work on proposed working areas. All MS projects will have a duration of 12 months.

**Table 5.1: Overview of proposed projects**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Country</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot test Ecosystem Extent and Condition Accounts in physical units</td>
<td>Bulgaria</td>
<td>The objectives of this project are to develop pilot test ecosystem extent and condition accounts, to improve existing data sources and to enhance capacity building through the establishment of a community of practice of national stakeholders. Final outputs will be a methodological report and a set of accounting tables.</td>
</tr>
<tr>
<td>Developing Ecosystem Services Accounts from Land Accounts</td>
<td>Denmark</td>
<td>The project will build ecosystem service accounts for 1-3 provisioning services (timber and crop production) based on an existing landcover map, which has been built as part of land accounts. Methods and tools for Ecosystem Service Accounts will be produced and documented in a report. Accounting results are planned to be disseminated.</td>
</tr>
<tr>
<td>Towards ecosystem accounting based on innovation and insights on natural capital knowledge</td>
<td>Finland</td>
<td>The project aims at identifying data sources and gaps for ecosystem accounting and to pilot test ecosystem services supply and use accounts in physical and monetary terms for three ecosystem services: Fish stock, carbon sequestration and recreation and nature-based tourism. Capacity building will be enhanced through workshops and meetings with national stakeholders. Deliverables will be monetary and physical ecosystem services accounts and a synthesis report of all pilot accounts, data availability and methodological work.</td>
</tr>
<tr>
<td>Assessment of ecosystem services provided by reed beds</td>
<td>Croatia</td>
<td>This project aims at assessing ecosystem services derived by different groups of reed beds in the Continental region, the Alpine region and the Mediterranean region in Croatia. A further objective is to provide capacity building for identified national stakeholders. The project builds on available datasets. Final products will be an ecosystem service assessment report, online published spatial data and leaflets.</td>
</tr>
</tbody>
</table>
Extending the condition accounts for the Netherlands

Netherlands

The project will develop an extended ecosystem condition account for the Netherlands. The work will comprise the development of core condition indicators and the development of condition indicators necessary to account for ecosystem services. The condition account and biodiversity account will be streamlined and the accounts will cover two time points: 2006 and 2013. Final output will be a report, covering the methodology applied, main results, data quality and future outlooks.

Project on Ecosystem Accounting in Italy

Italy

This project foresees to assess three ecosystem services: flood control, pollination and recreation. In addition, a spatially distributed hydrological model will be employed for including water-based ecological processes in the ecosystem service assessment. The final product will be a report, describing the methodology used, main results, data quality and future steps.

Ecosystem condition, extent and service accounts and restoration cost accounts for Mountain, Moorland and Heath and Peatland

UK

Building on a previous pilot project on restoration cost accounts for peatlands, this project aims at developing initial ecosystem extent and condition accounts, monetary and physical ecosystem service accounts and restoration cost accounts for Mountain, Moorland and Heath and Peatland in the UK. Final outputs will be two technical reports and two summary reports containing the developed ecosystem accounts and a description of the methodology used.

Also relevant is the MAIA (Mapping and Assessment for Integrated ecosystem Accounting) project. This aims to mainstream natural capital and ecosystem accounting (NCA) in EU Member States (MS). It relates to the work programme topic a) ‘Valuing nature: developing and implementing natural capital and ecosystem accounts in EU Member States and Associated Countries’.

MAIA uses the SEEA EEA as the methodological basis for NCA. In MAIA, a flexible approach will be followed, allowing for adaptation of the SEEA EEA framework to the conditions of the individual EU MS. The work will be based on the detailed, recent technical recommendations in support of Experimental Ecosystem Accounting (SEEA EEA TR), published by UN et al. (2017), recognising the experimental status of the SEEA EEA approach.

The specific objectives of MAIA are to: (i) assess policy priorities for accounting; (ii) test, pilot and mainstream NCA in EU MS; (iii) test innovative approaches for NCA in the European context; and (iv) support NCA in EU MS through various communication and dissemination activities such as the development of guidelines, a website and other facilitating actions.
5.1 Accounting Case Study: France

5.1.1 INTRODUCTION
Aichi Biodiversity Target 2 states that by 2020, ecosystem and biodiversity values need to be integrated into national and local planning, development processes, poverty reduction strategies and accounts. In France, there are currently no ecosystem accounts and there are no plans to develop ecosystem accounts \textit{per se} at the national level in the short term.

However, local experiments and some ecosystem-related accounts are being developed and France is reflecting on the potential uses of ecosystem accounts and their implication in terms of accounting methods in the context of its National ecosystem assessment (the EFESE program). This case study provides a non-exhaustive presentation of some on-going work.

5.1.2 FOREST STATISTICAL ACCOUNTS
The forest statistical accounts, generated from data between 2007-2014, are intended to provide for the follow-up of forestry resources and activities, both in physical and monetary terms. They are structured by a set of tables of accounts, consistent and harmonised at European level by the European Statistical office Eurostat. The last available version of accounts mainly contains information on wood production (including in the informal sector) and carbon sequestration (CGDD, 2018). Other important services such as recreation or water related services are absent from this accounting framework.
In complement, forest sustainable management indicators are regularly published and updated (MAAF et IGN, 2016). They contain a rich but less structured set of information on biodiversity and uses of forests in France.

5.1.3 CARBON ACCOUNTING OF THE LULUCF FOR THE UNFCCC

The LULUCF sector aims to monitor carbon fluxes (biomass and soil organic matter). Accounting for the emissions of this sector is a requirement of the UNFCCC. In France, the main flows are due to changes in land use (e.g. agricultural land converted to urban land), changes in agricultural practices (e.g. reduced or zero tillage in crops) or through long-term ecosystem dynamics (e.g. forest growth). Forest lands are particularly affected because of the high carbon stock of trees, litter and soil. Agricultural soils are also affected by the carbon content of soil organic matter. This sector does not cover emissions related to nitrogen fertilization, basic amendments and rearing which are part of the agricultural sector. The LULUCF sector accounts for both emissions and removals, and the net balance is negative in France i.e. it is a carbon sink (CiTEPA, 2017).

5.1.4 NEW WEALTH INDICATORS

In 2015, the French Government and National Institute of Statistics and Economic Studies (INSEE) adopted the ten ‘wealth indicators’ to monitor the state of the French economy and to implement a law which aims to consider new indicators of wealth in public policy. The indicators highlight three major themes of the public agenda: preparation for the future, social cohesion and quality of life. They include two environmental indicators: carbon footprint and land artificialization (land take). Since 2015, there is a yearly publication of these indicators.
that complement GDP (Prime Minister, The new indicators of wealth) and the impact assessment of reforms is considered in light of these indicators.

5.1.5 FRESHWATER ECOSYSTEMS ACCOUNTS

Some accounts have been experimented for freshwater ecosystems intending to measure unpaid ecological costs (Devaux, 2015). They estimate the costs that would have to be incurred for the conservation or restoration of a natural asset that has been damaged by human activities. These estimates could reflect the cost of ecosystem degradation and be interpreted as a form of ecological debt (Kervinio, 2018). In continuity with these experimental work, France supported a project that consists in developing an experimental system of ecosystem accounts for marine ecosystems at the national level that encompasses ecosystem extent and condition accounts which are both consistent with the SEEA-EEA and the French national regulatory frameworks, and a tentative economic assessment of the cost of ecosystem degradation.

5.1.6 MARINE ECOSYSTEM ACCOUNTING

A study by Martin et al. (2018) developed a method based on accounting principles which aims at providing estimates for the benefits for households from cultural ecosystem services at the local level. Specifically, the authors considered six types of recreational activities in the gulf of St Malo, France: onshore fishing and shellfish gathering; hiking; recreational boating and offshore fishing; canoeing and kayaking; light sailing; scuba-diving and underwater fishing. Results indicated that national accounting systems only capture 3% of the output of marine recreational activities. This highlights that recreational services that depend only on human activities need to be distinguished from other cultural ecosystem services which depend on outputs from ecosystem processes in order to avoid any overestimation of services (Martin et al, 2017). The production value of recreational activities was 210m-276m €, of which 89m€ is for immediate consumption (purchase of intermediate products), 98m € for the remuneration of unpaid work and 23m € for the consumption of fixed capital (depreciation of produced capital). About 82% of production means are devoted to the consumption cultural ecosystem services, while the remaining part of the production value is assigned to the consumption of sportive services. Hence, the production value associated to the main uses of marine cultural ecosystem services can be estimated at between 172 and 226M€, with respective value-added of 110M€ and 154M€. This highlights that recreational services that depend only on human activities need to be distinguished from other cultural ecosystem services which depend on outputs from ecosystem processes in order to avoid any overestimation of services (Martin et al, 2017).

In addition, the study results showed that most recreational activities were carried out in a personal context (not through companies or associations), and are thus not reflected in the System of National Accounts, which only captures 3% of the output of marine recreational activities. This demonstrates the potential advantages of a household account for marine recreational activities.
Martin et al. (2018) argue that such accounting values are more robust since they are based on current transactions and observed values rather than hypothetical values. Finally, they propose to include them in an ecosystem satellite account which could aim at describing the complex interactions between human activities and ecosystems by combining physical and monetary values. He argues that the accounting values in their ecosystem satellite account are more robust since they are based on current transactions and observed values rather than hypothetical values. However, there are some pending challenges including the fact that the current state of knowledge does not permit the construction of all physical indicators for all ecosystem services (Martin et al., 2018).

### 5.2 Germany

In Germany, work on natural capital accounting is still at an exploratory stage with an initial focus on physical and monetary accounts for urban ecosystem services (recreation and amenity values), natural soil fertility and biodiversity, no full ecosystem or ecosystem service accounts have been produced yet.
5.3 Environmental Accounting in Italian Marine Protected Areas

To oversee the state of natural capital nationally, Italy has established a Committee for Natural Capital (CCN), which is chaired by the Minister of the Environment, the protection of the Territory and the Sea (MATTM), and composed of 10 ministers, the National Association of Italian Municipalities (ANCI), the Conference of the Regions, 5 public research institutes and 9 subject matter experts appointed by the MATTM. Two key activities being undertaken in Italy are the development of a yearly Natural Capital Report and experimental accounts.

The Annual Reports provide a measure of physical and economic dimensions of Natural Capital stocks and flows, following the methodologies defined by the United Nations and the European Union, as well as ex ante and ex post assessment of the effects of public policies on Natural Capital and Ecosystem Services. In 2018, Italy published the Second Report on the state of Natural Capital in Italy that includes a project promoted by the Italian Ministry for the Environment on an environmental accounting system for Italian Marine Protected Areas (MPAs).

5.3.1 THE DEVELOPMENT OF EXPERIMENTAL ACCOUNTS

Marine Protected Areas (MPAs) play an important role in achieving global conservation targets. However, their development is often faced with conflict, where economic development and conservation are opposed. Restrictions on human activities (e.g. fishing, boating, mining and tourism) brought in by the MPAs can cause tension with local people, who rely heavily on the natural environment for their livelihood and wellbeing (Lopez et al., 2015). As such, MPAs require appropriate design and management to allow for the sustainable use of marine resources (Edgar et al., 2014; Ruiz-Frau et al., 2015).

Environmental accounting can be used to assign value to aspects of ecosystem services and natural capital in MPAs – especially allowing for the assessment of multiple aspects together, which can be used to aid management and decision-making. There has been much debate over assigning value to the environment – a report by UNEP-WCMC (2011) and references therein discuss the pros and cons of the different methods specifically in relation to marine and coastal ecosystems. Emergy Accounting (Odum, 1988, 1996) has been developed, which is a “donor-side” assessment that measures natural and human-made capital, through valuation of its cost of production in terms of the biophysical flows used to support its generation (Ulgiati et al., 2011; Franzese et al., 2017). It takes into account free environmental inputs (e.g. solar radiation, wind, rain and geothermal flow), human-driven flows, and indirect environmental support embodied in human labour and services (Brown & Ulgiati, 2004). Inputs are defined in terms of their solar energy, i.e. the total amount of solar energy available (exergy), directly or indirectly required to make a given product or support a given flow, and measured as solar equivalent Joules (sej).

In 2014, the Italian Ministry of the Environment and Protection of Land and Sea financed a 4-year research programme based on the implementation of an environmental accounting
system in all Italian Marine Protected Areas (see Figure 5.2 for approach employed). The main goal was the assessment of the ecological and economic value of the MPAs, with reference to the natural capital stocks and ecosystem services generated in each protected area, in addition to the human activities carried out. The results from these were complemented by other environmental accounting methods using a multi-criteria and multi-scale assessment framework. The conclusions drawn from the project sought to aid both managers and decision-makers in the preservation of areas targeted by conservation effort (Franzese et al., 2015; Franzese et al., 2017).

**Figure 5.2:** Flowchart of proposed methodological approach employed to implement an environmental accounting system in all Italian Marine Protected Areas (Franzese et al., 2015).

### 5.3.2 Natural Capital Assessment

Outlined by Vassallo et al. (2017), the natural capital assessment calculates the stock of autotrophs and heterotrophs in the habitats of the MPA. Natural flows supporting biomass production in the MPA are calculated as described by Odum (1996), and accounted for the time of stock formation. Inputs are converted into emergy units using UEVs, and the total emergy value of natural capital of the MPA is calculated.

### 5.3.3 Environmental Flows Assessment

The environmental flows assessment was based on the biomass database of taxonomic groups used in the natural capital assessment. The biomass density of each autotrophic group was converted into annual primary production, and consumption by heterotrophic groups was calculated. These values were used to produce the annual consumed carbon flow, which were subsequently combined with nutrient and natural flows and converted into emergy units to
assess the total annual emergy flows supporting the natural capital in each habitat and across the whole MPA.

5.3.4 MONETARY AND SPATIAL ASSESSMENT
The emergy value of natural capital and environmental flows can be transferred into monetary values, which can be used to aid decision-making. In addition, the natural capital values can be spatially plotted using a GIS tool, which provide context to the different values of the habitat types. This can help identify areas where natural capital stocks are highest, and to develop management strategies to ensure their preservation (Franzese et al., 2017).

5.3.5 CONCLUSIONS
The highest value of emergy density when assessing autotrophic natural capital was found to be the habitat *Posidonia oceanica* seagrass bed, and the sciaphilic (shade-loving) hard bottom habitat (coralligenous) showed the highest heterotrophic habitat. As such, the coralligenous habitat was highlighted to be one of the most important hotspots of species diversity within the Mediterranean Sea. By combining the results of this study with the MPA zonation map revealed that areas with high biophysical and monetary values were largely not included in the ‘A Zone’ (Figure 5.3), which had been established to afford the highest levels of protection to priority habitats and species. Information derived from studies of this type, and presented in easily communicable approaches can assist both local managers and policy makers alike to meet conservation targets and to undergo continued development in a sustainable fashion (Franzese et al., 2017).
Figure 5.3: Spatial distribution of natural capital value in the MPA. Darker red areas represent higher concentration of natural capital stocks. (SB = soft bottom, PSB = Posidonia oceanica seagrass bed, SHB = Sciaphilic hard bottom (coralligenous bioconstruction), and PHB = Photophilic hard bottom (covered by algal turf); A zone = “no-take/no-access zone”, B zone = “general protection zone”, and C zone = “partial protection zone”). Taken from Franzese et al. (2017).

5.4 National Natural Capital Accounting in the Netherlands

The motivation for the development of national NCAs in the Netherlands has been to contribute to initiatives at different scales which aim to improve the quality of life in the Netherlands. In 2016 Statistics Netherlands and Wageningen University started a three-year project ‘Ecosystem Accounting for the Netherlands’ on behalf of the Dutch Ministries of Economic Affairs and Infrastructure and the Environment. The study produced the first biophysical ecosystem service supply and use accounts for the Netherlands, following the SEEA EEA guidelines. This was built on a pilot study for Limburg province by Statistics Netherlands and Wageningen University (de Jong et al., 2015).

The biophysical supply and use accounts record the flows of ecosystem services from ecosystems to society and identify the economic beneficiaries of these services. It is one of the core ecosystem accounts and provides the basis for the monetary ecosystem service supply and use account.

5.4.1 THE DEVELOPMENT OF ECOSYSTEM SERVICE MODELS

Spatial models were developed for a set of ecosystem services, in order to assess the supply of ecosystem services for various areas in detail and represent the spatial heterogeneity of ecosystem service provision throughout the Netherlands. These spatial models were largely developed by the research team, based on existing methods and datasets (e.g. Remme et al., 2014), or by developing new methods. The data for the models originated from multiple Dutch institutes, including Wageningen University and Research, RIVM and Statistics Netherlands. The Ecosystem Type map, developed by Statistics Netherlands for the purpose of accounting, was used as input for multiple ecosystem service models and to analyse biophysical ecosystem service supply per ecosystem type.

Figure 1. Ecosystem Type map for the Netherlands in 2013.

Based on current data availability, experience from the previous pilot study for Limburg province and discussions with the Dutch Ministry of Economic Affairs, the Ministry of Infrastructure and Environment and other stakeholders, they selected 13 ecosystem services aiming to represent all 3 main ecosystem service categories from CICES (CICES, 2017). These included: crop production, fodder production, wood production, biomass from non-agricultural sources, drinking water, carbon sequestration in biomass and soil, pollination, natural pest control, erosion control, air filtration, protection against flooding due to heavy rainfall, nature recreation (hiking), nature tourism.
5.4.2 BIOPHYSICAL ECOSYSTEM SERVICE SUPPLY-USE TABLE

A biophysical ecosystem service supply table was developed for all spatially modelled ecosystem services, to account for supply per ecosystem type and per Dutch province. In addition, accounts were set up for the total quantity of an ecosystem service provided by an ecosystem or a province, as well as the mean quantity provided per hectare. The supply tables show which (and how much) ecosystem services are provided by each ecosystem type. For example, non-perennial crop land produces not only crops (93% of the total Dutch production) and fodder (59%), it also provides air filtration (11% of the total), and cultural services (recreation 8%, tourism 18%).

<table>
<thead>
<tr>
<th>Table 5.2: Example supply table: Biophysical ecosystem service supply account 2013 for the Netherlands, with total biophysical supply per ecosystem type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem service</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Crop production</td>
</tr>
<tr>
<td>Harvest production</td>
</tr>
<tr>
<td>Biomass production</td>
</tr>
<tr>
<td>Drinking water production</td>
</tr>
<tr>
<td>Carbon sequestration in biomass</td>
</tr>
<tr>
<td>Air filtration</td>
</tr>
<tr>
<td>Protection against heavy rainfall</td>
</tr>
<tr>
<td>Recreation</td>
</tr>
</tbody>
</table>

Two basic approaches were used to produce the physical supply account. First, for some services such as crop production and drinking water extraction a ‘top-down’ approach was used. This involves a spatial disaggregation of information that is already in the SNA. Second, for other services such as carbon sequestration and erosion control, a ‘bottom-up’ approach was used. This approach was used for services that are not in the SNA, and for which national aggregates were obtained by aggregating local information based on various models.
The biophysical supply tables show that forests and agricultural land supply the highest total quantities of ecosystem services, mainly because these ecosystem types cover the largest extents. More natural ecosystem types (e.g. dunes, heath and deciduous forest) supply higher average quantities of ecosystem services (per ha) compared to less natural ecosystem types.

5.4.3 BIOPHYSICAL ECOSYSTEM SERVICE USE TABLE
A biophysical use table was developed representing all modelled ecosystem services. To populate the use tables, beneficiaries were identified as the users of the ecosystem service, not the final produced good (i.e. the farmer uses crop related ecosystem services, not the consumer that buys the processed produce). For this, the classification of the International Standard Industrial Classification of All Economic Activities (ISIC) was followed, supplemented by additional sectors that are essential in an ecosystem services use account (i.e. households, government) and adding a Global Goods category. This last category applies when an ecosystem service is not used by specific (national) users but by the (global) community, for example carbon sequestration.

The main user groups were identified per ecosystem service and the supply totals were attributed to the relevant users, identifying which economic sectors are the most important users. The ISIC sector Agriculture, forestry and fisheries uses the most ecosystem services (seven), followed by households (four).
5.4.4 POLICY APPLICATIONS
Throughout the development of the accounts, the Ministry of Economic Affairs, the Ministry of Infrastructure and Environment, and a stakeholder group were consulted to better understand the uncertainties and accuracy of the accounts; these discussions are still ongoing as the Dutch ecosystem accounting project continues. The applicability of the information from the accounts for policy use varies, in particular depending on a number of factors, such as how the information is made available, the availability of time series data, and the spatial scale of the data. A number of policy applications have been identified for the accounts:

- Identifying important ecosystem types that supply services and important user groups who might be affected by a change in supply of services and should be involved in decision-making processes.
- Supporting spatial planning at different scales, e.g. national, provincial or municipal infrastructure projects, by showing areas which provide a high number of ecosystem services
- The accounts show the specific contributions that different (economic) sectors receive from different ecosystems, and – once the monetary accounts have been developed (in 2018) – the costs of converting these ecosystems to other uses.
- The accounts present opportunities to move towards (and monitor) a circular economy, for example where additional biobased materials can be sustainably harvested and therefore where flows from the ecosystems to the economy can be increased without depleting the ecosystem.
- The accounts facilitate comparison between different parts of the country, e.g. identifying areas that are particularly successful in protecting natural capital, or extracting revenue from natural capital. However, the information from the accounts must be put in context and will require more than just information on supply and use.
- The biophysical supply and use tables should be analysed together with other accounts, such as condition accounts, biodiversity accounts, asset accounts, and monetary supply and use tables.

5.4.5 SUMMARY
This was the world’s first national scale ecosystem services supply and use accounts developed in line with the UN SEEA Ecosystem Accounting methodology. The results from the biophysical supply and use account can be used for multiple policy applications, providing information for spatial planning, developing a circular economy, and assessing particular sectors, and providing a basis for monitoring existing policies. Additionally, the ecosystem service models can be used for other accounts including the monetary supply and use account and the ecosystem asset account. The high level of detail and expected regular repetition of the accounts provides the possibility to assess supply and use from national to local level and monitor changes over time.
The project identified several recommendations for improvements which can be applicable to other countries under taking their natural capital accounts. These include:

- There should be more effort devoted to developing the use account as the supply account is generally more advanced.
- Ecosystem service use has now generally been attributed to a single user group, while in practice other user groups may also profit.
- The contribution of goods and services (in biophysical units) to the Dutch economy can be analysed, however, true integration (i.e. connecting natural capital and national accounts) requires their analysis in monetary terms as well.

5.5 Use of ecosystems services and natural capital accounting in decision-making - Scotland

5.5.1 INTRODUCTION

The Scottish Government is committed to protecting and enhancing Scotland’s natural capital. That commitment is reflected in Scotland’s Economic Strategy\(^7\) and National Performance Framework\(^8\). The National Performance Framework sets out the Scottish Government’s vision for Scotland, how actions will improve the quality of life for the people of Scotland, and an extensive set of measures to track progress. The measure used to track Scottish Government’s performance on natural capital in the National Performance Framework is Scotland’s Natural Capital Asset Index, which is described below.

The Scottish Government has also been at the forefront of the international dialogue about natural capital. Scotland has hosted the World Forum on Natural Capital three times since 2013; and in 2017 hosted with the Dutch Government the inaugural meeting of the Government Dialogue on Natural Capital\(^9\).

A supplement to Scotland’s Biodiversity Strategy was published in 2013 which discusses the importance of taking into account ecosystem services in decision-making, and in natural capital accounting. It describes a set of principles for sustaining the value of Scotland’s natural capital, one of which is that “The value of natural capital assets should be incorporated into national accounting and business accounting to ensure this is fully considered in assessing the effectiveness and sustainability of Government and business.”\(^{10}\) The Scottish Government’s

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\(^8\) [http://nationalperformance.gov.scot/](http://nationalperformance.gov.scot/)

\(^9\) The Government Dialogue on Natural Capital, brings governments together to discuss their role in creating an enabling environment for natural capital approaches.

Land Use Strategy also stresses the importance of taking an ecosystems approach to the management of natural capital.\footnote{Getting the best from our land: A Land Use Strategy for Scotland 2016-2021 \url{https://www.gov.scot/Topics/Environment/Countryside/Landusestrategy}}

5.5.2 NATURAL CAPITAL ASSET INDEX

Scotland was the first country in the world to produce a Natural Capital Asset Index (NCAI), which was first published by Scottish Natural Heritage (SNH)\footnote{Scottish Natural Heritage is the Scottish Government’s adviser on all aspects of nature and landscape across Scotland.} in 2011. The NCAI is part of Scotland’s National Performance Framework and its inclusion reflects the high level importance which the Scottish Government accords the protection and growth of natural capital.

The NCAI analyses the quality and quantity of terrestrial habitats, according to their potential to deliver ecosystem services now and into the future. The NCAI assesses the potential to provide ecosystem services for 28 main land cover types. It then assesses the quality and extent of these habitats using 38 indicators and changes in land cover (see Figure 1). The NCAI does not include monetary values nor does it measure the marine environment.
The NCAI is an index, and takes a value of 100 in the base year, 2000. The index can be used to show changes through time in the Scotland’s potential to deliver ecosystem services compared to the base year. For example, Figure 2 shows that the index has grown slightly over the past 15 years and now is at its highest level since 2000, recovering from a low in 2012.

The headline index can be broken down into seven component habitat types (see Figure 3). Figure 3 shows that woodland and inland surface water habitats have improved significantly over the period 2000-2016. Over the same period there has been a decline in agriculture and cultivated habitats. Some of the factors which explain these changes through time are, for example: a significant increase in the quantity of broadleaved deciduous woodland in Scotland (woodland habitat); improvements in the ‘ecological status’ of rivers and lochs (inland surface...
waters habitat); and habitat extent loss (agriculture and cultivated habitat). A fuller range of factors is set out in the literature supporting the NCAI\(^\text{13}\).

\section*{Figure 5.6: Scotland’s Natural Capital Asset Index, 2000-2016 \textit{Source: Scottish Natural Heritage}}

One of the strengths of the NCAI is that it can be used to model the effect of land use change on ecosystem services. The Scottish Government and SNH are exploring the possibility of using the NCAI model to forecast changes in natural capital that result from policy changes. Work is underway to strengthen the index, such as exploring the scope to include the marine environment in the NCAI.

\subsection*{5.5.3 Natural Capital Accounts for Scotland}

The United Kingdom Office for National Statistics (ONS) produces natural capital accounts for the UK. In response to a request from the Scottish Government, the ONS is currently working on developing a set of accounts for Scotland which will include the stock and flow of specific habitats or ecosystem services.

\footnote{https://www.nature.scot/sites/default/files/2018-04/Scotland\%27s\%20Natural\%20Capital\%20Asset\%20Index\%20-%20Information\%20Note\%202018.pdf}
This work will produce a monetised set of natural capital accounts for Scotland. It will provide physical and monetary flow accounts for at least ten ecosystem services; as well as monetary ecosystem asset accounts which measure the value of the stock of Scotland’s natural capital. Both physical (non-monetary) accounts and monetary valuations will be presented in a time series to monitor change over time.

The natural capital accounts will complement and be consistent with the NCAI. The Sustainable Development Goals will also be considered to ensure consistency with wider global frameworks.

These accounts, along with the NCAI will help the Scottish Government to better understand and to raise awareness of the value of our stock of natural capital, and may help ensure that the impacts of Government decision-making on the environment can be more readily identified.

5.5.4 TESTING THE NATURAL CAPITAL PROTOCOL WITH LAND BASED BUSINESSES

Crown Estate Scotland\(^\text{14}\) recently led a partnership study which trialled ecosystem accounting. As part of its work to put Scotland at the forefront of developing new ways of managing land and the environment, the trial applied the Natural Capital Protocol to three land-based businesses on two estates in Scotland, managed by Crown Estate Scotland.

The Natural Capital Protocol aims to support better decisions by focusing on how businesses interact with nature. It seeks to help businesses measure, value and integrate natural capital into business processes by providing a standard framework through which businesses can structure their thinking about natural capital.

The study found that:

- Natural capital assessments – which help to define the value of natural assets – are especially useful for individual farmers and landowners
- Tenant farmers who took part found the Protocol useful in improving their understanding of different kinds of natural capital on their farms and how they impact on their businesses
- All participants felt that the Protocol would help in improving economic and environmental performance and resilience, and that it helped link existing tools and schemes

Scottish Natural Heritage is also looking to explore a natural capital accounting approach to their land, including nature reserves, which may assist with decision-making, communicating the value of non-market benefits, and engaging with local communities.

\(^{14}\) Crown Estate Scotland manages land and property on behalf of Scottish Ministers. It works with people, businesses and organisations to ensure that the assets are managed in a sustainable way that creates prosperity for the Scotland and its communities.
The Scottish Government’s Land Use Strategy highlights two pilot projects which demonstrated the use of an ecosystems approach to inform decision-making. The pilot projects were set up to test the practicality of preparing regional land use frameworks as a means of guiding local decision-making. The aim of the project was to pilot a mechanism which considers existing and future land uses in a collective and integrated way, and to establish a means to prioritise or guide decisions so as to optimise the use of the land, and to resolve competition or conflicts relating to land use change. \(^{15}\)

### 5.5.5 STRATEGIC ENVIRONMENT ASSESSMENT

In Scotland, all public bodies and some private companies\(^ {16}\) are required to assess, consult and monitor the likely significant impacts of their plans, programmes and strategies on the environment. This process is known as Strategic Environmental Assessment (SEA) and incorporates the requirements of the SEA Directive (Directive 2001/42/EC) which is implemented via The Environmental Assessment (Scotland) Act 2005.

The Scottish Government published “Integrating an Ecosystems Approach into Strategic Environmental Assessment\(^ {17}\)” in 2016. This information note sets out the potential benefits and valued added from taking an ecosystems approach when undertaking SEA, whilst acknowledging that not all SEAs of plans are suited to this approach. Where an ecosystems approach is integrated into a SEA, this can help decision-makers to look at the wider linkages between the plan’s actions and its impact on the environment, including how we value and use that environment.

The information note contains a number of Scottish case studies, including the SEA of the Scottish Government’s Land Use Strategy\(^ {18}\). The approach to this SEA was based on the consideration of potential impacts to the SEA topic areas, whilst also incorporating an understanding and consideration of ecosystem services and the linkages between the SEA topic areas. In this way, the approach to the SEA reflected the ambition of the Land Use Strategy to promote greater use of an ecosystems approach within land use decision making processes.

The information note also recognises that the principles of an ecosystems approach will be familiar for many SEA practitioners. For example, some Scottish SEAs already consider environmental effects in terms of ecosystem services, such as flooding regulation or the provision of water.

\(^{15}\) A full evaluation of the pilots is here: [https://www.gov.scot/Resource/0049/00492375.pdf](https://www.gov.scot/Resource/0049/00492375.pdf)
\(^{16}\) The private companies which are required to carry out an SEA are companies exercising functions of a public character (for example, utility companies).
\(^{18}\) [https://www.gov.scot/Topics/Environment/Countryside/Landusestrategy/LUS2consultation](https://www.gov.scot/Topics/Environment/Countryside/Landusestrategy/LUS2consultation)
5.6 Spain

5.6.1 ECOSYSTEM SERVICES ECONOMIC VALUATION AT NATIONAL LEVEL

The Spanish National Ecosystem Assessment (SNEA), supported by the Biodiversity Foundation of the Ministry of Environment, provides the first analysis at national level that evaluates the ability of the Spanish ecosystems and biodiversity to maintain our human well-being. It follows the initiative of the Millennium Ecosystem Assessment promoted by the United Nations. SNEA began in 2009, and completed its biophysical assessment in 2012 (SNEA, 2013) and during the last year has been carrying out an economic valuation of ecosystem services supplied by priority ecosystems in Spain (Santos-Martín et al., 2016). The aim of the economic valuation was to visualize the contribution that ecosystems and biodiversity make to human well-being, not only in ecological terms but also in economic terms.

The economic valuation has taken into account the different types of services (provisioning, regulating and cultural), and the various methodologies to estimate economic values (Figure 5.8). It is the first nationwide ecosystem services economic valuation, which also captures services outside conventional markets and include social and cultural aspects, for both use and non-use values.

![Figure 5.8: Methodological map used in the valuation of ecosystem services in Spain, in which one can see the different typologies of services derived from natural capital, and the different types of associated value according to the framework of Environmental Economy. Finally, the most appropriate methodologies for each case are presented for each case, and in blue one can see the services that have](image-url)
Table 5.3: Average economic value of the methods of valuation and the categories of services of the ecosystems expressed in €2012/year/ha; S.D: Standard deviation: Source (Santos-Martín et al., 2016).

<table>
<thead>
<tr>
<th>Provisioning services</th>
<th>N</th>
<th>Average value (€2012/year/ha)</th>
<th>SD</th>
<th>Minimum value (€2012/year/ha)</th>
<th>Maximum value (€2012/year/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>38</td>
<td>371.04</td>
<td>582.50</td>
<td>0.000052</td>
<td>1972.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regulating services</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation of natural disturbances</td>
<td>13</td>
<td>262.83</td>
<td>435.38</td>
<td>1.99</td>
<td>1364.45</td>
</tr>
<tr>
<td>Climate regulation</td>
<td>16</td>
<td>181.35</td>
<td>194.31</td>
<td>0.0023</td>
<td>528.44</td>
</tr>
<tr>
<td>Water purification</td>
<td>48</td>
<td>135.31</td>
<td>436.34</td>
<td>0.01</td>
<td>1970.31</td>
</tr>
<tr>
<td>Erosion control</td>
<td>29</td>
<td>31.99</td>
<td>44.29</td>
<td>0.87</td>
<td>234.72</td>
</tr>
<tr>
<td>Biological control</td>
<td>21</td>
<td>15.43</td>
<td>18.17</td>
<td>0.15</td>
<td>56.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cultural services</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational and ecotourism activities</td>
<td>117</td>
<td>186.36</td>
<td>364.07</td>
<td>0.44</td>
<td>1836.90</td>
</tr>
<tr>
<td>Aesthetic enjoyment of landscapes</td>
<td>47</td>
<td>84.84</td>
<td>372.99</td>
<td>0.41</td>
<td>1871.99</td>
</tr>
<tr>
<td>Satisfaction with conservation</td>
<td>42</td>
<td>6.26</td>
<td>16.29</td>
<td>0.12</td>
<td>100.03</td>
</tr>
</tbody>
</table>

A summary of the estimated average economic values for each service of the ecosystems is shown in Table 5.3. In general, food service was the most valued (371.04 €/ha/year; SD=584.50), followed by regulation of natural disturbances (262.83 €/ha/year; SD=435.38) and recreational ecotourism activities (186.36 €/ha/year; SD=364.07).

5.6.2 THE ‘NATURAL CAPITAL ACCOUNTING IN ANDALUSIA FOREST

In the context of forestry accounting, there is a long experience in Andalusia, in particular within the project RECAMAN coordinated by IPP-CSIC and funded by the Junta de Andalucia (Campos et al. 2017). This project developed a spatially-explicit extended ecosystem accounting framework which was applied in the Mediterranean forests of Andalusia (Spain). This framework goes beyond the production boundary of standard national accounting by considering four private activities (forestry, hunting, residential and private amenity) and six public activities (mushroom, carbon, water, recreation, landscape and threatened biodiversity). To keep valuation consistent with standard accounts, the project simulates exchange values for non-market goods and services (Caparrós et al., 2017). Manufactured capital and environmental assets are also integrated. RECAMAN constitutes the first attempt to measure, at a regional scale, forest ecosystem services, products, total income and environmental assets using an ecosystem accounting methodology, the “Agroforestry Accounting System” (AAS), which is consistent with the valuation criteria of standard accounts.
FIGURE 5.9: VALUE OF ECOSYSTEM SERVICES IN ANDALUSIAN FORESTS. SOURCE: CAMPOS ET AL. (2017)

5.6.3 SPANISH EXPERIENCE WITH SEEA EEA TO DATE

The Spanish national economic valuation of ecosystem services and the accounting experience at the regional level for the Andalusia forest brings together extensive experience including, for example: valuation ecosystem services, natural capital accounting, biodiversity assessment, mapping ecosystem services, environmental economics, the economics of biodiversity, environmental risks, undertaking surveys and statistics.

In the context of SNEA, 12 ecosystem services have been valued using different methods of valuation: 1) Food from agriculture, 2) Water for human consumption, 3) Gene pool (agrobiodiversity), 4) Climate regulation (carbon capture and storage), 5) Water purification (retention and elimination of nitrates and water quality), 6) Erosion control, 7) Natural disturbances (fire control), 8) Biological control, 9) Recreational service or nature tourism, 10) Local ecological knowledge, 11) Spiritual and religious feeling, 12) Aesthetic pleasure in landscape. For all these services, we have data at national level and for some of them we have maps showing the spatial distribution of values.

In the context of Andalusia, RECAMAN has valued and integrated in an accounting framework four private activities (forestry, hunting, residential and private amenity) and six public activities
(mushroom, carbon, water, recreation, landscape and threatened biodiversity). Spatially-explicit data and accounts are available for these activities for the part of Andalusia covered by forests and agroforestry lands (Campos et al., 2017; Caparrós et al., 2017).

In particular, Spain provides extensive experience in developing and applying the ecosystem approach and natural capital accounting. Although our past work, in particular in the case of the Andalusia, has not been done within the SEEA EEA framework, the accounting methodology developed in Andalusia is very close to the SEEA EEA framework and the differences between the two frameworks are clearly defined. Thus, the results obtained with our own methodology can be easily imported into the SEEA EEA framework.

5.6.4 EMBEDDING OF THE WORK IN ON-GOING RESEARCH PROGRAMS

This work will fit into an evolving international policy framework for compliance with a number of National obligations, conventions and agreements, including the following:

- Spanish biodiversity strategy
- European Biodiversity Strategy (2020)
- Intergovernmental Platform on Biodiversity and Ecosystem Services.
- Sustainable Development Goals
- Aichi targets

5.7 United Kingdom

In 2011, the UK National Ecosystem Assessment (NEA) was released, closely followed by the Natural Environment White Paper, which outlined the government’s vision for the natural environment over the next 50 years. The UK NEA was the first analysis of the benefits of the UK’s natural environment to society and economic prosperity (UK National Ecosystem Assessment, 2011). A number of changes to natural capital policy and management have since been made.

The UK NEA analysis assessed eight habitat types along with examples of the goods and services derived from each. It suggested that nearly a third (about 30%) of ecosystem services were declining, including soil quality and pollination. Many others were in a reduced or degraded state, including marine fisheries and wild species diversity. Reductions were associated with declines in habitat extent or condition, and changes in biodiversity.

One of the key actions was the establishment of a Natural Capital Committee.

5.7.1 NATURAL CAPITAL COMMITTEE

In 2012, the UK Government established the Natural Capital Committee as an independent advisory body, for a fixed period of three years. Later, the Natural Capital Committee was re-
established for a second period from 2016 to 2020. The role of the Natural Capital Committee includes:

- Incorporating natural capital into national accounts and making it policy-relevant
- Producing a manual with a step-by-step guide to using natural capital approaches in decision-making
- Helping mainstream natural capital across all decision makers (government, business, other) (Barter, 2017)

note: better to give all as references and not as hyperlinks, eg the manual

The UK was one of the first countries to apply the UN SEEA EEA guidance to its national context (ONS, 2015) and aim to include natural capital within national accounts by 2020. Work on natural capital accounting in the UK is set out in a set of roadmaps leading to 2020 and is overseen by the Office for National Statistics (ONS) and the Department for Environment, Food and Rural Affairs (Defra). The 2015 Roadmap sets short-term (by 2017) and long-term (by 2020) objectives for progress on natural capital accounts.

5.3.2 NATURAL CAPITAL MONETARY ESTIMATES

The purpose of the aggregated monetary estimates, as described in the 2012 Roadmap, is to provide an overview of the value of natural capital in the UK. Initial, and partial, aggregate natural capital estimates were published in 2014, including annual ecosystem service flow estimates for: energy and mineral reserves, farmland, timber, water, fisheries, outdoor recreation, and net greenhouse gas sequestration for the period 2007 to 2011. The monetary estimate of selected components of UK natural capital was £1,573 billion in 2011 (ONS, 2011).

Looking specifically at UK woodland ecosystems, for example, the study considered three ecosystem services (timber production, carbon sequestration, and recreation) and calculated monetary flows for each. The results showed that from 2009 to 2013, the value of a tree was, on average, 15 times higher than its timber value alone, based on these three ecosystem services only (Figure 5.10). These results highlight the importance of considering a range of non-timber values and services provided by forests to inform planning and decision-making.

As was the case above with regards to the Limburg Province natural capital maps, whilst this analysis of the monetary value supplied through three woodland ecosystem services doesn’t have any specific policy related link, the information presented is easily digestible and conveys a strong message. The development and presentation of these results to decision and policy makers can help to inform conservation and development related actions.
5.7.2 HABITAT ACCOUNTS

The ONS has also published ecosystem accounts for three of the eight broad habitats proposed in the 2012 Roadmap: freshwater, farmland, and woodland. These accounts remain experimental as methods are continually improved. The latest version of the three accounts was published in 2017 (ONS, 2017).

The freshwater, farmland, and woodland ecosystem accounts include:

- Extent accounts (i.e. the size of the area covered by the habitat)
- Condition accounts (i.e. indicators of the quality of the ecosystem and its ability to continue supplying services)
- Physical and monetary ecosystem service flow accounts (i.e. the quantity and value of services supplied by the ecosystem)
- Monetary asset accounts (i.e. the value of the asset, representing the stream of services expected to be provided over the lifetime of the ecosystem)

The 2017 ONS Statistical bulletin includes a list of ecosystem services that have been included and excluded in the habitat accounts.

5.7.3 SCOPING STUDIES

The ONS and Defra have published scoping studies for developing ecosystem accounts (including extent, condition, physical and monetary flow, and monetary asset accounts) for the remaining five broad UK habitats:
5.7.4 CROSS-CUTTING NATURAL ASSET ACCOUNTS

Cross-cutting natural asset accounts are available in the UK for:

1) **Land cover**: land cover accounts for the UK and at the country level based on: a) the SEEA EEA land cover classification, for international comparison; and, b) the UK National Ecosystem Assessment ecosystems, to provide a cross-cutting picture of the individual UK habitat accounts (ONS, 2015a).

2) **Land use**: an experimental physical asset account for UK land, describing six different land uses and their changes over the period 2000 to 2010 in physical terms (ONS, 2013).

3) **Protected areas**: ecosystem accounts for six pilot protected areas in England and Scotland, including extent and condition accounts (asset accounts), physical flow accounts, and monetary flow accounts (White et al., 2015).

4) **Carbon**: preliminary physical stock and flow accounts for geo-carbon over the period 2013 to 2014, and for bio-carbon between 1998 and 2007; and possible methods for estimating physical bio-carbon flows over the 2008 to 2014 period (ONS, 2016b).

5.7.5 METHODOLOGY REPORTS

The Office for National Statistics has published a series of methodology reports to support the integration of natural capital into environmental accounts in the UK. Most notably, together with Defra, the ONS has published principles of ecosystem accounting for the UK, based on the general principles set out by the UN SEEA EEA (Defra and ONS, 2014, 2017). Other methodology documents include:

- Developing estimates for the valuation of air pollution in ecosystem accounts (Jones et al., 2017)
- Discounting for Environmental Accounts (Freeman and Groom, 2016)
- Valuing Flood-Regulating Services for Inclusion in the UK Ecosystem Accounts (Smithers et al., 2016)
- Reviewing Cultural Services Valuation Methodology for Inclusion in Aggregate UK Natural Capital Estimates (Whiteley et al., 2016)
- Natural capital accounting 2020 roadmap – interim review and forward look (ONS, 2015)

5.7.6 SUMMARY

To date, the Office for National Statistics and Defra have produced experimental ecosystem accounts for three broad habitats, along with scoping studies for five further habitats, as well as
a number of cross-cutting natural asset accounts, ecosystem service accounts, and aggregated monetary estimates. They have also published a range of methodology reports to support the integration of natural capital into the UK’s environmental accounts. The overall aim of the UK is to move natural capital accounting from the experimental status into mainstream environmental accounting by 2020.
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Premier Ministre - Service d'information du Gouvernement, Les nouveaux indicateurs de richesse 2017, décembre 2017


UNSD 2018 https://seea.un.org/


Abbreviations

CICES: The Common International Classification of Ecosystem Services
CORINE: Co-ORDinated INformation on the Environment Land Cover classes (CLC).
EAP: Environment Action Programme
ECRINS: European Catchment and Rivers Network System
EUNIS: EU Nature Information System
GDP: Gross Domestic Product
IPBES: Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
INCA: Knowledge Information Project on an Integrated system of Natural Capital and ecosystem services Accounting in the EU
LEAC: Land and Ecosystem Accounting database
LUCAS: Land Use and Land Cover Survey
MAES: Mapping and Assessment of Ecosystems and their Services
NCA: Natural capital accounting
SEEA EEA: The UN System of Environmental-Economic Accounting – Experimental Ecosystem Accounting
SEEA CF: The UN System of Environmental-Economic Accounting – Central Framework
SNA: System of National Accounts
SNEA: Spanish National Ecosystem Assessment
TEEB: The Economics of Ecosystems and Biodiversity
WFD: Water Framework Directive
UK NEA: United Kingdom National Ecosystem Assessment