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The use of (economic & social) values of Natural Capital and Ecosystem Services in national accounting

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*** To be fine-tuned and acknowledgements added for text submissions, cases and/or comments.*

Contents

List of Tables and Figures

1. Developments of Natural Capital accounting

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1.1 Introduction

The concept of Natural and Ecosystem Capital

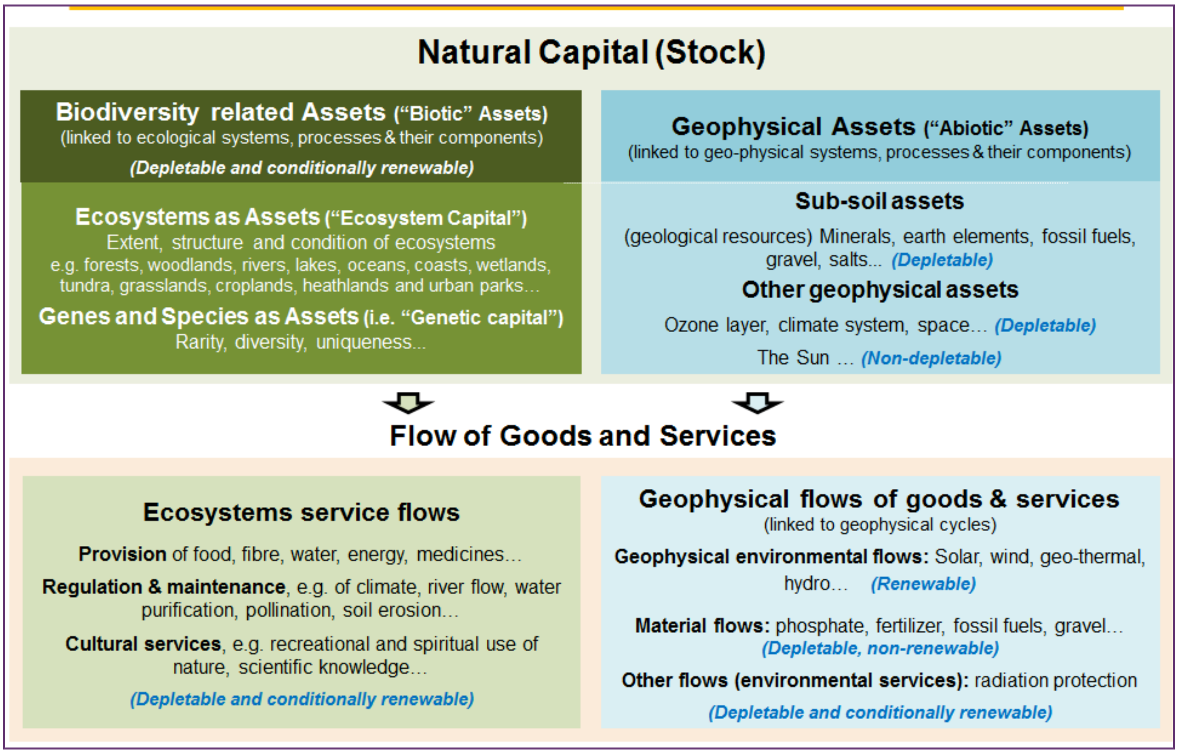
“Natural Capital” (NC) is a term proposed by the British economist E. F. Schumacher in 1973, as a metaphor to shed light on the role of nature in supporting the economy and human welfare. The concept builds on the idea of manufactured capital as one of the factors of production (together with land and labour), which was introduced by Adam Smith and David Ricardo in the eighteenth century.

The term “capital” refers to a stock of materials or information, which can generate a flow of goods and services that improve human wellbeing. Ekins (1992) defines four kinds of capital, i.e., manufactured, human, sociali and natural capital (see also Ekins, 2008), where the latter is constituted by the stock of natural assets that provide society with renewable and non-renewable resources (e.g., timber, water, fossil fuels, minerals) and a flow of ecosystem services. A five capitals model, developed by Forum for the Future during the 1990s and popularised by Porritt (2006) adds financial capital as a separate category. These capital stocks are in principle separately measurable, though in practice data are incomplete, and simplifying assumptions are necessary to derive simple measures at a national level for capital stocks that are in reality a combination of a vast array of complex elements. The methods presented in World Bank (2005, 2011) demonstrate the usefulness of the capitals model, breaking estimates of Total Wealth at the national scale into individual capital stocks, but the method does not currently distinguish between human and social capitals, and only accounts for parts of Natural Capital. The five capitals model has also been used successfully in simulation model of the integrated earth system, first in a non-spatial global model (GUMBO: Boumans et al., 2002) and subsequently in spatially-explicit modelling with MIMES (Boumans et al., 2015).

According to the analytical framework developed in the context of the EU ‘Mapping and Assessment of Ecosystem and their Services’ initiative (European Commission, 2013), Natural Capital includes stocks like sub-soil assets (geological resources) and abiotic flows like solar and wind energy. The Ecosystem Capital (EC) represents the biotic element of the Natural Capital and includes both ecosystems (which can be seen as stocks) and the flows of ecosystem services they provide to society (see Figure 1.1). This report will focus on the biotic components of Natural Capital, i.e., the Ecosystem Capital and the related ecosystem services.

However, it should be noted that the distinction between biotic and abiotic elements is not so clear-cut, as an ecosystem is "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity, 1992, art.2). For example, water is an abiotic element in itself, but ecosystems play a key role in its cycle, and also water is essential for nutrition and plays a key role in all ecosystems (Haines-Young and Potsschin, 2013). As another example, fossil fuels (an abiotic resource) were derived from the biological degradation of organic matter.

Figure 1.1 The components of Natural Capital and associated flow of goods and services



Source: own representation adapted from MAES analytic framework, European Commission (2013a)

All four types of capital are needed to support human welfare. However, Natural Capital is arguably the most important one, as it is incorporated in all other forms of capital, and underpins them. Also, an important share of Natural Capital is non-substitutable with manufactured or other kinds of capital, and the manufactured, human and social capital would not be built without Natural Capital (Costanza et al., 1997). For example, minerals, metals and energy are needed to build the components of manufactured capital; human and social capitals are heavily dependent on the physical health of individuals, who in turn are dependent upon ecosystem services to maintain good health, including food, freshwater, timber and fibre and a wide range of regulating ecosystem services (e.g., water purification, nutrient cycling, protection from floods and other extreme events).

In other words, the economy is embedded in the environment, and in order to be sustainable it needs to stay within its limits, both in terms of available resources and the capacity of the environment to absorb and process wastes.

The concept of Natural Capital is anthropocentric in nature, as it focuses on those aspects of nature that benefit humans, and makes no attempt to reflect the so-called 'intrinsic value' of nature or benefits to other species. However, in certain contexts it can play an important political role, as it can help to shed light on the benefits that nature provides to human society; and consequently on the need for nature protection not only for moral reasons but also as a way to enhance human wellbeing and economy. As such, it can contribute to influence policy-making towards an improved environmental protection, besides acting as an environmental education tool for awareness building. The benefits of anthropocentric values are that they can be known in principle, measured and integrated into decision making.

The Natural Capital concept also has risks – both practical and theoretical. Practical problems are that it will not be generally possible to known all the anthropocentric values of biodiversity and this might lead to bias (i.e., towards those that are easier to measure). The more theoretical problem of principle that could lead to problems of practice is that focusing only on benefits to society may lead to overlooking the non-anthropocentric benefits. Both problems could be seen as encouraging the commoditisation of nature (McCauley, 2006; Kosoy and Corbera, 2010; Mace, 2014) and they may lead to prioritising the protection of areas and environmental resources that are more directly used by humans over others with greater biological diversity. For this reason, the Natural Capital concept needs to be seen in conjunction with wider biodiversity objectives: similarly, accounting needs to be used as a complementary tool to wider biodiversity and sustainability indicators. Furthermore, it is important to understand to what extent accounts do (or could) take into account different types of Natural Capital, changes in the quantity and state of the natural assets, and the flow of associated ecosystem services, so as to understand the meaning of the accounts and how to interpret the outputs. This is a moving target as guidance and methods develop, as new data becomes available, and as initiatives at national (and subnational), EU and global scale improve our practices, tools, understanding and results.

Relevant initiatives for Natural Capital accounting at the European and global level

In recent years, there has been a growing interest in Natural Capital Accounting, which is reflected by recent international, European and national initiatives and legislation.

At the international level, the Strategic Plan for Biological Diversity 2011-2020 includes the commitment to integrate biodiversity into national accounting (Aichi Target 2), and commitments to accounting are also included in various National Biodiversity Strategy and Action Plans (NBSAPs). Also, a communiqué was issued at the 2012 Rio+20 Conference, supported by the EU and 57 countries to encourage the development of Natural Capital Accounting. In order to contribute to this process, the World Bank launched the Wealth Accounting and Valuation of Ecosystem Services (WAVES) Partnership, which aims to pilot methodological developments and experimentations with environmental accounts across the worldii, building on The System of Environmental-Economic Accounting (SEEA) developed by the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA)[iii], which provides detailed methodological guidance on how to prepare environmental-economic accounts (see next section on SEEA for details). Finally, target 15.9 of the new Sustainable Development Goals for 2030 calls on signatories to "integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts"[1] with a target date of 2020.

At the EU level, the first formal EU rules on environmental-economic accounting were established with Regulation 691/2011, which introduced the obligation for Member States to develop at least three kinds of accounts by 2013[iv]: air emission accountsv (in physical terms), accounts on environmental taxes[vi] (in monetary terms) and material flow accountsvii (in biophysical terms). The Regulation establishes that more modules can be added in the futureviii to respond to key policy needs; following this, an amendmentix in 2014 added modules for environmental protection expenditures accounts, environmental goods and services sector accounts, and physical energy flow accounts.

The commitment to the development of physical and monetary environmental-economic accounts is also included in the 7th EU Environment Action Programme. In addition, the EU Biodiversity Strategy to 2020 requires Member States to map and assess the state of ecosystems and their services by 2014, and to assess their economic value and promote the integration of these values into accounting by 2020. In order to meet these commitments, the initiative 'Mapping and Assessment of Ecosystems and their Services' (MAES), was established by the European Commission, with support of Member States, the EU Joint Research Centre and the European Environment Agency (EEA). It aims to contribute to the mapping and assessment of ecosystems and ecosystem services, in biophysical, and in a later stage possibly also monetary terms, by providing a coherent analytical framework to the EU and Member States, and includes a module on Natural Capital Accounting.

Finally, the EEA is currently developing experimental Ecosystem Capital Accounts (ECA), based on the available data at the European level. The ECA process does not aim to generate new data, but to integrate the available ones at the European level. In order to do so, all utilised data sets are transposed into a 1km2 grid across the entire area covered. The first experimental ECA will include land, organic carbon and water accounts.

Natural Capital and environmental/ecosystem accounting initiatives are also being taken forward in some Member States. The UK in particular has developed work under the Natural Capital Committee, an independent advisory body set up to advise the Government on the sustainable use of Natural Capital. Their 'State of Natural Capital' reportsx have presented evidence of significant economic and wellbeing benefits from better valuation and management of Natural Capital, highlighted where unsustainable use of assets place benefits at risk, proposed a long-term restoration framework, and recommended that the Government work closely with the private sector and NGO to develop a comprehensive strategy to protect and improve Natural Capital. The Committee has also worked with the major landowners (National Trust, Lafarge Tarmac, The

[1] https://sustainabledevelopment.un.org/sdgs

Crown Estate and United Utilities) to advance corporate Natural Capital accounting and produce guidelines. The UK Office of National Statistics, meanwhile, has developed various satellite accountsxi including environmental accounts, sustainable development indicators, and "initial and partial" estimates of the monetary value of Natural Capital.

1.2 Natural and Ecosystem Capital and ES

The system of environmental-economic accounting (SEEA)

The System of Environmental-Economic Accounting (SEEA) provides detailed methodological guidance on how to prepare environmental-economic accounts. The first version was published by the United Nations Statistics Commission (UNSC) in 1993, and it was recently subjected to a wide revision process, led by the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA), a body consisting of countries and international agencies under the auspices of the UN Statistical Commission. The revised version includes three volumes, as summarised in Table 1.1.

SEEA-Central Framework (SEEA-CF) - Volume 1- includes the biotic and abiotic stock and flows that cross the boundaries between the environment and human economy. It also covers typologies of environmental-economic accounts that are not part of Natural Capital Accounting, but can have a positive or negative impact on the Natural Capital, i.e., the environmental activity accounts, which include accounts for environmental protection expenditures, the environmental goods and services sector, environmental taxes and environmental subsidies. SEEA-CF provides standards for accounting that, when expressed in monetary terms, can be integrated into the System of National Accounts (SNA)xii (the international standard for national economic accounts).

SEEA-Experimental Ecosystem Accounting (SEEA-EEA) - Volume 2 - covers accounts of ecosystems and ecosystem services. This kind of account is still at an experimental level, and for this reason, SEEA-EEA does not provide an internationally agreed standard for Ecosystem Accounting, but only a discussion on the methodological options and challenges, and general guidance on how to structure and develop accounts. The accounts included in the SEEA-CF and SEEA-EEA are to a certain extent complementary, as accounts included in the former provide useful information to describe the state of ecosystems (e.g., water accounts, timber accounts, land accounts) and the latter can offer insight on the state of ecosystems that provide the natural resources recorded in the SEEA-CF accounts.

Volume 3, Applications and Extensions of SEEA, shows some applications of SEEA data for their use in policy making and research, such as the use of environmental indicators and the analysis of environmental taxes and subsidies. It also includes an overview of the methodologies that can be used with SEEA data, and in particular the Environmentally Extended Input-Output Tables, a discussion on the spatial disaggregation of SEEA data and an overview on possible extensions of the SEEA to cover specific sectors and topics.

Table 1.1 The SEEA guidance manuals

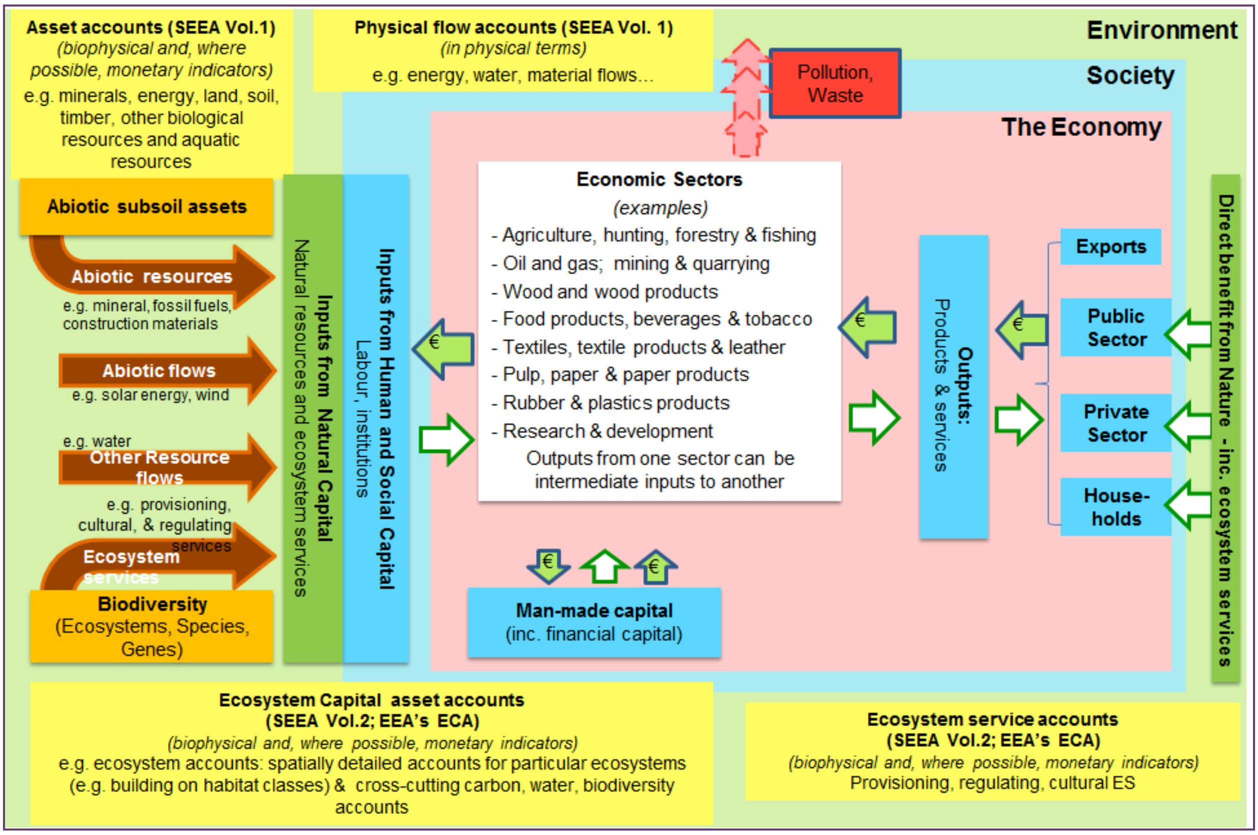
Publication	Year of publication	Scope	Standard	Possible integration into the SNA	Contents
Volume 1 Central Framework (SEEA-CF)	2012	Stock of natural resources, flows of natural resources towards the economy, their contribution to the economy and the impacts of economic activities on them.	Yes	Yes	1) Accounts of **flows** in physical terms for energy, water, material flows, air emissions, waste water and solid wastes. 2) Accounts of **assets** (in physical and monetary terms) for mineral and energy resources, land, soil resources, timber resources, aquatic resources, other biological resources and water resources. 3) **Environmental activity accounts** and related flows for environmental protection expenditures, the environmental goods and services sector, environmental taxes and environmental subsidies, in monetary terms. 4) **Combined physical and monetary accounts,** which provide the framework for the derivation of indicators such as resource efficiency and productivity.
Volume 2 Experimental Ecosystem Accounting (SEEA-EEA)	2013	The condition of ecosystems and the flows of ecosystem services.	No	No	1) Accounting for **ecosystem services** in **physical terms.** 2) Accounting for **ecosystem assets** in **physical terms** (**carbon** and **biodiversity accounts** illustrated more in detail). 3) **Main challenges** and **methodological options** for the **monetary valuation** of ecosystems and ecosystem services.
Volume 3 Applications and Extensions of SEEA	2014	Guide to the use of SEEA-based data in decision making, policy review and formulation, analysis and research. It includes the most common applications of the SEEA and possible extensions.	No	No	1) **Applications** of SEEA data, including the use of environmental indicators; the analysis of resource use and environmental intensity; the analysis of production, employment and expenditures relating to environmental activities; analysis of environmental taxes and environmental subsidies and similar transfers; analysis of environmental assets, net wealth, income and depletion of resources. 2) **Analytical techniques**: Environmentally Extended Input-Output tables (EE-IOT) and techniques for the analysis of input-output data (multiplier analysis; attribution of environmental pressures to final demand; decomposition analysis; computable general equilibrium analysis). 3) **Extensions of the SEEA**, including spatial disaggregation of SEEA data, extensions of SEEA to the household sector and to present environmental-economic accounts by theme (applied to the tourist sector as an example).

Source: own elaboration, based on the SEEA guidance manuals

Interestingly, whereas the MAES initiative and the European Environment Agency use the term "Ecosystem Capital Accounts" to define accounts covering both ecosystems and ecosystem services, in the context of SEEA, the wording "Ecosystem Accounts" is adopted, in order to underline that SEEA-EEA covers not only assets, but also flows. This chapter will adopt this convention.

Figure 1.2 provides a general overview of the different kinds of environmental-economic accounts and the role they can play in collecting and systematising the interactions between nature, society and the economy. The asset accounts included in the SEEA-CF measure the stock of Natural Capital (e.g. fossil fuels, minerals, timber, land) - generally in biophysical terms, but they can also be complemented by monetary information, if appropriate and where methodologies and data allow. The flow accounts included in SEEA-CF cover the flows of natural resources from the environment to the economy (i.e. inputs) as well as from the economy to nature (i.e. waste, water pollution and air pollution). SEEA-EEA accounts include both assets (ecosystem accounts) and flows (ecosystem services).

Figure 1.2 Environmental-Economic Accounts and Natural and Ecosystem Capital



Source: adapted by ten Brink from Russi and ten Brink, 2013

In principle, therefore, accounting should be able to integrate a wide set of Natural Capital types as well as flow of ecosystem services. In practice, data availability, limitations or lack of agreement on methods (i.e., still multiple experimental approaches being tested), and lack of actual development of accounts for some issues, means that there is only partial integration of Natural Capital and ecosystem services in accounts, with only a subset of issues represented in monetary terms. This underlines again the need to see the results of accounts in perspective of what they integrate and how. The section below looks at actual practice.

Examples of Ecosystem Accounting

Ecosystem Accounting is still at an early, experimental, stage and only a few examples have been developed at the national level. However, there has been considerable progress since 2012 in Europe and globally. In 2013, the UK Office of National Statistics have published experimental accounts and methodologies of UK land use, woodland area, timber resources, and woodland ecosystem assets and services[xiii]. France has regular forest accounts and is developing ecosystem accounts (EFESE), Portugal has been developing marine accounts and Germany is developing national accounts that build on the concept of landscape ecosystem capacity (e.g., for soil). The European Environment Agency has been finalising their first generation Experimental Ecosystem Capital Accounts, and the EU's MAES process is finalising the EU reference document on Natural Capital Accounting (Petersen and Gocheva, 2015). In addition, both UK and Spain have published National Ecosystem Assessments, which provide a snapshot of the ecosystems and the services they provide, both in biophysical and monetary terms.

Globally, the World Bank's WAVES initiative is supporting Natural Capital accounting in five countries (Botswana, Columbia, Costa Rica, Madagascar and the Philippines). In addition, the CBD had developed guidance on Ecosystem Natural Capital Accounts (Weber 2014a), accounts have been public developed for Mauritius (Weber 2014b) and Madagascar, and a range of new initiatives are underway to support the development of accounts (e.g., TEEB initiative, supported by Norway), with plans to support NCA in Bhutan, Chile, Indonesia, Mauritius, Mexico, South Africa, and Vietnam.xiv

The next chapters will discuss more in detail experiences of biophysical accounting (Chapter 2) and monetary accounting (Chapter 3). Chapter 4 will analyse the potential policy utility of both kinds of accounts.

Summary: Status of integration of NC/ES in actual accounting practice

While Figure 1.2 provides a comprehensive overview of the different components of Natural Capital and ecosystem services, there exist constraints as regards the implementation of the concept. Some components of Natural Capital can be captured relatively well, as data is generally available and as the accounting units are accessible to observation, even though the methods of measurement undergo constant improvement. Among these are for example water quantity, carbon stocks in vegetation and soils, fish resources, or the extent of ecosystems. For other components of Natural Capital stocks, such a stock-taking appears possible in principle, but is constrained by data availability and an incomplete understanding of the natural biophysical and ecological processes underpinning the maintenance of Natural Capital and the production of ecosystem services. Once the data and natural scientific foundations are improved, such analyses will be possible, for example about the overall state of land ecosystems.

Similar considerations apply to capturing the flow of ecosystem services. Some services such as the production of fish or local recreational values of landscape can be assessed with existing data and methods. In some cases like the services provided by wild pollinators, this is possible today, but an improved data basis is needed.

However, some aspects of Natural Capital are very difficult to capture, due to the characteristics of some of the stocks and flows. Marine ecosystems and water quality are examples of Natural Capital stocks that are difficult to capture in an accounting framework. In some cases, available methods do not allow reliable estimates at all, such as the complexity of ecosystems or the pool of genes.

Table 1.2 provides an overview of the level of feasibility of different kinds of Natural Capital accounts

Table 1.2 Feasibility of Economic Accounting for Natural Capital Stocks and Flows

	Not covered or not possible to cover	Less well covered and/or difficult to address by national accounts	Partially covered by national accounts but in principle possible	Well covered by national accounts – current status
Ecosystems as stock	Complexity of ecosystems, species and genes – too complex to integrate in accounts, need some proxy indicators.	Marine ecosystem condition (data intensive)	Ecosystem biodiversity: via different ecosystem types and land cover types	Extent of most ecosystems (e.g. land use by hectare)
			Carbon in vegetation and soils	Forest accounts: timber stock
		Water quality of stocks of water (e.g. ground, surface waters) *– exist out of accounts*	Carbon sequestration	Agricultural accounts – via landuse accounts
			Fish stock accounts	Water stock accounts
Flow of Ecosystem services		Locally important regulating services- *exist in local studies, but not in accounts*	Value of wild pollinators	Timber harvests *(doesn't integrate sustainable yields – i.e. no shadow prices)*
		Regulation services: natural hazards regulation *(as local; difficult to allocate to ES)*	Recreation values *(doesn't differentiate sustainable recreation)*	Agricultural production accounts *(doesn't distinguish ES from man-made service)*
			Tourism accounts *(doesn't differentiate sustainable tourism)*	Fish landing *(doesn't integrate sustainable yields – i.e. no shadow prices)*

Source: own elaboration.

Brouwer et al. (2013) prepared a review of EU MS ecosystem service national assessments and found that most studies cover different kinds of provisioning, regulating, cultural and (in some cases) supporting ecosystem services, but only a small subset of them use monetary valuation methodologies to assess the ecosystem services. The study found that most provisioning services are or will be valued using market prices, and most regulating services using methodologies based on costs, where possible. Monetary valuation of cultural ecosystem services, is much more complicated, because of methodological challenges, lack of data, lack of resources to conduct original valuation studies and also criticisms towards the use of monetary nonmarket valuation in some of the countries. However, the UK National Ecosystem Assessment Follow-on (2014) found that quantitative physical indicators of cultural ecosystem services can be developed using publicly available datasets.

1.3 Challenges for the development of ecosystem accounts and NC/ES integration in accounting

Ecosystem Accounts are still at an early stage of development, and, as explained above, only a few pilot experiments have been developed so far. This is partly due to a range of challenges that still need to be addressed.

One important challenge regards **data availability**. For many ecosystems and ecosystem services, significant data gaps represent an obstacle to the development of reliable accounts. In some cases, data may be available at a different scale than the one required for accounting, and therefore models and approximations need to be used. Also, it should be taken into account that data on some key ecosystems and ecosystem services may be very location specific, and for this reason they need to be translated into indicators relevant at the scale at which the accounts are developed, through an aggregation and extrapolation process. In some cases, accounts are compiled on the basis of a mixture of empirical data and outcomes of modelling exercises and in these cases data obtained through modelling should be compared, if feasible, with measurements taken in situ, in order to verify their robustness and reliability. It is important to remember that not all ecosystem services can be covered in Ecosystem Accounts, due to lack of data and methodological difficulties. For this reason, it is important to manage expectations, and find a balance between the demand for quick and easy indicators and for more detailed, time-intensive kind of accounts. It is also key to be transparent as to what accounts cover and clear on how to interpret the results. For example, accounts do not cover issues related to irreversible depletion or erosion of natural resources, ecosystems or ecosystem services in relation to ecological limits and thresholds (and nonlinearity), and in order to address these issues they would need to be combined with other analytical tools and data (Harris and Khan, 2013).

Another challenge to be addressed is the development of a coherent and agreed-upon **conceptual framework, methodology and definitions**. SEEA-EEA represented an important step in this sense, but since Ecosystem Accounting is still at an early stage, Volume 2 does not provide standards. For some of the most controversial topics, as for example monetary valuation, SEEA-EEA only offers an overview of the available methodologies and alternative definitions. The need for the development of a common vision on concepts and definitions is even more needed since many different typologies of experts are needed to develop and discuss accounts, including statisticians, economists, ecologists and hydrologists.

The **monetary valuation** of ecosystem services faces multiple methodological challenges due to the fact that many ecosystem services are not transacted in the market and for this reason do not have market prices. For this reason, economists have proposed three categories of methodologies to be used for monetary valuation of ecosystem services (see White et al., 2011, chapter 4 in ten Brink (ed.), 2011; Pascual et al., 2010, chapter 5 in Kumar P. (ed.), 2010; see also Brouwer et al., 2013, table 4 and SEEA Central Framework, Chapter 5):

1. Methodologies based on **costs**, which use market prices to indirectly estimate the monetary value of ecosystem services. Examples include methodologies based on the avoided costs, such as the economic damage from floods by managing floodplains in a sustainable way; methodologies based on the replacement cost, such as the cost of mechanical purification of water, which is needed to replace natural water purification provided by healthy ecosystems; and methodologies based on the restoration costs, which are the cost of restoring a degraded ecosystem.
2. Methodologies based on **revealed preferences** estimate values based on the preferences of individuals, shown by their behaviour. Examples are the Travel Cost Method and the Hedonic Pricing Method.
3. Methodologies based on **stated preferences** such as Contingent Valuation and Choice Experiments use the preferences that are directly stated by people through surveys. They investigate people's willingness to pay (WTP) for improved environmental conditions or their willingness to accept (WTA) compensation for a reduction in environmental quality.

Also, since monetary valuation studies are time and resource intensive, in many cases monetary values already calculated elsewhere for similar ecosystems are used. This procedure is called "**value (or benefit) transfer**" and needs to be carried out very cautiously because the provision of ecosystem services are often location-specific (see White et al., 2011, in ten Brink (ed.), 2011; Pascual et al., 2010, in Kumar P. (ed.), 2010; Brouwer et al. 2013, section 6.2.4.3, SEEA Vol2,section 5.6.3; and Kettunen and ten Brink (ed.), 2013).

There is an on-going debate as to whether to use methodologies based on costs, which employ market prices to indirectly estimate the monetary value of ecosystem services (e.g., estimates of the avoided economic damages from floods ensured by sustainable floodplain management or estimates of avoided water pre-treatment costs for municipal drinking water provision) or methodologies based on **individual preferences**, based on for example on surveys that investigate people's willingness to pay for improved environmental conditions (Brouwer *et al*., 2013). In general, the methods based on revealed and stated preferences are based on the measurement of changes in individual welfare, whereas accounts are based on the exchange value.

For example, Weber (2011) states that for environmental accounting, monetary valuation should be carried out on the basis of restoration costsxv because he considers monetary valuation methodologies based on stated or revealed preferences as incompatible with environmental accounting, because they are based on subjective evaluations, which make up-scaling and aggregation disputable. On the contrary, others maintain that because revealed preference techniques make use of real world, actually observed behaviour, they avoid charges of subjectivity that are sometimes valid criticisms against stated preference studies (Bateman et al., 2011; Bateman et al., 2014). Moreover, advances in benefit transfer methods (see Bateman et al., 2011) can offer some response to disputes over up-scaling and aggregation. Finally, the methods applied throughout the UK NEA, for instance, maintained that restoration and replacement costs should not be used as proxies for the economic value of ecosystem services. Ecosystem service values reflect the change in the stakeholders' wellbeing due to a marginal change in the provision of ecosystem services. This is not dependent on what is arguably the exogenous cost of restoration. Moreover, restoration costs reflect technological ability rather than the value of an environmental asset: if a technology was developed that reduced restoration costs by 50%, it does not necessarily follow that the value of the asset has also been cut by half.

Using valuation methods aimed at identifying the impact on welfare of changes in ecosystem services (i.e. methods based on stated or revealed preferences) implies to include the consumer surplus, i.e., the difference between the price consumers are willing to pay for a good or service and the market price. Cost benefit analyses include the consumer surplus in the monetary valuation of environmental goods and services, but this is not coherent with the with the SNA approach, which is based on market prices. This point will need further discussion among experts.

SEEA-EEA allows both categories of valuation methodologies to be used (i.e., the ones based on preferences and including the consumer surplus and the ones based on costs), but warns that if methodologies based on preferences are used, some adjustments need to be done (e.g., using shadow prices) (see SEEA-EEA, Chapter 5 for more details on this discussion).

A 'third way' option is provided by the concept of 'simulated exchange values' (Caparrós Gass & Campos Palacín 2009; Oviedo, 2010) which estimates the value of ecosystem services in terms of potential revenue if a market were to exist. This arguably represents a more consistent basis for including their value in national accounts alongside monetary transactions, because consumer surplus is excluded. The method aims to measure the income that would occur in a hypothetical market where ecosystem services were bought and sold. It involves estimating a demand and a supply curve for the ecosystem service in question and then making further assumptions on the price that would be charged by a profit-maximising resource manager under alternative market scenarios. The method then takes the hypothetical revenue associated with this transaction (excluding the associated consumer surplus) as a measure of value of the flow of ecosystem services. It should be noted, however, that this drives a wedge between the quantity of ecosystem service associated with the valuation (at the intersection of supply and demand curves) and the quantity actually observed. For example, with a paid market in recreation, one would expect lower numbers of visits than when access is free. This has the potential to add confusion between the monetary and physical accounts.

Other related issues are whether and how to aggregate results obtained with different methodologies and how to scale up results obtained through valuations at the local level. In general, if different methodologies are used for monetary valuation (such as in the UK NEA), the outcome values of different ecosystem services may not be fully comparable or compatible (as they may measure different things in different units) or additive, and care will be needed to avoid double counting, interpreting of meaning and aggregation. To be additive requires, inter alia, the value of a given hectare of land and its interaction on the value of other hectares of land need to be factored into account (new facilities for recreation in one park may increase its recreation value but also reduce the recreation value in other parks (Kettunen and ten Brink 2013). This may pose a problem if monetary valuation is to be used for accounting purposes, as different units are used in accounting (market exchange values) and welfare economics (Brouwer et al., 2013).

Another problem related with monetary valuation based on stated or revealed preferences is the fact that people may not be aware of the ecosystem services they benefit from (typically in the case of regulating ecosystem services). For this reason, stated preference (SP) techniques should arguably only be used for end-services (though values for regulating services can be derived from SP for end-services, e.g., benefits of reduced flood risk can shed light on regulating services of flood control).

Also, the high costs related to data collection and processing usually represent an obstacle for monetary valuation of Natural Capital. Furthermore, though experts agree on the principle of discounting and the formula to be used, they do not agree on how to derive the parameters (Arrow et al, 2013), and therefore do not agree on the discount rate to be used for the valuation of natural resources[xvi].

Finally, **gaps in the scientific evidence base** regarding the key biophysical and ecological processes that replenish Natural Capital and generate ecosystem services remain a key challenge for environmental accounting.

In summary, many challenges as regards integrating monetary aspects of Natural Capital in accounting remain and national experimentation is crucial to be able to highlight potential promising ways forward.

2. Ecosystem Accounting through biophysical indicators

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2.1 Introduction

Human economies are open systems that depend on a flow of renewable and non-renewable resources (e.g. timber, water, fossil fuels, minerals, biomass) and ecosystem services (e.g. provisioning, regulating and cultural services), which are provided by stocks of natural assets and ecosystems (MA, 2005; TEEB, 2010, 2011). These natural assets and flows can be defined as natural capital, which is a term proposed by economist E. F. Schumacher in the Seventies (1973) as a metaphor to shed light on the role of nature in supporting the economy and human welfare.

The increasing use of natural resources over the last decades resulted in unprecedented level of pollution in many areas of the world, in an increasing level of greenhouse gas emissions, in the depletion of renewable resources such as fish stocks and clean water, and the loss and degradation of biodiversity and ecosystems (ten Brink et al., 2011). Designing effective policies aimed at improving the environmental sustainability of modern economies requires measuring the availability and use of natural capital and the impact of the economy on ecosystems.

Natural capital accounting (NCA) provides a systematised approach to measure the stock of natural resources and the flows of resources and ecosystem services that underpin the functioning of the economy (see also Chapter 1). This paper focuses on ecosystem accounting, which includes the biotic component of natural capital, i.e. the ecosystems and the flows of ecosystem services they provide.

Ecosystem accounting can be carried out in biophysical terms and also, in principle, in monetary terms (see Chapters 1 and 3). Accounting for the stock and flows of natural resources and ecosystem services in biophysical terms is important because monetary valuation is characterised by important methodological challenges, uncertainties and data gaps (for wider discussion see Chapter 3).

This chapter summarises the guidance on Ecosystems Accounts provided by the System of Environmental-Economic Accounting (SEEA) process and the progress at the European and national level, based on the available published material, the results of the MESEU (Mapping of Ecosystems and their Services in the EU) workshop held in Brussels in July 2015, and a survey addressed to the relevant national bodies, which has been answered by experts from the UK, Germany, the Netherlands, Sweden and Spain.

2.2 Ecosystem accounting in physical terms

As explained in Chapter 1, the System of Environmental-Economic Accounting (SEEA) is the result of an initiative lead by the United Nations Statistics Commission (UNSC) aiming at providing an internationally agreed and detailed methodological guidance to prepare Environmental and Ecosystem Accounts.

SEEA-Central Framework (SEEA-CF) (United Nations, 2014) represents a very detailed standard on Environmental-Economic Accounting, whereas SEEA-Experimental Ecosystem Accounting (SEEA-EEA) (United Nations, 2014b) provides a general guidance on how to structure and develop Ecosystem Accounts, including an overview of the main methodological options and main challenges. A separate, more detailed SEEA manual was published in 2012 for Water Accounts, whereas SEEA-Energy and SEEA Agriculture, Forestry and Fishery (SEEA-AFF) are currently in preparation.

Both SEEA-CF and SEEA-EEA include biophysical indicators for ecosystems and ecosystem services. **SEEA-CF** covers accounts of assets (i.e. stocks) in physical and monetary terms for:

1. Mineral and energy resources
2. Land,
3. Soil resources,
4. Timber resources,
5. Aquatic resources,
6. Other biological resources and
7. Water resources.

And accounts of flows in physical terms for:

1. Energy,
2. Water,
3. Material flows,
4. Air emissions,
5. Waste water and
6. Solid wastes

SEEA-EEA covers accounting for ecosystem services and ecosystem assets in physical terms, and develops carbon and biodiversity accounts in more detail.

The accounts included in SEEA-CF and SEEA-EEA are to be seen as complementary, and together they can contribute to provide a picture of the state of the ecosystems and the flows of ecosystem services they provide. The accounts covered by SEEA-CF include information on key factors that influence ecosystems and ecosystem services, whereas SEEA-EEA focuses on describing more specifically the conditions of the ecosystems and the flows of ecosystem services they provide. For example, the variation recorded in the timber accounts over time, included in SEEA-CF, can provide an indirect indication of the state of forest ecosystems. And water accounts, also included in SEEA-CF, collect and systematise information on one of the most important elements that influences the state of ecosystems and the related flow of ecosystem services.

Ecosystems Accounts in SEEA-EEA cover both **ecosystem assets**[2] and **ecosystem services**. Ecosystem assets are measured in terms of ecosystem extent, ecosystem condition and also in terms of expected flows of ecosystem services[3].

In general, the **ecosystem extent** is measured using data on land cover to distinguish between areas covered by different types of ecosystems (e.g. forests, wetlands, grasslands) and assess the changes therein. **Ecosystem condition** is measured using a set of key characteristics of ecosystems like carbon, water, nutrient flows, vegetation, or proxies like, for example, the presence of key species, or potentially partial proxies in the form of designations such as Forest Stewardship Council (FSC) certificates, organic agriculture, high nature value (HNV) farmland. The former characteristics are measured through indicators that are then related to a reference condition, which is to be intended as a baseline, not as a target condition. The reference condition can be the one at the beginning of the accounting period, or a typical ecosystem in stable conditions or undisturbed by humans, pending the state of the ecosystem measured.

Each ecosystem can also be measured using different indicators of key characteristics (e.g. for water bodies' water flows, concentration of pollutants and changes in key fish species). For this reason, SEEA-EEA suggests to develop a number of **basic resource accounts** as a basis for the development of accounts on ecosystem conditions, including land accounts, carbon accounts, water accounts, soil and nutrient accounts, forest accounts and biodiversity accounts, many of which are covered in SEEA-CF (Chapter 5). For example, accounts of opening and closing stocks of water resources, timber resources and carbon and biodiversity can provide valuable information for ecosystem accounts. In particular, land accounts can play an important role as a basis to generate Ecosystems Accounts. For example, the European Environmental Agency is using the EU Corine Land Cover (CLC) database as a basis for its Simplified Ecosystem Capital Accounts (SECA). However, the basic resource accounts can only indirectly be used to assess ecosystem conditions by combining different relevant data on ecosystem characteristics.

[2] The term "natural capital" is often used as short-hand for "ecosystem assets" – for wider discussion see Chapter 1 - Russi et al. 2015

[3] The capitalisation of the value of a flow of services in the future (i.e. its expected net present value, NPV) gives a measure of value of the stock. This is much like capitalisation of firms on stock markets – a measure of perceived worth, linked to expectations of profitability into the future.

Accounts for a given snap shot year, could in principle allow an **assessment of trade-offs** between services by comparing ecosystem service provision across different land uses for a given ecosystem type. Where accounts exist for two (or more) years (in a time series), they could support **ex-post assessment** of trade-offs linked to land use and management decisions (see Chapter 4 on discussion of policy utility).

To estimate the **expected flows of ecosystem services** requires estimating the extraction and regeneration in the future, using a set of assumptions on the expected future use of ecosystems (which is not necessarily the present one). Measuring the expected flows of ecosystem services can help discuss trade-offs (e.g. between policies aiming at increasing the flow of provisioning ecosystem services and others aiming at improving the flow of regulating ecosystem services) and in general the consequences of changes in land use.

The flow of a range of **ecosystem services** can be measured in physical terms using a variety of indicators and unit of measurements, depending on their physical characteristics and the service provided (e.g. tonnes of agricultural products, joules of bioenergy and cubic metres of water, tonnes of carbon stored in a forest, number of visitors in a protected area), as shown in Table 2.1.

Table 2.1 Physical flows of ecosystem services for an EAU[4]

	Type of LCEU				
Type of ecosystem services (by CICES)	Forest tree cover	Agricultural land[a]	Urban and associated developed areas	Open wetlands	…
Provisioning services	For example, tonnes of timber	For example, tonnes of wheat			
Regulating services	For example, tonnes of CO_2 stored/released	For example, tonnes of CO_2 stored/ released	For example, tonnes of CO_2 stored/released	For example, tonnes of phosphorus absorbed	
Cultural services	For example, number of visitors and hikers		For example, hectares of parkland	For example, hectares of habitat for ducks	

a Medium to large fields of rain-fed herbaceous cropland.

Source: United Nations (2014b)

In general, SEEA-EEA suggests special effort should be dedicated to the two areas of water and carbon accounting, as water and carbon are key characteristics of all ecosystems, and are able to provide a (very general) indication on the state of ecosystems and on several of the services they provide. As regards water accounts, this includes not only water quantity

[4] EAU = Ecosystem Accounting Unit; LCEU= Land Cover/Ecosystem Functional Unit

accounts (i.e. the provisioning service of fresh water) but also accounts covering other key ecosystem services (e.g. the regulating ecosystem service of water purification). As regards water quality accounts, there is still little standardisation on the choice of metrics to be used, the threshold levels to define quality classes and the measurement methodologies. For this reason, different countries tend to use different indicators, based on their specific problems and needs, but water quality accounts have not been developed yet in an integrated and systematic way (Russi and ten Brink, 2013).

The development of Ecosystems Accounts may require particular ecosystem assets and flows to be prioritised for inclusion and measurement, depending on data availability, political priorities and policy needs, characteristics of the area and methodological challenges related e.g. to scaling up and aggregating. This prioritisation exercise needs to be carried out with caution, because prioritising indicators with the highest data availability may result in a bias against the less analysed ecosystems, which may be characterised by a high level of biodiversity and provide valuable ecosystem services.

Ecosystems Accounts will benefit if developed in a **spatially explicit way** using, for example, geographic information systems (GIS). Geo-spatial analysis re-organises existing data according to standard geographical classifications, resulting in maps that visualise the state of ecosystems or the flows of ecosystem services they provide. Spatial accounts tend to require a large amount of data and a considerable amount of work, but they are a promising approach and have an important potential to be explored, both for analysis and for policy making (see Chapter 4). For example, they can be used to set priorities and to better identify environmental pressure points by seeing at a glance where intervention is mostly needed. This kind of approach can provide very valuable information because national averages can hide important differences in the level of stocks and flows in different locations, and the environmental importance of an ecosystem or an ecosystem service is closely related to its location. For this reason, information about the localisation of key ecosystems and ecosystem services can have high policy relevance. Also, spatial accounts can provide information on flows of ecosystem assets or services across different spatial areas, like for example organic carbon and water.

As explained by Schröter et al (2014), spatial models need to meet the following requirements in order to be used in ecosystem accounting: 1) they need to be based on measurable indicators that are representative for the ecosystem services to be modelled; 2) they need a high resolution that is sufficient to capture spatial variability of ecosystem services; 3) they need to ensure sufficient accuracy to be incorporated in an accounting framework. Many spatial models can be used for ecosystem accounting (see, for example, Schröter et al (2014), who reviewed 29 different models that are used in accounting exercises).

Spatial accounting for ecosystem services is still in the early development phase (Heink et al). Moreover, many maps are still difficult to compare and combine (Jacobs et al 2015).

2.3 Initiatives, processes and examples of ecosystem accounting in biophysical terms

International and EU initiatives and processes

Different initiatives at the international and national level have contributed in recent years to develop natural capital and ecosystem accounting. For example, the Strategic Plan for Biological Diversity 2011-2020 includes a commitment to integrate the values of biodiversity into national accounting (the Aichi Target 2, under the global Convention on Biological Diversity) and resulted in commitments on accounting in National Biodiversity Strategies and Action Plans (NBSAPs). Also, a communiqué was published after the international conference Rio+20 to encourage the development of Natural Capital Accounts. The WAVES programme (Wealth Accounting and the Valuation of Ecosystem Services), promoted by the World Bank, is currently supporting many initiatives on natural capital accounting in various countries (see Chapter 1).

At the EU level, the EU Biodiversity Strategy (COM/2011/0244 final) established the commitment to map and assess the state of ecosystems and their services in all Member States by 2014 and to promote the uptake of their economic value into accounting and reporting systems at EU and national level by 2020 (Target 2, Action 5). In order to reach this aim, the EU Commission established the Mapping and Assessing Ecosystem Services process (MAES). MAES involves a consortium formed by the European Environment Agency (EEA), DG Environment and the Joint Research Centre (JRC), which work together with Member States to progress in the mapping, assessing and valuing of ecosystems and their services (see European Commission, 2013, for the conceptual framework of the MAES process). Other research projects are ongoing, including the inter-DG Knowledge innovation project on Accounting for natural capital and ecosystem services (KIP-INCA)[5].

The process of mapping and assessing the EU ecosystem and their conditions, led by the EEA resulted in a collection of available data on pressures on ecosystems and ecosystem conditions, a European ecosystem map, a collection of information on habitats to be used to map the distribution of ecosystem types across Europe and finally a map of the ecosystem condition carried out by combining the ecosystem maps with environmental monitoring data (European Environment Agency, 2015)[6].

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[5] The project focuses on establishing an accounting system for the EU level, primarily using EU-wide data sources. https://circabc.europa.eu/sd/a/f2c8f9c1-f8a4-4b1a-a4f2-76c750270821/Scoping%20paper%20KIP%20Natural%20Capital%20-%20public%20version%20of%2022%20June%202015.pdf

[6] The maps that have been produced are collected here http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/draft-ecosystem-map-europe.

The process of mapping and assessing the EU ecosystem services was led by JRC and resulted in a study on the trends in the ecosystem services in the EU based on 30 indicators, which were built using global and European land cover and land use datasets (JRC, 2015)[7].

Finally, DG Environment established a three-year contract study called MESEU (Mapping of Ecosystems and their Services in the EU) to support the MAES process, using case-studies in the Member States and a survey on the status of MAES implementation in each MS[8].

The DG RTD funded ESMERALDA project[9] (enhancing ecosystem services mapping for policy and decision making) builds on existing ES projects and databases (e.g. MAES, MESEU, OpenNESS, OPERAs, national studies), to develop flexible mapping approaches which integrate biophysical, social and economic assessment techniques 5 aims.

At the national level, only a few countries have completed and integrated mapping exercise of ecosystem services so far, including the UK and Spain (see Boxes 2.1 and 2.2). At a regional level, this has been carried out in Flanders (see Box 2.3).

[7] The study focuses only on terrestrial ecosystems, and not on marine ones. Also, the information on fresh water ecosystems only focuses on water provision but not on the other ecosystem services provided by water bodies.

[8] More information on the case studies can be found in the following webpages http://biodiversity.europa.eu/maes/maes-catalogue-of-case-studies and http://biodiversity.europa.eu/maes/maes-digital-atlas.

[99] http://www.esmeralda-project.eu/showpage.php?storyid=11754

Box 2.1 The UK National Ecosystem Assessment

The UK National Ecosystem Assessment (UK NEA) was published in 2011 and covered terrestrial, freshwater and marine ecosystems of eight broad habitats, i.e. 1) Mountains, moorlands and heaths (18% of the UK's land area); 2) Semi-natural grasslands (high diversity grassland, which comprises ≥ 1% of total land area); 3) Enclosed farmland (40% of land area); 4) Woodlands (12% of land area); 5) Freshwaters (open waters, wetlands and floodplains); 6) Urban (7% of the land area); 7) Coastal margins (0.6% of land area); 8) Marine (more than three and half times the land area)

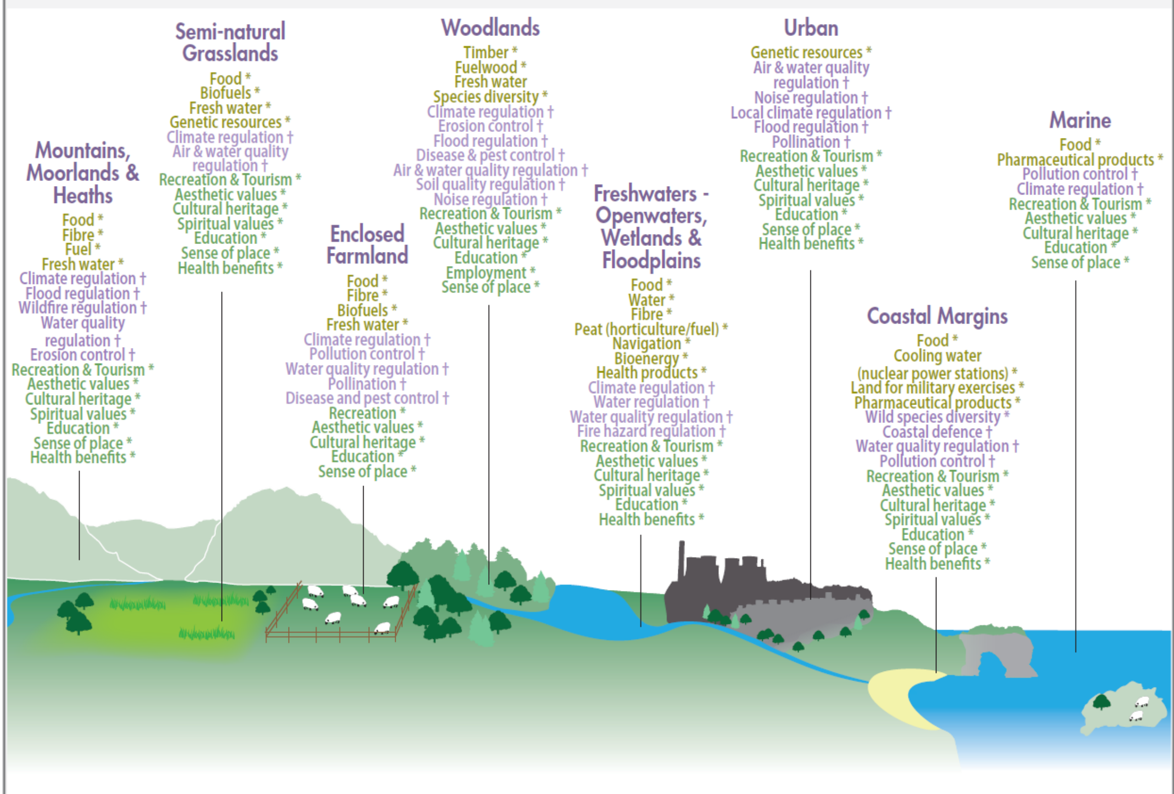


Figure 1.1 The eight Broad Habitats assessed in the UK NEA and examples of the goods and services derived from each. Items marked with an * denote goods, those with † denote services. Items in yellow are considered to be from provisioning services, purple from regulating and green from cultural. The supporting services, including primary production and nutrient cycling, are not listed against individual habitats as they are considered necessary for the production of all other ecosystem services. Source: adapted from the Millennium Ecosystem Assessment (MA 2005).

The UK-NEA included a two years follow-on phase, which was finalised in 2014 and included work on economic valuation of ecosystem services, further analysis on cultural ecosystem services, research on future changes in ecosystems and the development of tools and other supporting materials. All reports produced by the UK-NEA process can be found in the UK-NEA webpage (http://uknea.unep-wcmc.org).

Box 1.2 The Spanish National Ecosystem Assessment

The Spanish National Ecosystem Assessment (EME, from its name in Spanish: "Evaluación del Milenio de España") is an ambitious assessment exercise of the Spanish ecosystem services. It was structured following the categories proposed by the Millennium Ecosystem Services, i.e. provisioning, regulating, supporting and cultural ecosystem services. Table 2.2 below**Error! Reference source not found.** shows the 22 ecosystems services covered by EME, which were assessed over 14 kinds of Spanish ecosystems: sclerophyllous scrub and forests; continental Mediterranean forests and scrub; Atlantic forests; Alpine forests; Mediterranean mountains; arid areas; ecosystems in the Canary Islands; agroecosystems; marine ecosystems; rivers and riparian areas; lakes and internal wetlands; aquifers; coastal ecosystems; urban ecosystems.

Table 2.2 Ecosystem services included in the Spanish National Ecosystem Assessment

Provisioning ecosystem services	Regulating ecosystem services	Cultural ecosystem services
1. Food	8. Climate regulation	16. Scientific knowledge
2. Fresh water	9. Regulation of air quality	17. Local ecological knowledge
3. Biotic primary resources	10. Hydrological regulation	18. Cultural identity and sense of belonging
4. Geological primary resources	11. Erosion control	19. Spiritual and religious enjoyment
5. Renewable energy	12. Soil fertility	20. Esthetical enjoyment of landscapes
6. Gene pool	13. Regulation of natural perturbations	21. Recreational activities and ecotourism
7. Natural medicine and active principles	14. Biological control	22. Environmental education
	15. Pollination	

The analysis was performed using five case studies at different spatial scales: national scale, regional scale (Biscay region); ecosystem scale; river basin scale; detailed scale (case studies on Doñana natural park and transhumance in the Real Conquense glen).

The assessment was carried out using more than 400 indicators, aiming at evaluating the change in the human use of the ecosystem services and the change in their state, and covering the period between 1960 and 2000.

The results were used as a basis for the economic valuation of 12 ecosystem services, using market-based, stated preferences and participatory scenario methodologies.

The results of the EME process are uploaded in the dedicated webpage, http://www.ecomilenio.es.

Box 2.3 the Flanders Ecosystem Assessment

Flanders, the northern region of the Belgian federal state, has seen a surge in ecosystem services projects and networks during the last 6 years (Segers *et al.* 2013), resulting in a ‘Flanders Regional Ecosystem Assessment’ (Flanders-REA, Stevens *et al.* 2015).

The 1500p technical report of Flanders REA was authored by an interdisciplinary team from different research institutes, agencies and administrations. Flanders REA consists of 16 ecosystem services chapters by specialist author teams, preceded by 10 overarching analysis chapters. Intensive editing framed the variety of ecosystem service types and author styles into a flexible yet comparable conceptual framework and provided a reporting structure geared towards regional policy-relevant research questions. All chapters, maps and reports are publicly available on www.nara.be.

Ecosystem Service	Demand	balance	Supply	State
Food production	↑	>	↑	● (red)
Game production	↗	>	↘	● (yellow)
Wood production	↗	>>	↗	● (red)
Energy crop production	↑	>>	↗	● (red)
Water production	↘	>	↘	● (yellow)
Pollination	↗	<<	↓	● (green)
Pest control	↗	>>	↘	● (red)
Soil fertility maintenance	↓	>	↓	● (yellow)
Air quality regulation	↓	>>	↑	● (red)
Noise reduction	↗	>	→	● (yellow)
Regulation of erosion risk	↑	>	↑	● (red)
Regulation of flooding risk	↑	>>	↑	● (red)
Coastal protection	↑	>	↘	● (red)
Climate regulation	↑	>>	↘	● (red)
Water quality regulation	↗	>>	↑	● (red)
Space for outdoor activities	↑	>	↘	● (red)

Tab. 1: Trends in ecosystem service supply and demand, supply-demand balance and state assessment for 16 ecosystem services in Flanders.

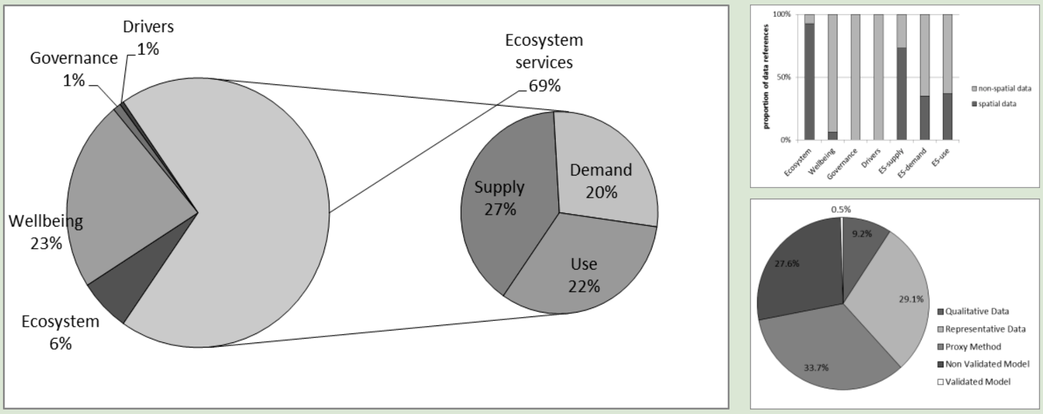
State assessment	
● (green)	Balanced demand/supply and no negative use effect on other services
● (yellow)	Vulnerable demand/supply balance or negative use effect on other services
● (red)	Unbalanced demand/supply or strong negative use effect on other services

Demand/Supply trend		Demand versus supply balance	
↑	Increase	>>	Much larger demand
↗	Slight increase	>	Larger demand
→	No clear trend	~	About equal
↘	Slight decrease	<	Smaller demand
↓	Decrease	<<	Much smaller demand

Reliability
Unknown
Low
Moderate
High
Very high

Towards 2020: from state to trends and accounts

Reporting on the state of ecosystem services was based on a transparent and traceable meta-review methodology of the ecosystem service reports, including quantification of reliability. Assessment of the state of an ecosystem service relates to four aspects: the trend in demand, the trend in supply, the balance between demand and supply and the impact of ES use on other services. This required capturing information from all available information sources (statements, model results, measurements data, expert judgments, arguments, case studies and maps) within the 16 ecosystem service chapters. Only a minority consists of validated quantitative models, and about 40% of the information sources underpinning the assessment are mapped data. The main data gaps are situated in the ecosystem function, drivers and governance aspects of the assessment (fig. 1).



Data availability varies between components of the assessment framework (left panel), varies over different data types (sensu Schägner *et al.* 2013, lower tight panel) .and between mapped versus non-mapped data (upper right panel).

The Flanders regional ecosystem assessment delivers detailed input to the EU biodiversity targets, answers a number of locally relevant policy questions and lays the basis for development of indicators and reporting/ accounting system for the Flanders region. However, putting the assessment challenge into real practice also generated some lessons concerning ecosystem assessments and potential for accounting:

- Mapping is a powerful and useful way to organize and show data, but confidence of maps should be known and addressed to perform accounting or draw reliable conclusions.
- A regional accounting system and trend assessment ideally consists of a repeated state assessment based on a broad range of data, information and knowledge types.
- Obtaining policy relevance on regional levels is both a challenge and an obligation for EU level accounting to draw on regional public (human) resources.
- EU guidance should focus on quality standards and facilitation of transdisciplinary networking, explicit legitimation of the assessment's goals and an elaborate description of concepts.

On a national or regional level, there is a need of indicators on different components of ecosystem services. These have to aggregate a large and diverse amount of data, taking into account clear criteria Jacobs et al 2014). This entails a significant personal and professional challenge for assessment teams, transforming traditional scientific work in several ways. Local, regional, national assessments and larger-scale assessments should share methodologies and lessons to aid this transformation.

Source: Jacobs et al., (2015)

The ecosystem assessment exercises described in the previous section can be seen as a first step to develop Ecosystems Accounts. They both provide information that can feed into accounts, and, where accounts are developed in a spatially explicit way with sufficient resolution, could also provide a type of snapshot of results that accounts could develop. With regular updates this could also allow trends over time to be monitored.

Developing accounts at the EU and national level

The process of building Ecosystems Accounts is ongoing both at the EU and at the national level. At the EU level, the EEA is currently preparing Simplified Ecosystem Capital Accounts (SECA), which include four kinds of accounts, i.e. organic carbon accounts; water accounts, landscape/species accounts and land accounts. These accounts are being developed only in physical terms, because of the additional methodological challenges and uncertainties that a monetary accounts would imply (see Chapter 3). In the future, other accounts may be added, like for example fish accounts or nutrient accounts. SECA is being compiled with a spatial resolution of a 1km2 grid, based on available datasets and statistics at the EU level10.

Also, some EU countries have started developing different kinds of Ecosystems Accounts at the national level. For example, in the UK initial accounts for woodland and freshwaters have been published, together with scoping studies for marine ecosystems and peatlands [see Box 2.4 and 2.5]. In Germany, water, carbon and forest accounts have been already developed [ref to add]. Also, in Sweden pilot water and forest accounts have been developed[11].

In general, these accounts are not developed in a spatially explicit way because developing spatial explicit accounts at the national level implies the need for a high amount of detailed data and human resources. However, some first attempts to develop spatially explicit accounts at regional level have already being developed. For example, experimental spatial biophysical accounts were developed for the province of Limburg, in the Netherlands (see Box 2.6).

The biophysical accounts discussed so far were prepared with the objective of using the information collected to prepare monetary accounts. For example, in the UK monetary accounts were included in the National Ecosystem Assessment, whereas in Spain monetary

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[10] The most important data source for SECA is the Corine land cover database, which is used for the land accounts and as a basis for the other accounts. It covers the years 1990, 2000, 2006 and 2012.

[11] To do: add ref - see comments from DE just in (27 November 2015)

accounts were published in 2014, three years after the publication of the accounts in biophysical terms – the use of monetary accounts will be discussed in more detail in Chapter 3.

Box 2.4 Ecosystem accounts for woodland in the UK

In the UK, eftec developed woodland ecosystem accounts for DEFRA in 2015 (eftec, 2015a). They include: a physical account (condition and extent of the stocks), an account for ecosystem service flows, and a monetary account (presenting values for the stocks and flows):

1) Ecosystem Accounting Unit: accounts prepared for Great Britain, and (in greater detail due to better data) for the Public Forest Estate (PFE) in England

2) Land cover/ecosystem service unit: woodland with a focus on – timber provision, carbon sequestration, recreation and water flow regulation

3) Basic spatial unit: 1km2 either through detailed spatial units or through disaggregation of national/regional data

For every ecosystem service considered here, a methodology in 5 steps has been implemented to create the different accounts:

1. selection of ecosystem services (listed above);
2. development of logic chain models to specify the productivity of the ecosystem and the provision of services (based on a review of evidence/literature about the link between ecosystem assets and the benefits for society);
3. gathering of physical data for the physical stock account;
4. gathering physical data and/or ecosystem service models for the physical flow account;
5. identifying valuation evidence for the monetary stock and flow accounts.

Flows of timber production are far from constant for any given area, due to long forest production cycles. For accounting, the profile of flows over 20 years is based on “constant flow” assumption averaged over areas. In reality this service flow in the future will depend on economic and environmental conditions and woodland management, but full analysis of possibilities would be difficult to incorporate in accounting. An assumption has also been made about the age of harvested (between 40-60 and 80-120 years for conifers and broadleaves respectively). For more details on time horizon, see Chapter 3.

The resulting physical stock (Table 2.3) and flow (Table 2.4) accounts were then used to build monetary accounts (Table 2.5), using market values for timber, official government values for carbon, and imputed values based on travel costs for recreation.

Table 2.3 Physical account of ecosystem condition and extent (stock) at the end of an accounting period for GB woodland

Ecosystem: Woodland 2012	**Ecosystem extent**	**Characteristics of ecosystem condition**														
	Total Area	Species Type *(Extent and Volume)*				Age *(years)*				Biomass Stock	Carbon Stock		Woodland in Flood Risk Areas[10]			Woodland SSSI
		Broadleaved (BL)	Coniferous (C)	BL	C	0-40	41-60	61-80	>80	Total	Total Biomass	Total Soil	FZ1	FZ2	FZ3	
	(million ha) [1]	*Extent (million ha)* [2]		*Volume (mill m3)* [3]		*Age by Volume (mill m3)*[4]				*Million tonnes (Mt) oven dry*[5]	*MtCO2*[6]	*MtCO2*[7]	*Extent (mill ha)*[8]			*Extent (mi ha)*[9]
Coverage (Countries/ regions)	GB	GB		GB		GB				GB	GB	SW England	E&W	E&W	E&W	GB
Closing Stock (2012)	**2.78**	**1.27**	**1.51**	**239**	**375**	**163**	**251**	**105**	**109**	**426**	**780**	**133**	**2.61**	**0.094**	**0.075**	**0.243**

Table 2.4 Physical account of ecosystem service provision (flow) for GB woodland

		Type of ecosystem			
		Woodland			
		Flow (Annual, 2012)		Expected future Flows ('20' years)	
Provisioning	Biomass for Timber	Broadleaved BL	Coniferous C	Broadleaved BL	Coniferous C
		-	-	-	-
	FC Estimates	*0.587 million m^3(overbark)*	*11.78 million m^3 (overbark)*	*11.74 million m^3 (20 yrs; 2012-2031)*	*235.60 million m^3 (2012-2031)*
Regulating	Carbon Sequestration	*6.01 $MtCO_2$*	*6.55 $MtCO_2$*	*120.20 $MtCO_2$*	*131.00 $MtCO_2$ (2012-2031)*
	FC Estimates[1]	*10.3 $MtCO_2$ (2010)*		-	
	Water flow regulation	*Difficult to measure in physical terms*		*Difficult to measure in physical terms*	
Cultural	Recreation	*481 million visitors*		*9,620 million visitors (2010-2029)*	

Table 2.5 Monetary account of ecosystem stock and flow for GB woodland (2012, £ million)

		Type of ecosystem service					
		Biomass for Timber		Carbon		Recreation	Water Regulation
		Broadleaved	Coniferous	Broadleaved	Coniferous		
Value	Flow (Annual)	9	165	341	372	1,669 (2010)	Not modelled
	Stock (PV of future flows over 20 years)	127	2,431	5,738	6,254	24,552	Not modelled

Box 2.5 Marine ecosystem accounts in the UK

Building marine ecosystem accounts face several challenges such as the lack of good habitat maps, the mobility of the different species within the ecosystems/habitat, lack of data, and uncertainties about future ecosystem dynamics (such as fish stock recovery). In the UK, alongside the full woodland accounts, eftec also developed a scoping study for DEFRA about how marine ecosystem accounts can be developed in the UK (eftec, 2015b). Again these include: a physical account (condition and extent of the stocks), an account for ecosystem service flows, and a monetary account (presenting values for the stocks and flows):

1) Ecosystem Accounting Unit: the spatial boundary is within the limits of the UK Exclusive Economic Zone (EEZ) and the mean high water mark (HWM), limits to estuaries on the coast and to the surface of the sea bed.

2) Land cover/ecosystem functional unit: Marine ecosystem with a focus on 3 ecosystem services (fish, carbon and recreation) to provide examples

3) Basic spatial unit: variable, depending on the service (see tables below).

These accounts generally follow the same steps as the woodland accounts, with logic chain models and the definition of marine metrics for each one of the considered ecosystem services, and assessment of physical data and ecosystem service models for the physical stock and flow accounts. However, they have been adapted to the specificities of the marine system and the lack of robust data. For example, the study explains that, in part because of international stock recovery plans, the landings (flow of fish) will vary. The accounts should thus not assume a constant flow, which would be inconsistent with current scientific assessments. Short-term, medium-term and long-term approaches have been proposed. For the short-term, the accounts should use data on pressures (for surface water, pelagic environment and benthic environments) instead of only using data on the spatial extent of marine characteristics, with steps to incorporate progress made on fish stock analysis, pressure analysis, and recreation. The medium-term approach would focus on the use of scientists' stock assessment advice for ecosystem accounts, the carbon sequestration rate of saltmarsh, maerl and shellfish varying according to their condition, and the costs of different recreational visits/activities in different areas. Finally the long-term approach should focus on the link between ecosystem characteristics, their contribution to ecosystem service provision, and the impact of pressures on the ecosystem characteristics.

Valuation of some ecosystem services is carried out to create the monetary accounts. For the value of fish/fishing service, two calculation options are proposed: using the market price data, or assessing the final ecosystem service value by removing from the exchange value the costs of harvesting and management. The latter is more correct, but runs into practical/political problems since in the present situation fisheries rents are often negative (because stocks are overfished, the industry is over capitalised, and management is costly). The value of marine carbon sequestration could be assessed in various ways - through non-traded carbon price, short-term traded carbon price or the social cost of carbon – but the value needs to be consistent with the one used for the carbon sequestration from UK woodland and in other accounts. The value of recreational benefits from coastal margins and the marine environment is valued based on the unit value per trip estimated in Sen et al. (2014) (defined £4.11/trip according to a meta-analysis).

Thus, the resulting physical stock (Table 2.6) and flow (Table 2.7) accounts were used to build monetary accounts (Table 2.8).

Table 2.6 Physical account of ecosystem asset condition and extent (stock) at the end of an accounting period

Ecosystem Asset: Marine 2014		**Ecosystem extent**	**Characteristics of ecosystem condition**						
		Total Area	North Sea cod (volume) Single species model			North Sea carbon pump	Blue flag beaches	Coastal paths	Scuba diving sites
			TAC	UK quota*	Discard as a % of total catch	Area (covers entire area of North Sea)	Number of awarded sites	Length of coastline	Number of sites
	Habitats	*km²*	*tonnes*	tonnes	*tonnes*	km²	Number of awarded sites	Km of coastline	Number of sites
Closing Stock (2014)	Marine	773,676	33,391	10,977	23%	261,026	99	2,650	732
	Saltmarsh	337							
	Offshore sediments (50-200m depth)	230,599							
	Offshore sediments (>200m depth)	218,167							
	Maerl beds	84							
Data Sources		Sea Around Us Project	ICES simulations			Environment Agency, MESH Atlantic Habitat Map, Thomas et al. (2007)	British Marine Federation, MENE, Natural England		
Coverage (Nations)		**UK**	**North Sea**			UK	UK	UK	UK

* The Total Allowable Catch (TAC) indicates overall state of the stock. Quota indicates the share of TAC which the UK can exploit. TAC reflect scientific judgement on numerous characteristics of marine fisheries including population, age structure, maximum sustainable yield as well as other pressure on the stock.
Note: the habitats listed are not mutually exclusive. Moreover, they are considered both as 'characteristics' of the marine habitat as well as habitats in their own right.

Table 2.7 Physical account of ecosystem service provision (flow)

		Type of ecosystem asset	
		Marine	
		Flow (Annual, 2014)	Profile of Flows ('20' yrs)
Provisioning	**Fisheries**	North Sea cod UK quota	North Sea cod UK quota
	Single species model (Cod)	*10,977 tonnes*	*1.02 million tonnes (20 yrs; 2014-2023)*[1]
	Fisheries Single species with multi-species interaction (Cod)	*10,977 tonnes*	*0.51 million tonnes (20 years, 2014-2023)*[1]
Regulating	Carbon Sequestration[2]	*Saltmarsh: 67,375 tC* *Offshore sediments (50-200m depth): 0.98 tC* *Offshore sediments (>200m depth): 0.004 tC* *North Sea carbon pump: 2,161,296 tC* *Maerl beds: 16,707 tC*	*44,907,590 tC (20 years, 2014-2033) i.e. constant flow assumption*
Cultural	Recreation	*99 million visits to coastal margins and the marine environment in Great Britain in 2013*	*1,980 million visits to coastal margins and the marine environment in Great Britain (20 years, 2013-2032) i.e. constant flow assumption*

Notes:
[1] Information on the profile of North Sea cod UK quota is provided in Annex 6. The two models used have the same estimates for 2014 but the profile of flows changes subsequently due to different assumptions under each model. In contrast to the results presented for the single species model with no multi-species interaction, the modelling which includes multi-species interaction is assessed over a 10-period after which UK quota stabilises at 29,916 tonnes per year until 2033.
[2] Half the estimate for the amount of carbon sequestered in the UK is allocated to international waters. This is because the North Sea carbon pump is an interaction between the North Sea and deep waters in the international waters of the North Atlantic.

Table 2.8 Monetary account of ecosystem asset stock and flow

		Type of ecosystem service			
		Fisheries Single species	**Fisheries** Single species with multi-species interaction	Carbon sequestration	Recreation
Value (2012)	Flow (Annual, 2014)	£22m	£22m	£490 m	£407m
	Stock (PV of future flows over 20 years[29])	£1,331m	£719m	£8,372m	£5,987m

Note: The value of the flow and stock of all marine ecosystem services is expressed in 2012 prices. This consistent with the approach for the woodland ecosystem account. The value of benefits from marine carbo sequestration is calculated using central non-traded carbon prices from DECC. Present values are calculated accordance with HM Treasury (2003) Green Book Guidanc

Box 2.6 The physical accounts developed in the Netherlands

In the Netherlands, spatial biophysical accounts have been developed for 2010 for the province of Limburg at three scales (Remme et al., 2014):

1) Ecosystem Accounting Unit: administrative boundaries of Limburg province

2) Land cover/ecosystem functional unit: pastures, cropland, forest, water, urban, infrastructure, heathland, other nature

3) Basic spatial unit: 25 x 25m

A specific spatial model was developed for every ecosystem service, using the ESRI ArcGIS 10 and Geospatial Modelling Environment software. The study covered the ecosystem services detailed in Table 2.9, presenting results in totals, mean/km/yr, and estimated standard deviations on the means.

Table 2.9 Ecosystem services covered by the accounts developed for the province of Limburg (the Netherlands)

Category	Service	Unit of measurement	Total per year for the area	Range across LCEU types of the means	
Provisioning	Crop production	10^6 kg produce	1,868	t/ha/yr	41.8
	Fodder production	10^6 kg dry matter (dm)	784	t / ha / yr	10.9-12.0
	Drinking water extraction	10^3 m^3 water	26,995	$10^3 m^3$/ha /yr	1.3-2.4
	Hunting	kg meat	34,193	kg/km^2/yr	13-32
Regulating	Air quality regulation	10^3 kg PM_{10}	2,254	kg/km^2/yr	0.5-2
	Carbon sequestration	10^3 kg carbon	61,429	10^3 kg/ha/yr	0-1.45
Cultural	Recreational cycling	10^3 trips	9,122	Trips/ha/yr	84-128

Source: Remme et al., 2014

The results were used to build monetary accounts, as related by Remme et al. (2015)

2.4 Interpreting the results

As explained above, Ecosystem Accounting is still at an early stage. At the EU ecosystems and their services are being mapped through the MAES process, and some countries are developing water, forest and carbon accounts. Also, in the UK, scoping studies for accounts on marine ecosystems and peatlands are being developed.

When interpreting the results of physical (and also monetary) indicators, it is very important to be aware of their scope, definition and required assumptions and hence their meaning and robustness, and therefore utility (i.e. for what are they fit-for-purpose) – see wider discussion on policy utility in Chapter 4. In general, ecosystems in better conditions will generate more ecosystem services than ecosystems in poor conditions, even though the link between ecosystem conditions and flows of ecosystem services is not straightforward.

For example, the way ecosystem services are defined and accounted for imply the existence of beneficiaries. For this reason, an increase or decrease in ecosystem services may depend on a variation in the number of beneficiaries and not on a change in the quantity or quality of the ecosystem services per se. As an example, the construction of a road in a forest or an increase in population near a natural area can result in an increase in the related ecosystem services, even though they may also mean a higher pressure over its ecosystems.

In general, since the areas more pristine and rich in biodiversity tend to be located in less densely populated areas, the actual flows of ecosystem services cannot be taken as a measure of the quality of ecosystems nor of the *potential* for the ecosystems to support services in future. For this reason, accounts of ecosystem services can be useful to compare similar areas or to monitor trends over time of a specific area, but cannot be used alone to prioritise conservation intervention across different areas. Their policy relevance can be increased if they are combined with accounts of ecosystem condition, in order to be able to provide a full picture, and also with other kind of indicators not based on the benefits provided by ecosystems to human societies, like for example biodiversity indicators.

In addition, the aggregation process should be carried out very cautiously. Even if SEEA-EEA suggest not to aggregate ecosystem services across different types of Land Cover/Ecosystem Functional Units (LCEUs), it allows aggregation of the same type of LCEU across different regions of each country. However, this process may uncover regional differences, as the importance of ecosystem services is strictly related to the characteristics of each area. Also, aggregation needs to be carried out cautiously if information on the flow of ecosystem services is not measured in each area, but needs to be estimated on the basis of data from other sites and using scaling and transfer techniques to provide estimates for other areas. In general, both measurement in terms of simple indicators, and the subsequent aggregation of those indicators, inevitably imply a loss of information, and for this reason spatial accounts will represent an important development of biophysical accounts. On the other hand, the measurement and aggregation processes also transform information into more comprehensible, useable and comparable forms: spatial accounts will be better for certain purposes, but will not replace the need for aggregate accounts.

Accounting requires the use of methodologies to adjust the available data to the required scale and occasionally to develop estimates based on scaling and transfer methodologies. This results in the use of a range of assumptions, and in an inevitable degree of uncertainty. For this reason, it is very important to be aware of the level of uncertainty associated with the accounting exercise and also on the assumptions employed, in order to put the results of accounts in context and interpret them correctly.

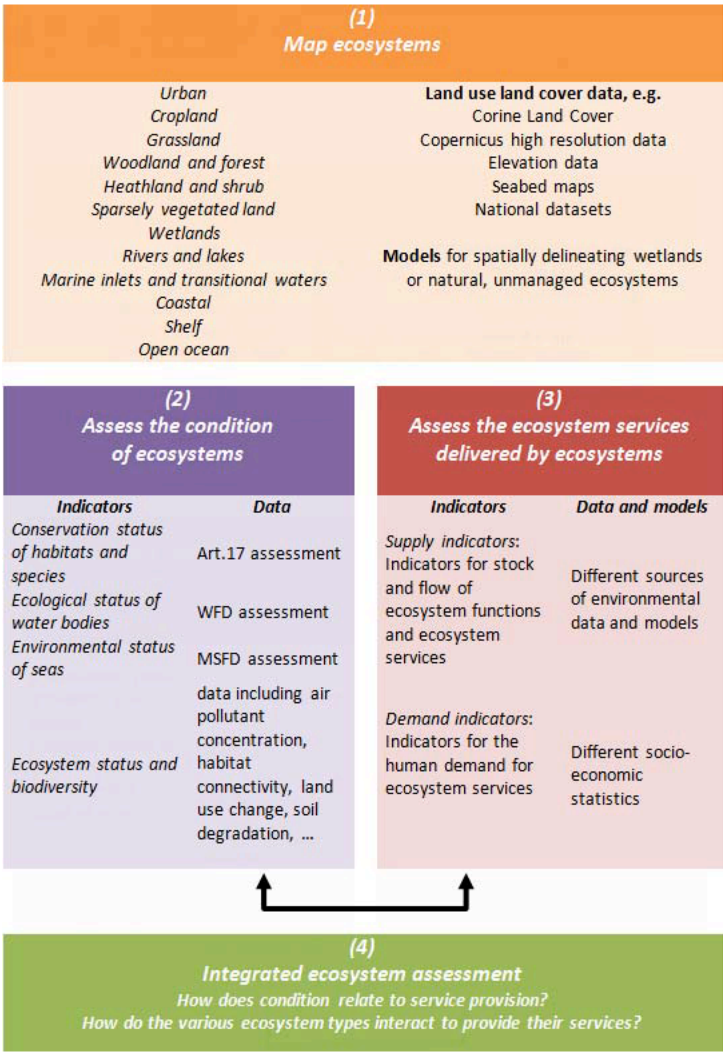
In general, Ecosystems Accounts can be useful to discuss policy priorities, for example by allowing trends of ecosystem services in different areas to be compared, or showing a decreasing trend in a specific area that needs to be addressed. They can also be useful to discuss trade-offs between alternative land uses. For example, a change in the ecosystem condition may increase the provision of certain ecosystem services (e.g. recreational ones and provisioning ones) at the expense of others (e.g. regulating ecosystem services). In many cases (but not always), an increase in provisioning services tends to be linked to an increased environmental impact, resulting in the decrease of other ecosystem services. In addition, Ecosystem Accounts can give an important indication on the trends in biodiversity at the level of ecosystems, by linking e.g. land use accounts to water and organic carbon accounts. Some promising potential in this direction is represented by the EU Earth observation programme Copernicus, which will provide vast amounts of accurate and easy-to-access satellite data on, among other areas, land management, the marine environment and climate change. The potential policy use of Ecosystem Accounts will be developed more in-depth in Chapter 4, whereas Chapter 3 will focus on the use of monetary valuation in the context of accounting.

2.5 Future developments of ecosystem accounting

As explained above, the EU Biodiversity Strategy requires Member States to map and assess the condition of ecosystems and the flows of ecosystem services both in physical and monetary terms. In order to progress towards this objective, a number of initiatives are in place, including the MAES process, the MESEU study and the development of SECA by the EEA.

The mapping exercise of the MAES process will be used to develop accounts, as shown in Figure 2.1. According to the MAES roadmap, by 2016 biophysical ecosystem asset accounts will be ready at the EU level and in some Member States, accounts for ecosystem services will be prepared by 2018 and by 2020 accounts for ecosystems and ecosystems services will be developed in monetary terms. The final objective is to develop a data set at the EU level.

Figure 2.1 A common assessment framework for ecosystems and ecosystem services



Source: European Commission, 2014

As regards the SECA process, the data of the SECA land accounts are already accessible in the EEA webpage for the years covered by Corine[12]. A first time series of SECA carbon accounts will be prepared by the end of 2015, covering the years between 2000 and 2010, and an update including the years between 2000 and 2012 is scheduled for early 2016. As regards water (quantity) accounts, they are being developed at the EEA as part of SEEA water accounts and integration in SECA is scheduled for 2016. Finally, the EEA is developing specific indicators at macroscopic level and based on changes in the 'ecosystem condition', to be used to build landscape/species accounts, including the Net Landscape Ecosystem Potential (NLEP) for landscape structure, the indices of EU protected species

[12] http://www.eea.europa.eu/data-and-maps/data/data-viewers/land-accounts

(article 17 reporting) for biodiversity and some additional data layers on bird population trends and ecotones.

At the national level, different countries are in the process of developing Ecosystems Accounts and assessments of ecosystems and ecosystem services. For example, Germany is developing water, carbon and forest accounts (all in physical terms), and also studies on the steps needed to develop other kinds of physical and monetary Ecosystems Accounts, including the development of a set of indicators to assess ecosystem services at a national level. UK has already published accounts for woodland and freshwaters, as well as land use and land cover stock accounts and scoping studies for marine ecosystems and peatland. Work is ongoing in the UK to develop enclosed farmland accounts, carbon accounts and cross-cutting service accounts for recreation and water-related regulatory services). In France an assessment of ecosystems and ecosystem services is currently being developed, aiming at being finalised by 2017 and covering six types of ecosystems (agro-ecosystems; forests; marine and coastal ecosystems; freshwater and wetlands; urban ecosystems and mountains and rocks).

In general, developing accounts, and especially geographically explicit accounts, require a notable effort and consequently an investment from national or international bodies. For this reason, the degree to which accounts will be developed depends on the political will and the consequent availability of funding from national governments and EU bodies like Eurostat.

For example, in the Netherlands there are plans to develop accounts at the national level for a range of ecosystem services, including provisioning ecosystem services (crops, fodder, groundwater), regulating ecosystem services (carbon sequestration, air quality regulation, pollination, natural plague resistance) and cultural ecosystem services (amenity services, nature tourism, biking tourism). However, these accounts are going to be developed only if enough funding is secured.

In addition, developing accounts requires collaboration among different kinds of experts, including statisticians, ecologists and economists and the use of different sets of databases that are developed by different institutions and at different scales. For this reason, institutional collaboration among different bodies at the national and EU level is key, and needs to be promoted in order to cover data gaps, create synergies and improve the effectiveness of the process. The development of ecosystem accounts will proceed hand in hand with the development of biophysical assessments, mapping and data as well the development (or adaptation of existing) of valuation methodologies for accounting contexts, and the development of policy uses for accounting information. The next two chapters focus on these central aspects of the accounting research agenda.

3. The use of monetary valuation for natural capital and ecosystem service accounting

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3.1 Introduction

Standard national accounts focus mostly on traded goods and services, with some important exceptions for which imputed values are used. This means that these accounts do not reflect several fundamental factors that underpin economic activity. In particular, depletion of resource stocks are 'invisible' to GDP accounts, and changes in non-traded natural capital and ecosystem services are not included. Environmental accounting and ecosystem accounting seek to address important parts of these shortcomings, by measuring the value of non-marketed natural services, and taking into account changes in the condition and value of natural capital stocks.

Physical accounts can be developed with little concern for issues of valuation or comparability with the SNA (see chapter 2). For monetary accounts, however, valuation is a central and contentious issue. Values can be defined and measured in different ways, and the appropriate choices will depend on the purpose of the assessment. A particularly important distinction is between exchange values and welfare values: while the valuation of non-market ecosystem goods and services is well established, there is a crucial inconsistency between the welfare-based values that are usually derived for use in CBA and the exchange values used according to the SNA principles that underpin ecosystem accounting. Other relevant issues include the treatment of different spatial scales, assumptions about future flows and time horizons, and the distinction between realised and potential values. The need to develop and improve the application of valuation in ecosystem accounting is the subject of growing attention (see for example Pittini et al., 2013; Defra and ONS, 2014; Obst et al., 2014).

A crucial distinction must be made between valuing natural capital assets and valuing the flows of ecosystem service they generate. These are related, but not identical. In principle, the value of the capital asset is simply the net present value of these flows, which could be calculated by modelling the future supply of ecosystem services, valuing them using appropriate non-market valuation methods and finally, discounting them to present year currency. In practice, each of these steps is possible, but difficult. For instance, many natural capital stocks are managed over very long time scales (e.g. 150 year rotation for some timber stocks), but associated economic models have little relevance over these time scales.

A further challenge is that many environmental valuation methods are appropriate for valuing particular quantities or levels of ecosystem services, such as a unit reduction in air or water pollutant concentrations, tonnes of timber, or a number of recreational visits. These can be considered 'marginal' values in that they are appropriate within a particular range of ecosystem service supply. Only in relatively rare cases is it appropriate to extrapolate these marginal values across large changes in the supply of ES (the notable exception is for valuing GHG flows). For instance, while Fiquepron et al (2013) show that on average 1 hectare of *new* woodland generates a savings of around €22 per year (in 2004 Euros) on French household water bills, it would be inappropriate to assume that 10,000ha of *existing* woodland already saves domestic users €220,000 per year. The point here is that valuing ecosystem services flows is not quite the same as valuing natural capital stocks, and economic methods are often better suited to valuing *marginal changes* in flows and in natural capital stocks than they are to valuing total flows and entire stocks. This is an important distinction when attempting to 'relate the environment to national accounts'.

3.2 Valuation principles for accounts

Non-market valuation is a well-established tool of environmental economics, with a rich theoretical background comprising several valuation methods, and an extensive literature of applied valuation work. OPERAs deliverable D3.2 covers the topic in some detail. Specifically for environmental and ecosystem accounting purposes, however, there is some disagreement over the appropriate methods and approaches that should be taken. In particular, this relates to the focus in the SNA, SEEA-CF and SEEA-EEA family on the use of exchange values, but there are also issues regarding time horizons, levels of accuracy required, dealing with future uncertainty and so on. These issues are discussed further in this paper.

National accounting is a method of collecting, organising and reporting desirable information on economic activity that is ultimately relevant for measuring trends and making decisions (Agarwala in preparation; Agarwala et al in preparation; Binner et al 2016). Here, desirable is key. National accounts and their constituent parts are not determined by economic theory, nor are they necessary fundamental components of a working economy (the UK's industrial revolution took place before the modern era of GDP accounting). Crucially, they are not and were not intended to be a measure of human wellbeing (Agarwala et al 2014a; Coyle 2014). Rather, national accounts are human constructs, deliberately and strategically designed to tell specific stories over time. The body commissioning the accounts has considerable influence over what these stories might contain, and how the information might be used[13]. Apart from tradition, there is no fundamental reason that national accounting procedures cannot be amended to incorporate the value of natural capital, or indeed the value of the final ecosystem goods and services it generates.

It is important to recognise that developing valuation protocols for environmental and ecosystem accounting will inevitably involve compromise, with no single "right" answers. With this in mind, Pittini et al. (2013) identify some important principles for valuation of non-marketed goods and services for national accounting:

- Accept that accounting frameworks will never capture **all** values for the natural environment. The point is rather to "expand the production and asset boundaries of the national accounts, starting with values that are as close as possible to the market and proceeding to include non-market values that probably still reflect direct and indirect use values";

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[13] Historically, accounts were developed in order to assess the taxable wealth of a territory, and the information was used to determine the prospects for war. Indeed, military interests have provided a basis for compiling accounts since at least 1085, when William the Conqueror commissioned the Domesday Book (World Bank 2011) for precisely this reason. Nearly 600 years later, William Petty's 1665 accounts for the King of England contained the following passage:

"the Warr cannot well be sustain'd beyond the year 1698 upon the Foot it now stands, unlesse

1. The Yearly Income of the Nation can be Increas'd.
2. Or the Yearly Expence Diminish'd.
3. Or a Forreign of Home Credit be Obtain'd or Establish'd.
4. Or the Confederacy be Inlarg'd.
5. Or the State of the Warr Alter'd.
6. Or a General Excise, in effect Introduced." (Bos 2008, p13)

By the 1930s, national accountants were firmly back on the war path as economists (including Nobel Laureates Simon Kuznets, James Meade and Richard Stone) were developing the basis of our current system of national accounts: initial estimates deducted government spending (e.g. on the military) from national income on the grounds that it represented a reduction in the resources available for consumption (Coyle 2014). It was only after US President Roosevelt, in preparation for the US entry into WWII demanded a set of accounts that showed military expenditure having a positive effect on the economy, that government spending was considered a contribution to gross domestic product (GDP) (Coyle 2014). Political influence over what is and is not included in the national accounts is not exclusively limited to military interests, however. For example, as recently as 2012 the Greek government, was declined for loans from the International Monetary Fund and the European Central Bank because the country's debt to GDP ratio was too high. In response, Greece's national accountants amended their GDP calculation to incorporate estimates of the informal economy, effectively expanding GDP by approximately 25% and bringing the official debt to GDP ratio within acceptable limits for securing international loans.

What William the Conqueror, President Roosevelt, the Greek debt crisis and the national accountants have in common is that the accounts they generate are and can be strategically designed to convey whatever information is desirable and deemed relevant for decision making at the time. Historically, this has not included natural capital, nor has it included ecosystem services except where they have been traded in markets. However, many of today's big societal challenges relate to environmental sustainability, making the incorporation of ecosystem information within the accounting system at least timely and useful, and perhaps long overdue and essential.

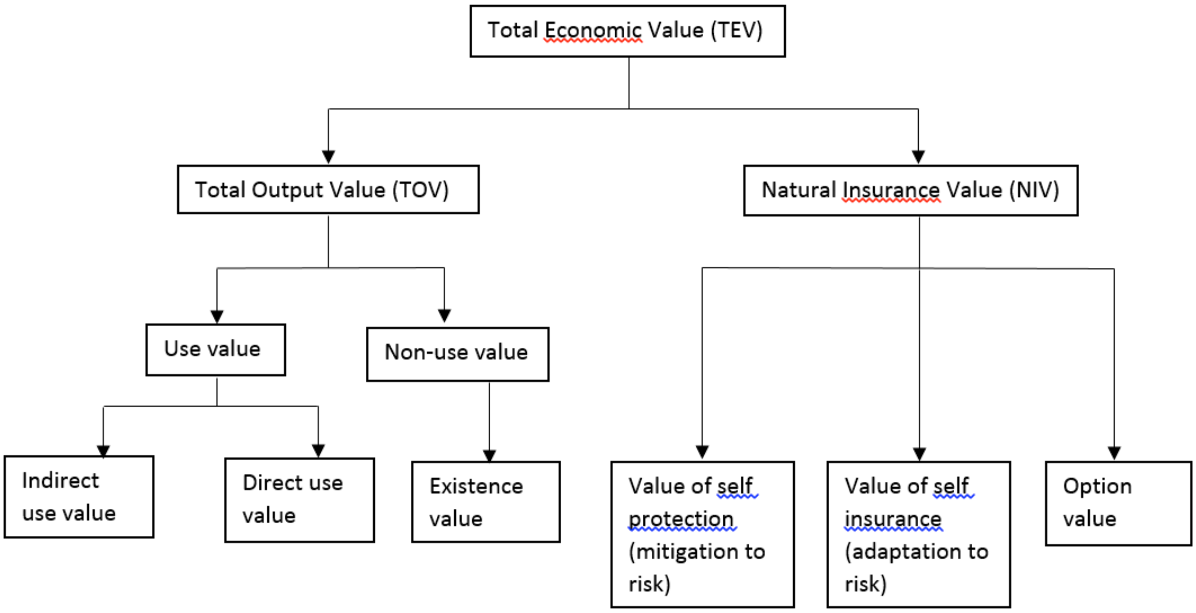
- Accept that some loss of precision in value estimates may be acceptable, for the sake of greater inclusivity;
- Accept that monetary valuation, whether through exchange or welfare values, cannot fully address sustainability concerns: there are inevitable challenges such as non-linearity, irreversibility and the limitations of marginal valuation that "point to the need for complementing monetary valuation and wealth accounting approaches with assessments of critical stocks, as well as to the importance of developing physical accounts and indicators"; and
- Recognise, therefore, that monetary accounting depends upon and must be developed in parallel with physical accounting.

Exchange and welfare values

In economics, the term 'economic value' generally refers to a measure of the contribution of a good or service to human welfare (Brouwer et al. 2013). Under the assumptions of economic theory, analysis of (changes in) ecosystem services aims to measure (changes in) 'total economic value' TEV), through estimates of (changes in) consumer and producer surpluses, or in some cases through proxies for these measures.

TEV is conventionally divided into use and non-use values for a good or service. Recent proposals (e.g. Pascual et al 2015) make space for 'natural insurance value' (NIV) as a component of TEV, with the more conventional components (use and non-use values) being classified as 'total output value' (TOV). Pascual et al further divide NIV into 'self-protection' (lowering the risk of a disturbance event) and 'self-insurance' (reducing the size of loss from an event).

Figure 3.1 TEV including NIV (adapted from Pascual et al. 2015)



This TEV framework for measuring surpluses is different from the notion of exchange value, defined as "the total value of income, production and expenditure as evidenced by transactions" (Brouwer et al. 2013) and measured as the product of market prices and quantities. Exchange values are used in economic impact assessment, generally adjusted for indirect and induced effects via the use of multipliers derived from input-output analysis.

The SNA uses exchange values, not welfare values, and the same basis is called for in ecosystem accounting (SEEA-EEA 2012). Exchange values are defined as amounts of money that willing purchasers pay to acquire goods, services or assets from willing sellers. The exchanges should be made between independent parties on the basis of commercial considerations only, sometimes called "at arm's length" (SNA 2008; 3.119). Formally, the

> *"SNA does not attempt to determine the utility of the flows and stocks that come within its scope. Rather, it measures the current exchange value of the entries in the accounts in money terms, that is, the values at which goods, services, labour or assets are in fact exchanged or else could be exchanged for cash (currency or transferable deposits)."* SNA (2008; p50 3.118).

This clearly states that exchange values do not capture the full benefits (utility) derived by the agents participating in a transaction. Thus, while walking in an open access woodland may entail an exchange value of €0, the benefits people derive from such walks may significantly exceed €0. Sen et al (2014) estimate that recreational users might be willing to pay as much as £3.59 per visit to forests and woodlands in the UK, on average, above any exchange value cost entailed in visiting the forest. This 'consumer surplus' is not included in exchange value, but is an important component of welfare value.

The focus in accounts on exchange values creates a challenge, since many ecosystem services and assets are not traded in markets and do not have observable exchange values.

Similarly, in the SNA and the SEEA-CF 2012, the valuation of assets is limited to those assets over which property rights can be enforced, because it is the existence of property rights that generates the potential for a stream of economic benefits that in turn gives economic assets their exchange value. This is problematic in the context of ecosystem accounts, where ecosystem services are often provided without any transaction and with no clear property rights. Quantities can often be observed, but not prices: to include these flows in the accounts, prices or values will have to be imputed. However, there are precedents for using imputed values in the SNA, as discussed further below.

Approaches to estimating exchange values

One option for ecosystem accounting purposes is to attempt to simulate exchange values – in other words, answer the question, what would willing purchasers pay to acquire ecosystem services and assets if they did in fact have to pay for them? To do this, we need to estimate the marginal WTP of consumers of the services involved.

In theory, if access to these services is not constrained, consumers faced with a zero price will use them up to the point at which their marginal WTP is equal to the marginal (opportunity) costs they incur in using the service. These costs will often be greater than zero, even if there is no direct market price; for example, people incur travel and time costs to enjoy outdoor recreation. These indirect costs form the basis of the revealed preference family of valuation techniques.

Day (2013) identifies three options for proceeding where no price can be observed:

1. Use a price of zero: this is a strict application of the SNA use of exchange values, valuing consumption of non-traded goods at zero;
2. Use a representative marginal price: create a model to estimate the price that would arise in a perfectly competitive market; or

- Use representative discriminatory prices: select *any feasible set* of discriminatory prices that fall below the demand curve and pass through the observed quantity.

The first option of zero price maintains maximum compatibility with the SNA. It is implicitly widespread (i.e. for all non-traded goods and services that are not included in accounts) but defeats the object of ecosystem accounting, since it effectively excludes all non-marketed ecosystem services from the monetary (though not physical) accounts. Of particular concern is the idea that this could create perverse dynamic incentives (or interpretations) - moves to create markets in environmental goods and services would result in higher values recorded in accounts – even in cases in which aggregate welfare values fell due to some consumers being excluded by higher pricing.

Option 2 is the basis of the 'simulated exchange value' approach, and seems to be the most likely option for use in practice. The simulated exchange value aims to estimate the value of ecosystem services in terms of potential revenue in a hypothetical market (Oviedo et al. 2010). Practically, this requires estimating a demand and a supply curve for the ecosystem service in question and then making further assumptions on the price that would be charged by a profit-maximising resource manager under alternative market scenarios. The hypothetical revenue associated with this transaction, excluding the consumer surplus, is taken as a measure of value of the flow of ecosystem services.

This arguably represents a more consistent basis for including their value in national accounts alongside monetary transactions, and would avoid the perverse incentives noted above – though there could still be a temptation to move to 'realise' the flows recorded in the accounts, that concern is common to any inclusion of imputed values for ecosystem services. On the other hand, it introduces a logical inconsistency, since at any given price consumers would demand a lower quantity of the environmental service compared to when it is free at the point of use. This has the potential to add confusion between the monetary and physical accounts. Using the simulated price with the existing quantity would overstate the value of the service by valuing some units at a price above the maximum WTP. Using the simulated price with the simulated quantity would avoid this, but would then involve a fictitious quantity, which could be seen as introducing an inconsistency between the physical and monetary accounts.

This would be avoided by Option 3, using any feasible set of discriminatory prices - in effect, matching each unit of the service with a price that theoretically could exist under some possible market institution. But beyond that constraint, the choice of the price function is essentially arbitrary, which could be open to manipulation and could reduce comparability across different accounting exercises. Day (2013) proposes the use of the demand curve as a solution to the arbitrariness. This would also remove any confusion or inconsistency between values recorded in accounts, and surplus values used in welfare assessments and cost-benefit analysis. However there would be practical problems where marginal WTP is very high for first units of a service, as would be the case for essential services. And, by including all consumer surplus, this would drive a wedge between the treatment of marketed goods and services (valued at exchange values excluding consumer surplus) and non-marketed goods (valued at hypothetical exchange values where all surplus is captured in the exchange). This would skew comparison between marketed and non-marketed components and would likely be strongly resisted within the national accounting / statistics community, even if it were welcomed by environmental economists steeped in the welfare values and cost-benefit analysis traditions.

The fundamental point in the above is that exchange values are dependent on market institutions and structures and the definition of property rights, whereas welfare values are not. Where actual market prices is zero, we needs must estimate some imputed value if we are to include the flow in monetary accounts. Any price function meeting the conditions of option 3 above would be sufficient. The use of a single simulated exchange value would not meet these conditions, because the price would involve exclusion of consumers with lower WTPs. Nevertheless, the simulated exchange value may be favoured for its simplicity and its reasonable fit with the valuation basis of the SNA.

Valuation methods for accounts

As previously noted, where markets exist there is relatively little trouble in deriving exchange value estimates for accounting purposes – market prices, seen as second-best proxies in the context of welfare valuation in the TEV framework, are ideally suited for accounting purposes. For non-market goods and services, however, most applied valuation studies are carried out in the context of cost-benefit analysis, or at any rate analysis of welfare changes using the 'total economic value' framework. Therefore most non-market valuation methods and applications developed in the field of environmental economics include consumer surplus, as discussed in OPERAs D3.2.

Unadjusted, therefore, these estimates are generally not directly applicable to the context of estimating exchange values for comparison with standard economic accounting estimates. However, there is considerable potential for using some of these methods to estimate exchange values, because the 'true' valuation methods (as opposed to the proxy-based methods), when applied in full, seek to estimate demand curves for environmental goods and services, thereby furnishing the core element of the simulated exchange value approach.

On the other hand, the literature on non-market valuation is thin for some important ecosystem services. Brouwer et al. (2013) reviewed EU national ecosystem assessments, and reported that while most studies cover several different kinds of provisioning, regulating, cultural and sometimes supporting services, relatively few services are assessed using non-market valuation techniques.

- Most provisioning services are valued using market prices. This is ideal for accounting purposes, and could also be extended to imputed values for certain provisioning services (e.g. wild food collection) where (a) there are market-equivalents for non-marketed provisioning services and (b) the services are significant enough to warrant inclusion.
- Regulating services are generally 'valued' using cost-based methods, notably the replacement cost approach. These are relatively easy to apply, but do not have any particular relationship with the TEV value of services (e.g. the costs to replace a service could exceed the maximum willingness to pay for it). However, where we can assume costs do not exceed maximum WTP, then the costs could be used as a simulated exchange value. The argument is that buyers who had to buy the service would be willing to do so at that price. Hence, cost-based methods may often give a reasonable estimate of (simulated) exchange value, whereas they would only be good estimates of welfare values by coincidence.
- 'Cultural' and supporting services are much less commonly valued in monetary terms. The main exception is recreation, which is relatively easy to observe/quantify in physical terms, and for which non-market valuation is quite common.

The suitability of valuation methods for accounting purposes is discussed further in **Table 3.1**.

Table 3.1: The main valuation methods and their applicability to environmental and ecosystem accounts

Family and methods	Description	Suitability for environmental and ecosystem accounts
Market-based methods: • Market prices • Production functions • Resource rent (residual value approach)	Market prices are appropriate for exchange values. There may be a need to correct for taxes and subsidies, or to estimate how values change with quantity.	Actual market transactions should already be in the SNA. Where market prices exist for equivalent or similar goods or services, this is likely to be suitable for deriving estimates of imputed values. Where the value could rather be derived from considering a non-marketed service as part of a production function, this could be appropriate, but if the final output is itself marketed there is a risk of double-counting, depending on the boundaries of assessment, and the service might be better considered as intermediate consumption.
Revealed preference • Travel cost • Hedonic pricing • Random utility model • Avertive behaviour	Methods based on values for environmental resources that are 'revealed' by behaviour in associated markets.	Applicable to non-marketed goods/ services that are part of marketed goods, or include marketed components (the 'weak complementarity' assumption). Fully applied, these methods seek to estimate demand curves (and therefore consumer surplus) but the demand curves could also be used in estimation of simulated exchange values. Potentially applicable to recreation, aesthetic values and also for mitigations e.g. to value role of natural services in screening noise, disagreeable views, air or water pollutants
Stated preference • Contingent valuation • Choice experiments	Methods based on surveys in which people express preferences through responses to hypothetical payment questions or choices about alternative states of the world.	Applicable to all goods and services and capable of covering non-use as well as use values. Most applications seek surplus measures, but the methods could be used to estimate full demand curves and therefore any simulated exchange value Double-counting is a risk, in particular due to embedding / part-whole bias.
Cost-based techniques • Avoided costs • Replacement/ restoration costs	Proxies that do not assess economic value, but rather the costs that are avoided due to some ecosystem asset, or the costs that would be incurred to replace or restore the asset.	Many services could be treated using avoided or replacement cost techniques, for example flood regulation. Widely applicable to restoration of ecosystems, potentially where targets for conservation/restoration exist. Risk of double counting if these combined with values of services supported by the systems. Could be used as proxies for exchange values, if it is assumed that the estimated cost is one that would actually be incurred if necessary (i.e. the buyer would be willing to pay that price).
Expenditure measures • Expenditures • Gross value added	Measure expenditure, not economic value: the bases of estimating regional economic impacts through input-output modelling and multipliers.	Actual expenditures will appear already in the SNA. The methods are used to assess the economic impact of recreation and tourism, but are not directly appropriate for valuing the ecosystem service. Could be used in studies of simulated exchange values.

3.3 Extending valuation boundaries

To the extent that flows are traded, they are already included in the accounts, both through the SNA and in the SEEA-CF 2012. This includes, for example, trade in agricultural output, timber, and fish catches. Ecosystem accounts seek to develop a more holistic, ecosystem-based assessment. The accounts need to record changes in the status/condition of the assets that support service flows, as well as changes in flows.

However, although the existing SNA provides a framework for measuring and reporting activity within an economy that includes final environmental goods and services that are traded in markets, their contribution to the total value of output (formally, their value added) is not attributed to the environment, but is instead implicitly attributed to other factors of production (e.g. other capital and labour inputs). For instance, the value added from the agricultural sector depends on the combination of farm labour, farm machinery, and productive ecosystems. However, because current accounting practices do not recognize the environment as a factor of production, the value added that it generates is implicitly attributed elsewhere in the economy. This leaves two challenges:

1. How to account for non-market final environmental goods and services; and
2. Attributing value added from market-traded FEGS appropriately.

With respect to the first challenge, the simultaneous desires to (i) keep the definition and calculation of GDP the same, and (ii) to incorporate the value of FEGS within the GDP calculation, are incompatible. A central feature of the SNA is its production boundary, which sets out what does and does not 'count' as economic production, and therefore what is included and excluded from the national accounts. The SNA defines economic production as "an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital, and goods and services to produce outputs of goods or services." (SNA 2008; p97, 6.24). It clearly states that natural processes "without any human involvement or direction [are] not production in an economic sense… the unmanaged growth of fish stocks in international water is not production, whereas the activity of fish farming is production." (SNA 2008; p98. 6.24). Thus, many sources of FEGS are specifically excluded from the SNA.

This means that the production and asset boundaries of the SNA have to be *extended* for ecosystem accounting, to take account of feedbacks within and across ecosystems, because the consequences of resource use and economic activity can reach far beyond the immediate area and time. This gives rise to a number of issues in valuation.

In principle, the SNA can allow imputed prices for a whole range of non-marketed natural resource services, including private production/consumption of wood fuel, fishing, water abstraction, food production, and solar power. These could all fall within the production boundary of the SNA, but in practice they are generally omitted – both for practical reasons (lack of data) and because they are relatively minor compared to industrial sectors and are not directly relevant to monetary policy.

However, in moving to environmental and especially ecosystem accounting, it becomes important to estimate exchange values for these goods and services.

The second challenge mentioned above refers to correctly attributing value added to an ‘environmental sector’ within the SNA. In principle, values already recorded in the SNA can be disaggregated to reflect the value added at various stages along the production process. Sectoral production functions describing how various sectors (e.g. forestry, agriculture, manufacturing, etc) actually utilise inputs could be developed to identify relative contributions to output (formally, the value added) from labour, capital and other inputs such as ecosystem services. These could then be used to add various ecosystems as lines in the value added sector of the input-output tables used to construct SNA accounts (Leontief 1970; Miller and Blair 2009). This would not affect the total value of GDP, but rather reattribute value from sectors that consume ecosystem services as inputs to an environmental sector that generates FEGS as outputs. Of course the process is not straightforward, and the primary challenge lies in identifying production functions that can adequately identify the share of value added that should be attributed to FEGS.

Imputed values in the SNA

Not all productive services are considered to be within the “production boundary” of the SNA. For example, most services produced and consumed by households (such as housework, cooking, gardening, childcare, etc.) are not included, though when these services are directly paid for, for example through employing domestic staff, they do then fall within the production boundary and should be recorded. There are arguments for extending the production boundary in such cases, in order to give a fuller picture of productive activity and to avoid some anomalies. However being too comprehensive would reduce the usefulness of the accounts as an indicator of the market economy: “inclusion of all activity which is productive (in the economic sense) but which does not have a monetary value would swamp the monetary flows, obscure what is happening in the markets, and reduce the usefulness of National Accounts data for analysis” (ONS, 2014b).

Nevertheless, there are many cases in the SNA in which values are adjusted or imputed values in order to ‘correct’ for certain features of institutional structures, where important services are not fully traded in monetary transactions but are nevertheless included within the ‘production boundary’ of the SNA. Perhaps the most significant imputed transaction in the national accounts is the measurement of consumption of fixed capital (depreciation). Generally, these flows are internal to an institutional unit, so no actual monetary flows occur: accounts need to impute the value of these internal transactions in order to take account of these important changes in capital stocks.

Another imputed value concerns the services of financial intermediaries: “institutional units that incur liabilities on their own account for the purpose of acquiring financial assets by engaging in financial transactions on the market” (SNA 2008; 4.101), where there is a need to split interest payments and buy-sell price differentials into a real component and a charge for financial intermediation services (see Akritidis, 2007 and SNA 2008 for further details).

Imputed values are also widely used for health and education services. These can be market or non-market goods, depending on institutional structures, and to enhance comparability across accounts the SNA classifies non-marketed cases as 'transfers in kind' for which no counterpart flow or payment is received. The rule here is to value these flows at the market prices that would have been received if the resources had been sold in the market, i.e. to infer the value from market equivalents. If that information is lacking, the SNA suggests use of the value assigned by the donor as a rule of thumb for valuing transfers in kind (SNA 2008; 3.130).

It would of course be possible to carry out accounting using welfare-economic concepts of value rather than exchange values. However, for comparisons, this would require a re-estimation of SNA based accounting valuations from an exchange value concept to a welfare economic concept of value. This possibility is explored in approaches such as inclusive wealth accounting where the aim is to incorporate shadow prices for all assets, including ecosystems. In practice, the estimation of shadow prices is a challenging task and often market prices (based on exchange value concepts) are used as proxies. There are also problems associated with estimating total welfare values for essential goods and services (such as drinking water) since marginal values are very high for the first units supplied: welfare analysis is best suited to looking at marginal changes and can struggle to cope with large or total changes. Ecosystem accounts using exchange values avoid this problem, but it must be clearly understood that such accounts are not attempting welfare valuation and do not replace the need for CBA appraisal of policy changes.

The key point here is that current accounting practices mask important environmental-economic relationships, and that to address these omissions would require an expansion of the production boundary and a willingness to impute values for (notional) ecosystem service transactions. There are precedents for expanding the production boundary, as the GDP calculation is often adjusted to incorporate a broader set of economic activities. The most recent example is the inclusion of illegal drugs and prostitution, which together contribute between £7 and £11 billion to UK GDP, annually (ONS 2014). Such expansions face the same issues of how to accurately value economic transactions when they cannot be reliably observed in standard data collection exercises. In this way at least, drugs, prostitution and environmental accounting are alike: they all require an estimation of values that cannot be readily observed in market transaction data.

Time horizons for asset valuation

The intent of asset accounts is to record the opening and closing stock of environmental assets and the different types of changes in the stock over an accounting period. Asset values can be measured in different ways, including:

- Values observed in markets (capitalised exchange values);
- Written down replacement cost (a cost-based valuation method that may or may not reflect the economic value of an asset); and
- Discounted value of future returns (i.e. summing a flow of either exchange-based values or welfare-based values over time).

The last involves estimating the present value of a stream of future flows of services. If the service flow is relatively straightforward to value – in particular, if it is traded in a market – but the asset itself is not traded, this can be the most practical approach for ecosystem asset valuation. However, while in principle, assets should be valued over an 'infinite' time horizon, in practice, assumptions about flows over long horizons are likely to be extremely uncertain, and the impact of discounting means that distant years contribute relatively less to present values. Arguably the change in value between accounting periods is of greater interest than the absolute value (which would be higher for a longer asset life). Merely for consistency across accounts, any arbitrary time period could be used, but there also a need to be consistent within accounts, including with physical accounts. This may mean there are 'natural' periods that might be considered – for example, in forest accounts, a long enough horizon to account for a full production cycle.

Actual vs potential flows

There is a distinction to be made between actual service flows and potential service flows. The difference can be very significant, due to three main situations:

- Spare capacity: services that could be economically valuable but that are not currently used fully or at all
- Changing condition: where deterioration or recovery of the 'condition' of a natural resource asset can cause large changes in future flows (or potential flows)
- Changing demand or preference conditions.

Generally, accounting frameworks prioritise the use of actual flows: see eg Defra and ONS (2014), principle 9.2. Valuation aims to assess the value of goods and services produced during an accounting period (for flow accounts) and at the present value of current and future goods and services (for asset accounts). The main rationale is that valuing actual flows is more consistent with general national accounting principles. This is generally true, and it will usually be appropriate to reflect this difference, noting for example that many regulating and cultural services will provide greater value where there are more people or businesses making use of the service.

On the other hand, there are situations in which a focus on actual flows could be misleading, in particular where flows are manifestly unsustainable, or otherwise likely to change for predictable reasons, and also in situations where the generation of benefits is highly variable or uncertain over time. For example, in forest accounts, a more representative picture of local ecosystem service flows may be derived by focusing on the annual increment rather than on the actual timber extraction, which follows very long term cycles. Similarly, for natural insurance values such as flood control or pest control, it may be more appropriate to value the potential service flow rather than actual damages avoided, which depend on variable conditions.

This also applies to calculating the asset values for accounting purposes. Ecosystems are also assets that may be capable of producing enhanced services in future – or that may be suffering unsustainable exploitation, leading to unavoidable decline in flows. In the SNA, consumption of fixed capital is tracked to account for some aspects of declining capital values. However depletion of non-produced assets (land, minerals etc.) is not accounted for.

One option is to take the position that accounts should not attempt to cover issues related to such complex and uncertain factors as ecological thresholds, non-linear ecological relationships, irreversible depletion of natural capital, and path-dependent functions. To assess these issues, other analytical tools and data would be needed. However, this could limit the usefulness of accounts, and potentially facilitate misinterpretation of accounting data. It would be possible to some extent to consider sustainability directly within environmental and ecosystem accounting, at least by attempting to account for future changes in service flows when estimating asset values.

Where current flows are sustainable, the constant flow assumption is relatively unproblematic. Although the assumption ignores any potential for enhanced future flows, this can be seen as a conservative position, and it is appropriate that any claim of increased future flows should be justified and evidenced.

When current flows may not be sustainable, for example due to over-harvesting or environmental pollution, however, the constant flow assumption could be dangerously wrong. A precautionary approach would require demonstration that a constant flow is a reasonable assumption. Where sustainability cannot be established, that begs the question of what future decline should be assumed. Dynamic models of ecosystems and service provision could help to account for possible changes and risks. Uncertainty in these models may be large, and almost certainly greater than that in measurement of current flows - but this does not mean that the assumption of constant future flows is less uncertain, or more justified.

3.4 Conclusions

Where markets exist, there is relatively little difficulty in using the exchange values in environmental and ecosystem accounts. Indeed in most cases these values will already be included in national income accounting. The extension to environmental and ecosystem accounts may involve different bundling and treatment of the values, and there may be issues associated with asset valuation, sustainability of future flows and uncertainty about future market conditions, but fundamentally the valuation issue for marketed goods and services is not a source of major concern for accounting.

Where problems arise is in the treatment of non-market goods and services. At present there is a lack of clarity as to the appropriate assumptions and adjustments that can be made with respect to the provision of ecosystem services and the estimation of exchange values. A strict interpretation of the exchange value criterion would see non-marketed goods included at zero value. However, there are notable precedents for non-traded values being included in the national accounts via imputed values (e.g. consumption of fixed capital, health, education, and intermediate financial services). It is also relevant that monetary transaction prices are not an unchanging feature of markets – they reflect the institutional setting through which the exchange takes place – and indeed this is recognised in the treatment of imputed prices in national accounts which 'correct' for specific features of institutional structures. Fundamentally, choices about what lies inside and outside the 'production boundary' of accounts reflect practical considerations and the uses to which the accounts will be put, rather than any theoretical necessity.

For some non-traded services, cost-based techniques (e.g. avoided cost, replacement/restoration cost) may be quite readily accepted as proxies for exchange values, if it is assumed that the estimated cost is one that buyers would actually be willing to pay if they had to. Care is needed to ensure that the use of cost-based proxies for ecosystem accounting purposes does not lead to confusion regarding values for use in welfare-based analyses, because where the cost of supplying a service has no relationship to the benefit derived from its consumption.

More generally, 'true' non-market valuation methods can be, and have been, applied to derive welfare measures for many environmental goods and services. These methods and evidence could be adapted to estimate part-estimates of exchange values (e.g. simulated exchange, or other 'below-demand-curve' functions). All options for imputing values for ecosystem goods and services involve introducing a fictitious exchange, so no individual option is 'better' from that perspective. A (monotonic) price function approach - passing through the current quantity and everywhere below the demand curve - would be logically consistent in representing one feasible market structure for efficient use of the service, but could be seen as arbitrary, as reducing comparability, and as confusing due to the use of different prices for different units.

The simulated exchange value has the advantage of providing a clear single price. It suffers from introducing a logical inconsistency (the single simulated price will often be inconsistent with the actual quantity), but perhaps this is of secondary concern. Obst (2013)xiv reported that economists involved in the SEEA editorial process "felt that the simulated exchange value approach had not been sufficiently tested in the economic literature", flagging this as an important area for research.

The main research agenda is clearly to develop and test approaches for imputing exchange values that are consistent with SNA principles and the way in which value is derived from natural assets with public good attributes. Existing non-market valuation methods appear to provide a ready starting point, with their use in deriving simulated exchange values a particularly promising avenue.

Research might also profitably explore the actual and likely uses of ecosystem accounts and how simulated values – both single prices and sets of discriminatory prices - would be interpreted and used by users and stakeholders. One area to address is the potential for confusion between welfare-based analyses (such as CBA for projects and investments) and the exchange value based accounts. How would stakeholders respond to having very different valuations for the same services and assets, underpinned by different conceptual bases with distinctions that are somewhat opaque to non-specialists? Is there a risk of damage to decision processes, or to the perceived relevance and robustness of valuation evidence, as a result of sending mixed signals about the value of ecosystem assets? Similarly, there could be confusion if multiple hierarchies of

[xiv] Valuation for Natural Capital Accounting: A Seminar organised by the UK Department of Environment, Food & Rural Affairs and the UK Office for National Statistics, November 2013.

accounts (national ecosystem accounts, protected area accounts, corporate ecosystem accounts…) are constructed using different valuation assumptions.

The methods and evidence base are far from perfect, and data availability and gaps in understanding are a barrier to the development of reliable valuations and accounts in many cases. This applies both to the scientific understanding of ecosystem functions and the economic understanding of how humans benefit from them. Some modelling, transfer and approximation will likely be appropriate where relevant data exist at other locations or scales. But it can be argued that accounts do not necessarily have to be strictly accurate, so much as consistent across space and time. Specific values can be hard to interpret, but observing a significant change in those values over a period of years gives a clear signal that something important is happening which policy-makers should be concerned about. The main usefulness of accounting is for monitoring and tracking trends and changes (see Chapter 4). This does not mean that accuracy is of no concern, but it does suggest that the standards could be somewhat lower for accounting purposes, provided methods can be applied consistently over space and time.

4. The policy use of ecosystem accounting

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4.1 Introduction

As discussed in Chapter 2, the development of Ecosystem Accounts at the EU and national level is still at an experimental level. At the moment, the European Environment Agency is developing Simplified Ecosystem Capital Accounts (SECA), and a number of countries are starting to build different typologies of Ecosystem Accounts, including forest, water and carbon accounts (see Chapter 2).

The ambition behind this effort is to employ Ecosystem Accounts to collect and organise available raw data (and in some cases to create new data) in a systematic and coherent way, in order to provide information that is relevant for policy making and research. This process is still in an early stage for most types of Ecosystem Accounts, and it will require a strong commitment over the next years to address the many methodological issues, to collect the necessary data and to ensure that the accounts outputs are in a suitable form, in order for them to be useful as inputs into policy making processes.

This chapter discusses the actual and potential policy uses of Ecosystem Accounts, based on a literature review, engagement with expert groups and the answers to a questionnaire sent to national experts of different countries, including the UK, the Netherlands, Germany, Spain and Sweden.

4.2 Overview of uses of accounts

The use of an ecosystem accounting framework defines the stock of ecosystems (ecosystem assets) and flows from ecosystems (ecosystem services) in relation to each other (as noted in Chapters 1 and 2 above), and also in relation to various other environmental, economic and social information – to the extent that these are linked in practice. Through the accounts, ecosystems can be linked explicitly to economic and other human activity, both in terms of the services provided by ecosystems, and through the impacts that economic and other human activity have on ecosystems and their future capacity to support and supply services.

[xv] To do: others to add who replied to the questionnaire and pier review.

Physical ecosystem accounts (as noted in Chapter 2) can provide useful information about the stock of resources ('quantity'), the physical condition of ecosystems ('quality'), that in turn supports the provision of ecosystem services. The changes of biophysical information over time also gives insights in changes in natural capital stock (e.g. degradation) and changes to service flows – all issues of policy interest. The physical accounts by their nature do not address issues of economic scarcity, human demand for services, and supply of labour and manufactured capital required to actualise ecosystem services: for this, monetary accounts are potentially useful (as explored in Chapter 3). To the extent that monetary accounts can reflect ecosystem services (at the moment quite a partial coverage), they can highlight the different values arising from ecosystems as current flows, and in the future through the asset values, and help track changes in these values over time. They can also be used to estimate the cost of losses of natural capital (i.e. similar to natural capital depreciation). Furthermore, they can be useful to explore the potential trade-offs between the different mixes of ecosystem services that arise from alternative uses of ecosystems (also possible with using only biophysical indicators). Ecosystem accounts provide national-level monitoring of ecosystem services and assets. Where monetisation is possible, the result of monetary valuation of ecosystem services can be linked to other economic indicators, including e.g. job creation and added value provided by well maintained ecosystems.

Accounts can also be used to develop indicators to support different phases of the policy cycle. This includes the diagnosis and prioritisation of environmental issues, the definition of objectives and associated targets, the design of policies for conservation and other sectors, and the monitoring and assessment of their impacts. By integrating data in a common framework, accounts facilitate assessment of trade-offs and synergies across policies, in particular where the accounts are based on spatially-explicit mapping.

There are many other potential areas of application, for example mapping and tracking information under the Water Framework Directive compliance, identifying areas of water stress, and informing the next round of River Basin Management Plans (see water section below). Accounts could be compiled at the river basin/catchment level. Extended analysis using accounts could also be useful in scenario planning exercises, as an alternative framework for presenting information. The usefulness of accounts for policy processes should grow over time as accounts become more robust and comprehensive, and also more familiar to policy makers. However, for the most part these uses remain hypothetical, and it remains to be seen how useful accounts prove to be in practice, in light of the uncertainties and methodological challenges (see Chapter 1, 2 and the conclusions of this chapter).

4.3 The potential added value of Ecosystem Accounts to policy making

In principle, in the future Ecosystem Accounts may be useful at different levels of the policy-making process, from the European to the national and regional level. Their potential as a support tool for policy making will depend, among other factors, on the scalexvi and the level of detail of the accounts, the type and precision of output indicators they produce and the type of issues they cover (e.g. land, water, carbon on the one hand, and links to spatially specific elements such as population centres and/or industrial installations on the other.

In general, the information collected in the Ecosystem Accounts seems to be more useful at a **higher level** (i.e. linked to objectives and targets such as carbon biomass targets, NNL objectives, as well as plans and programmes) and less at the level of specific instruments (like for example the establishment of Payment for Ecosystem Services or biodiversity offsetting programmes in specific locations), because the latter kind of instrument tend to require information at a much lower scale that the one that will be offered by ecosystem accounting. For example, the Simplified Ecosystem Capital Accounts (SECA) that are currently being developed by the European Environment Agency, adopt a grid of 1 km^2, given the EU wide focus. Other accounts, especially regional and local ones can have significantly more precision and hence site specific utility.

That said, in some cases specific instruments could be directly linked to the higher level targets (eg carbon sequestration payments) and even for offsetting it's important to set the local details in the regional/national context which the accounts can provide. In other words, while the assessment of the level of service provided by a particular landowner would not be given by accounts, the level of payment could well be informed by broad-scale analysis. If e.g. accounts reveal a decline in provision/quality of a particular habitat type across a nation, that could be a signal for increasing conservation payments associated with that habitat type.

In general, Ecosystem Accounts seem more likely to play a role, when fully developed, in setting up, or monitoring performance against environmental objectives, targets and strategies to be used in **plans and programmes** (e.g. on land use change or on organic carbon stored in biomass), and also to assess their **impact**. This is particularly true for environmental issues that need to be addressed at a **global** level, like for example targets to be established for GHG emissions. For other environmental policy areas targets cannot be set in quantitative terms at a national level because the desired state depends very much on the specific local conditions. An example of this latter category is water policy, because specific targets on water availability and quality generally need to be set depending on the specific characteristics of each water body. As regards biodiversity, which is highly local in terms of specific management interventions and specific

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[xvi] SEEA-EEA does not prescribe a specific scale for Ecosystem Accounts, but it proposes three kinds of units that can be used, depending on the purpose of accounts and resource availability: basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU). BSU is a small spatial area and is generally defined by overlaying a grid on a map. The squares of the grid (i.e. the BSUs) will be as small as possible, according to available information, landscape characteristics and also the policy or research needs. BSU can be aggregated to form LCEU or EAU. LCEU are areas satisfying a pre-determined set of factors related to the characteristics of an ecosystem (e.g. as regards land cover type, water resources, climate, altitude and soil type), and will have different dimensions according to the specific conditions in the areas covered by the accounts. Examples of LCEU are pastures and natural grassland; forest tree cover; open wetlands and inland water bodies. The definition of an EAU depends on the purpose of the analysis and reporting requirements, and thus on the administrative boundaries, large scale natural features, environmental management areas and similar. Examples of EAUs are national parks and river basins.

performance, there may be benefits of regional/national aggregate data, which can show how national policies and measures are performing, especially where there are spatial considerations such as metapopulations, or where the service is providing suitable habitat rather than necessarily actual presence at any specific point in time (see biodiversity section).In general, the potential in terms of policy-making will be more substantial when Ecosystem Accounts will be linked to spatial data – i.e. spatially defined accounts that are linked to other spatially important issues such as human population centres, thereby linking the supply of services (ecosystems) to the demand for them (human needs and preferences). This kind of development will need further research, methodological development and experimentations, but it is already seen as a promising direction and it is mentioned in the third volume of the SEEA revised version (section 4.2). More generally, spatial assessment and mapping of ecosystem services, and linking spatial land use models to human and economic models for spatially explicit valuation, is at the cutting edge of valuation research (see e.g. OPERAs task 4.4.2).

Debates on methodological and conceptual issues continue, alongside a range of experimentation at national and other levels. It is to be hoped that this process will result in the development of one or more coherent frameworks and sets of methodological guidance. Ecosystem Accounts will ideally ensure **comparability** across countries and over time. Comparability is particularly important when dealing with multi-country and cross-border environmental issues, like for example carbon storage in biomass and management of international river basins.

However, multiple levels or hierarchies of accounts, using different indicators and scales to meet different specific needs of assessment, monitoring, management and policy, can be useful for different policy areas. For example the size of basic accounting units may vary between national ecosystem accounts and protected area or corporate accounts (not covered in this article). Issues of scaling up and compatibility across different hierarchies of accounts are an important area for research and debate.

One specific issue is the need to avoid confusion between ecosystem accounts within the SEEA family and wealth-based accounts, and more generally cost-benefit assessments, with the SEEA family relying on exchange values and the latter focused on welfare values, as discussed in Chapter 3. Another issue is the classification of ecosystem services and the potential conflict between the Common International Classification of Ecosystem Services (CICES: Haines-Young & Potschin 2013), Final Ecosystem Goods and Services Classification System (FEGS-CS: Landers & Nahlik 2013).

4.4 The use of Ecosystem Accounts in the policy cycle

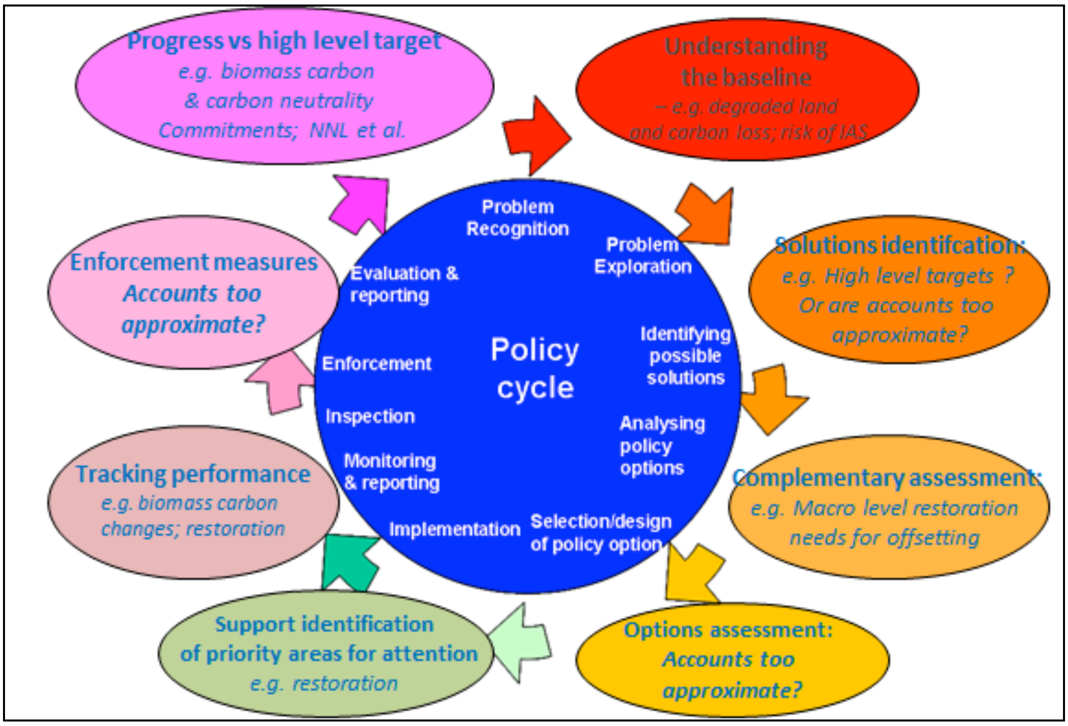
Policy making includes different phases and follows a cycle of understanding, action, reviews updating knowledge and further action (ten Brink et al., 2011):

- Problem recognition (e.g. endangered habitats, degradation, loss of ecosystem services; areas of soil loss and low biomass carbon; scale of potential risk of invasive alien species);

- Identification of solutions (e.g. management activities for favourable conservation status; potential restoration areas, if and where, suitable spatial definition);
- Assessing and identifying linkages between policy options (e.g. investment in protected areas, green infrastructure);
- The implementation process (e.g. restoration expenditure, subsidy reform, payment for ecosystem services); and
- Ongoing monitoring and evaluation (e.g. status and trends and how this compares to objectives and targets, e.g. supporting insights on carbon neutrality ambitions, water storage and stress, soil erosion, contributions to NNL objectives and areas of net positive gain).

In some areas accounts seem to have a potential to contribute (see Figure 5.1 and discussions in sections below). In other areas questions can clearly be raised as to whether the tool can offer sufficient detail to be fit for purpose and provide added value in those steps of the policy cycle.

Figure 4.1 The potential utility of Ecosystem Accounts in the policy cycle: examples and questions



Source: own elaboration, after ten Brink et al. (2011)

In principle, Ecosystem Accounts can be used to develop indicators that can support different phases of the policy processes aiming at improving the condition of the ecosystems and the provision of ecosystem services. These phases include the diagnosis and prioritisation of environmental problems to be tackled, the definition of objectives and targets, the design of sectorial policies and the assessment of their impacts.

In this respect, an added value of accounts over raw data that are not integrated in a common framework and data set is the capacity to support the analysis of trade-offs and synergies among policies, by enabling analysis of the links between different components of ecosystems and different datasets (e.g. between land use and organic carbon accounts). This is especially true if accounting is combined with spatial mapping.

In general, the answers to our questionnaire show that the accounts have not yet been used in policy making, because they are still in an early stage. For example, in the UK they are classified as experimental statistics, meaning that they are not expected to be used in a policy context. However, the interviewees from the UK and the Netherlands underlined that the interest from several ministries in the development of Ecosystem Accounting is high. At the moment, the use that has been made of accounts can be defined as awareness raising, contributing to the first phase of the policy cycle, i.e. problem recognition/exploration. For example our UK interviewee said that the estimate of the total value of UK Natural Capital (Khan et al, 2014) has been widely quoted both inside and outside Government, and also the estimate that the asset value of UK woodland ecosystem recreation and carbon sequestration services is 19 times the value of timber provision has raised interest from within the Government.

As regards Spain, according to the answers to our questionnaire provided by the Spanish expert, the National Ecosystem Assessment has already been used in a number of occasions(see Box 5.1)[xvii]. However, assessments, while having certain similarities to accounts and providing information that could input into accounts, are generally not accounts per se, because they provide a snapshot.

[xvii] Assessments, while providing information that could input into accounts, are generally not accounts per se, because they provide a snapshot of the situation at a certain time, while accounts are updated regularly in order to allow to monitor trends.

Box 5.1 The contribution of the Spanish National Ecosystem Assessment to national plans, strategies and laws and international processes:

The information collected and systematised in the Spanish National Ecosystem Assessment (The Spanish National Ecosystem Assessment (EME, from its name in Spanish: "Evaluación del Milenio de España") – see Chapter 2 of this report - has contributed to a number of national and international policy processes by:

- Providing information for the implementation of the Spanish Strategic Plan for Biodiversity and Natural Heritage (2011-2017), and in particular helping to:
  - Establish monitoring indicators of the main drivers of change in ecosystems.
  - Promote coordinated projects to connect basic research and the development policies applied for biodiversity conservation.
  - Promote studies addressing the economic valuation of biodiversity and conducting systematic reviews and analyses of available studies in Spain.
  - Create lists of and mapping ecosystem services in Spain.
  - Improve mechanisms for communication with society related to biodiversity.
  - Promote the consideration of biodiversity and ecosystem services, including their economic value, in the design of the policies of the General State Administration.
  - Encourage the consideration of biodiversity and ecosystem services, including social and economic values, in the activities of Spanish institutions.
  - Develop environmental indicators related to human wellbeing in addition to the gross domestic product for incorporation into social and political debates.
- Providing information for the implementation of Law on Natural Heritage and Biodiversity 42/2007 and Law for Sustainable Rural Development 45/2007.
- Providing socio-ecological information on specific habitat types to establish Special Areas of Conservation in communities under Natura 2000.
- Providing information for the development of the Water Framework Directive of the EU.

EME also contributes to a number of international processes, including:

- The European Biodiversity Strategy (2020). Representatives of the Spanish NEA have been actively collaborating with the MAES Working Group to support the implementation of Action 5, which calls MS to map and assess the state of ecosystems and their services
- Intergovernmental Platform on Biodiversity and Ecosystem Services: The work of the Spanish NEA has already been included in the "Assessment Catalogue"

- Convention of Biological Diversity: The Spanish NEA provides up-to date information to progress in the assessment of ecosystems and biodiversity, and meet international goals.
- Millennium Ecosystem Assessment Follow-Up. The Spanish NEA was approved as a new sub-global assessment in 2012 for the follow-up process, and has been in constant collaboration with the relative Sub-Global Assessment Network.

Source: questionnaire carried out for this study

4.5 Ecosystem Accounts in the different policy areas

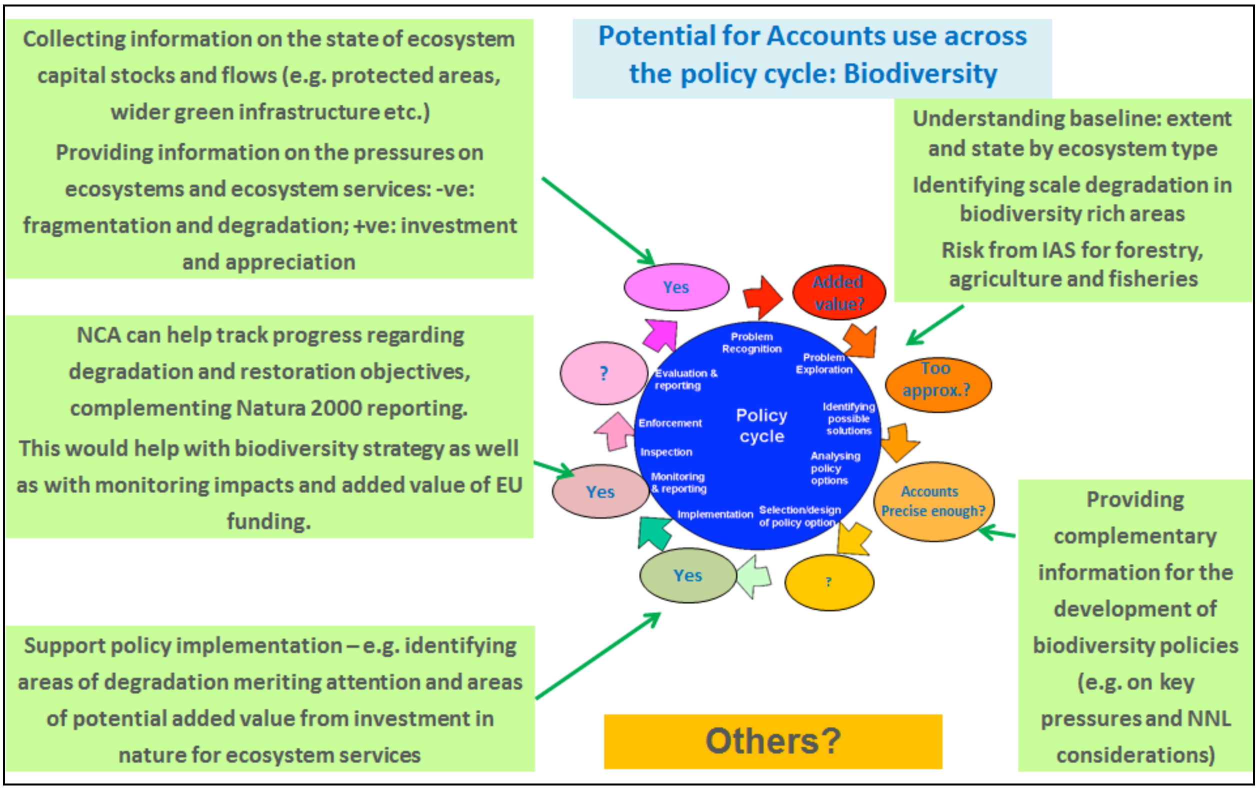
As discussed in Chapter 2, Ecosystem Accounts are as yet at an early development stage, and their present contribution to policy processes is still limited. As they progress and develop a robust and coherent set of data, they will be able to support policy making in a range of areas. This chapter explores the potential use of Ecosystem Accounts in key environmental policy arenas.

Biodiversity

The EU Biodiversity Strategy (COM(2011) 244 final) state that by 2050 the EU biodiversity and the ecosystem services it provides shall be protected, valued and appropriately restored. In order to reach this objective, Target 2 (Action 5) requires Member States to map and assess the state of ecosystems and their services in all Member States by 2014 and to carry out a monetary evaluation to integrate their value into accounting and reporting systems at EU and national level by 2020 (Target 2, Action 5). Ecosystem Accounts are therefore explicitly included, and as they develop they will play a key role in a number of stages of the policy cycle (see Figure 4.2).

Information on the physical state of ecosystems and the stocks of ecosystem assets are central to tracking targets associated with restoration of degraded ecosystems and halting the loss of biodiversity. Information on flows of ecosystem services and human activities impacting on ecosystems are important in identifying pressures on ecosystems. Ecosystem accounts can track this information at a broad scale. This could be complementary to existing reporting at smaller scales, for example Natura 2000 site-level reporting. This broader-scale assessment could potentially inform trade-offs across sites or priorities – for example, where coastal squeeze and other marine pressures is leading to ongoing loss of wading bird habitats, ecosystem accounts tracking the decline of the quantity and quality of intertidal habitats could be used to promote conversion of other, less-threatened habitats to intertidal through coastal realignment.

Figure 4.2 Potential for Ecosystem Accounts for biodiversity policies



Source: own elaboration

Ecosystem Accounts can prove useful for the problem recognition and problem exploration phase of biodiversity policies, by providing systematised and coherent data on the state of ecosystems and the flows of ecosystem. The support function of Ecosystem Accounts will be maximised when data will be made spatially-explicit, as in this way they will provide useful information on e.g. the ecosystem services provided by protected areas in order to support management strategies and evaluate their impacts. Ecosystem services can provide information on the pressures on ecosystems and on the related change in the provision of ecosystem services due to fragmentation and degradation, which will help to address them. Of course the information provided by Ecosystem Accounts will need to be complemented by more detailed information, as the scale and level of detail of Ecosystem Accounts will not be enough to support the decision-making process. However, Ecosystem Accounts can provide an overview of key processes and can give a first indication of priorities to address.

In general, Ecosystem Accounts may help to assess the key pressures on biodiversity, as they will allow to link information coming from different kind of data, all in the same scale. For example, comparing land accounts and water accounts can help identify degraded areas and risks for key ecosystems (e.g. in wetland areas). Similarly, Ecosystem Accounts can help link information on changes in land use in areas with high biodiversity with other relevant variables (e.g. population, water use and availability, carbon storage and sequestration in biomass and soil).

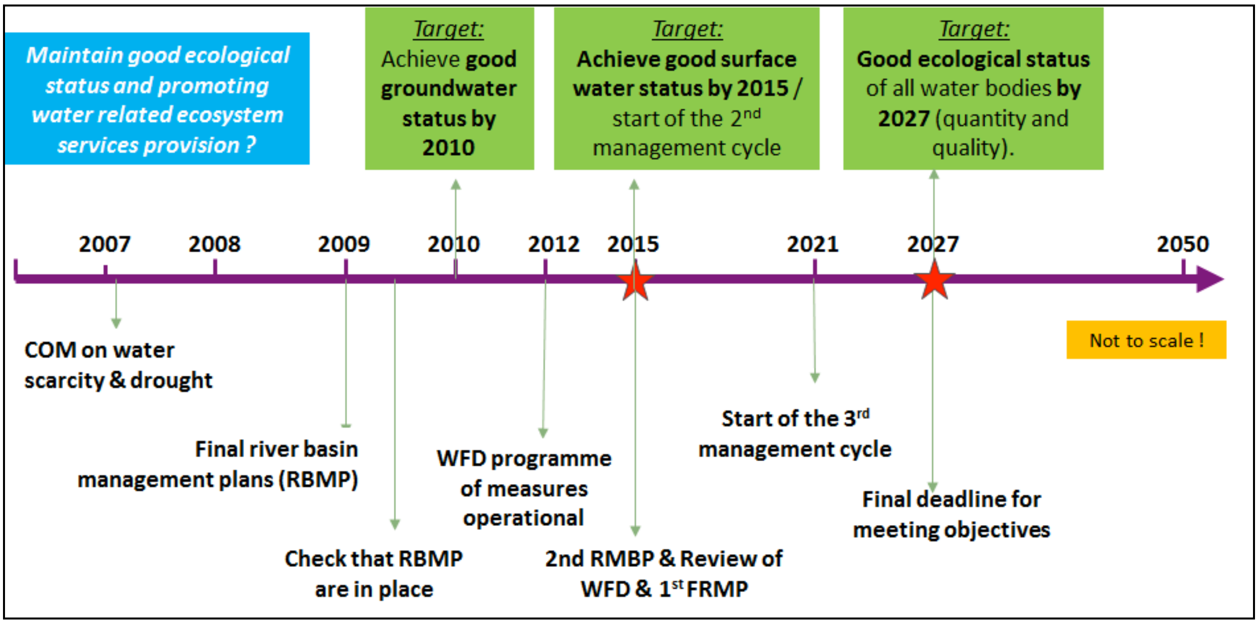
In addition, Ecosystem Accounts can provide an overview on the ecosystem services provided by areas rich in biodiversity, contributing to build up strong arguments to be used in the policy arena to defend their designation and management.

.On a practical, operational level, accounts could be useful tools within the context of Cohesion Policy (CP), where the proactive investment in Natural Capital is seen as supporting a range of policy objectives of the period 2014-2020 (see Hjerp et al., 2011), notably *Objective 6: Protecting the environment and promoting resource efficiency,* but also others such as *Objective 4: Shift towards a low-carbon economy in all sectors (see climate policy),* and *Objective 7: Promoting sustainable transport* (which includes green infrastructure investments, as well as routing choices*).*

Water policy

In principle, Ecosystem Accounting can support the implementation of the main pieces of legislation on freshwater, i.e. the Water Framework Directive (2000/60/EC) (WFD) and the EU Floods Directive (2007/60/EC) (FD) (see Figure 4.3 for key objectives and dates). All these Directives require detailed data on the quantity and quality of freshwater over time, which are already being collected at the water body level. The process of developing Ecosystem Accounting may potentially play a key role in this context, by integrating this kind of information in a coherent and wide assessment of ecosystem state and condition and ecosystem services, thereby supporting a more effective protection and management of freshwater.

Figure 4.3 Water policy timeline: context for Ecosystem Accounts



Source: own elaboration

In particular, the WFD requires river basin management authorities to prepare River Basin Management Plan (RBMPs), which include data to monitor the progress towards the achievement of a good ecological status, which is the objective of the Directive. The data collected in the RBMPs could also potentially be used to develop water accounts. Furthermore, synthesising information on water intake, water availability and water quality and exploring the links between water use and land cover will help to identify areas of water surplus & stress. With regards to specific targets, accounts could help support the 2nd river basin management plans (RBMP), due in 2015). Furthermore, where sufficiently detailed, they may help with WFD legal requirements regarding detailed ecological flow objectives (by 2020), as they may help identify limits of abstraction that are consistent with the objectives. They could also help with the target of good status for groundwater and good ecological status/potential for surface waters (2027).

Indeed, a few countries are already developing water accounts, including the UK, Germany and Sweden (see Chapter 2). At the EU level, the Simplified Ecosystem Capital Accounts, which are being currently developed by the European Environment Agency, include water accounts. These accounts focus on water stocks and flows, whereas water quality accounts are not being developed yet in an integrated way at the national level (Russi and ten Brink, 2013).

In general, water accounts can help assess water demand, and give information on available water, exploitable water and water that is not exploitable because of ecological limitations. In addition, water accounts may help inform the application of the WFD, by collecting and summarising information on water intake at the sub-basin level.

Other kinds of accounts can support analysis and policy making for water policy. For example, land accounts can provide information on the link between forest areas and water availability and the link between water and cities (e.g. dependency of cities on upstream areas for water supply). This will be of interest to cities and regions. Within a European context there may be some policy links to Territorial Cohesion under the Cohesion Policy, given the importance of access to clean water for urban and rural populations.

Ecosystem Accounts may also contribute to the application of the WFD, providing a link between water and land use, e.g. to help define which wetlands are used as flood plains and to provide information on the ecosystem services related to flood management, by for example identifying the areas that allow water infiltration and reduce run-off. Finally, Ecosystem Accounts may help address the potential for water retention measures though water and land accounts integration.

In the future, Ecosystem Accounts could potentially cover quality elements, by e.g. providing information on the provision of ecosystem services like e.g. water purification, sediment treatment.

In general, benefits of quantity-related water accounts will not be high in areas of high water availability (as access to water is not a problem) or high stress areas (as problems are relatively obvious), but in those basins with intermediate levels of water stress.

Challenges remain, in particular developing integrated land-biomass-water accounts to provide (real world) indicators for the inter-linkages and hence prove added-value beyond existing indicator set. Also, it will be necessary to find resources for river basin management accounts and buy-in for these to become part of river basin management plans that integrate natural assets and ecosystem services

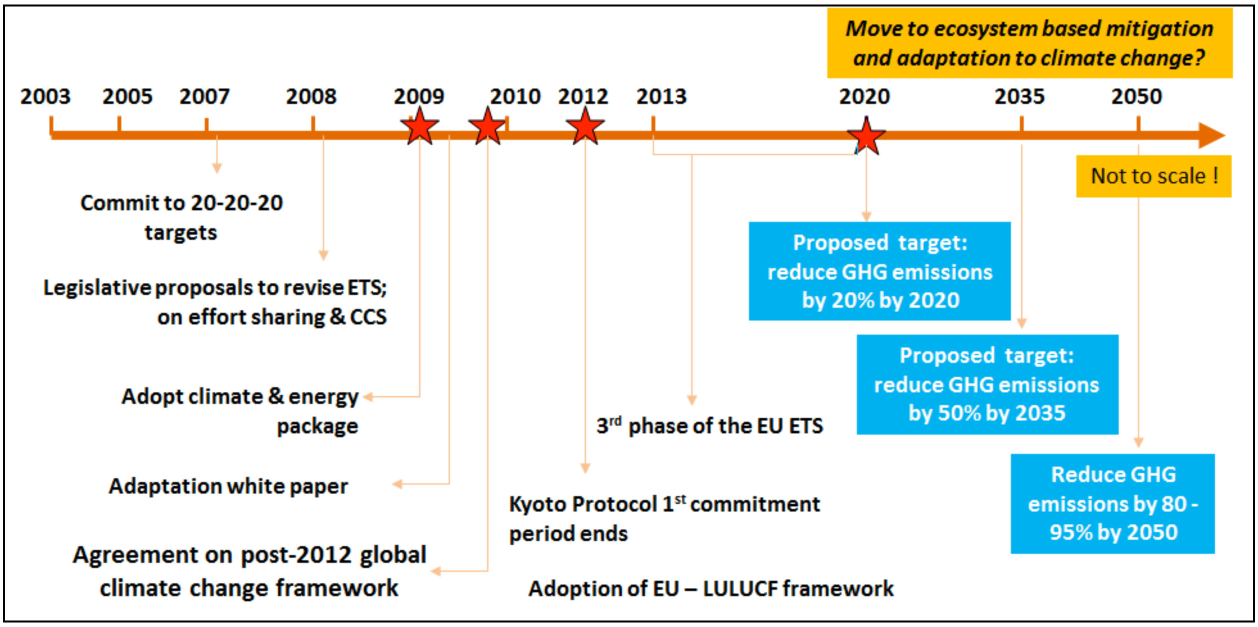
In principle, the accounts – had they been available on time - could also have helped with the Floods Directive (FD) and Flood risk areas (2015) – i.e. where ECA is linked to demographic data this can help identify which areas are at risk from flooding (2015) and priority to address, e.g. linking water surpluses and proximity to population centres. However, given the target, the state of accounts and the existence of alternative measures (i.e. maps, indicators/monitoring, and hydrological monitoring), accounts will not be able to offer added value for the 2015 target. It is unclear whether and when accounts could offer higher added value than current tools.

Climate: mitigation and adaptation

As regards climate change mitigation, Ecosystem Accounts can provide useful information on the carbon stored in biomass and soil, thereby helping monitoring the trends in carbon emissions due to changes in land use like for example deforestation, afforestation and increase or decrease of important carbon sinks like peatlands. Ecosystem Accounts can complement data collected by the United Nations Framework Convention on Climate Change (UNFCC) on Land Use, Land-Use Change and Forestry (LULUCF), and may help shed light on the links between changes in land use and carbon stored in biomass and soils. Changes in carbon storage and changes in soil fertility will also be a useful link to explore to help communicate the multiple benefits of certain agricultural practices that support soil carbon levels, avoid erosion and help with soil fertility levels.

Accounts can therefore help in monitoring progress of the carbon-biomass element to the overall targets of reducing GHG emissions over time (see Figure below for policy time line) and keeping to within a 2 degree rise target.

Figure 4.4 Climate policy timeline: context for Ecosystem Accounts[xviii]



Source: own elaboration

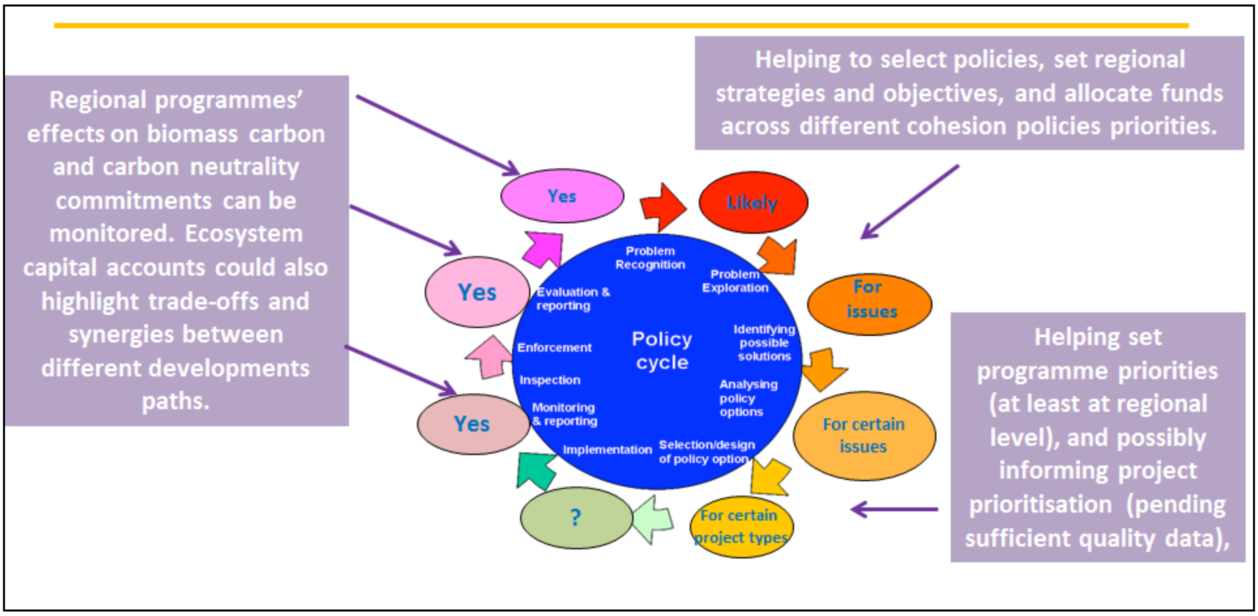
Ecosystem Accounts can in principle also support adaptation policies, by collecting and systematising data on the ecosystems that prevent downstream and coastal flooding or droughts, and thereby supporting ecosystem-based adaptation policies. This will require an integration of other spatially critical elements in the accounts, notably location of population centres.

This will be of importance at the EU and national level, and also at regional levels. For example, commitments by regions to no net loss of carbon (as exist for emissions in some regions) could be expanded to net positive carbon sequestration by integration of positive fluxes of biomass carbon. This could support the Cohesion Policy[xix] in the development, monitoring and assessment of operational programmes, as well as in the prioritisation of large projects. See figure below on the policy cycle and accounts utility for cohesion policy and climate change.

[xviii] To do: update in light of Paris and other recent developments.

[xix] Objective 4: Shift towards a low-carbon economy in all sectors; Obj. 5: Promoting climate change adaptation, risk prevention.

Figure 4.5 Potential for Ecosystem Accounts for climate change mitigation through Cohesion Policy



Source: own elaboration

In addition, accounts of biomass carbon could support the Common Agricultural Policy's Regional Development Programmes, by providing information on the consequences of changes in land use on carbon emissions.

Marine policy

The EU Marine Strategy Framework Directive requires Member States to achieve a good environmental status of their marine waters by 2020. In order to achieve these objectives, Member States should provide an assessment of the use of marine waters and develop action plans and explicit measures. At the moment, not much information is available yet on the current status of marine waters, and in this context Ecosystem Accounts may provide a useful framework to organise and systematise relevant information on the condition of marine ecosystems and the ecosystem services they provide. They can also help analyse the link between the status of marine ecosystems and important stress factors like water and land use in coastal areas.

As in most accounting work to date, research in the UK (eftec 2015b) on scoping marine accounts focuses on the conceptual framework, data availability and quality, and methodological issues, much more than on the potential policy relevance of the finished accounts. However, methodological choices are justified with reference to policy uses:

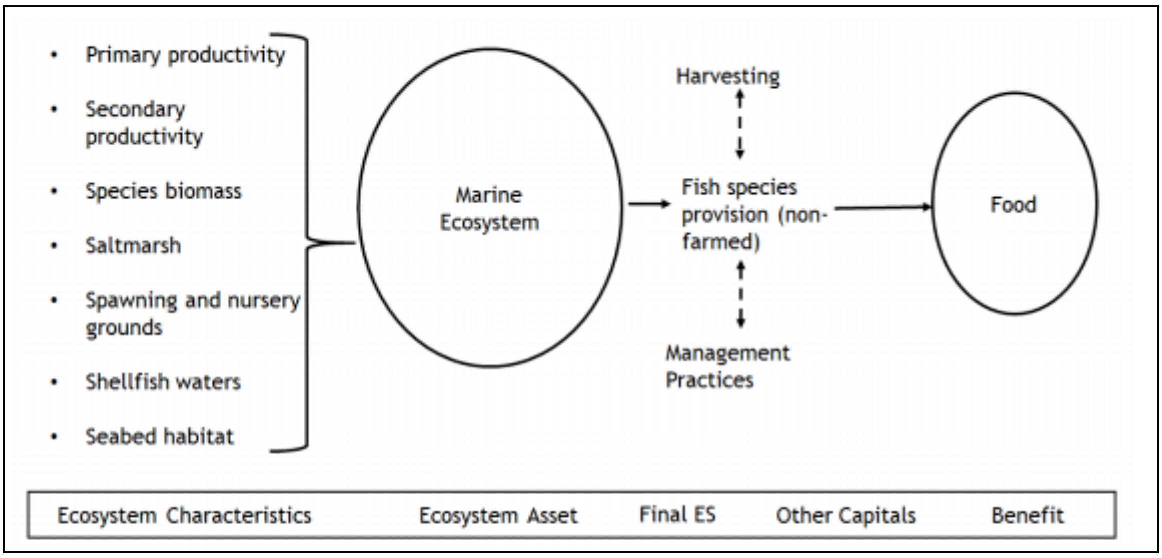
- The purpose of structuring ecosystem asset accounts by extent and condition, with condition reported by focusing on the state of those ecosystem characteristics that determine its productive potential, is so that the current and future capacity of an ecosystem to produce ecosystem services is accounted for.

- Information on the capacity of the stock to produce flows over time that is represented in an account has the potential to inform limits in the capacity of the stock to produce flows and the identification of thresholds. Updating ecosystem accounts to obtain time-series data provides more information on such limits and threshold.

The eftec (2015b) scoping study notes that, particularly for marine environments, scientific understanding that links habitats to the provision of ecosystem services is uncertain in many areas. Data on both quantity and quality of marine habitat characteristics that are important in determining the capacity to produce ecosystem service flows are poor. This leads to the conclusion that developing accounts using data on the spatial extent of marine characteristics, in line with conventional stock and flow accounts, is not feasible in the short term. However, data exist on the pressures on the marine environment that impact its capacity to produce ecosystem service flows. This leads to the short-term solution of developing accounts using data on pressures, broken down into those related to surface water, the pelagic environment and the benthic environments.

So for example flows are observable for capture fisheries, but much of the detail in understanding how marine habitats support capture fisheries is lacking (see **Error! Reference source not found.**). In the short term, accounts can evaluate fisheries ecosystem flows on landings volumes and value from the previous year, while fisheries ecosystem stock accounts can be based on expected landings under ICES or other relevant stock predictions and harvesting rules. The long term ambition, however, is to develop an understanding of relationships among ecosystem characteristics, human pressures, and fish provision, including parameterised food-web models, incorporating economic models that take into account fishing fleets' behaviour in response to altered availability of fish species.

Figure 4.6 "Logic chain" underpinning capture fisheries in marine accounts



Source: eftec 2015b

The research also flagged the importance of thresholds in marine environments and exploitation, though this also applies to other ecosystems. For fisheries, overfishing and stock collapse are common problems, making the constant flow assumption of accounts questionable for certain cases. As noted in Chapter 3 of this report, a precautionary approach would require demonstration that a constant flow is a reasonable assumption. Where sustainability cannot be established, that begs the question of what future decline should be assumed. Dynamic models of ecosystems and service provision could help to account for possible changes and risks. Uncertainty in these models may be large, and almost certainly greater than that in measurement of current flows - but this does not mean that the assumption of constant *future* flows is less uncertain, or more justified. eftec (2015b) report that the position taken in the SEEA is that accounting for thresholds does not fit in well within a model based on assessment of change over successive accounting periods, and conclude that further work is required on how to incorporate limits and thresholds into the accounts.

Forestry policy

NCC (2012b) note three main analytical requirements for informing forestry policy:

- Financial analysis assessing the incentives for any farmer or other private land owner to plant and manage: focus on market prices and costs, and available subsidies.
- Social cost-benefit analysis: removes subsidies and other transfer payments, corrects for market distortions, includes non-market costs and benefits
- These analyses need to reflect the complexity of the environment, in particular regarding spatial targeting of investments.

For example, planting forest over peat soils is likely to be detrimental in terms of carbon balance; planting forest near urban populations gives substantial recreational potential. However, “policy making (and in particularly the CAP) typically fails to embrace this spatial complexity”. Individual project appraisals may take account of some spatial factors, such as the location of a proposed investment with respect to human populations, but are less likely to take account of more complex interactions such as the availability of substitute sites or conservation network effects.

Spatial optimisation models such as TIM (Bateman et al 2014)[xx];) seek to combine detailed land-use modelling with valuation of ecosystem services, taking account of spatial interactions across services and with human populations, and allowing exploration of different strategies and policies, including constrained optimisation of land-use choices with respect to welfare-based assessments of value for monetised services, and sustainability constraints on provision of non-monetised services.

Ecosystem accounts will report aggregates of physical and monetary values based on data at the spatial scale of the BAU used in the accounts. They will not, however, illustrate the local details of

[xx] To do: introduce more TIM so as to make accessible and relevant to readers; see OPERAs task 4.4.2 for more detailed discussion

spatial trade-offs in the way that spatial optimisation models can. But they will track changes over time in the forest cover, and will provide a high-level overview by quantifying both in physical and monetary terms the provisioning and non-provisioning ecosystem services provided by forests, including carbon sequestration, protection from natural hazards, recreation and tourism opportunities. This kind of information will help raise awareness on the full range of benefits forests provide to human economy and wellbeing, and thereby support policies aiming at an improved protection of forest resources.

The intended uses of accounts will influence methodological decisions made in their construction. As discussed in eftec (2015a), where the purpose is national-level monitoring then the use of coarse aggregated indicators (at the national/regional scale) for service provision may be sufficient. If the wider application of accounts in establishing variation in the condition and the relative importance (value) of woodland stands (or other ecosystems) across the nation is of interest, then spatial disaggregated accounts will be required. For services which are spatially dependent, this may also have the added benefit of leading to improvements in the national estimates. Spatially disaggregated accounts represent a conceptually consistent foundation for understanding ecosystem service provision, since both stocks of ecosystem assets and the provision of ecosystem services and associated economic benefits are not uniform over locations. Overall service provision is dependent on spatial variation in quality, quantity and spatial configuration of the ecosystems. Hence if ecosystem accounts are to be applied to inform decisions at lower EAU levels, then a bottom-up, spatially-explicit approach should be preferred over attempts to breakdown highly aggregated (national/regional) level reporting.

However it is moot to what extent the benefits of these approaches should be ascribed to accounting itself, rather than to analysis that is conducted alongside or as part of the accounting exercise. For example, modelling and mapping ecosystem services can be used for spatially explicit prioritisation, targeting of habitat creation/restoration, and exploring synergies and trade-offs among different ecosystem services. Changes in the quantity of one habitat will lead to changes in others at a national level, and this will be reflected in the accounts, via changes in physical quantities, service flows, asset values and cross-cutting accounts (e.g. carbon balance sheet). But the policy insights and explicit recognition of trade-offs and synergies come from the spatially explicit modelling, rather than from accounts directly.

4.6 Conclusions

Ecosystem Accounts can in principle shed light on the benefits society obtains from a sustainable use of ecosystems and their services, both in monetary and biophysical terms. At the current state of development of accounts, biophysical accounts are arguably more robust and valuable for policy use than the monetary accounts. They are also likely to be intrinsically more robust than monetary accounts and the utmost case is needed when using monetary accounting. With a few exceptions (see further below), monetary accounting should be avoided over the period to 2020 (the Aichi target deadline linking to environmental accounting). Some developments will be possible with monetary accounts as the tools, methods, and data develop, but even then it is fundamentally important to assess whether accounts are fit-for-purpose for each policy applications on a case by case basis.

As an example, accounts can provide evidence on the ecosystem services provided by a forest area in terms of natural hazard protection, recreation and carbon storage, as well as potentially the economic income derived from timber logging and sale. In this way, they can provide strong arguments in the policy debate in favour of the sustainable management of areas that provide valuable ecosystem services. Of course they need to be complemented by indicators focussing on the biodiversity value of natural areas (i.e. intrinsic value via range of biodiversity indicators), in order not to incur in the risk of privileging areas that provide a large amount of ecosystem services (e.g. because they are located near intensively populated areas) over more remote areas with a potentially higher biodiversity importance.

Accounts are for primarily for trends, not snapshots

The primary usefulness of ecosystem accounts is likely to be in the trends that they reveal over time, rather than the specific values recorded at a given point in time (which can build on assessments). NCC (2012a) stresses that, while knowledge of the absolute level of national wealth gives some guide to future development prospects, “it is changes in wealth that are particularly important. These give the clearest guide to the sustainability of development.”

Related to this, it should be noted that, given uncertainties over measurement and valuation, the specific values in accounts can be hard to interpret. But observing a significant change in consistently-estimated values over a period of years can signal important issues and/or areas which should be of particular concern for policy-makers.

This is similar to the observation that Costanza et al’s (1997) attempt to value global ecosystem services produced numbers that were eye-catching but arguably of little or no direct policy relevance beyond raising awareness of the importance of nature for an audience that listened in particular to economic arguments. Likewise, the update (Costanza et al. 2014) produced numbers that, alone, were striking, but difficult to interpret. However the latter analysis also revealed changes, and helpfully broke these down into components of physical changes and changes due to revised economic values for services, and this provided key insights into important trends.

Even then, however, the observation of trends through ecosystem accounting or similar exercises only reveals that some intervention may be required. Accounts do not directly address the question of what that intervention should be. For this, policy and project appraisal methods are required in order to examine the costs and benefits of different options for addressing the problems identified by accounting. Ideally, these methods should be applied in spatially-explicit ways, recognising the trade-offs across services and the dependence on location with respect to human populations. It remains possible that CBA using estimates of the opportunity costs of each option for action could suggest that the options to combat the decline may not be as attractive as alternative uses of resources. Accounting could therefore help indicate where appraisal is needed, but does not replace the need for project appraisal. These are complementary tools, not alternatives.

Accounts as a tool for communication and debate A major role of accounts is in processing and summarising a vast range of complex data into a smaller more comprehensible set of indicators that has the additional advantages of facilitating consistent comparisons over time and also enabling comparisons between economic activities and investments and ecosystem services and assets.

At the same time, this role comes with risks attached. In particular, a focus on monetary comparisons may weaken attention to sustainability constraints, though emphasis on trends in the physical accounts could mitigate this risk. Secondly, accounts using exchange values will contain different flow and asset value estimates from social cost benefit analyses using welfare values. The latter are a better guide to the social desirability of policy decisions. Thirdly, the way ecosystem services are defined and accounted for imply the existence of beneficiaries, and therefore a change in the flow of ecosystem services may depend on a variation in the number of beneficiaries and not on a change in the ES quantity or quality.

Fourthly, but perhaps most importantly, there is a risk that managers and policy makers could be encouraged to focus on the indicators rather than the underlying processes. There could be an inappropriate focus on actualising potential services (maximising flows) with potentially negative consequences for biodiversity and ecosystem condition, where in fact it may be more desirable, and certainly more robust and sustainable, to operate with considerable spare capacity. Similarly, there may be a desire to convert simulated exchange values to actual exchange values, by introducing property rights and payment mechanisms. This converts non-marketed services to market activity, increasing GDP and expanding the tax base, but in most cases would be regressive in distributional impact, and in many cases would also be inefficient in welfare terms, excluding some users from non-rival (public) goods and services.

Accounts are a work in progress

The policy utility of Ecosystem Accounts is expected to grow over time for different environmental policy fields, across the stages of the policy cycle and geographic scales. At the moment they are still at an experimental level, and mostly not yet ready to be directly used in the policy arena, even though there are already some examples of Ecosystem Accounts supporting policy processes (see for example the Spanish experience in Box 4.1).

According to a recent questionnaire targeting experts at the EU Member State level (Gocheva et al., 2014), difficulties in implementing a more rigorous approach beyond single pilot actions appear to be due both to the need of multidisciplinary scientific work and to the need for international alignment in adopting uniform and statistically correct procedures for data collection and reporting. Also, data availability is an issue, as most experts report a lack of data needed to develop accounts.

Over time, as more quantitative and more monetary data become available, the policy benefits will grow and involve different policy areas. In general, the potential use of accounts for policy making will depend on their data availability and quality, the spatial resolution (i.e. the level of detail they allow) and the time series that they cover (i.e. on to what extent they cover a period long enough to monitor trends over time).

A range of issues still need to be resolved – for example on the treatment of thresholds (ecological tipping points leading to social or economic tipping points), and a range of methodological challenges regarding monetary valuation still need to be addressed (e.g. the use of exchange vs. welfare values).

Arguably they will be mostly used in areas where there is high policy need (e.g. climate policy), where a policy instrument like the Water Framework Directive requires collecting a large amount of data over a long period of time and where the accounts can provide new insights by integrating and connecting different factors (.e.g land use, biomass carbon, water, demography.), and discussed below.

Accounts integrate across sectors and issues

One of the main added values of Ecosystem Accounting over existing indicators and data set is the opportunity to tackle integrated issues, and have a comprehensive view on key pressures and ongoing processes. For example, the integrated use of water, land and organic carbon accounts can provide relevant information on pressures on ecosystems and biodiversity and the link between water and land accounts can help identify areas with water stress.

Also, while monetary valuation can be useful to raise awareness on the multiple benefits provided by the sustainable management of environmental resources and to help argue for the protection of valuable ecosystems, it is necessary to be aware of its limits, due both to methodological challenges and data availability (see Chapter 3 for a full discussion on pros and cons of monetary accounts), as well as the risks of interpretation that arise from only a partial monetary representation.

All in all, Ecosystem Accounts have the potential to support a wide range of environmental policies. In order to make full use of their potential, it will be necessary to invest in data gathering and promote interaction among different categories of experts, including statisticians, economists, ecologists, in order to progress in the development of common methodologies to allow integration of different set of data and comparability across geographical areas. The instrument should be used with full awareness of what it can already say and what it cannot, to what level of precision and hence where the results are truly “fit-for-purpose” in policy deliberations. There should be an understanding of how the tool can evolve and what experimentation now can help make the instrument valuable as an evidence-base for practical policy making.

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[i] Financial capital can be seen as part of social capital.

[ii] WAVES is funded by the European Commission, Denmark, France, Germany, Japan, the Netherlands, Norway, Switzerland, and the United Kingdom and it is being overseen by a steering committee. At the moment, the core WAVES countries - Botswana, Colombia, Costa Rica, Guatemala, Indonesia, Madagascar, the Philippines and Rwanda- are developing natural capital accounting.

[iii] The UNCEEA is a body consisting of countries and international agencies under the auspices of the UN Statistical Commission.

[iv] However, Spain, France, Cyprus, Malta, Austria, Poland were granted partial or total derogations and were allowed to present the accounts up to two years after the 2013 deadline.

[v] At least 14 different gases emitted by 64 industry groups and by households.

[vi] Including at least four tax types – on energy, transport (other than fuel), pollution, and resources – all broken down into 64 industry groups, households and non-residents who pay these taxes.

[vii] Material flow accounts for 50 material types showing domestic extraction, imports and exports. Then, Domestic Material Consumption = domestic extraction + imports – exports, for each type of material and in total.

[viii] This is possible every three years, and the next window of opportunity is December 2016. The potential candidates for the next batch of modules are 1) Environmentally Related Transfers (subsidies); Resource Use and Management Expenditure Accounts (RUMEA); Water flow accounts; Forest Accounts, through the development of Integrated Environmental and Economic Accounting for Forests (European Commission, 2013).

[ix] Regulation (EU) No 538/2014 of the European Parliament and of the Council of 16 April 2014 amending Regulation (EU) No 691/2011 on European environmental economic accounts

[x] https://www.naturalcapitalcommittee.org/state-of-natural-capital-reports.html

[xi] http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Environmental+Satellite+Accounts

[xii] SNA accounts are the main source of information for internationally comparable economic aggregates and indicators such as Gross Domestic Production (GDP), economic growth rate and government deficit.

[xiii] http://www.ons.gov.uk/ons/rel/environmental/uk-environmental-accounts/2014/stb-stat-bulletin.html#tab-Experimental-natural-capital-accounts

[xiv] https://www.wavespartnership.org/en

[xv] Restoration costs are the costs to restore an ecosystem to its original state before degradation. Complications arise in that restoration rarely gets the ecosystem back to the original state – i.e. ex post actual costs may not be a fully adequate measure. Similarly, assessing degradation costs for not restored areas poses significant methodological challenges as it require assumptions on how the restored ecosystem should be. An added complication is the choice of the re-introduced species, as if degradation has gone beyond the ecological tipping point restoration can be very expensive (or even de facto infinite in price in the case of extinct species). Finally, the cost of restoration is only a proxy of value and depending on the context can be an over-estimate or under-estimate. Each of these elements poses important challenges.

[xvi] A discount rate is used to translate future benefits and costs into present values. The question of the discount rate, which attributes more relevance to costs and benefits in the present than to the ones in the future, has caused an animated debate among researchers, and the choice of a discount rate is one of the most disputed subjects of economic theory (see TEEB 2010 and 2011).