Stage 1 deliverable: Review of Ecosystem Services Assessment Methods

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Contents

Introduction

This document describes a range of methods and approaches for ecosystem service valuation and assessment used in major international initiatives and frameworks. In addition, a number of important ecosystem service classification systems are summarised (see section entitled *'Classification'*). The final section (entitled '*Methodologies*') summarises various methodologies, both monetary and non-monetary, which are utilised for ecosystem services valuation. It should be noted that this is not a comprehensive review of the numerous existing frameworks, classification systems or methodologies.

Major International Initiatives and Frameworks

For each of the conceptual framework listed below, a description and schematic image is provided along with links to relevant resources. The relative strengths and weaknesses of each framework were assessed and are provided along with examples of methodologies utilised. Frameworks are listed in chronological order, beginning with the Millennium Ecosystem Assessment, which was the first substantive study to focus on the impacts of ecosystem changes on human well-being. Subsequent frameworks built upon the Millennium Ecosystem Assessment refining it and developing particular themes.

Background information on conceptual frameworks

Within ecosystem assessments, conceptual frameworks are concise summaries that, either in words or as a schematic image, depict the relationship between people and nature. Conceptual frameworks show how different factors within an ecosystem interact - as distinct or interlinked factors - and how they are organised. Conceptual frameworks are used for a variety of reasons, including: (1) to understand ecosystem services and/ natural capital; (2) to demonstrate the interactions between different environmental features and elements (including the interaction between humans and their well-being); and (3) to account for internal and external drivers that affect the environment, be that positive or negative.

A variety of different conceptual frameworks have been developed for assessment of ecosystems, ecosystem services and natural capital, with each reflecting evolutions in how we think about ecosystem services and natural capital. When conducting an ecosystem services assessment, a team may use more than one conceptual framework for an assessment but an assessment must 'own' one key conceptual framework in order to be internally consistent. In terms of design, many ecosystem services frameworks rely on a 'cascade model'. Figure 1 below represents a simple cascade model which has been adapted from (Haines Young and Potschin, 2010).

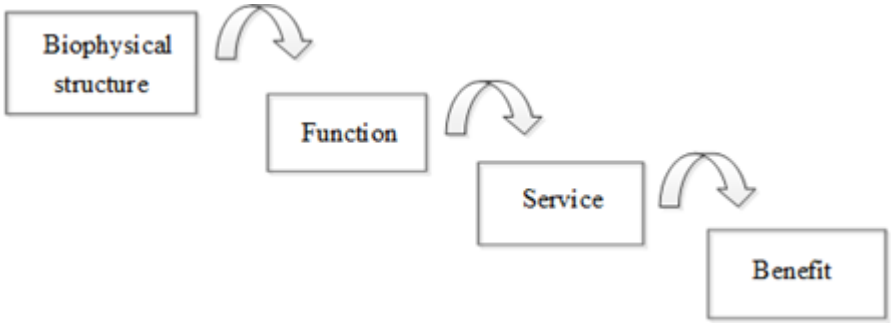

Figure 1. Simplified representation of the cascade model (adapted from Haines Young and Potschin, 2010).

For further information on the development and use of ecosystem assessment frameworks, see Ash *et al.*, (2010) (Chapter 3): http://www.ecosystemassessments.net/resources/ecosystems-and-human-well-being-a-manual-for-assessment-practitioners.pdf.

In an overarching review of the ecosystem service concepts, Ingram *et al.* (2012) identified a number of strengths and weaknesses that could be relevant to all ecosystem service assessment frameworks. Examples of strengths include their support for interdisciplinary approaches to ecosystem services understanding and assessment, their usefulness as communication tools that recognise the relationship between people and nature, and the facilitation of improved integration of nature and natural values into decision making. However, general weaknesses of conceptual frameworks include their reliance on an often incomplete scientific basis, the potential for inconsistency between, and in the application of, multiple frameworks, and that an emphasis on anthropocentric value risks under-recognising the intrinsic value of nature. These general considerations are applicable to all frameworks and should be taken into account when considering the application of any framework in an ecosystem service assessment or valuation. For more information on the challenges and benefits of ecosystem service frameworks overall, see: https://sapiens.revues.org/1459.

Relevant terminology and definitions:

There are many different definitions of ecosystems services and natural capital, however the ones used here are:

- **Ecosystem services:** Benefits people obtain from ecosystems. These include provisioning services, such as food and water; regulating services, such as regulation of floods, drought, land degradation, and disease; supporting services, such as soil formation and nutrient cycling; and cultural services, such as recreational, spiritual, religious and other nonmaterial benefits (Hassan *et al.*, 2005).
- **Natural capital:** Natural assets in their role of providing natural resource inputs and environmental services for economic production. Natural capital includes land, minerals and fossil fuels, solar energy, water, living organisms, and the services provided by the interactions of all these elements in ecological systems (UN Environment, 2012; OECD, 2007).

For further details on related terminology and definitions, please see the UN Environment World Conservation Monitoring Centre (UNEP-WCMC) Biodiversity A-Z: http://www.biodiversitya-z.org/.

Millennium Ecosystem Assessment (MA) - 2003

Relevant resource: http://millenniumassessment.org/documents/document.48.aspx.pdf

The Millennium Ecosystem Assessment (MA) conceptual framework was developed to guide and structure the Millennium Ecosystem Assessment (MA) process (MA, 2003). The framework focuses upon four main components: ecosystems and their services; human well-being and poverty reduction; indirect drivers of change; and direct drivers of change (Figure 2). The framework allows for a dynamic approach, with no 'natural' state, instead being responsive to changes in drivers, and avoiding any comparison between pristine 'natural' baseline conditions with increasing degrees of human intervention and impact extent (Ash *et al.,* 2010).The framework considers the interactions between spatial (local, regional and global) and temporal (long and short term) scales and includes feedback loops between components (MA, 2005), as depicted by Carpenter *et al.* (2006) in Figure 3.

Developed by policy-orientated scientists (MA, 2005), the MA framework was designed as an integrated assessment which is multi-sectoral and considers perspectives from natural science and social science (UN Environment, 2005). The MA framework was the first substantive study to focus on the impacts of ecosystem changes on human well-being and therefore, is considered unique in its approach (UN Environment, 2005). Subsequent international frameworks have since built upon the MA approach, for example, The Economics of Ecosystems and Biodiversity (TEEB) (2008), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2015). These subsequent frameworks were developed in order to enable further identification of links between ecosystem functions and human well-being (UNEP-WCMC, 2016). The MA framework has influenced national ecosystem assessment frameworks including the United Kingdom National Ecosystem Assessment (NEA) framework (Brown *et al.,* 2016).

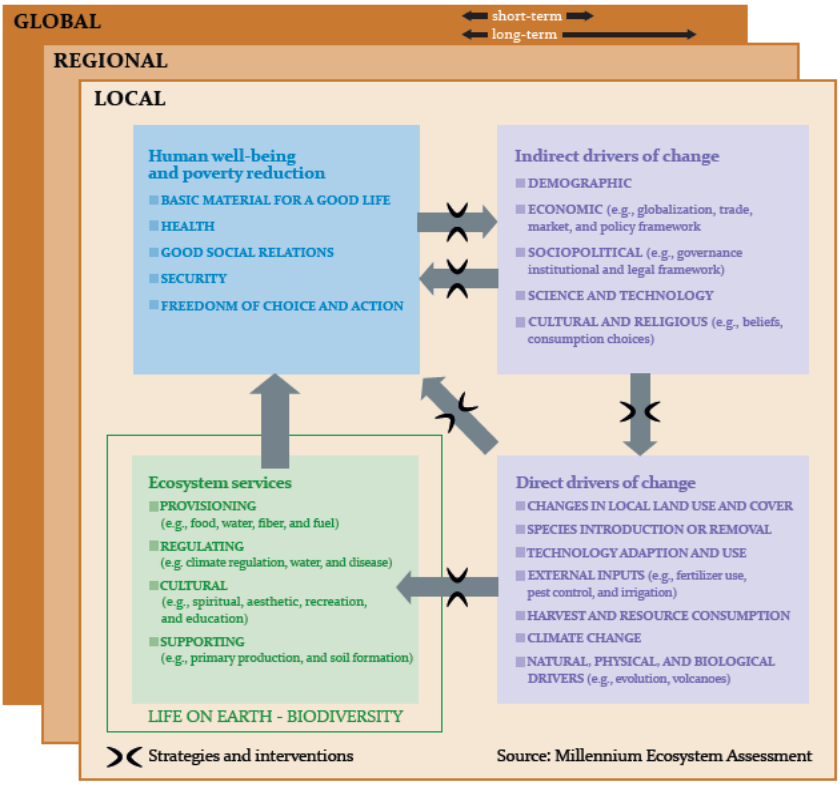

Figure 2: Millennium Ecosystem Assessment (MA) Conceptual Framework (MA, 2005).

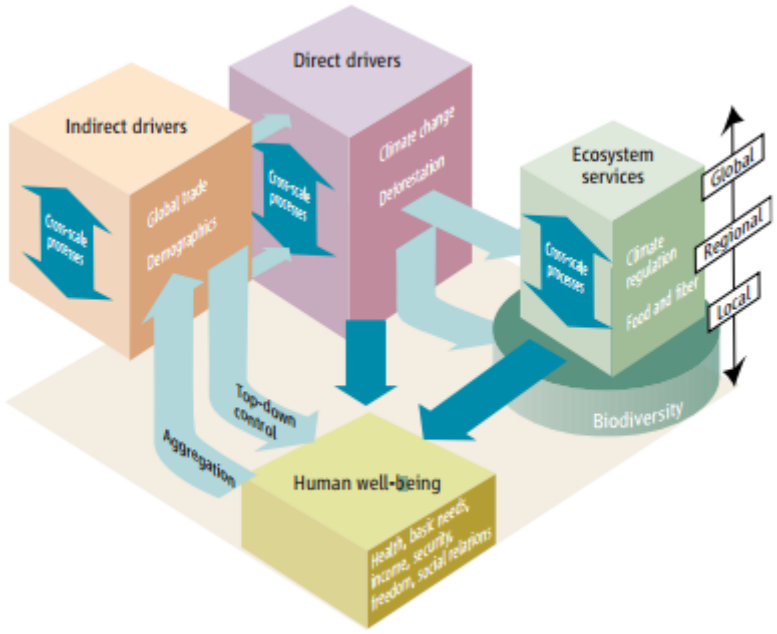

Figure 3: Modified version of the Millennium Ecosystem Assessment (MA) Conceptual Framework illustrating examples of connections between the local, regional and global scale (Carpenter *et al.*, 2006).

Strengths and weaknesses

The MA framework differentiates itself from commonly used pressure-state-impact-response (PSIR) frameworks by incorporating feedback loops and including multi-scale considerations in terms of temporal (short-term and long-term) and spatial (local, regional and global) scales.

Although the MA framework cannot portray complexity of such interactions between temporal and spatial scales, interactions between multiple scales can been identified. This multi-scale approach better reflects the nature of decision-making and enables examination of impacts of ecosystem change in different regions and groups within regions (MA, 2003; Ash *et al.,* 2010).

Particular focus is placed upon ecosystem services and human well-being (MA, 2005). Assumptions of the framework include dynamic interaction between people and ecosystems with changing human conditions serving as direct and indirect drivers of change for ecosystems, and changes within ecosystems affecting human well-being.

As the MA framework is focused around drivers of change, the assessment outputs produced have strong alignment with decision-making processes. Specific points for strategies and intervention, as well as opportunities for discussion, are presented within the framework (see Figure X). By doing so, key points at which decision-making can achieve change are identified (Brown *et al.,* 2016).

One of the criticisms of the MA is that it "double counts" ecosystem services by including supporting services on equal standing with the other three ecosystem service groupings (provisioning, regulating and cultural). As the supporting services underpin the other groups of service, the overlapping nature of the framework can result in some values being counted more than once (La Notte *et al.,* 2017). Subsequent work suggests that supporting services should be generally considered to be similar to the concept of ecological functions to avoid the double counting issue (Haines-Young and Potschin, 2009). Classification systems, such as the Final Ecosystem Goods and Services (FEGS) Classification System, have been developed in order to avoid double counting (La Notte *et al.,* 2017).

Methodologies

The MA was conducted as a multi-scale assessment, consisting of interlinked assessments undertaken at local, watershed, national, regional and global scales. Following completion, the MA framework has been utilised in a number of different ways, including use in research programmes (Ash *et al.,* 2010). Many regional and sub-global ecosystem assessments have been conducted using the MA scenarios which has generated substantial uptake of the MA conceptual framework (Bennett *et al.,* 2005; Ash *et al.,* 2010).

Over the past few decades, scenario-based approaches have become commonly used to support ecosystem assessments (Ash *et al.,* 2010). Four scenarios were developed for the Millennium Ecosystem Assessment in order to explore different plausible futures. These scenarios consider ecosystem services provision in relation to different governance and economic development scenarios (whether on a regional or global scale) and ecosystem service management (whether it is reactive or proactive):

- Global Orchestration *(globalized, with emphasis on economic growth and public goods))*;
- Order from Strength *(regionalized, with emphasis on national security and economic growth)*;
- Adapting Mosaic *(regionalized, with emphasis on local adaptation and flexible governance)*; and
- TechnoGarden *(globalized, with emphasis on green technology).*

The Economics of Ecosystems and Biodiversity (TEEB) - 2008

Relevant resources: http://www.teebweb.org/publication/teeb-for-business-executive-summary/

The Economics of Ecosystems and Biodiversity (TEEB) conceptual framework (Figure 4) was developed to promote integration of economic valuations of biodiversity and ecosystem services within decision-making (TEEB, 2010). The TEEB framework is similar to that of the Millennium Ecosystem Assessment (MA) conceptual framework (2005) in terms of its use of drivers including human well-being and ecosystem change (*de* Groot *et al.,* 2010). However, there is clearer distinction between the functions, services, values and benefits of ecosystems which reduces the risk of double accounting and illustrates more clearly the flows of benefits and values arising from ecosystems. The TEEB framework refined distinction between ecosystem services and ecosystem benefits. As such, a new group, entitled 'habitat services' was introduced which included 'maintenance of life cycles' and 'maintenance of genetic diversity' (La Notte *et al.,* 2017).

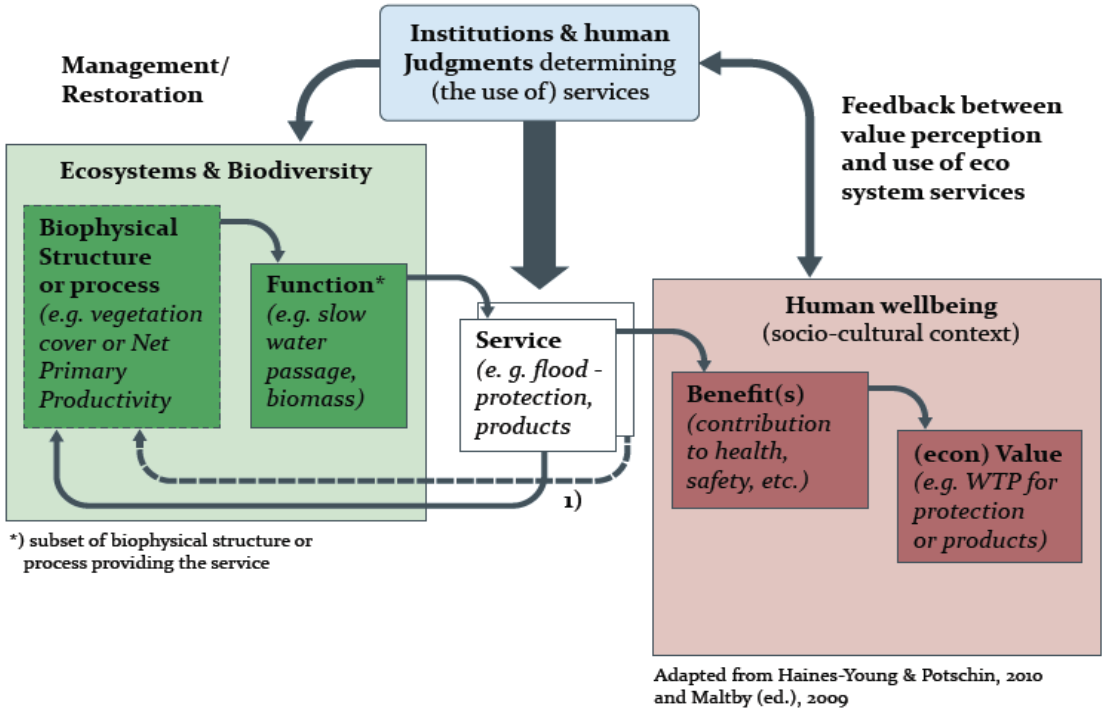

Figure 4: The Economics of Ecosystem and Biodiversity (TEEB) conceptual framework (*de* Groot *et al.,* 2010).

Strengths and weaknesses

The TEEB framework has a strong focus on economic valuation (TEEB, 2010) which is a strength where economic valuation is the primary objective of an ecosystem services assessment. The key strength of the TEEB framework is its separation of supporting services from those being valued which reduces the risk of double counting (a particular problem in economic valuation). Conversely, the TEEB framework is less effective at recognising the monetary values associated with cultural values arising from marine ecosystems. It should be noted that findings from the VALMER Project (Friedrich *et al.,* 2015) suggest that non-monetary ecosystem services

assessments (ESAs) can be more useful for stakeholder engagement in certain circumstances. Therefore it is important to consider what the framework is being used for and who the target audience is when undertaking an assessment.

UK National Ecosystem Assessment (NEA) - 2011

Relevant resources: http://uknea.unep-wcmc.org/

The UK NEA conceptual framework (Figure 5) builds on the MA and TEEB frameworks, visually representing the processes linking human societies and their well-being with the environment. Of particular importance in this framework is the use of scenarios to explore how drivers of change may impact on ecosystems and the subsequent change in services. The role of ecosystems in providing flows of services and goods, and how they are valued, is another focus. Within this framework, ecosystem services are described as the outputs of ecosystems from which people derive benefits including goods and services. Some services can be valued economically, for example, food and water purification, while other values, such as spiritual experiences, have non-economic values. The combination of these goods, services and values provide overall human well-being (expressed in society as health, wealth and happiness). The values that people receive from ecosystems may alter the way that they choose to use and manage the environment. This in turn leads to further changes in the environment.

Under the UK NEA Follow-on (UK NEA, 2014), the 2011 conceptual framework was further developed and adapted to include governance and institutions, reflecting the importance of these factors in decision-making processes (Figure 5). Further additions included natural capital and other types of capital (i.e. built, social and human capital), reflecting the important role they play in transforming ecosystem services into ecosystem goods and benefits.

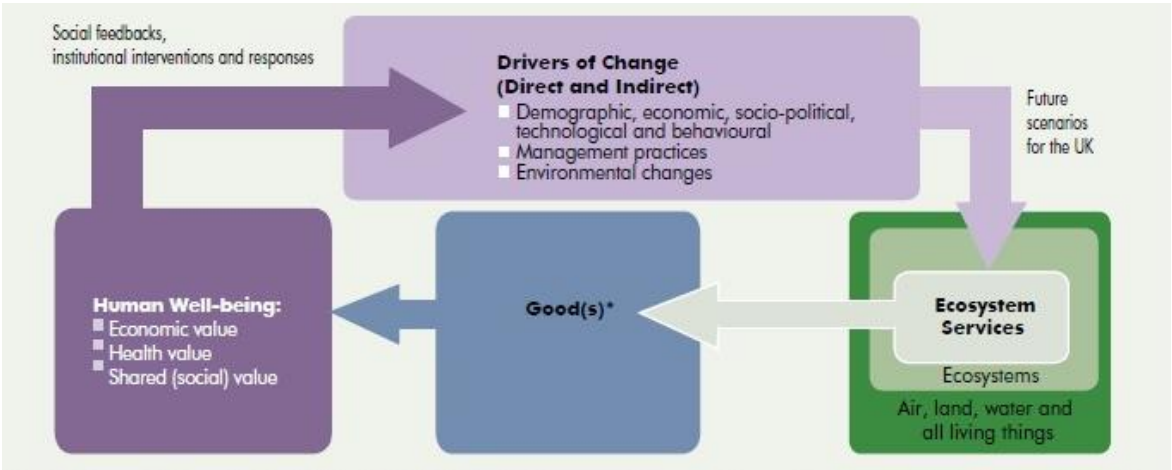

Figure 5: The UK National Ecosystem Assessment conceptual framework.

Strengths and weaknesses

Due to the focus upon the United Kingdom, the UK NEA framework may have limited applicability elsewhere. The framework is also limited with no marine orientation.

UN System of Environmental-Economic Accounting Central Framework (SEEA CF) - 2012

Relevant resources: https://unstats.un.org/unsd/envaccounting/seeaRev/eea_final_en.pdf

http://unstats.un.org/unsd/envaccounting/ceea/meetings/eleventh_meeting/BK-11-3b-2.pdf

The System of Environmental-Economic Accounting (SEEA) Central Framework is the international statistical standard for environmental-economic accounting adopted in 2012 by the United Nations Statistical Commission. The framework is a multi-purpose statistical approach that describes three main areas:

- the interaction between the economy and the environment;
- the stocks of environmental assets and the flows of products and services provided; and
- expenditure on environmental protection and resource management.

Ecosystems are specifically considered within the complementary System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA, 2014) framework (Figure 7). Within the SEEA-EEA, ecosystems are spatially explicit units ('assets') that are characterised on the basis of their type, extent and a range of condition characteristics (including species assemblages) relevant to their capacity to deliver ecosystem services. The data on ecosystem extent and condition are organised within a set of supporting accounts, which are developed from biophysical measures, such as ecosystem area and species abundance. The accounting model proposes that changes in the stock of the ecosystem asset is measured via changes in the biophysical measures of extent and condition. Ecosystem assets also produce a flow of ecosystem services over time, which contribute to the production of benefits and, ultimately, well-being. Data on ecosystem services is organised within the physical and monetary ecosystem services supply and use accounts. These accounts record the flow of ecosystem services from ecosystems to economic user's occurring within an accounting period (typically a year), in physical and monetary units respectively (SEEA-EEA TR, 2015). Figure 7 also recognises the importance of supporting ecosystem services (termed 'inter-' and 'intra-ecosystem flows') to ecosystem functioning (termed 'ecosystem processes') due to their role in transferring energy and nutrients both within and between ecosystem assets.

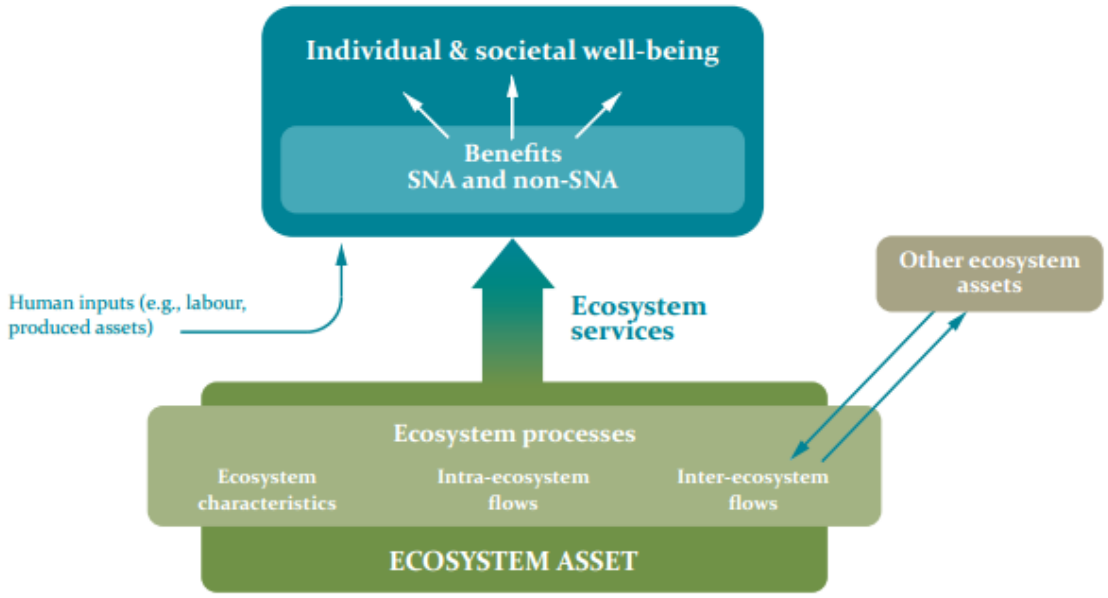

Figure 7: System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA) accounting model (SEEA-EEA TR, 2015).

Strengths and weaknesses

Due to its design, the SEEA framework generates a wide range of statistics and indicators which enable monitoring of economic-environment interactions. The SEEA assessment via the SEEA framework can aid monitoring of progress towards a green economy and identify trends in natural capital use by economic activities. SEAA can establish environmental and impact measures for the following:

- Stocks of natural resources;
- Emissions to the environment and waste generation;
- Land-use and land cover;
- Expenditure on environmental protection and resource management;
- The condition and health of ecosystems; and
- Regulatory services provided by ecosystem

The SEEA-EEA provides a framework for coherent coverage of information relating to ecosystem assets and ecosystem services. Yet, from an analytical perspective, it is challenging to focus on a whole system or holistic approach that considers the interactions between all accounts within the framework. More commonly, our views of managing ecosystems, and our policy responses, are framed using themes that concern specific aspects of the economic-environment relationship. Four main themes that are identified within SEEA-EEA are land, water, carbon and biodiversity (SEEA-EEA, 2014). Figure 8 illustrates how such thematic accounts are used to organise information that feeds into supporting accounts of ecosystem extent, condition, and services supply and use. Thematic accounts may also be used in their own right to address policy questions of interest.

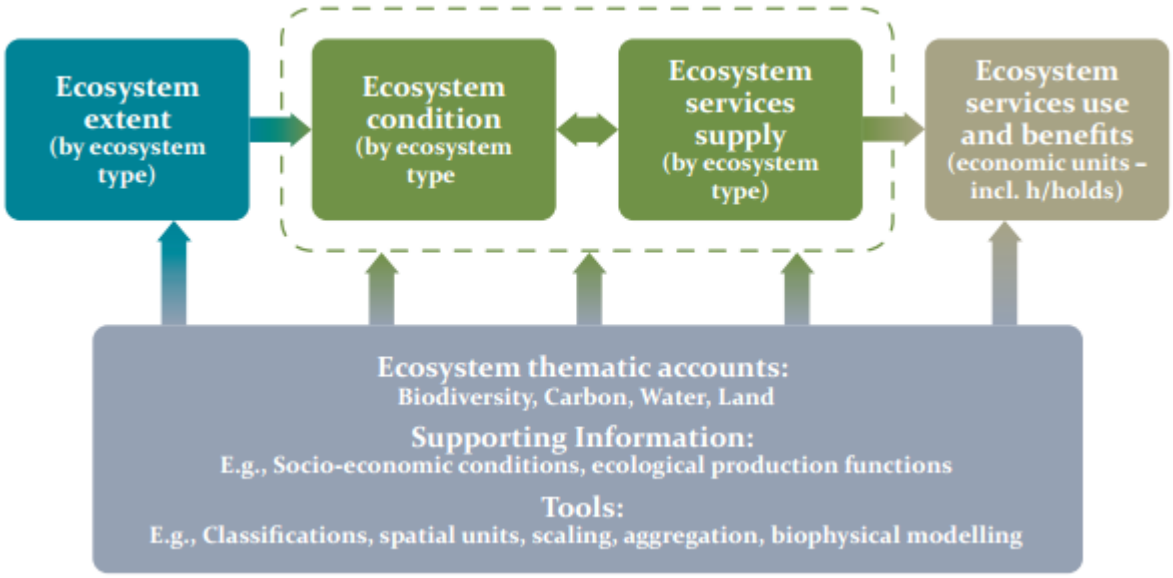

Figure 8: Relationship between thematic accounts and other System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA) accounts (Chow, 2016).

Mapping and Assessment of Ecosystems and their Services (MAES) - 2013

Relevant resources: http://ec.europa.eu/environment/pubs/pdf/factsheets/maes/en.pdf

The Mapping and Assessment of Ecosystems and their Services (MAES) conceptual framework (Figure 6) was developed as part of the MAES initiative within the EU Biodiversity Strategy and is applied by the European Union and its Member States. The MAES framework links human societies and associated human well-being with the environment through the flow of ecosystem services and drivers of change that affect ecosystems - either as a result of service use or indirect impacts of anthropogenic activities (European Union, 2013). The framework was developed to enable a harmonised approach to assessment across the European Union.

The MAES framework is based upon the ecosystem services cascade model (Haines-Young and Potschin, 2010) and, as such, maps the biophysical flows and social values emanating from ecosystems. The MAES framework is also based upon previous frameworks, such as The Economics of Ecosystems and Biodiversity (TEEB) framework and the UK National Ecosystem Assessment (UK NEA) framework. Similarities are also identified with the Millennium Ecosystem Assessment (MA). Elements of the DPSIR framework (Drivers - Pressures - States - Impacts - Responses) are also included in structuring the interactions between the environment and socio-economic activities. However, the DPSIR framework has been adapted in order to better fit the needs of ecosystem assessments under Action 5 (European Union, 2013). The MAES framework involves physical mapping of ecosystems in addition to quantification of ecosystem condition and identification of services supplied (see Maes *et al.*, 2012).

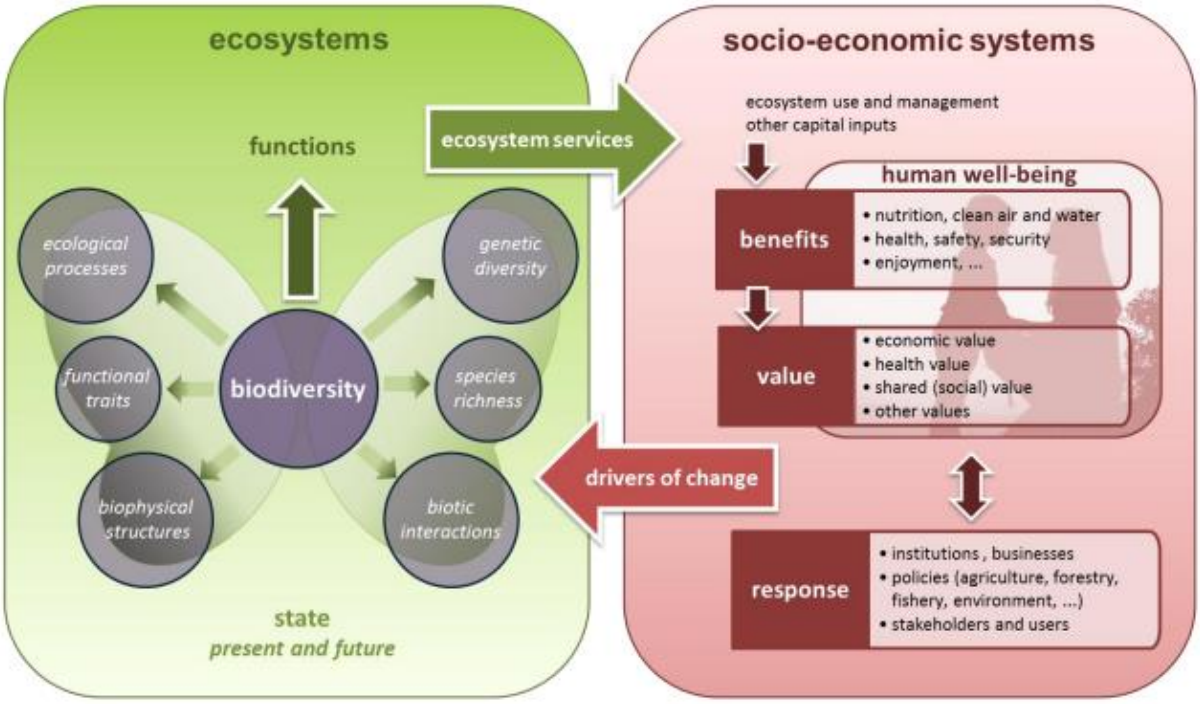

Figure 6: Mapping and Assessment of Ecosystems and their Services (MAES) Conceptual Framework (European Union, 2013).

Strengths and weaknesses

Key strengths of this framework are its scope to function effectively across the whole of the European Union and its strong application to policy as a result of its development in consultation with experts and stakeholders. Its applicability to other non-European locations is less clear. This framework supports the ability to use maps to visualise the stages for assessment. Furthermore, the ecosystem service cascade can be used as a frame to map the stages in visualising the final service (Maes, 2012).

National Ecosystem Services Partnership (NESP) - 2015

Relevant resources:

https://nicholasinstitute.duke.edu/focal-areas/online-guidebook#.U30QVtJdV8E

https://nespguidebook.com/

The US National Ecosystem Services Partnership (NESP) conceptual framework was developed by Duke University's Nicholas Institute for Environmental Policy Solutions, and was supported by the US Environmental Protection Agency, and various donors, to incorporate ecosystem services into Agency planning processes. The NESP conceptual framework draws upon ecological and social analysis relevant to ecosystem services and was developed to enhance consistency and credibility of its application by federal agencies. In order to support Agency planning processes it was important to highlight the use of ecosystem services assessments to federal resource managers and planners (NESP, 2016).

The framework utilises benefit relevant indicators (BRIs) of the connections between ecosystem processes to the benefits experienced by people. BRIs are quantitatively and qualitatively measurable indicators that capture this connection by considering whether there is demand for the service, how much it is used (for use values) or enjoyed/valued (for non-use values), and whether the site provides the access necessary for people to benefit from the service, among other considerations (NESP, 2016).

Strengths and weaknesses

The framework draws insights and methods from natural, social, behavioural, and economic sciences, and incorporates socio-cultural context and stakeholder engagement during the scoping stages of planning and management. Ecosystem services concepts are integrated into decision-making with direct application to local and national-level scales. The assessments can be adapted and applied to a variety of different decision contexts, including: species management, ecological restoration, risk management, infrastructure decisions, selection of performance metrics, and identification of data and monitoring needs. However, its specific focus on the work of Federal Agencies in the US might reduce its applicability to other contexts.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) - 2015

Relevant resources:
http://www.ipbes.net/sites/default/files/downloads/pdf/2a%20PLOS_A_Rosetta_Stone_for_Natures_Benefits_to_People-2.pdf

http://www.ipbes.net/sites/default/files/downloads/pdf/ipbes-5-inf-8.pdf

http://www.ipbes.net/sites/default/files/downloads/pdf/2016.methodological_assessment_report_scenarios_models.pdf

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework illustrates the spatial and temporal interactions between biodiversity and ecosystems, and human quality of life from the perspectives of different worldviews. The framework differs from previous frameworks as it places a stronger emphasis on human actions, such as institutions and governance systems, and as these being the underlying causes for change generated outside of ecosystems (i.e. anthropogenic drivers which directly affect nature). The IPBES framework builds upon, and draws from lessons learned from previous frameworks, such as the 2003 Millennium Ecosystem Assessment (MA) framework. Examples of shared attributes between the MA and IPBES conceptual frameworks include scale (temporal and spatial) and emphasis on environment-human interactions (Díaz *et al.*, 2015).

The IPBES framework highlights the crucial role of human institutions as sources of environmental problems as well as solutions. Within the valuation of nature's contribution to quality of life, the framework considers a range of values including: monetary, spiritual, instrumental and relational. Furthermore, the IPBES framework is unprecedented in its efforts to further develop the initiatives within the current international environmental science-policy interface by considering and incorporating knowledge systems other than western science, and

including indigenous and local knowledge. This aims to facilitate cross-disciplinary and cross-cultural understanding and, as such, the framework is comprised of six interlinked and highly inclusive elements (shown in Figure 9 and listed below):

1. nature;
2. nature's benefits to people;
3. drivers of change;
4. institutions and governance systems and other indirect drivers;
5. direct drivers; and
6. good quality of life.

The framework also contains two drivers of change: 'direct drivers' and 'institutions and governance systems'. These are defined as all external factors which affect nature, anthropogenic assets, nature's benefits to people and good quality of life. Temporal and spatial scales are considered (as illustrated by the coloured arrows in Figure 9 below to the right of the central panel).

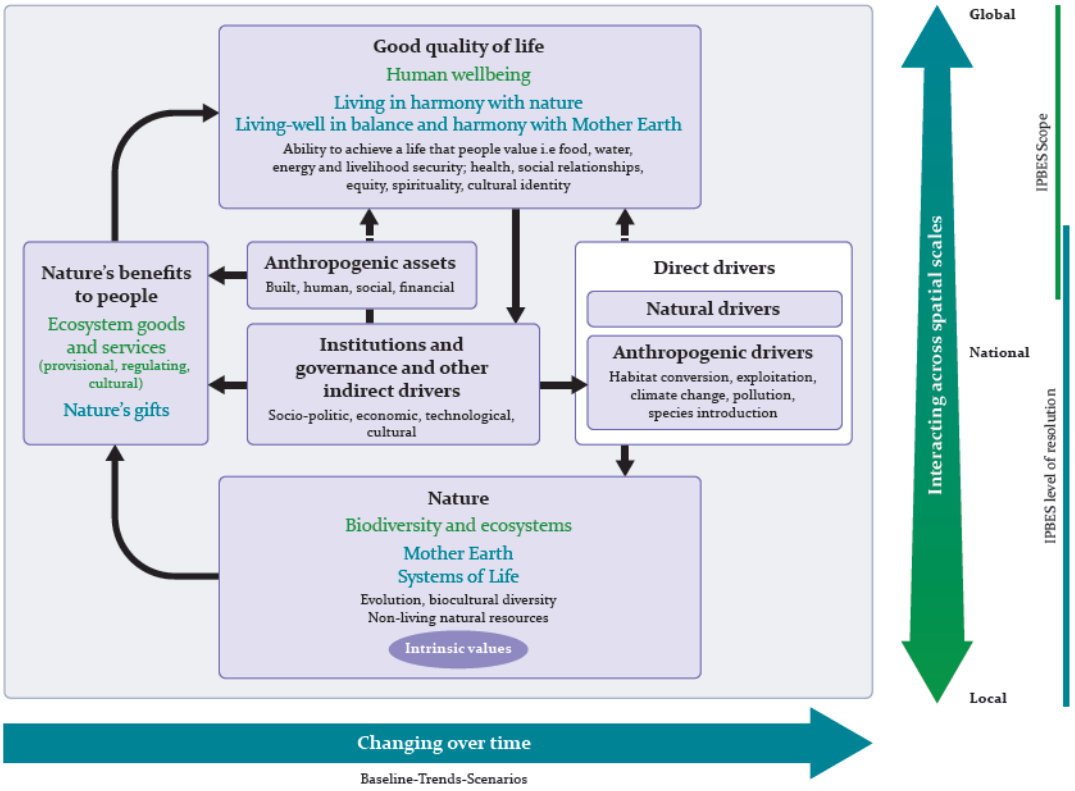

Figure 9: The Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) Conceptual Framework for ecosystem services analysis and policy engagement.

The evolution of the IPBES framework from the initial Millennium Ecosystem Assessment (MA) has developed with the redefining of 'ecosystem services', referring those which are regulatory, provisioning and cultural. Upon publishing, the 2015 IPBES framework utilised the term 'Nature's Benefit to People' to refer to all benefits (including detriments and losses) that humans derive from nature. These benefits have a human value which ranges from market / economic value to that of spiritual inspiration. Certain benefits are directly provided (e.g. oxygen) although most are dependent on the joint contribution of nature and human interventions (e.g. the

catching of fish for provision of food). In 2016, the framework evolved to utilise 'Nature's Contribution to People' (NCPs). See '*Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)*' within '*Classification*' section for further details on NCPs.

Figure 10 illustrates this evolution of the IPBES framework from the MA. Of note, cultural issues permeate through many provisioning and regulating NCPs. NCPs have been designed in order to generate common discourse between different assessments and also with the global assessment.

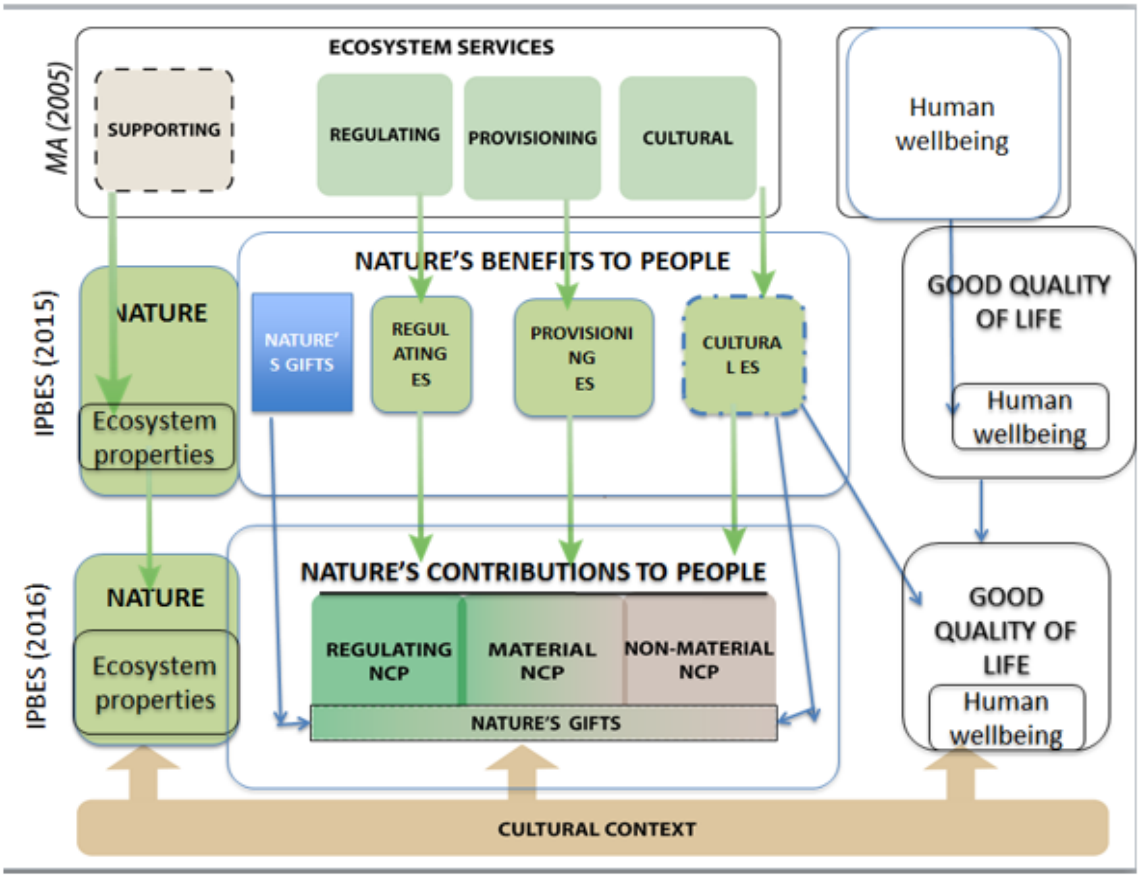

Figure 10: Evolution of several major groups within the IPBES conceptual framework (*schematic is work in progress*).

Strengths and weaknesses

The IPBES framework is highly innovative, embracing a number of different scientific disciplines (natural, social and engineering science), stakeholders at different levels (the scientific community, governments, international organisations and civil society) and knowledge systems (western science, indigenous, local and practitioners'). The six main elements of the framework (Figure 10) are broad and inclusive categories to enable all stakeholders to relate (Díaz *et al.*, 2015). The framework therefore enables shared understanding across disciplines, stakeholders, and knowledge systems throughout the assessment process and within outputs. Outcomes of IPBES framework assessments are utilised within decision-making (Brown *et al.*, 2016). The multi-scale approach of the framework (temporal and spatial) is a further strength, enabling adaptation to national, regional and global assessments.

Classification systems

A number of different ecosystem services classification systems are available for use with an ecosystem assessment. Each classification may be more or less suited to specific contexts of ecosystem services assessments. There are arguments for bespoke classifications being developed and/or chosen for each individual ecosystem service assessment to ensure context specificity and that analysis focuses on ecological systems or socio-economic systems. There is, however, movement towards identification and development of classifications that have general application. The following describes a number of different classification systems used in ecosystem services assessments. For each classification system, a description and schematic image is provided along with links to relevant resources. Classifications are listed in alphabetical order.

Millennium Ecosystem Assessment Classification (MA)

Relevant resource: http://www.millenniumassessment.org/en/index.html

The Millennium Ecosystem Assessment classification system is structures within four different categories: provisioning services; regulating services; cultural services; and supporting services. Figure 11 below summaries this classification (MA, 2005; Ash *et al.*, 2010).

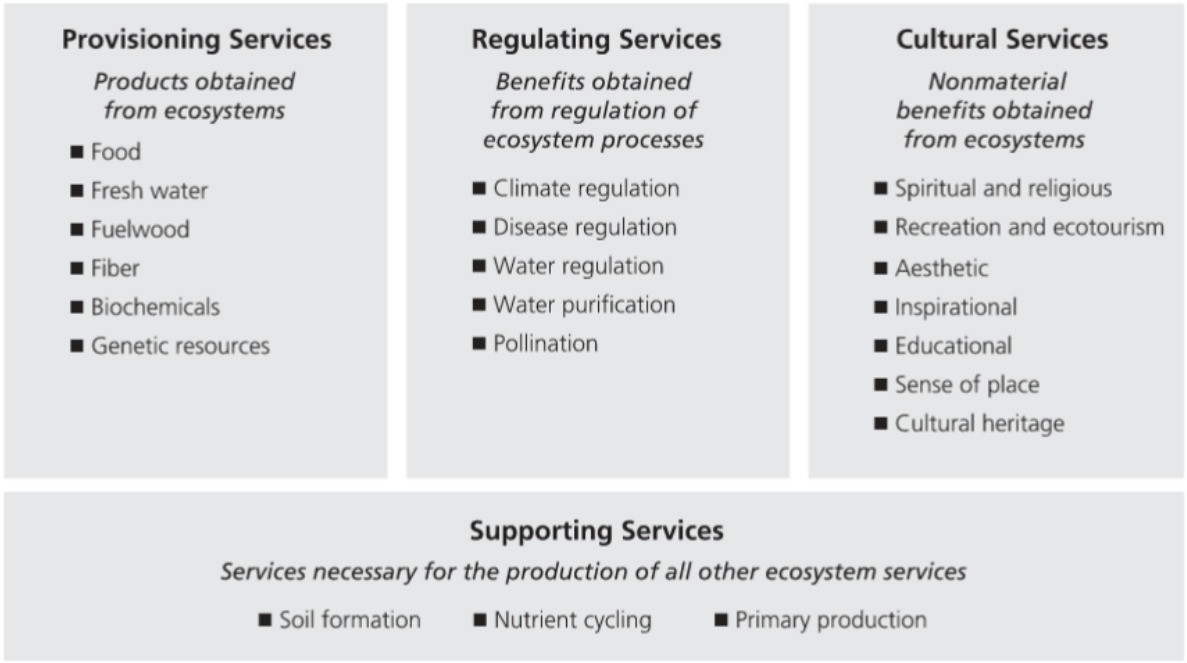

Figure 11. The Millennium Ecosystem Assessment classification system (MA, 2005).

Final Ecosystem Goods and Services Classification System (FEGS-CS)

Relevant resources:
https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=257922&CFID=139720405&CFTOKEN=59303549&jsessionid=cc303f3c529fb2342dd56e52d7c80353e2a2

https://gispub4.epa.gov/FEGS/

In order to ensure clear separation between services, and to avoid double counting, the US Environmental Protection Agency has proposed additional classifications. These include Final Ecosystem Goods and Services Classification System (FEGS-CS) which is described below. The main focus is on benefits and beneficiaries reducing the risk of double counting (Notte *et.al*, 2017).

There are two independent components used to define goods and services by the FEGS-CS classification:

1. **Beneficiary Category** (who values the potential good or service?), and;
2. **Environmental Class** (Where does the FEGS occur on Earth e.g. the hydrosphere and lithosphere).

FEGS are therefore defined by the landscape in which they occur and the interests of people that interact with them.

"Environment + Beneficiary => FEGS"

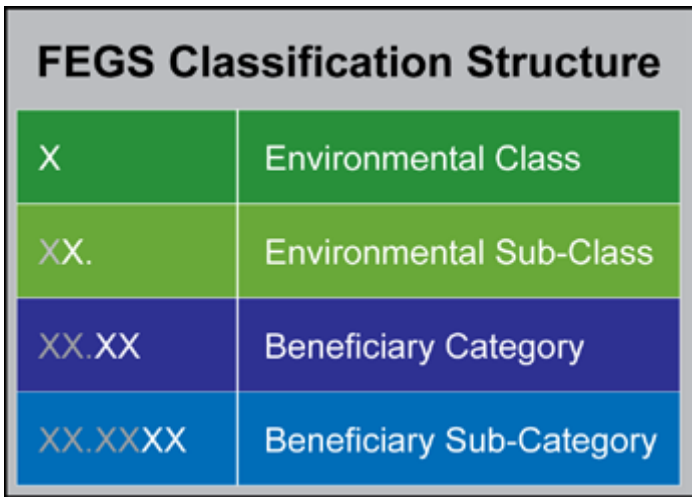

Figure 12. The general classification structure for the Final Ecosystem Goods and Services Classification System (FEGS-CS).

Twenty-one categories are used to organize FEGS in the FEGS-CS (See Table 1). These 21 categories are not FEGS themselves, but must be connected to a specific environment (e.g. rivers and streams) and to a specific beneficiary (e.g. farmer). See Figure 13 for an example of how the classification structure works.

Table 1: List of the 21 categories used to organise Final Ecosystem Goods and Services (FEGS) in the FEGS Classification System (FEGS-CS)

1.	*Water*	12.	*Pollinators*
2.	*Flora*	13.	*Depredators and (Pest) Predators*
3.	*Presence of the Environment*	14.	*Timber*
4.	*Fauna*	15.	*Fungi*
5.	*Fibre*	16.	*Substrate*
6.	*Natural Materials*	17.	*Land*
7.	*Open Space*	18.	*Air*
8.	*Viewscapes*	19.	*Weather*
9.	*Sounds and Scents*	20.	*Wind*
10.	*Fish*	21.	*Atmospheric Phenomena*
11.	*Soil*		

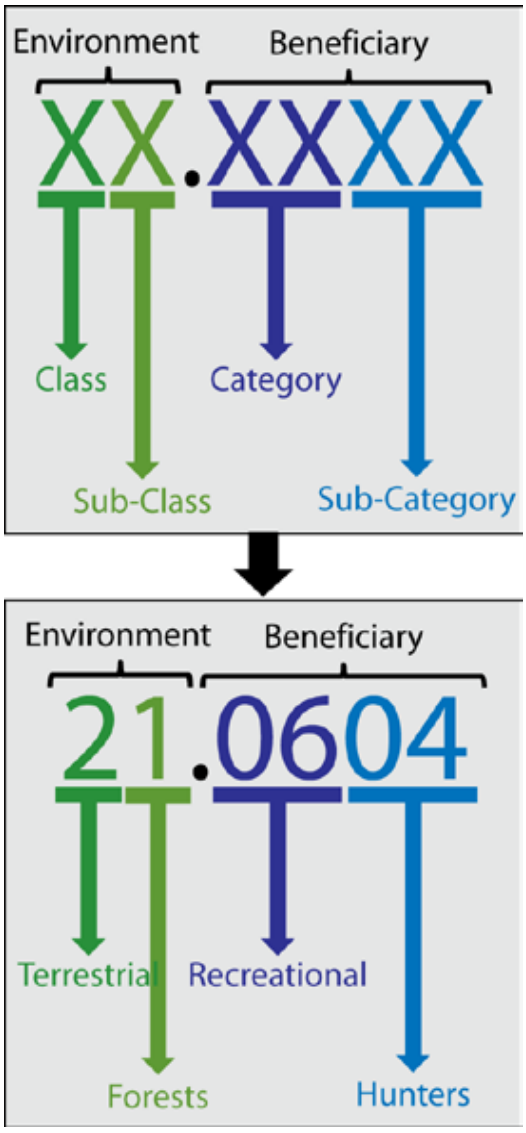

Figure 13. Schematic image depicting an example the FEGS organisational structure is used in practice.

In FEGS-CS, processes such as photosynthesis or carbon sequestration, are grouped together as '*ecosystem structural components*' and considered as *intermediate* goods and services. These intermediate services are a step along the pathway to a final service that would be possible to value. The intermediate services are excluded because they are not directly used by humans (Notte et. al., 2017). The main focus of this classification system is the beneficiaries, which is consistent with the suggestion that the ecosystem services that should be accounted for are those *'components of nature directly enjoyed, consumed or used to yield human well-being'* (Boyd and Banzhaf, 2007).

Common International Classification of Ecosystem Services (CICES)

Relevant resources: http://cices.eu/

The Common International Classification of Ecosystems Services (CICES) is currently a very prominent classification system, particularly in Europe. Similarly to the TEEB classification, CICES does not include "*supporting services*" from the MA. Instead it includes a category called '*regulating and maintenance services*' which merges the TEEB's 'h*abitat services*' with regulating services (Notte, et.al, 2017). For CICES, the services are divided by the following levels; Section, Division, Group, Class and Class type. Table 2 describes the full list of Section and Division levels. These Section and Division levels are further divided by including Group and class services to make a full list of 33 classes. Table 3 illustrates an example of the full level breakdown of the ecosystem classification.

Table 2. Common International Classification of Ecosystems Services (CICES) Section and Division levels.

Section	***Division***
This column lists the three main categories of ecosystem services	*This column divides section categories into main types of output or process.*
Provisioning	*Nutrition*
	Materials
	Energy
Regulation & Maintenance	*Mediation of waste, toxics and other nuisances*
	Mediation of flows
	Maintenance of physical, chemical, biological conditions
Cultural	*Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]*
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]

Table 3. Example of the full level breakdown of the Common International Classification of Ecosystems Services (CICES).

Section	*Regulation & Maintenance*
Division	*Maintenance of physical, chemical, biological conditions*
Group	*Pest and disease control*
Class	*Pest control*
Class Type	*By reduction in incidence, risk, area protected*
Examples for illustrative purposes	*Pest and disease control including invasive alien species*

CICES promotes a clear distinction between ecosystem services and ecosystem benefits. Biophysical structure and function are included as supporting or intermediate services. Final ecosystem services are the contributions that ecosystems make to human well-being as flows. Ecosystem goods and benefits are created or derived by people from final ecosystem services. (La Notte *et al.*, 2017) The Common International Classification of Ecosystem Services (CICES) system seeks to hierarchically structure ecosystem services such that indicators can be used at different levels. This may help avoid double counting (European Union, accessed 2017)

A study that tested the applicability of the CICES classification at the national level, found it useful because of the ability to bundle the services at different levels. This bundling allowed the re-use of indicators which had been developed under other frameworks or reporting systems, making it easier to integrate ecosystem services into decision-making. However, applying the CICES classification to marine or freshwater ecosystems is less clear. Some of the CICES classes are not applicable to the marine environment. Confusion could be generated by the current CICES classifications because it is possible to interpret the classes differently depending on whether marine, terrestrial, or freshwater systems are considered (Maes *et al.*, 2016). However, it is understood that additional work is being undertaken to refine the classification system to include marine systems more clearly. CICES is an evolving classification system. The current version is **CICES-V4-3** (2013).

For detail in the differences between FEGS and CICES, see La Notte *et al.* (2017): http://dx.doi.org/10.1016/j.ecolind.2016.11.030

For more information on the comparison between CICES, TEEB and MA, see Potschin and Haines-Young (2016): http://www.nottingham.ac.uk/cem/pdf/A5_chapter%203_Potschin_RHY_2016_Defining-ES_CICES.pdf

Böhnke-Henrichs *et al.* Classification- 2013

Relevant resources: http://dx.doi.org/10.1016/j.jenvman.2013.08.027

In 2013, Böhnke-Henrichs *et al.* proposed a classification of ecosystem services designed to specifically support marine spatial planning (Figure 14). This novel and bespoke marine classification has been applied to marine spatial planning (MSP) and Ecosystem-based Management (EMB), thus demonstrating application of ecosystem services assessment within marine planning and management contexts. This classification (Table 4) enables consideration of multiple uses and impacts, in addition to the analysis of different management and development options, in terms of conflict, use, and trade-offs. This classification differs from monetary assessments, as it links ecosystem state with human well-being in a non-monetary assessment.

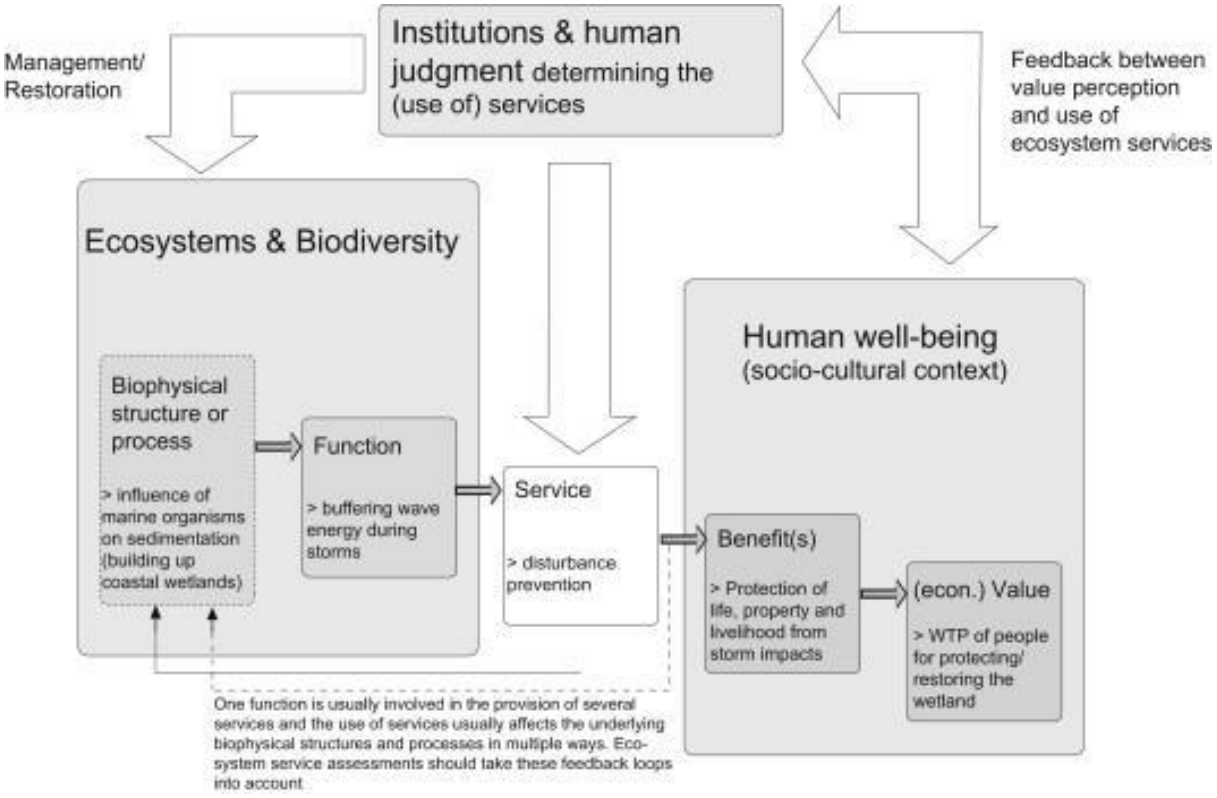

Figure 14. Schematic image of marine ecosystem services from the Böhnke-Henrichs *et al.* Classification (Böhnke-Henrichs *et.al.*, 2013).

Table 4. Classification of marine ecosystem services (Böhnke-Henrichs *et.al.*, 2013).

Category	***Ecosystem service***
Provisioning services	Sea food
	Sea water
	Raw materials
	Genetic resources
	Medical resources
	Ornamental resources

Category	*Ecosystem service*
Regulating services	Air purification
	Climate regulation
	Disturbance prevention or moderation
	Regulation of water flows
	Waste treatment
	Coastal erosion protection
	Biological control
Habitat services	Life cycle maintenance
	Gene pool protection
Cultural and amenity services	Recreation and leisure
	Aesthetic information
	Inspiration for culture, art and design
	Spiritual experience
	Information for cognitive development
	Cultural heritage and identity

The Economics of Ecosystems and Biodiversity (TEEB)

Relevant resources:

http://www.teebweb.org/resources/ecosystem-services/

http://www.teebweb.org/wp-content/uploads/2013/04/Do-Chapter-1-Integrating-the-ecological-and-economic-dimensions-in-biodiversity-and-ecosystem-service-valuation.pdf

The Economics of Ecosystems and Biodiversity (TEEB) process produced a classification of ecosystem services, displayed in the table below. These are similar to the Millennium Ecosystem Assessment (MA) services although the supporting service grouping has been replaced. Instead, there is a category called 'habitat' services.

Table 5. Typology of ecosystem services within The Economics of Ecosystems and Biodiversity (TEEB).

Provisioning Services	
1	Food (e.g. fish, game, fruit)
2	Water (e.g. for drinking, irrigation, cooling)
3	Raw Materials (e.g. fiber, timber, fuel wood, fodder, fertilizer)
4	Genetic resources (e.g. for crop - improvement and medicinal purposes)
5	Medicinal resources (e.g. biochemical products, models & test - organisms)
6	Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)
Regulating services	
7	Air quality regulation (e.g. capturing (fine)dust, chemicals, etc)
8	Climate regulation (incl. C sequestration, influence of vegetation on rainfall, etc.)
9	Moderation of extreme events (eg. storm protection and flood prevention)
10	Regulation of water flows (e.g. natural drainage, irrigation and drought prevention)

11	Waste treatment (especially water purification)
12	Erosion prevention
13	Maintenance of soil fertility (incl. soil formation)
14	Pollination
15	Biological control (e.g. seed dispersal, pest and disease control)
Habitat Services	
16	Maintenance of life cycles of migratory species (incl. nursery service)
17	Maintenance of genetic diversity (especially in gene pool protection)
Cultural & Amenity Services	
18	Aesthetic information
19	Opportunities for recreation & tourism
20	Inspiration for culture, art and design
21	Spiritual experience
22	Information for cognitive development

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

Relevant resources: http://www.ipbes.net/sites/default/files/downloads/pdf/ipbes-5-inf-24.pdf

Three broad categories of 'nature's contributions to people' have been defined for IPBES. These are:

1. **Regulating contributions** – Functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people, and/or sustain and/or regulate the generation of material and non-material benefits. These NCP include, for example, water purification, climate regulation, or soil erosion regulation. They are often not experienced directly by people. Regulating ecosystem services, as defined in the Millennium Ecosystem Assessment, largely fit within this category.
2. **Material contributions** –Substances, objects or other material elements from nature that sustain people's physical existence and infrastructure (i.e the basic physical and organizational structures and facilities, such as buildings, roads, power supplies) needed for the operation of a society or enterprise). They are typically physically consumed in the process of being experienced, such as when plants or animals are transformed into food, energy, or materials for shelter or ornamental purposes. Provisioning ecosystem services, as defined in the Millennium Ecosystem Assessment largely fit within this category.
3. **Non-material contributions** –Nature's contribution to people's subjective or psychological quality of life, individually and collectively. The entities that provide these intangible contributions can be physically consumed in the process (e.g. animals in recreational or ritual fishing or hunting) or not (e.g. individual trees or ecosystems as sources of inspiration). Many cultural ecosystem services as defined in the Millennium Ecosystem Assessment fit within this category, while some cultural ecosystem services are now considered part of "values" or a "good quality of life".

A set of 18 specific categories, described as 'natures contribution to people' have been develop

(Table 6). Each of these may not be available in all regions. Some can be further broken down and others can be grouped together. The classification system recognises that many of nature's contributions to people do not always fit into the three broad groups of non-material, material or regulating contributions.

Table 6. Description of 18 reporting categories of nature's contributions to people

1	Habitat creation and maintenance	11	Energy
2	Pollination and dispersal of seeds and other propagules	12	Food and feed
3	Regulation of air quality	13	Materials and assistance
4	Regulation of climate	14	Medicinal, biochemical and genetic resources
5	Regulation of ocean acidification	15	Learning and inspiration
7	Regulation of freshwater and coastal water quality	16	Physical and psychological experiences
8	Formation, protection and decontamination of soils and sediments	17	Supporting identities
9	Regulation of hazards and extreme events	18	Maintenance of options
10	Regulation of organisms detrimental to humans		

Methodologies

The following summarises various methodologies which are utilised for ecosystem services valuation, sourced from Hooper *et al., 2015* and Fletcher *et al.,* 2014. Methodologies are divided into those which are monetary and non-monetary in nature. Please note, this is not a comprehensive list.

Monetary methodologies

Market values/Market price
This method considers the sale and purchase price of the ecosystem service in question, most commonly valuing provisioning ecosystem services. The market price method estimates the economic value of ecosystem services that are bought or sold on commercial markets. Valuation is based on the quantity of ecosystem services purchased at different prices and the quantity supplied at different prices.

Travel Cost Method (TCM)
This method is based on the premise that marine sites hold high value for tourists and local residents for the purpose of recreation, leisure and tourism. It is one of the most commonly applied methods for estimating the value of recreational sites.

Hedonic pricing
This method is based on the premise that the value of a good will be related to its characteristics or to the services it provides. Therefore it can be valued by assessing how the price people are willing to pay for it changes as its characteristics change. It is used to estimate the economic value of ecosystem services that directly affect market prices.

Payment for ecosystem services (PES)
This method values the payments made to undertake actions that increase the quality and quantity of desired ecosystem services. It involves provision of incentives for people whose activities could or do cause damage or degradation to ecosystems. Direct but voluntary payments are given by beneficiaries to those providing ecosystem service to maintain or enhance service provision.

Contingent Valuation Method
This method utilises questionnaires to construct a hypothetical market for a non-market commodity of interest. Respondents to the questionnaire are generally presented with a scenario (or series of scenarios) on a hypothetical change in policy where the good or services which they desire will be affected. Respondents are then asked what they would be willing to pay to obtain the good or service or what they may be willing to accept in exchange of being deprived of it. Values are provided in monetary terms.

Choice modelling
This method utilises surveys to present policy options as a collection of policy attributes. Respondents are invited to make a choice between different combinations of the options and attributes or rank their preference for different combinations.

These following four methods are all based on the assumption that a particular beneficial ecosystem service will be worth at least the amount that people will pay to protect, replace or substitute it.

Avoidance/prevention cost
This method estimates the value of BES based on the cost of avoiding damage due to lost services.

Damage cost avoided
This method values the cost that was avoided by not allowing the beneficial ecosystem service to degrade.

Replacement/substitute cost
This method values the cost of replacing/providing substitutes for lost ecosystem service. This method relies on three key conditions: (1) that the substitute provides the same ecosystem service, of the same quality and magnitude as that which is being replaced, (2) that the alternative is the cheapest method possible to produce an alternative, and (3) that society has demonstrated a WTP for the services to be provided artificially.

Averting behaviour method
This method considers the costs associated with changing behaviour to avoid damage to the marine environment.

Non-monetary methodologies

Citizen Juries
This method requires the involvement of the public in the decisions of public authorities. The jury is typically comprised of between 5-20 members of the public, selected to represent a cross-section of the community. The jury are provided with information about ecosystem service values, which they discuss and formally deliberate in a transparent process.

Place Based Valuation
This method focuses specifically on identifying the value that communities place on features and areas within marine and coastal environments, taking into consideration cultural and social values as well as biological considerations.

Health Valuation
This method aims to qualify and quantify the estimated increase in physical and mental health and quality of life related to the access to a protected area. Surveys, statistics and research on restorative effects are utilised to assess concepts such as decreased levels of stress and mental fatigue, increased levels of physical activity and lower levels of aggression.

Indicator approach
Indicators are variables that estimate complex parameters that cannot be measured directly. Data can be translated from primary data, for example household surveys which produce mainly qualitative indicators. As well as from secondary data, which can save time and costs when compared to other methods indicators can be selected by researchers or can be selected by stakeholders, following a participatory process.

Q-methodology
This method combines the benefits of both qualitative and quantitative research. Interviews are used to investigate the in-depth perspectives of stakeholders allowing amenity values to be explored and the environments for which stakeholders have most affinity to be identified.

Useful resources

Useful resources for natural capital and ecosystem services valuation include:

- UNEP The Economics of Ecosystems and Biodiversity (TEEB) (http://www.teebweb.org/)
- UNEP Ecosystems Services and Economics (http://www.ese-valuation.org/)
- Wealth Accounting and the Valuation of Ecosystem Services (WAVES) (http://www.wavespartnership.org/)
- The Natural Capital Project (http://www.naturalcapitalproject.org/)
- The Environmental Valuation Reference Inventory (https://www.evri.ca/Global/Splash.aspx)
- Natural Capital Asset Check (NCAC) (Dickie et al., 2014)

Useful resources for natural capital accounting include:

- UN System of Environmental Economic Accounting (SEEA) (http://unstats.un.org/unsd/envaccounting/seea.asp)
- UNEP TEEB Advancing Natural Capital Accounting project (http://www.teebweb.org/areas-of-work/advancing-natural-capitalaccounting/)
- European Environment Agency (http://www.eea.europa.eu/ – search 'ecosystem accounting')
- UNEP's Valuation and Accounting of Natural Capital for Green Economy (VANTAGE) initiative
- CBD Ecosystem Natural Capital Accounts (www.cbd.int/doc/publications/cbd-ts-77-en.pdf)

Useful resources for indicator development include:

- Guidance for national biodiversity indicator development and use (Biodiversity Indicators Partnership, 2011)

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