THE GUIDEBOOK ON
"THE INTRODUCTION TO THE ECOSYSTEM SERVICE FRAMEWORK AND ITS APPLICATION IN INTEGRATED PLANNING"

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1.ECOSYSTEM SERVICE CONCEPT AND CLASSIFICATION SYSTEMS

1.1. Ecosystem service concept

Ecosystems have potential to supply a range of services that are of fundamental importance to human well-being, health, livelihoods, and survival (Costanza et al., 1997; Millennium Ecosystem Assessment (MEA), 2005; TEEB Synthesis, 2010). Different ways of defining ecosystem service have been developed so far – they can be described as the benefits that people obtain from ecosystems (MEA, 2005) or as the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). More recent publications define the **ecosystem services (ES) as contributions of ecosystem structure and function (in combination with other inputs) to human well-being** (Burkhard et al., 2012; Burkhard B. & Maes J. Eds., 2017).

Ecosystem cannot provide any benefits to people without the presence of people (human capital), their communities (social capital), and their built environment (built capital). Thus ecosystem services should be perceived as a contribution of the natural capital to human well-being, which forms only by interaction with human, social and built capital (Fig. 1.1.).

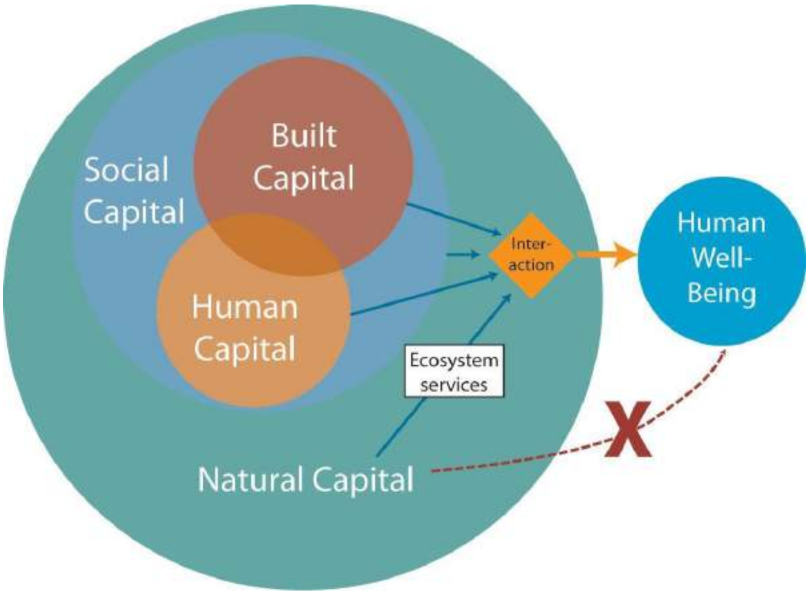

Figure 1.1. Interactions between built, social, human and natural capital required to produce human well-being (Source: Costanza et al., 2014).

Ecosystem services can be perceived also as an interface between people and nature, which is illustrated by so called 'cascade model' (Haines-Young and Potschin, 2010; Potschin and Haines-Young, 2016; Burkhard and Maes (Eds.), 2017). This model describes the pathway of causal interrelations between ecosystem at one end and the human well-being at another (Fig. 1.2). The ecosystem within this model is characterized by its biophysical structures and processes. The **biophysical structure**, in a more simple way, can be labelled as a habitat type (e.g. woodland, wetland, grassland etc.), while **processes** refers to dynamics and interactions forming the ecological system (e.g. primary production). The **ecosystem functions**, in the context of the cascade model, are understood as the characteristics or behaviours of the ecosystem that underpins its capacity to deliver an ecosystem service (e.g. ability of the woodland or grassland to generate a standing stock of biomass). Those elements and features, which are behind the ecosystem capacity to deliver services, are sometimes called 'supporting' or 'intermediate' services, while the **'final' ecosystem service** is what we actually can harvest (e.g. hey, timber) or gain from ecosystem (e.g. flood protection, beautiful landscape etc.). The 'final' services directly contribute to human well-being through the **benefits** that they support (e.g. health and safety). People are used to assign values to the benefits, therefore they are also referred as 'goods' and 'products'. The **value** can be expressed in many different ways – using monetary as well as moral, aesthetic or other qualitative criteria.

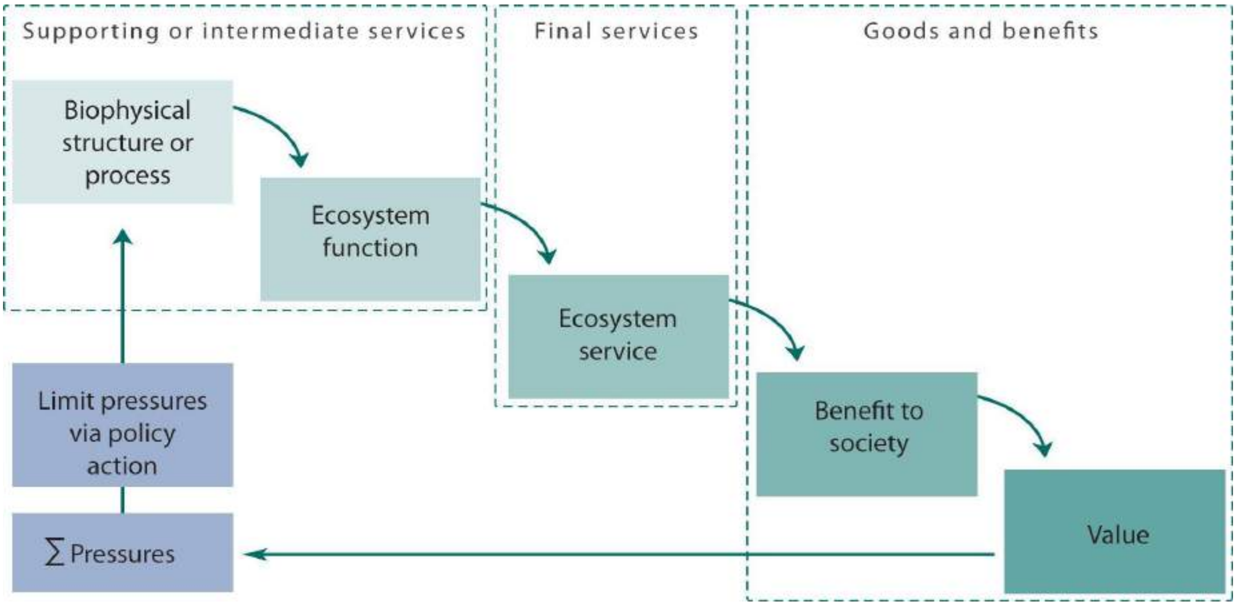

Figure 1.2. The cascade model (Source: Potschin and Haines-Young, 2016).

The capacity of the ecosystem to supply services for human well-being directly depends on the **ecosystem condition** (its structure and processes). While increasing the pressure on ecosystem or by changing the land use type (and thus fundamentally impacting or destroying the previous ecosystem), people influence the ecosystem service supply or trade-offs between different services. For example, by draining a wetland people can gain arable land and thus valuable food products, but at the same time lose such services as flood protection, natural habitats and species diversity as well as possibilities for nature tourism. In counting together all the benefits (in monetary or other valuation system), the value of wetland most probably would be much higher that the value of arable land.

Biodiversity has essential role in supply of the ecosystem services although this interrelation not always is so straightforward. Mostly it is associated with so called 'supporting or intermediate services', although few studies demonstrated a direct linear relation between **species diversity** and ecosystem productivity, biomass production, nutrient cycling etc. (Haines-Young and Potschin, 2010). For example there is experimental evidence that maintaining high levels of plant species diversity increases grassland productivity (e.g. Fagan et al., 2008). The productivity is an ecosystem function that underpins a range of ecosystem services (e.g. biomass production, soil formation and erosion control). However, it is not only the species richness, which supports the ecosystem service supply – there are also other ecosystem properties, which plays significant role, e.g. presence of particular species or species groups with particular features, that have certain function in ecosystem or its performance. For example, the ability of vegetation to store nutrients (used in establishing buffer stripes along water bodies) might depend on presence of species with the particular feature and their abundance in relation to the level of nutrients in the system. Such features of species are called **functional traits.** There is an agreement among researchers that functional diversity, formed by type, range and relative abundance of functional traits in a community, can have important consequence for ecosystem processes (De Bello et al., 2008). Ecosystems, where **functional groups** (i.e. groups of species with similar functions) are formed by ecologically similar species with different reactions on environmental pressures, are more resistant to adverse effects and thus can continue to supply services essential for human well-being.

The interrelation between biodiversity, ecosystem and socio-economic system via flows of ecosystem services and drivers of change is reflected also within the conceptual framework for EU and national ecosystem assessment developed by MAES initiative under Action 5 of the EU Biodiversity strategy (Maes et al., 2016) (Fig. 1.3).

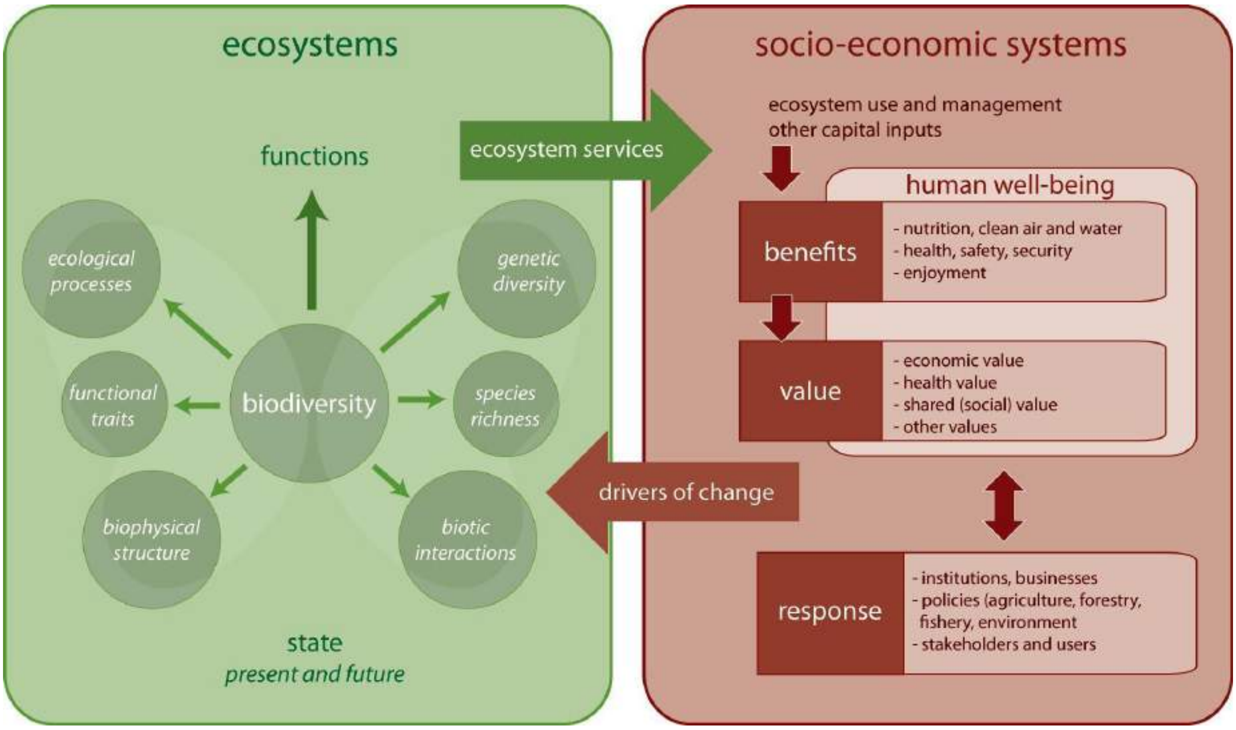

Figure 1.3. Conceptual framework for ecosystem assessment (Source: Maes et al., 2016)

Based on changes of the values or preferences/demand for the benefits provided by ecosystem, people make judgements about the kinds of interventions in the ecosystem either by protecting ecosystem or enhancing the supply of ecosystem service. Therefore knowledge on ecosystem service supply and their links to biodiversity as well as limits of ecological functioning and how external pressures may impact on ecological structures and processes is crucial when making decisions on land use or development projects, which are impacting ecosystem condition.

1.2. History of the concept development and its role in policy making

The ecosystem service concept is relatively new. It appeared on research agenda during the last decades of the 20th century, when the first publication on this topic were issued. An important milestone in ecosystem service evaluation was de Groot's publication "Functions of Nature" (1992), followed by Costanza et al. (1997) and Daily (1997), who further developed and promoted the concept in a global context. However, the idea was brought up already in 1970 within the Study of Critical Environmental Problems (SCEP), when a concept of 'environmental services' was first mentioned.

The concept gained recognition among policy makers when the United Nations published the **"Millennium Ecosystem Assessment" (MA)**[1] in 2005. The work on the MA started in 2001 involving over 1300 international experts. The study provided a comprehensive, global assessment of human impacts on ecosystems and their services, analysis of ecosystems condition and trend as well as possible solutions for restoration, maintenances and sustainable use. The key finding of the MA was that currently 60 per cent of the ecosystem services evaluated are being degraded or used unsustainably.

The following international initiative – **The Economics of Ecosystems and Biodiversity – TEEB**[2], carried out in 2007 – 2010, brought in the economic perspective of the ecosystem services in the policy debate. TEEB aimed to highlight the economic value of biodiversity as well as the costs arising from biodiversity loss and ecosystem degradation. TEEB was initiated by the European Commission and the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, responding to proposal of environment ministers from the G8+5 countries meeting in Potsdam, Germany in March 2007. The study was performed by wide network of international and national organisations involving expertise in different fields of science, economics and policy. The findings of TEEB were published in several report including: TEEB Ecological and Economic Foundations; TEEB in national and International Policy making; TEEB in Local and Regional Policy; TEEB in Business and Enterprise; as well as the TEEB Synthesis Report, which summarise the main findings and recommendations. The international TEEB initiative has been followed up by several national TEEB studies in order to demonstrate the value of ecosystems for national policy makers.

Ecosystem services mapping and assessment have become high on the agenda of all EU Member States after the adoption of the **EU Biodiversity Strategy to 2020**[3] in 2011. The strategy aims at halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible. In line with its Action 5 "Improve knowledge of ecosystems and their services in the EU", mapping and assessment of the ecosystems and their services in national territories would have to be carried out by 2014 and the economic values of ES have to be assessed by 2020. In the context of the Strategy 'mapping' stands for the spatial delineation of ecosystem as well as quantification of their condition and the service supply, while 'assessment' refers to the translation of this scientific evidence into information that is understandable for policy and decision making (Maes et al., 2016).

To support implementation of the Action 5 of the EU Biodiversity Strategy 2020 European Commission has established a working group on '**Mapping and Assessment of Ecosystems and their Services' – MAES**), which involves experts of the European Commission, the member states and the research community. It provides analytical framework (consisting of

[1] http://www.millenniumassessment.org/en/Index-2.html

[2] http://www.teebweb.org/

[3] http://eur-lex.europa.eu/legal-content/LV/TXT/PDF/?uri=CELEX:52011DC0244&from=EN

four different steps: 10 mapping of the ecosystems; 2) assessment of the ecosystem condition; 3) assessing of ecosystem services; and 4) and integrated assessment) as well as guidance for implementation of the Action 5 within EU and in the Member States. Several Member States have made already good progress in this field and performed their national MAES process, while many countries including the Baltic States are just at the initial stage for mapping of ecosystems and their services at national level. The **Biodiversity Information System for Europe - BISE**[4] holds the information on completed as well as ongoing initiatives at EU and national level with regard to mapping and assessment of ecosystems and services they supply.

At the same time several international co-operation platforms are established, linking researchers, research organisations and national authorities involved in the field of ecosystem service assessment. For example, **Ecosystem Service Partnership - ESP**[5], launched in 2008 by the Gund Institute for Ecological Economics (University of Vermont, USA) is formed by institutional and individual members from all over the world. ESP aims to enhance communication and cooperation in the field of ecosystem services by organising international conferences, trainings, data and experience exchange and building a strong network of experts.

The **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services - IPBES** was established in 2012, aiming at strengthening the science-policy interface for biodiversity and ecosystem services as well as for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development. It is supported by four United Nations entities: UNEP, UNESCO, FAO and UNDP and administered by UNEP. One of the main directions in the work programme of the IPBES is assessment of biodiversity and ecosystem services at regional and global level.

1.3. Classification of ecosystem services

Categorisation of ecosystem service is a precondition for any attempt to measure, map or value them and to communicate the findings in a transparent way (Burkhard and Maes (Eds.), 2017). A number of different typologies and approaches to classify ecosystem services are developed using different criteria, e.g. spatial character and scale; service flow (see the cascade model described before); service beneficiary (private vs public); type of benefit ('use' vs 'non-use'), or whether the use of a service by one individual or group affects the use by others ('rival' vs 'non-rival').

One of the perspectives how to approach ecosystem services classification can be raising awareness in society about the different benefits what humans gain from the ecosystem. This approach was also in foundation of the **MA classification system**, which was proposing four main ecosystem categories:

- Provisioning services – food, materials and energy, which are directly used by people;
- Regulating services - those that cover the way ecosystems regulate other environmental media or processes;
- Cultural services – those related to the cultural or spiritual needs of people.

[4] http://biodiversity.europa.eu/

[5] https://www.es-partnership.org/

- Supporting services – ecosystem processes and functions that underpin other three types of services.

Examples of services under each of the four categories and their relationship to different components of human well-being are presented in the Fig. 1.4.

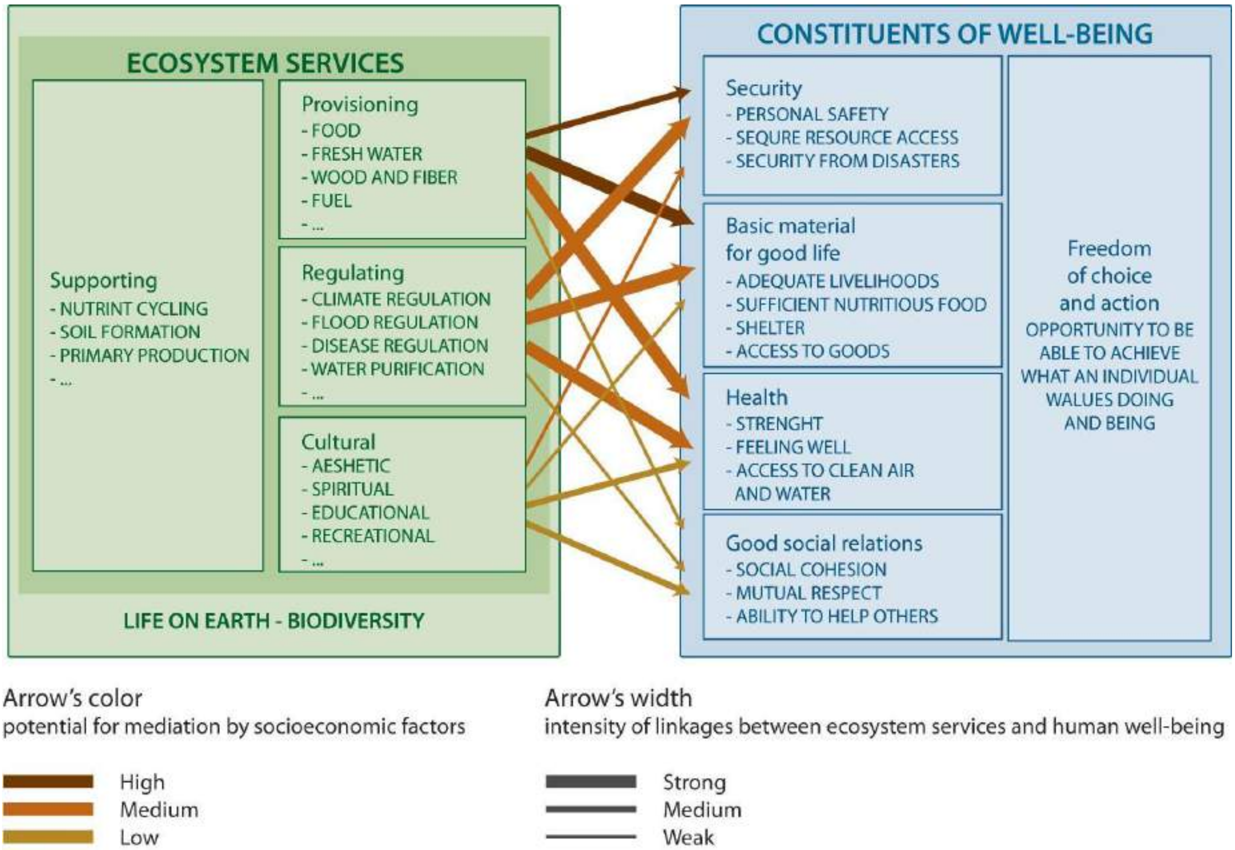

Figure 1.4. The links between ecosystem services and human well-being as described by MA classification system (Source: MA, 2005).

The **TEEB** study applies similar classification approach as proposed by MA, distinguishing 'provisioning', 'regulating' and 'cultural' services, while the forth category is labelled 'habitat or supporting services', which cover habitats for species and maintenance of genetic diversity.

In order to overcome a 'translation' problem between different classification systems, which are not always comparable due to different perspectives or definitions of the categories, **the Common International Classification of Ecosystem Services – CICES**[6] was proposed in 2009 and later revised in 2013. It was originally developed as part of the work on The System of Environmental-Economic Accounting – SEEA[7], led by the United Nations Statistical Division (UNSD), aiming to collect internationally comparable statistical data on environment in relation to economy and thus creating a basis for ecosystem service accounting system.

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[6] https://cices.eu/

[7] http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf

The CICES is hierarchically organised – it applies the three major 'sections' of services - 'provisioning', 'regulating' and 'cultural', defined basically in the same way as in the MA and TEEB classification, and then splits them further into 'divisions', 'groups' and 'classes' (Fig. 1.5). The hierarchical structure allows users to go down to the most appropriate level of detail required by their application as well as combine results when making comparisons or more generalised reports. If refereeing to the 'cascade model' described above, this classification system is targeted to the 'final services' – the 'end-products' of nature from which goods and benefits are derived. CICES does not include the supporting services – ecosystem structure, processes and functions, from which society is not benefiting directly, but throw the flow of final service. Though, it does not mean the supporting services are less important, but such narrowing down of the assessment scope is essential to avoid the double accounting when valuing the ecosystem services – i.e. assessing the importance of a nature component more than once because it is embedded in, or underpins, a range of other service outputs (Burkhard and Maes (Eds.), 2017).

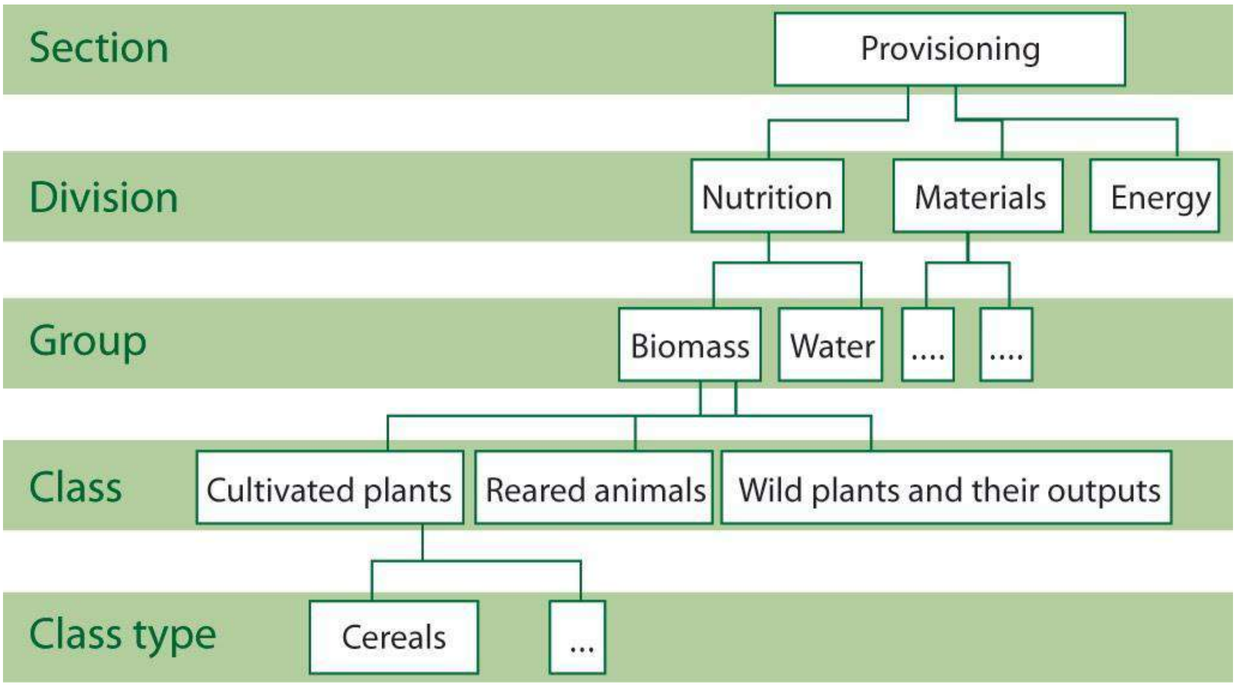

Figure 1.5. The hierarchical structure of CICES, illustrated with reference to a provisioning service (cultivated plants- cereals) (Source: MA, 2005).

The CICES is applied in various international project as well as ecosystem service assessment at national scale. It also forms a part of the ecosystem service assessment and mapping framework, develop by the MAES working group to support implementation of the EU Biodiversity Strategy 2020. CICES version 4.3 was applied until 2017, however a need for its further improvement has been realised (e.g. better representation of abiotic ecosystem services as well as integration with typologies for underlying ecosystem functions). Therefore after extensive period of consultation and peer review the new 'CICES version 5.1' was developed and now available at the CICES website, including also a guidance document. The new version is consistent with but extends CICES version 4.3.

Another, more complex approach is applied by IPBES, which provides an overarching typology of values related to nature and quality of life, intended to guide the assessment of values within IPBES activities[8]. This typology presents a renege of values, arising from very different worldviews and is organized around the three broad categories:

- **intrinsic value of nature -** including individual organisms, biophysical assemblages, biophysical processes and biodiversity;
- **nature´s benefits to people**, which includes:
    - o biosphere‘s ability to enable human endeavour (i.e. embodied energy; human appropriation of net primary production; total material consumption; life cycles, carbon and water footprint; land cover flows etc.);
    - o nature‘s ability to supply benefits (i.e. habitats for fisheries, contribution of soil biodiversity to sustenance of long-term yields, biodiversity for future options);
    - o nature‘s gifts, goods and services (i.e. regulating services: climate regulation, regulation of water flows, pollination, biological control etc.; provisioning services: food, medicine, timber, water, bioenergy etc.; cultural services: ecotourism, education, psychological benefits etc.);
- **good quality of life** – including security and livelihoods; sustainability and resilience; diversity and options; living well and in harmony with nature and Mother Earth; health and well-being; education and knowledge; identity and autonomy; good social relations; art and cultural heritage; spirituality and religions; governance and justice.

Nevertheless, taking into account the complexity of the issue, one comprehensive classification system, suitable for all assessment purposes, most probably would not be possible. The choice of the appropriate classification approach depends on the objective of the study or the decision making context. However, the comparability and transparency of the results of the various studies and approaches still remains a challenge.

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2. FACTORS AND DRIVERS DETERMINING ECOSYSTEM SERVICES SUPPLY

The capacity of an ecosystem to supply ES depends on the state of its structure, processes and functions determined by interactions with socio-economic systems (Maes et al., 2013). To understand factors and drivers determining ES supply requires study and understanding of underlying processes in ecosystem, because the change in ES supply is directly linked with the changes in ecosystems. A driver is any natural or human-induced factor that directly or indirectly causes a change in ecosystem. A direct driver clearly influences ecosystem processes, where indirect driver influences ecosystem processes through altering one or more direct drivers. MA categories of indirect drivers of change are demographic, economic, socio-political, scientific and technological, cultural and religious. Important direct drivers include climate change, land-use change, invasive species and agro-ecological changes. Collectively these factors influence the level of production and consumption of ecosystem services and the sustainability of production. Both economic growth and population growth lead to increased consumption of ecosystem services, although the harmful environmental impacts of any particular level of consumption depend on the efficiency of the technologies used in the production of the service. These factors interact in complex ways in different locations to change pressures on ecosystems and uses of ecosystem services. Driving forces are almost always multiple and interactive, so that a one-to-one linkage between particular driving forces and particular changes in ecosystems rarely exists. Even so, changes in any one of these indirect drivers generally result in changes in ecosystems. The causal linkage is almost always highly mediated by other factors, thereby complicating statements of causality or attempts to establish the proportionality of various contributors to changes.

2.1. Indirect drivers

Demographic changes are important driver affecting both demand and supply of ecosystem services. High population density puts high pressure on ecosystems and produces great demand, when low density as in rural depopulation withdrawals demand and increases farmland abandonment. Valuable source to assess demographic drivers of change are demographic statistics where population density, age structure, migration rates and their prognosis are key variables.

Main economic drivers are consumption, production and globalization. Consumption could be expressed as market fluctuations, where changes in demand/prices for certain products (i.e. energy crops) or closure of certain markets (decrease in milk industry) directly drive land use change (i.e. pastures turn into arable land). Taxes and subsidies are important indirect drivers of ecosystem change. Fertilizer taxes or taxes on excess nutrients, for example, provide an incentive to increase the efficiency of the use of fertilizer applied to crops and thereby reduce negative externalities. Currently, many subsidies substantially increase rates of resource consumption and increase negative externalities.

Socio-political drivers encompass the forces influencing decision-making and include the quantity of public participation in decision-making, the groups participating in public decision-making, the mechanisms of dispute resolution, the role of the state relative to the private sector, and levels of education and knowledge. Political drivers also express themselves in taxes and subsidies, applied to foster or depress certain land-use activities. Studies have shown that for instance joining to Common agricultural policy of new member states of EU have intensified agricultural land use (Nikodemus et al., 2010). Other expressions of socio-political drivers are administrative division and management of territories, political “climate”, laws and restrictions, as well ownership structure.

Scientific drivers of change are connected with advancement in technologies and often occurring as intensification of production and land management. The development and diffusion of scientific knowledge and technologies that exploit that knowledge has profound implications for ecological systems and human well-being. The impact of science and technology on ecosystem services is most evident in the case of food production. Much of the increase in agricultural output over the past 40 years has come from an increase in yields per hectare rather than an expansion of area under cultivation (MA). At the same time, technological advances can also lead to the degradation of ecosystem services, for instance, the development of infrastructure is considered as important driver to degrade ecosystems over which this infrastructure is created.
To understand culture as a driver of ecosystem change, it is most useful to think of it as the values, beliefs, and norms that a group of people share. In this sense, culture conditions individuals' perceptions of the world, influences what they consider important, and suggests what courses of action are appropriate and inappropriate (MA). Cultural drivers are traditions, "public opinion", mentality, education level, involvement in community. Rural lifestyle in form of subsidiary farming is an example sustaining outdated land management practices. "Public opinion" towards certain land management practices (i.e. controlled burning) could limit the management of ecosystems dependent on occasional fire.

2.2. Direct drivers

Land cover/land-use change is one of the most important drivers of ecosystem and ecosystem service supply change. For terrestrial ecosystems, the most important direct drivers of change in ecosystem services in the past 50 years, in the aggregate, have been land cover change (in particular, conversion to cropland) and the application of new technologies (which have contributed significantly to the increased supply of services such as food, timber, and fiber). Semi-natural grasslands are one of the most threatened ecosystems, that are highly dependent on certain management practices – low cattle density grazing or late mowing. As lot of semi-natural grasslands are found on low soil fertility, where any other agricultural land use is out of margins of economic viability, these grasslands are subjugated to abandonment.
Climate change is direct driver of ecosystem change which deservedly have had great attention. Climate change in the past century has already had a measurable impact on ecosystems. Earth's climate system has changed since the preindustrial era, in part due to human activities, and it is projected to continue to change throughout the twenty-first century. During the last 100 years, the global mean surface temperature has increased by about 0.6° C, precipitation patterns have changed spatially and temporally, and global average sea level rose by 0.1-0.2 meters. Observed changes in climate, especially warmer regional temperatures, have already affected biological systems in many parts of the world. There have been changes in species distributions, population sizes, and the timing of reproduction or migration events, as well as an increase in the frequency of pest and disease outbreaks, especially in forested systems. The growing season in Europe has lengthened over the last 30 years.
Change in agro-ecological conditions directly influences ES supply and could be human induced and natural. Agro-ecological conditions are considered for managed agro/forest ecosystems and are expressed as combination of soil (humidity, acidity, stoniness), landform (slope, aspect) and climatic (microclimate) characteristics. Some of these characteristics are relatively static, others are more variable. These changes could be both sudden – as in clear-cut or forest fire or could be expressed more gradually – for instance, loosing soil carbon because of ploughing or aggregating soil carbon due to the succession. Land amelioration (drainage, irrigation, liming, removing micro-relief, nutrient loading etc.) during second half of 20th century in its more drastic from – land reclamation – not only changed conditions but

often completely destroyed entire ecosystems (wetlands, broad-leaf forests). Over the past four decades, excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems. (See table 4.1.) While the introduction of nutrients into ecosystems can have both beneficial effects (such as increased crop productivity) and adverse effects (such as eutrophication of inland and coastal waters), the beneficial effects will eventually reach a plateau as more nutrients are added (that is, additional inputs will not lead to further increases in crop yield) while the harmful effects will continue to grow. Extending a field (often a basic spatial unit of agro-ecosystem) size is another widespread change of agro-ecological conditions that impacts supply potential of ES.
Introduction of alien species – species outside their normal distribution, have been both deliberate and non-intentional. Invasive alien species spread and change ecosystems and habitats, thus impacting wide range of ES, for instance, spread of Giant Hogweed, once introduced as fodder crop, have spread occupying farmland, river banks and even forests, degrading biodiversity and aesthetical value.

2.3. Scale of drivers

Scale of drivers is another dimension that should be considered to understand underlying processes determining ES supply. Issue of scale could be seen as threefold composition of spatial, temporal and institutional components (Fig. 2.1). Spatial scale varies between m^2 and continent/planetary sizes. Temporal scale varies between instant and millennia, where institutional scale varies between individual and transnational bodies (EU, UN)

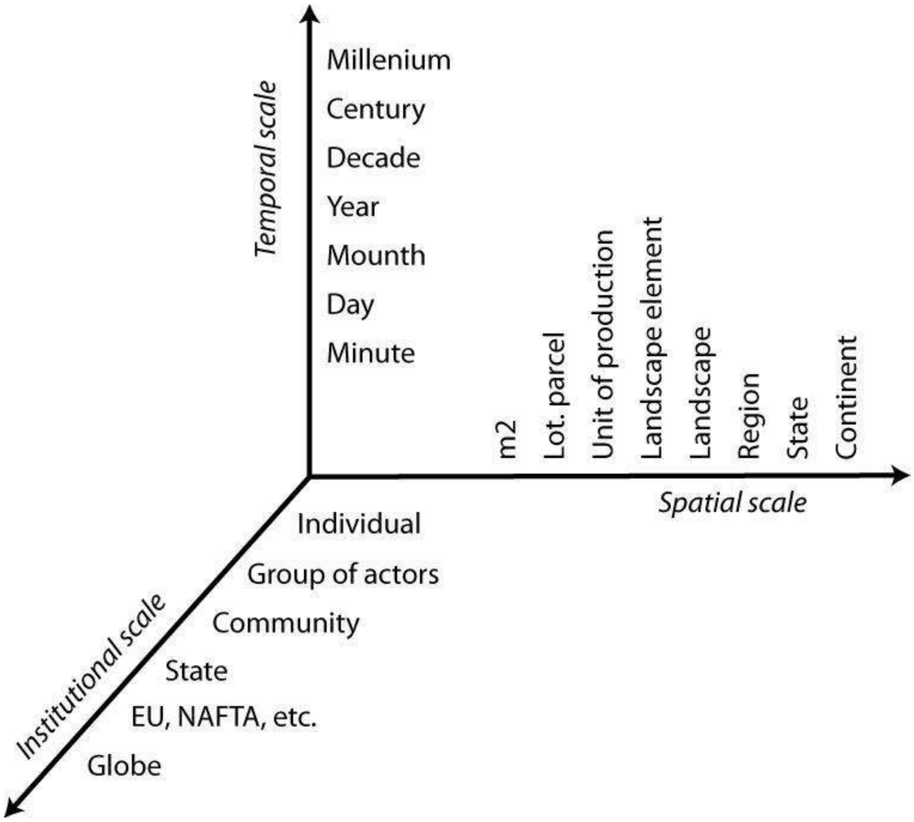

Figure 2.1. Scale of drivers of change (Source: Bürgi et al. 2004).

Every study requires appropriate scale of investigation, but this does not mean that other levels of scale can be ignored (Bürgi et al., 2004). For instance, climate change operates on global or continental spatial scale, Political change operates at spatial scale of political body – from municipality to state. Socio-cultural change typically occurs slowly, on a time scale of decades (although abrupt changes can sometimes occur, as in the case of wars or political regime changes), while economic changes tend to occur more rapidly. As a result of this spatial and temporal dependence of drivers, the forces that appear to be most significant at a particular location and time may not be the most significant over larger (or smaller) regions or time scales (MA).

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3.MAPPING AND ASSESSMENT OF ECOSYSTEM SERVICES

3.1. Introduction

Since the European Commission stated in the Action 5 of the Biodiversity Strategy to 2020, that Member States "…will map and assess the state of ecosystems and their services in their national territory…", there has been a growing need to value the provision of ecosystem services, but also to map, in a spatially explicit manner, the provision and demand of ecosystem services at a wide variety of scales, from transnational to local.
A question may be asked then, **why is there a need to map ecosystem services?** Firstly, the processes that lead to the production of ecosystem services are of a spatial nature (Fig. 1.3). The ecosystems functions and processes that are responsible for the production of ecosystem services vary greatly in time and space and are scale dependent. Moreover, the drivers of change which affect and modify ecosystems functions and processes show a strong spatial variation: Land use patterns, fragmentation of the land or agriculture intensification, just to name a few.

Therefore, ecosystem services maps are much needed in order to describe and assess the production of ecosystem services as a function of ecosystem processes, patterns of land use, climate and environmental variation (Maes et al., 2013).
The supply of ecosystem services is a complex process and it is often the case when different ecosystem services are interrelated. Synergies and trade-offs within different ecosystem services, and between ecosystem services and biodiversity are common. In some cases the production of a certain ecosystem service will be increased at the expense of another service, or the increase in the production of one service causes the increase in another service (bundles and synergies). Only if the ecosystem services are mapped and their spatial distribution is known, we will be able to disentangle this complex system.
As explained in Chapters 1 and 2, the ecosystems services framework has two interrelated dimensions: supply and demand. The demand for ecosystem services is defined as "ecosystem goods and services currently consumed or used in a particular area over a given time period" (Burkhard et al., 2014). This demand can change over space and time, and may be independent of the actual supply. Once again, maps of the supply and demand of ecosystem services are needed in order to assess and quantify the flows of benefits from ecosystem service supply areas to near and distant human populations.
Ultimately, the visualization of ecosystem services as supply and demand maps can be used in a wide array of processes by decision makers, e.g. Land use planning, Environmental Impact Assessment or landscape management.

3.2. A framework for modelling ecosystem services

An essential first step before the quantification and mapping of ecosystem services is the definition of a modelling framework. These decision frameworks vary in terms of data required, scale, drivers and knowledge required and therefore the model choice will be driven by our project's characteristics. Kienast and Helfenstein (2016) compiled a classification of ecosystem services models:

- Process based models
- Empirical models
- Tiered approaches
- Indicator-based assessments
- Landscape models

Kienast and Helfenstein (2016) also propose a 6 point framework to describe ecosystem services models. This 6 point framework should also work as a guide for choosing the right model given the project requirements:

Variable (used) knowledge: Refers to the level of knowledge available about the ecosystem services under study, from very basic, narrative-based or experience-based to process-oriented and analytical knowledge.

Spatial scale: The scale of the ecosystem service assessment may vary from local or municipal level to global level and will be a main driver of the type of data required for the ecosystem services assessment.

Temporal scale: Similarly, the temporal scale of the ecosystem services assessment will directly influence the results and the data needs. The temporal scale may vary from months to decades or centuries.

Available (used) data: Data availability and data characteristics (spatial and thematic scales) will drive the choice of models for ecosystem services assessments. For example, if high spatial and thematic resolution data are available, then more complex process-based model could be used.

Stakeholder involvement: Refers to the degree to which we want to open the ecosystem services assessment to the wider public. For example, if stakeholder involvement is a key requirement in our project, we may need to use bottom-up and participatory assessment tools.

Output: The output of an ecosystem services assessment may be qualitative or quantitative and is directly related with the data needs and the choice of model. Quantitative outputs usually require detailed data and mathematical models, whereas qualitative outputs may need expert opinion assessment and qualitative scales.

3.3. Indicators

An essential step in the implementation of the ecosystem services framework is the biophysical quantification of the ecosystem services. Most of the ecosystem services under the provisioning category can be directly quantified. However, the measurement of regulating, supporting and cultural services is more complex and therefore indicators or proxy data are needed (Egoh et al., 2012). As defined by Wiggering and Müller (2004) "indicators generally are variables that provide aggregated information on certain phenomena". Robust biophysical indicators are required not only to evaluate ecosystem services, but also to assess the change of ecosystem services provision over time. In an attempt to structurize the quantification of ecosystem services and the choice of indicators, the DPSIR framework (Drivers, Pressures, State, Impact, Response) (Fig. 3.1) has been widely adopted (Müller &Buckhard, 2012).

According to the DPSIR framework, political decisions, production systems and societal developments (**drivers**) generate **pressures** in environmental systems. These pressures eventually lead to changes in the **state** of environmental systems. Consequently, **impacts** on human and natural systems may lead to changes in the provision of ecosystem goods and services. Finally, societies try to minimize these impacts or adapt to them through **response** strategies.

The DPSIR framework also captures the connexions between the environmental state (ecosystems and biodiversity) and the human systems. Following this framework, **ecosystem services indicators should capture cause-effect relations between pressures, states and impacts**.

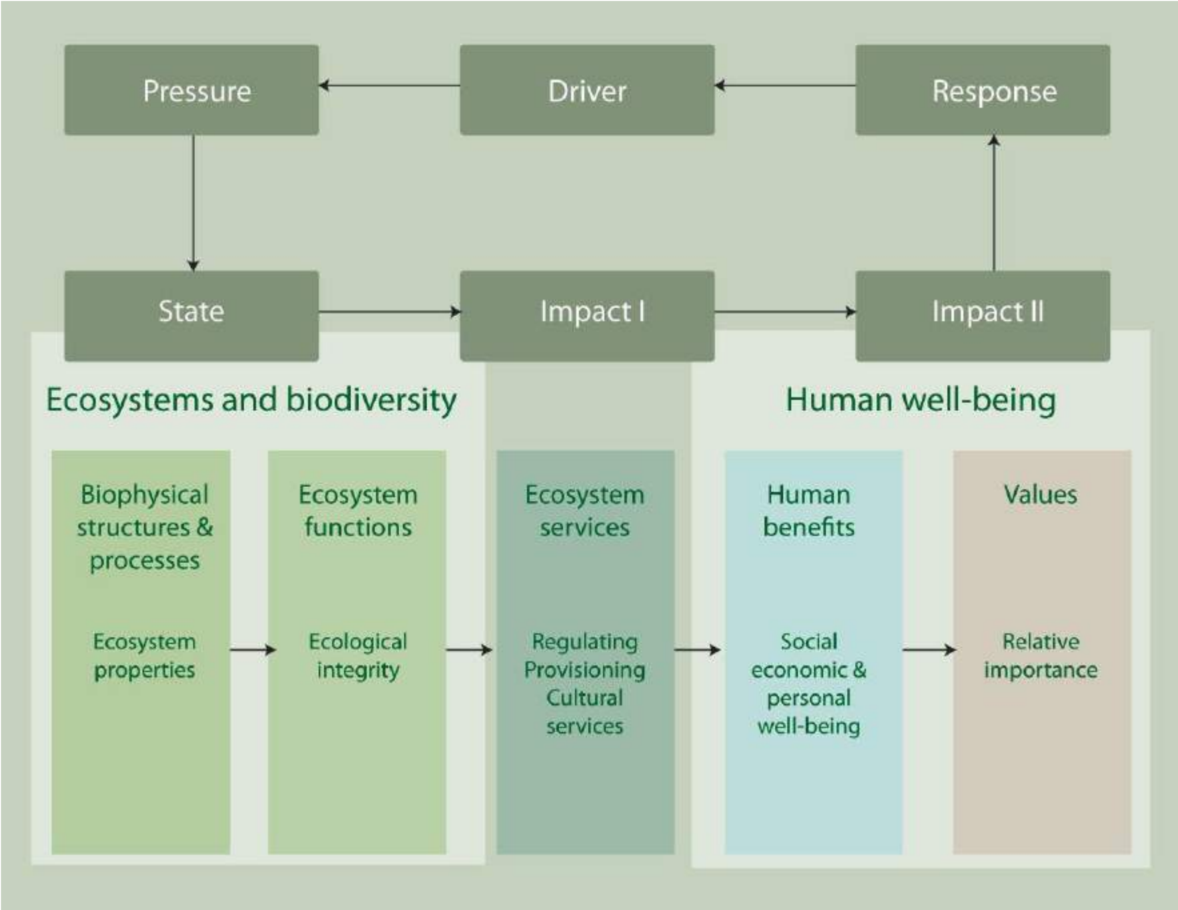

Figure 3.1. The DPSIR framework adapted to the concept of ecosystem services (Müller and Burkhard, 2012).

The role of **scale** should also be taken into account in the choice of indicators for ecosystem services. The scale (temporal or spatial dimension) of ecological patterns and processes that lead to the provision of ecosystem services should be assessed before an adequate indicator is chosen (Postchin and Haines-Young, 2016). Most provisioning services can be assessed at multiple scales, whereas certain regulation services (e.g. local climate regulation or flood protection) depend strongly on the local or regional context.
Given a particular project, the choice of indicators will mainly be driven by:

- Scope of the study and selection of ecosystem services to be assessed
- Scale of the study
- Data availability

Several guidelines and indicator sets have been proposed at a wide variety of scales. We provide just a few examples in this chapter:

- Mapping and Assessment of Ecosystems and their Services (Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020) (Maes et al., 2013): The second MAES report presents a wide selection of ecosystem services indicators aimed at the European and Member State’s level, based on the CICES classification.
- Indicators for mapping ecosystem services: A review (JRC scientific and policy reports) (Egoh et al., 2012): A review of spatial information and indicators for mapping and modelling ecosystem services at global, continental and national level.

- A European assessment of the provision of ecosystem services (JRC scientific and policy reports) (Maes et al., 2011): A set of indicators is provided, based on spatial data available at the European scale.

3.4. Methodologies for assessment and mapping of ecosystem services

In an attempt to group and classify all the available methodologies for mapping and assessing ecosystem services, three main approaches may be distinguished:

1. Biophysical methods
2. Socio-cultural methods
3. Economic methods
4. Expert-based quantification.

3.4.1. Biophysical methods

Biophysical methodologies are the most widespread approach to map and assess both the supply and the actual use and demand of ecosystem services. A biophysical quantification is the measurement of ES in biophysical units (e.g. quantities of water infiltrated in an aquifer, volume of timber produced in a forest or amount of carbon stored in the soil). Therefore, biophysical methods rely strongly in indicators, proxies and biophysical models. Indicators and biophysical models allow not only to quantify ecosystem services but also to assess the conditions of the ecosystems in terms of structure and function.

In order to guide the biophysical evaluation of ES, we need to answer two questions:

1. What do we measure?
2. How do we measure?

- **What to measure?**

When the set of ES relevant to our project has been selected, ES indicators must be chosen to assess and monitor the state and provision of ES (see section 3.3). The choice of an indicator depends on multiple factors such as the purpose of the analysis, the audience, spatial and temporal scales and data availability. An important aspect to consider when choosing indicators is whether they will be used to measure stock (potential to deliver ES), or flow (the actual use or realisation of the service). Flow indicators are usually expressed by unit of time. As an example, the grass produced in meadows can be measured as harvested hay (ES flow) in t/ha/year. However, the total amount of standing biomass may not be harvested and can be expressed as t/ha. If the stock is harvested, stock becomes flow (Burkhard and Maes, 2017).

- **How to measure?**

When the set of ES has been selected, and appropriate indicators have been chosen to assess the stock and provision of ES, the following step would be the actual quantification of the biophysical stock and flow of ES. Burkhard and Maes (2017) distinguish three general approaches: direct measurements, indirect measurements and ES modelling.

3.4.1.1. Direct measurements of ecosystem services

Direct measurements of an ecosystem service indicator are those derived from observations, monitoring surveys or questionnaires. Examples of direct measurements are: measuring the total amount of grass produced in a grassland (biomass production) or counting the total

number and number of species of pollinating insects along a transect in a grassland plot (pollination).
Direct measurements are the most accurate way of quantification, but require a high amount time and resources. Therefore, these type of measurements of ES are appropriate at the site or local level. However, in some cases these indicators have already been measured for different purpose (e.g. crop and timber production statistics) and can be used to assess stock and flow of ES.

3.4.1.2. Indirect measurements of ecosystem services

Indirect measurements also provide a biophysical value, but further interpretations, assumptions or data processing are needed in order to be used as measures of ES.
Data collected through remote sensing techniques is a good example of indirect measurements (e.g. vegetation indices or surface temperature). Most of these products are originally not designed to measure the stock and flow of ecosystem services. However, if the relation between the measured variables and the ecosystem functions and processes are know, ES values can be derived. For example, erosion protection is strongly related with the presence, volume and type of vegetation, which can be derived from vegetation indices such as NDVI (Normalized Difference Vegetation Index).
The use of landcover or habitat maps for ES stock and flow assessments can be considered a form of indirect measures. The most common approach is to generate an average value of each ES per land cover type (e.g. the average value of biomass produced in Estonian coastal meadows is 3050 kg/ha of dry biomass). The ES stock or flow values are averaged from either scientific literature sources or fieldworks. These values can be further linked to landcover units in a map in order to make the analysis spatially explicit.
Indirect measurements are usually a more resource-efficient strategy to assess the provision of ES. Moreover, earth observation datasets are regularly updated, which allows to assess the rate of change in the stock and flow of ES.

3.4.1.3. Ecosystem services modelling

Models are simulations or representation of an ecological system. When direct and indirect data are unavailable, other ecological and socio-economic data and knowledge can be used as surrogate data to estimate the provision and demand of ecosystem services.
The advantage of using ES models is that the input data can be modified in order to simulate hypothetical scenarios of land management, landcover change, climate change, etc. in order to predict possible impacts on the provision of ES.

3.4.2. Socio-cultural methods

Socio-cultural methods generally aim at assessing human preferences for ecosystem services, leaving aside monetary valuations. Values and perceptions of both demand and supply of ecosystem services are commonly assessed and mapped through a wide array of methods based on eliciting social needs and preferences. It is important to make a clear distinction between socio-cultural methods and socio-cultural ecosystem services. Socio-cultural methods are used to quantify and map the three categories of ecosystem services: Provisioning, regulating and cultural. There are several methodologies available, here we highlight three: *Preference assessment*, *PPGIS* and *time-use assessment*.

Preference assessment: Preference assessments aim at assessing values, perceptions knowledge, supply, use and demand of ecosystem services through “traditional” socio-cultural data collection techniques: (ecosystem services) rankings, questionnaires, preference and rating assessments or free listing exercises.

Participatory Mapping and Assessment (PPGIS): PPGIS methodologies allow end users to utilize very basic GIS capabilities, usually through an online platform. In the context of ecosystem services, PPGIS allow to assess the spatial distribution of ecosystem services based on local knowledge, preferences or perceptions. PPGIS approaches are integrative and spatially explicit, therefore allowing for spatial comparisons between supply and demand. Trough PPGIS tools, users are commonly able to mark point or area in a map and answer a questionnaire about the perceived supply or demand of one or more ecosystem services.

Time-use assessment: Time use assessment utilize time as a proxy for assessing the value of certain ecosystem services by directly asking people how much time they would be willing to invest to change the quantity or quality of a given ecosystem service. Similarly to *willingness to pay* approaches, time-use assessments are based on hypothetical scenarios for willingness to invest time.

3.4.3. Economic methods

Economic methodologies for mapping and assessing ecosystem services aim at quantifying the welfare (in monetary terms) that society gains from the use of ecosystem services. The spatial variation of economic values can be assessed through mapping approaches. The economic valuation of ecosystem services is a very complex field and there are publications that deal specifically with this. For a deeper understanding of economic valuations, we recommend: Brander and Crossman (2017). Economic methods for the evaluation of ecosystem services support decision making processes in which several management, project or policy options are considered. Three economic methods have been selected to illustrate the wide collection of methods available: *Cost-effectiveness analysis, cost-benefit analysis* and *multi-criteria analysis*.

Cost-effectiveness analysis (CEA): Cost-effective analysis compares alternative options in terms of their costs. The different options considered aim at achieving one specific goal and all costs can be expressed in monetary terms. Cost-effective analysis identifies the option with the lowest cost. In the context of ecosystem service, CEA is a relatively limited approach, since it is often not the case that a single goal for ecosystem services provision can be set.

Cost-benefit analysis(CBA): CBA is often used to asses multiple planning and policy options in which all impacts can be quantified in monetary terms. CBA considers and compares all costs and benefits from the different options being assessed. This approach is applied in the ecosystem by estimating the costs and benefits that different planning and policy options have on the delivery of ecosystem services, but it requires a deep knowledge of ecosystem processes.

Multi-criteria analysis (MCA): MCA is commonly used when not all the costs and benefits of a certain option can be valued in monetary terms. The basic idea behind MCA is to allow the integration of different objectives (or criteria) without assigning monetary values to all of them. MCA is used to establish preferences between different options referencing to a common set of criteria established by a decision making body.

3.4.4. Expert-based quantification of ecosystem services

When other sources are lacking, expert knowledge can provide the information needed for an ES stock, flow and demand assessment. Moreover, when experts from multiple disciplines are

engaged in the assessment, a deeper understanding will be gained about the complex interrelations of drivers, pressures, state, impacts and responses in the ES stock, flow and demand system.
In an expert based-assessment, a deliberative process among the experts leads to an agreement on the estimates of ES supply and demand. When biophysical or other forms of data are missing, expert assessment are an efficient way to obtain an approximation of ES values.
Expert-based quantifications are commonly used together with the lookup table approach for mapping ecosystem services (see section 3.5). The combination of these two techniques is a cost-efficient way to obtain reliable maps.
A common technique to quantify the provision of ES in the context of expert-based assessments is the use of **relative scores:** Experts are asked to value the provision of a certain ES in a relative scoring scale of e.g. 1 to 5.

3.5. Mapping ecosystem services

As explained in section 3.3, the indicators used to quantify ecosystem services vary in scale. Therefore, the mapping resolution at which ecosystem services can be mapped depends on the spatial scale of the biophysical models used to calculate the indicators and the spatial scale at which data is available (Maes et al., 2011).
Similarly, different ecosystem services, related to different biophysical processes, require specific thematic maps in order to precisely capture the spatially explicit character of ecosystem functions. For example, soil related services such as carbon storage in soils or nutrient retention will require a soil map. On the other hand, production-related services such as fodder or timber production will be best captured through a landcover map, a habitats map or a forest types map. In this regard, it is essential to identify what is the **service providing unit** (SPU) of an ecosystem services map. Burkhard et al. (2014) defines a service providing unit as "*spatial units that are the source of an ecosystem service (Syrbe and Walz, 2012). Include the total collection of organisms and their traits required to deliver a given ecosystem service (Vandewalle et al., 2009) as well as abiotic ecosystem components (Syrbe and Walz, 2012). Commensurate with ecosystem service supply (Crossman et al., 2013)".* SPUs should be carefully chosen and should match the scale of their geobiophysical supply origin (Burkhard et al., 2014) in order to avoid spatial mismatches that would lead to misinterpretations and misleading results of the ecosystem services quantification.
Broadly, ES mapping approaches can be classified into 5 categories (Burkhard and Maes, 2017):

1. **Lookup table:** Also known as matrix. Land cover classes are used as proxies for ES provision. Each land cover class is linked to an ES average value (this data is commonly obtained from statistical databases or scientific literature).
2. **Lookup table with expert-based estimates:** Similarly to the lookup tables, landcover classes are linked to ES values that have been previously agreed by a panel of experts (see section 3.4.4).
3. **Causal relationships:** ES are estimated spatially based on known relationships between ES and spatial information. For example, the amount of grass produced in a grassland can be estimated using yield statistics for different regions, soil fertility and slope.
4. **Extrapolations from primary data:** Direct measurements or primary data are collected in field surveys and linked to spatially defined units. ES value are extrapolated from these.
5. **ES models:** A combination of field data of ES, socio-economic data as well as information from literature and statistics can be structured in the form of complex

models that predict the provision of ES under different scenarios. This models can be linked to spatial units in order to make spatially explicit predictions or elicit the demand of certain services.

Ecosystem services mapping is a complex process that requires data at a wide variety of scales. Therefore a flexible methodology is need to account for all possible biophysical models, data needs and mapping scales. In a **tiered mapping approach (**Fig. 3.2), each tier of level adds more mapping complexity, uses more detailed data and requires more expertise:

Tier 1 maps: It is the simplest of the three tiers. In tier one, land cover and landuse data are used to map ecosystem services supply and demand. LULC maps are often combined with vegetation and habitats maps. From these maps, inferences about the relative quantity of services are estimated.

Tier 2 maps: In tier 2, previous LULC and/or vegetation and habitats maps are linked to datasets that reflect the provision of ecosystem services. These datasets could be location-based information, scientific literature or statistics datasets. The linkage between maps and datasets allow for ecosystem services quantifications at different locations and scales. Tier 2 quantifications require basic GIS processing.

Tier 3 maps: The third and most detailed level of mapping involves modelling the biophysical processes responsible for the delivery of ecosystem services. Environmental biotic and abiotic variables are combined in models in order to predict the spatial distribution and quantity of ecosystem services. Tier 3 requires complex GIS processing and in-depth knowledge of the processes being modelled.

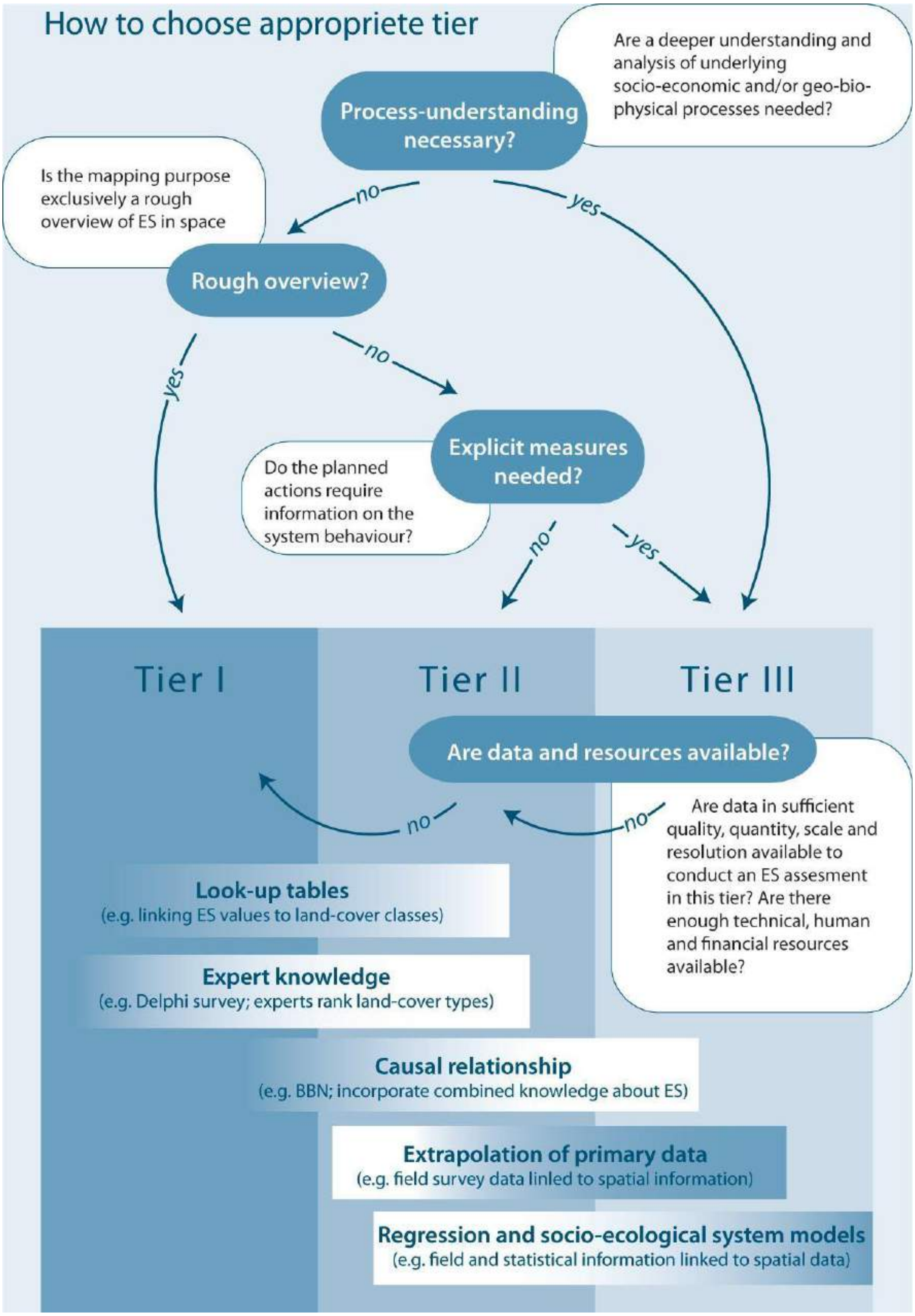

Figure 3.2. Decision tree guiding the selection of tiers for ES mapping (Source: Burkhard and Maes, 2017).

3.6. Assessing and mapping the demand

The demand is often an overlooked component of ecosystem service mapping and assessment processes. However, mapping the demand for ecosystem services should be a key aspect of the ecosystem services framework and several important points should be taken into account:

- The provision and demand of ecosystem services often occur at different locations. It is not uncommon that the beneficiaries of ecosystem services are located far away from the actual ecosystem services provision spots. Consequently, the demand for ecosystem services should be specifically quantified and mapped, and flows from supply to demand estimated. The spatial relations between the supply and the demand, as defined by Burkhard et al. (2014) are:
    - In situ: Supply and demand happen at the same location.
    - Omni-directional: A certain ecosystem service is produced in one location but benefits the surrounding landscape without a directional bias. It is the case of many regulation ecosystem services.
    - Directional: There is a clear flow direction from the ecosystem service produced at a certain spot to the area where beneficiaries are located.
    - Decoupled: The ecosystem service flows over long distances.

- Supply and demand of ecosystem services may occur at different spatial scales and spatial units responsible for supply and demand are often times not the same. The areas were ecosystem services are used are often not related to ecosystems or geobiopysical units. More commonly, areas where the use of ecosystem services is realized are urban areas and rural settlements.

- The indicators and/or methods used to quantify the supply of a certain ecosystem services are rarely the same methods used to quantify the demand of the same ecosystem service. In most cases, the demand cannot be measured directly; therefore proxies such as the density of population or density of housing are used. In numerous occasions, social methods (see section 3.4.2) are used to measure the demand of ecosystem services, by directly asking the users of the service.

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4. INTERACTIONS AMONG ECOSYSTEM SERVICES

Following chapter explores three specific policy-relevant interactions among ecosystem services: synergies, trade-offs and bundles. By highlighting these three types of interactions, we are recognizing that although some properties of ecosystems may be susceptible to human intervention and control, others are not; understanding this distinction is essential if we are to manage ecosystem services to maximize human wellbeing (MA, 2005). Interactions among ecosystem services occur when multiple services respond to the same driver of change (chapter 2) or when interaction among the services themselves cause changes in one service to alter another (Raudsepp-Hearne et al., 2010).

4.1 Interactions among ecosystem services in trade-offs and synergies

Ecosystems provide multiple ecosystem services which influence each other. For decision making purposes we have to pay our attention to all relevant services and their interaction as simultaneous deliverance of several demanded ES could not be possible, restrain each other or create conflict. Decisions relating to natural resource management often revolve around ecosystem service trade-offs and involve services that interact synergistically (MA, 2005).

Term "trade-off" comes from economic analysis where it described losing one quality in return for gaining another. It is now more generally used for situations where a choice needs to be made between two or more things that cannot be had at the same time (Martín-López et al., 2014).

A synergy (win-win) can be viewed as where the use of one service increases the benefits supplied by another and a trade-off as a situation in which the use of one service decreases the benefits supplied by another service, now or in the future (after Bennett et al., 2009; Lavorel et al., 2011). ES synergies and trade-offs are causally linked (i.e. respond to the same driver or functionally interact), but it is not essential that they occur in the same location (e.g. upstream land-use conversion versus downstream flood risk).

ES trade-offs or synergies only occur if the considered ES interact with each other. It may be due to simultaneous responses to the same driver or due to physical interaction among ES (i.e. fodder/biomass) (Bennett et al., 2009). Drivers could include ES use, ecological changes, management regime, investment choices, etc.

Many trade-offs can be modified by technology or by human or institutional services that regulate access to and distribution of ecosystem services. For instance, a trade-off may exist between agricultural production and species richness, yet we can use technological advances to increase agricultural production and make our farms more diverse at the same time.

In ES context term "trade-off" is used to describe instances such as conflicting land-uses, a negative correlation between spatial occurrences of ES, ES incompatibilities, rivalry and excludability of ES. The opposite term "synergies" is used to describe situation where the use of one ES directly increases the benefits supplied by another service. In other words, a synergism occurs when ecosystem services interact with one another in a multiplicative or exponential fashion. Synergisms can have positive and negative effects. Synergistic interactions pose a major challenge to the management of ecosystem services because the strength and direction of such interactions remains virtually unknown (Sala et al., 2000). But synergisms also offer opportunities for enhanced management of such services. For example, if society chooses to improve the delivery of an ecosystem service, and this service interacts in a positive and synergistic way with another ecosystem service, the resulting overall benefit could be much larger than the benefit provided by one ecosystem service alone. Trade-offs, in contrast, occur when the provision of one ecosystem service is reduced as a consequence of increased use of another ecosystem service. Trade-offs seem inevitable in many

circumstances and will be critical for determining the outcome of environmental decisions (Fig.4.1). In some cases, a trade-off may be the consequence of an explicit choice; but in others, trade-offs arise without premeditation or even awareness that they are taking place. These unintentional trade-offs happen when we are ignorant of the interactions among ecosystem services or when we are familiar with the interactions but our knowledge about how they work is incorrect or incomplete. As human societies transform ecosystems to obtain greater provision of specific services, we will undoubtedly diminish some to increase others.
The simplest approach to deduce positive and/or negative associations among ES is visual map comparison to outline spatial relationships (Anderson et al., 2009), trade-off curves to detect trends (White et al., 2012) or star diagrams to compare the relative provision of ES within a bundle (Foley et al., 2005; Raudsepp-Hearne et al., 2010), but none of these graphic methods provide a quantification of the strength of the association. The most popular quantitative method to assess associations among continuous quantitative indicators is pairwise correlation coefficients. In the case of two categorical indicators, a chi-square test on the two-way contingency table can replace the correlation analysis. However, multivariate analyses represent a better alternative when considering more than two ES and are flexible regarding the nature of the indicator (i.e. quantitative, qualitative): Principal Component Analysis (PCA) when all ES indicators are quantitative, Multiple Correspondences Analysis (MCA) when all ES indicators are qualitative (nominal or binary) and Factorial Analysis for Mixed Data (FAMD – which combines a PCA on quantitative variables and a MCA on qualitative ones) to handle a combination of quantitative and qualitative indicators simultaneously. Regression-based methods between two ES indicators can also detect ES associations (Bennett et al., 2009).

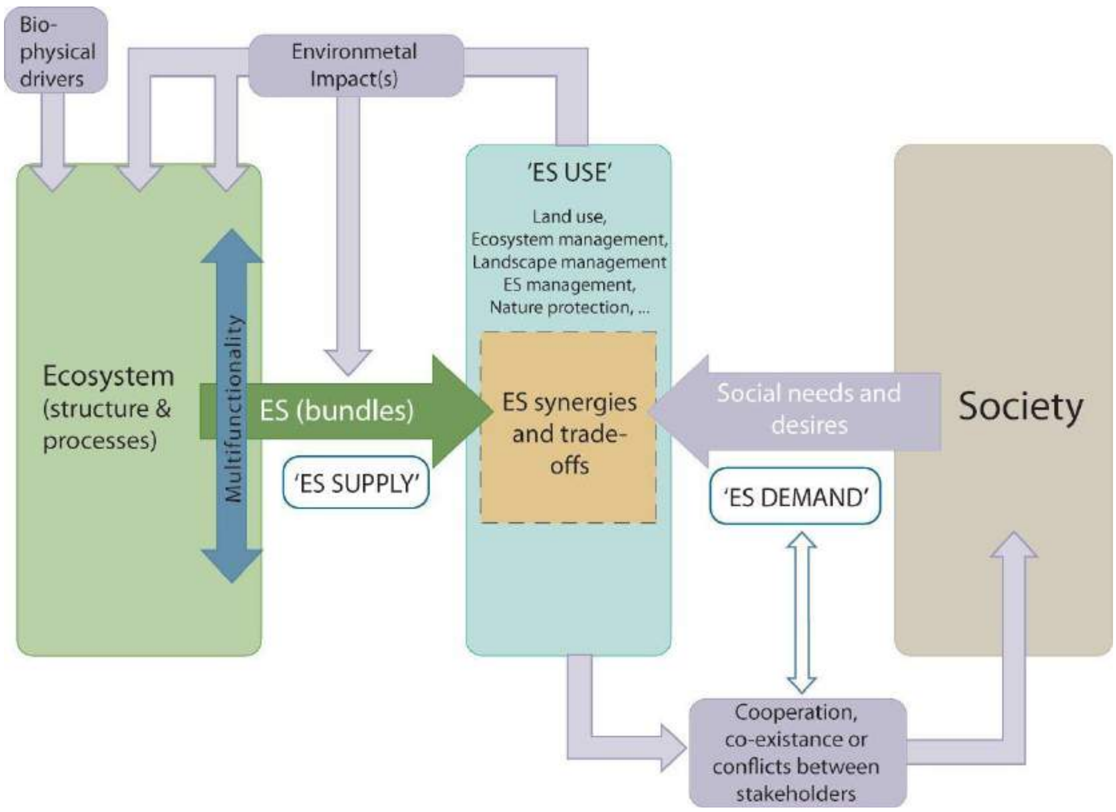

Figure 4.1. Visualisation of analytical links between related concepts and the trade-off mechanism (Source: OpenNESS synthesis paper)

4.2 Interactions among ecosystem services in bundles

Particular way to assess trade-offs is to analyse their interaction spatially and/or temporally, where it is observable that ES appear in associations or so called "bundles". ES bundles is the spatial coincidence of the delivery of a range of ecosystem services. Some authors expand the definition: Raudsepp-Hearne et al. (2010) suggest that they are "sets of ecosystem services that repeatedly appear together across space or time. Researchers (OpenNESS synthesis paper) propose that ES bundles are defined as "a set of associated ecosystem services that are linked to a given ecosystem and that usually appear together repeatedly in time and/or space". Bundle analysis can identify areas where land management has produced exceptionally desirable or undesirable sets of ecosystem services.
Main methods to assess ES bundles are cluster analyses that objectively define the groups of ES that are significantly associated. Interaction between ES and their association in bundles can be analysed both by spatial analysis, where overlaps of ES supply potential are identified in landscape or administrative unit level, and by analysing matrix of assessed ES values. Different cluster analyses can produce different clusters as a result of the hypotheses specific to each clustering algorithm. Hierarchical clustering has successfully been used to define ES bundles using the distance between the economic values or social preferences (Martin-Lopez et al., 2012).
As an alternative, the K-means clustering algorithm can be applied to segregate ES into a pre-defined number of groups by minimizing within-group variability. Additional analyses can then be performed to obtain a more dynamic picture of ES associations by estimating their recurrence in space and time. A way to do so would be to compare correlation coefficients, multivariate or overlap analyses among different spatial units to check the spatial consistency of the observed associations. Results of statistical analysis could be represented as maps and can be used as basis to future scenarios (Fig. 4.2).

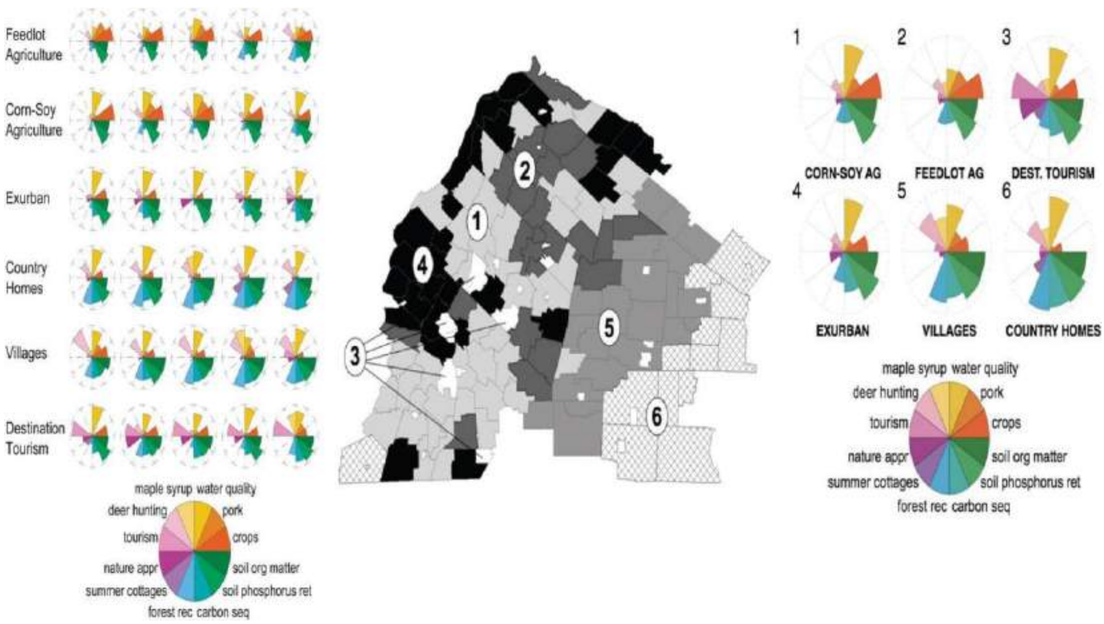

Figure 4.2. Ecosystem service bundle types represent the average values of ecosystem services found within each cluster. Clusters in the data were found to also be clustered in space, and each ecosystem service bundle type maps onto an area of the region characterized by distinct social–ecological dynamics, rep-resented by the bundle names. (Source: Raudsepp-Hearne, et al., 2010.)

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5.ECOSYSTEM SERVICE CONCEPT IN POLICY AND LAND USE MANAGEMENT

Nowadays ecosystem services are acknowledged as an important concept for policy and decision making, because of its holistic view on interactions between nature and humans and potential to address conflicts and synergies between environmental and socio-economic goals. First, policy makers have realised that ecosystem services or nature based solutions (e.g. using wetlands for water purification or flood prevention) might be more cost efficient than technical infrastructures (Maes et al., 2012). Moreover, ES concept can provide a comprehensive framework for trade-off analysis, addressing compromises between competing land uses and help to facilitate planning and development decisions across sectors, scales and administrative boundaries (Fürst et al. 2017).

5.1. Contribution of the ecosystem services concept to different policy sectors

The interest of policy makers in the concept of ecosystem services arose, when it was clear that the global target to prevent the loss of biodiversity by 2010 has not been met. Thus it was first applied for strengthening nature conservation policy in frame of the Convention on Biological Diversity and the EU Biodiversity strategy 2020. However, as proposed by the European Commission, mapping and assessment of ES, required by the Action 5 of the EU Biodiversity Strategy 2020, is not only important for advancement of biodiversity objectives, but has strongly related with implementation of other related policies, including water, marine, climate, agriculture, forestry as well as regional development *(Maes et al, 2014; Burkhard B. and Maes J. (Eds.), 2017)* (Fig. 5.1). Ecosystem service mapping and assessment results can support sustainable management of natural resources, to be applied in development of nature-based solutions, contribute to spatial panning as well as environmental education.

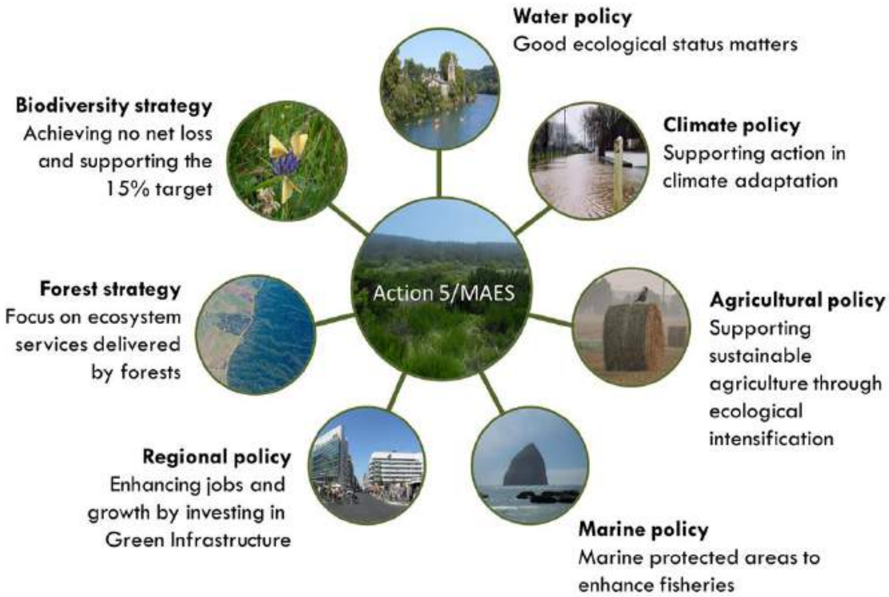

Figure 5.1. Applying of the EU Biodiversity Strategy 2020 Action 5 outputs in different policy sectors (Source: Maes et al., 2014)

5.1.1. Nature conservation and biodiversity policy

The ecosystem services were first introduced into the international policy for protection of biodiversity in 2010 at the tenth meeting of the Conference of Parties to the Convention on Biological Diversity (CBD), where the global Strategic Plan for biodiversity for the period 2011–2020 was adopted. The Plan includes so called "Aichi targets"[9], which besides traditional conservation-based biodiversity targets aims to enhance benefits to people from biodiversity and ecosystem services. It was followed by adoption of the EU Biodiversity Strategy 2020, which set the goal to maintaining and restoring ecosystems and their services and included mapping and assessment of ecosystem services as one of 20 actions to be implemented by the EU member States. EU supports implementation of this policy through its framework programme for research (Horizon 2020) as well as the other financial instruments, e.g. LIFE + programme.

The process of Mapping and Assessment of Ecosystems and their Services (MAES) first of all contributes to the knowledge on the status and trends of ecosystems and related services as well as helps to target measures for ecosystem restoration and management. ES mapping results can be applied in assessment and planning of protected area/ green network. Furthermore, MAES outputs demonstrates the contribution of ecosystems and biodiversity to human well-being, which helps to justify the importance of nature conservation measures to society.

5.1.2. Environmental Policy

Ecosystem service mapping and assessment results can contribute to environmental policy in relation to assessment of risks and impacts to ecosystem or human health from different human activities as well planning various mitigation or management measures.

In particular, ecosystem services are directly engaged in the following environmental policy issues (Maes et al, 2014):

- ***Water policy***: Implementation of the EU legislation for management of water resources (e.g. the Water Framework Directive, the Groundwater Directive) requires high quality and comprehensive information on the quality and quantity of freshwater resources. The outputs from the MEAS process will complement the available information and facilitate more efficient protection and management. For example, mapping of nutrient retention and maintenance of chemical condition of freshwater provide direct input to river basin management plans. Furthermore, MAES process helps to integrate this information into wider assessment of ecosystem conditions.
- ***Climate policy***: Ecosystems play important role in carbon sequestration and consequently in mitigating climate change as well as in adapting to its impacts. Therefore the recent communication in the climate change adaptation policy puts considerable emphasis on nature-based solutions. Several regulating ES (e.g. climate regulation, maintenance of hydrological cycle and water flow and control of erosion rates) are essential for planning climate change mitigation and adaptation measures, including reduction of disaster risk related to extreme weather conditions and flood prevention as well as cooling capacity provided by green infrastructure in urban areas. At the same time, the impacts of climate change can be assessed in relation to all categories of ES.

[9] https://www.cbd.int/sp/targets/

- ***Marine policy***: marine and coastal ecosystems provide essential contributions to human well-being in multiple ways, including food, jobs, security as well as quality of life and possibilities for recreation. The Marine Strategy Framework Directive is the main legal instrument in EU for protecting of marine ecosystem, which sets objective to achieve or maintain good environmental status (GES) of European marine waters by 2020. It requires Member States to assess the status of marine waters as well as to applying ecosystem-based approach to the management of human activities in order to ensure that the collective pressures are kept within levels compatible with the achievement of good environmental status and enables the sustainable use of marine goods and services. Thus data collected for MSFD for assessment of status of marine ecosystem is complementary to MAES process and *vice versa*, contributing to assessment of impacts of collective pressures and implementation of the Programmes of Measures for achievement of GES.
- ***Pollution control***: Measures for controlling dispersal of pollutants can be based on mapping potential of mediation by biota or ecosystem (e.g. bio-remediation, filtration, sequestration, storage and accumulation) as well as mediation of flows (including water flow maintenance and air ventilation).

5.1.3. Agriculture and rural development policy

Another field with high potential of the ecosystem service concept is agriculture and rural development, involving planning of grassland management practices. Agriculture land as heavily managed ecosystem is directly involved in ecosystem service production (e.g. crops for human consumption, biomass for animal feeding, fertilizers or energy, recreational potential and aesthetic value etc.) as well as depends on ecosystem service supply (e.g. pollination, pest and disease control, maintaining of soil fertility), and at the same time is having direct impact on ecosystem service supply (e.g. maintaining habitats, chemical condition of freshwaters, global climate regulation etc.) (Burkhard B. and Maes J. (Eds.), 2017). Supply of these services directly depends on the management practice. It is assumed that low input (extensive) farming systems usually are more dependent on ecosystem service supply and have less impacts compared to conventional high input (intensive) farming. Supply, impacts and dependencies of different services and their management possibilities also vary depending on scale – for example provisioning services are mostly associated with farm level, while habitat maintenance, recreational potential and aesthetic value, water quality and climate regulation might be more relevant if looking at landscape or regional scale. Thus understanding of ecosystem service flows and their multi-level aspects are crucial for effective management of rural areas and related ecosystem service supply.

Mapping and assessment of agriculture ecosystem services can assist in:

- visualisation of the scale at which different services operate;
- assessing distribution of the ES supply and demand and highlighting dependencies;
- visualisation of positive as well as negative impacts of agriculture practice;
- targeting interventions required to ensure or improve ES supply.

ES mapping and assessment results can also contribute in targeting the rural policy objectives and required measures for improving ES supply and related payment schemes. For example, restoring and preserving ES has been already included as one of the priorities in the rural development pillar of the EU’s Common Agricultural Policy.

5.1.4. Forestry policy

Forest ecosystems are crucial element of landscape and biodiversity and at the same time providing essential contribution to human well-being. While in former times timber production was the main focus in management of forests, the new challenges of the 21st century have stimulated a multi-functional approach, involving the delivery of multiple goods and services including climate regulation, erosion control and hydrological regulation (Luque et al. 2017). A new EU Forest Strategy: for forests and the forest-based sector[10], introduced by the European Commission in September 2013, comes up with a new framework in which forest protection, biodiversity conservation and the sustainable use and delivery of forest ecosystem services are addressed. The strategy promotes a coherent and holistic approach for forest management including: i) the multiple benefits and services of forest; ii) internal and external forest-policy issues and iii) the complete forest value-chain. Thus, mapping and accounting of forest ES provides an integrated and systematic view of the forest systems and the effects of different pressures (Maes at al. 2014).

5.1.5. Regional development policy and spatial planning

Assessment of the ES supply and demand as well as optimising delivery of ES (e.g. by planning and creating of green infrastructure or green network) can contribute significantly to regional and urban development, support decision making on future investments, enhance jobs and economic growth. Furthermore, the use of ES assessment and mapping results in spatial planning provides greater opportunities to integrate environmental considerations into decisions making on land use change or management (e.g. by introducing it into the Strategic Environmental Assessment process). ES mapping and assessment has already been widely used to support planning and decision making from national to local level in several EU countries. For example, in Finland many regional strategic and local practical plans aim at enhancing, restoring or crating ecosystems and related services. The ES mapping has been also introduced in the ongoing European maritime spatial planning initiatives (e.g. in Latvia and Sweden), in order to assess the use potential as well as possible impacts on marine ecosystem.

The ecosystem service concept also has a great potential to be applied in landscape planning, which aims at enhancing, restoring or creating landscapes and related services. This is demonstrated by the German landscape planning practice, which involves the analysis of the current state of landscape concerning a set of landscape functions and its capacity to fulfil the human demands.

The main inputs of the ecosystem service mapping and assessment to the spatial planning can be summarised as follows (Albert et al., 2017):

- identification of the so-called ecosystem service ‘hotspot’ areas with high potential of ecosystem service supply and/or sensitivity to particular impacts related to planning decision, which might require planning solutions for their safeguarding or restoration;
- assessing the impacts of the planning solutions on ecosystem conditions and service supply (i.e. application within the SEA procedure);
- visualisation of the trade-offs in ecosystem services supply resulting from different lands use alternatives;

[10] http://eur-lex.europa.eu/resource.html?uri=cellar:21b27c38-21fb-11e3-8d1c-01aa75ed71a1.0022.01/DOC_1&format=PDF

- identification of mismatch between areas of ecosystem service supply and demand (when combining the ecosystem service maps with assessment of people's values and actual use of the services);
- enhancing stakeholders’ and decision-makers’ engagement in the planning process by communicating the overall benefits and shortcomings of the planning proposals;
- enhancing citizens’ participation in the planning and decision making by gathering people’s local knowledge and perceptions and enhancing knowledge exchange on ecosystems and their services.

Nevertheless, it shall be remembered that for successful integration of the ES mapping and assessment in the spatial planning process the given time frame and financial limitations as well as needs and interests of the users and decision makers shall by respected. The degree of ES mapping detail, applied methods and indicators depends upon the planning purpose and statutory requirements of the particular planning instrument. Also, the uncertainties of the assessment results shall be communicated to the decision-makers and public.

5.2. Instruments and methods for applying ES in decision making

5.2.1. Trend analysis and nature capital accounting

The trend analysis is usually applied in the policy-making process for setting the policy objectives (i.e. targets to be reached) as well as for monitoring of the policy implementation and its impacts. Applying the trend analysis to different components of ecosystems and related services can contribute to understanding of the past and current developments as well as possible future of ecosystems. Thereby the results of trend analysis allow to better design and describe future scenarios of ecosystem development (Guerra et al 2017).

As described before, the ES assessment results and trend analysis can provide essential information on implementation of various EU policies, e.g. in field of nature conservation, climate change, water management, marine protection as well as to assess impacts of policy sectors based on use of ES, e.g. agriculture, forestry, fishery etc. However this requires comparable time series of the ES assessment results, which currently are not available for most of the courtiers.

To facilitate the regular data collection on ES, the EU Biodiversity Strategy within the Action 5 sets a task to assess the economic value of ES and integrate these values into accounting and reporting systems at EU and national level. Therefore, as part of the MAES process, a methodological framework for the Natural Capital Accounting (NCA) has been developed. This involves step-by-step approach, which begins with building of the biophysical foundation for subsequent valuations steps. Such biophysical foundation requires clearly categorized, well-structured as well as spatially explicit input data sets (Maes et al. 2014). The United Nations Statistical Division (UNSD) has set up the System of Environmental-Economic Accounting (SEEA) for collecting internationally comparable statistical data on environment in relation to economy and thus creating a basis for ES accounting system. By now several EU Member States have started the development of their natural capital accounts.

5.2.2. Scenario analysis

A scenario can be defined as a description of possible future situations, including path development leading to that situation. Scenarios are not intended to represent a full description of future, but rather to highlight central elements of possible future and to draw attention to the key factors that will drive future developments. Many scenario analyst, underline that scenarios are hypothetical constructs and do not claim that they represent reality practices (Schoemaker, 1995). Nevertheless, scenarios are often applied as supporting instrument in policy development and decision-making (Schoemaker, 1995; Guerra et al. 2017):

- to generate knowledge about the present and the future and to identify the limits of that knowledge;
- to serve a communicative function, since scenario development is often based on an exchange of ideas between people with different perspectives;
- to aid decision makers in formulation of policy goals;
- to explore implications of alternative development pathways and policy options;
- to examine the potential effectiveness of proposed decision and management practices;
- to support development of adaptive management strategies.

Scenario analysis has been successfully implemented in many local studies as well as national, regional and global assessments for examining how different land use or management option would interact with ecosystem service supply. This includes assessment of the trade-offs in ES supply between different management alternatives as well as comparing the spatial distribution of certain ES bundles (or synergies) and conflicting (or trade-off) areas, where interests in supply of certain ESs would need to be balanced.

Scenario development and analysis includes three major phases (Guerra et al., 2017):

- Initial phase: defining of the major tendencies for a specific region or subject and to analyse the underpinning drivers of change. This phase can result in a few plausible scenarios.
- Second phase: translating of the identified scenarios qualitatively or quantitatively into variables that describe the major drivers of change (e.g. economic development or demography). The drivers of change then can serve as input for models that relate these changes to environmental change, or impacts to biodiversity and ES.
- Third phase: analysis of the outcomes of these models and formulation of policy options to avoid undesired developments.

Depending on policy of decision making context different types of scenarios can be distinguished (IPBES, 2016): i) “***exploratory scenarios***” represent different plausible futures, often based on storylines, and provide means of dealing with high levels of unpredictability, associated with the future trajectory of many drivers; ii) “ ***intervention scenarios***” evaluate alternative policy or management options – through either “target-seeking” or “policy-screening” analysis (in case of “***target-seeking scenarios***” alternative pathways are examined for reaching an agreed-upon future target, while in case of “***policy-screening scenarios***” (also known as “ex-ante scenarios”), various policy options are considered); “***retrospective policy evaluation***” (also known as “ex-post evaluation”) compares the observed trajectory of a policy implemented in the past to scenarios that would have achieved the intended target.

The IPBES methodological assessment of scenarios and models of biodiversity and ES (2016) illustrates how different types of scenarios and modelling approaches can serve the major phases of the policy cycle, including agenda setting, policy design, policy implementation and policy review (Fig. 5.2).

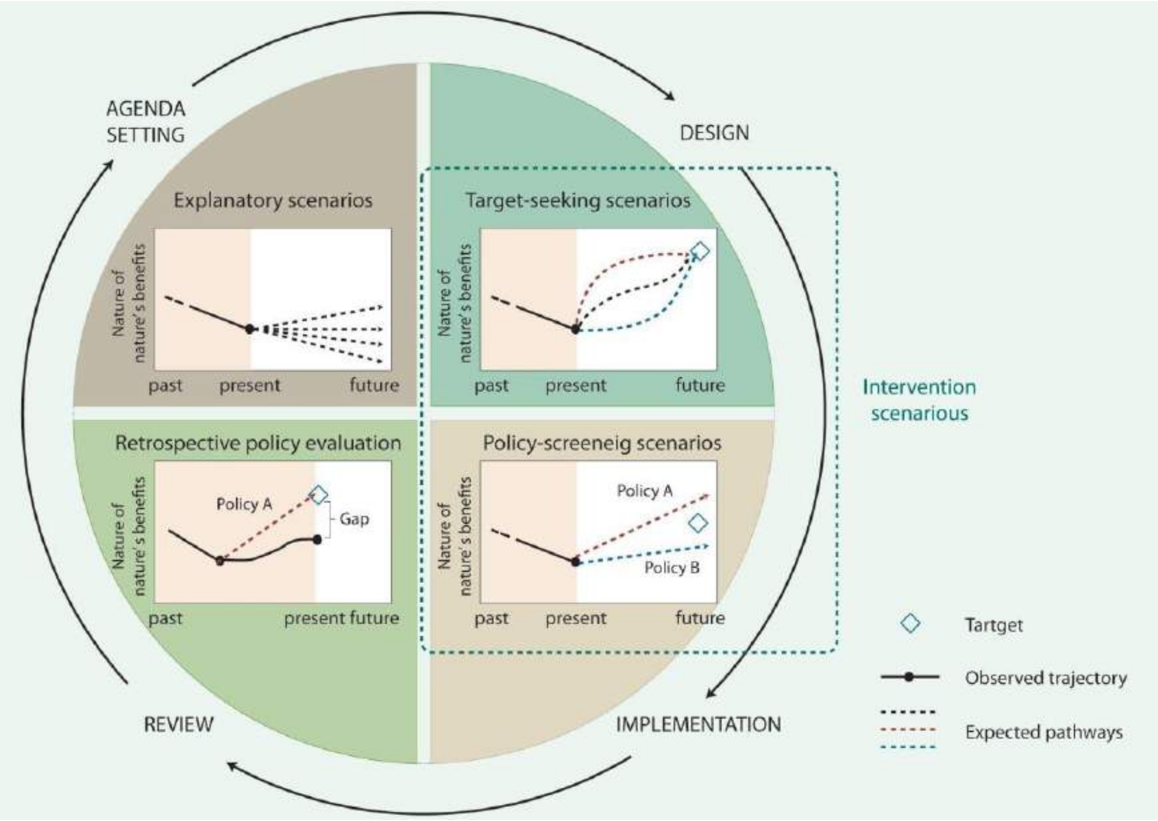

Figure 5.2. Different types of scenarios and their applicability policy making and implementation. (Source: IPBES, 2016)

For example, "exploratory scenarios" can contribute to problem identification and agenda setting, while "intervention scenarios", which evaluate alternative policy of management options, can contribute to policy design and implementations. IPBES assessment states that exploratory scenarios are most widely used in assessments on the global, regional and national scales while intervention scenarios are usually applied in the decision-making on national and local scales.

5.2.3. Impact assessment

Impact assessment aims to identify the future consequences of proposed actions in order to support decision-making. ES mapping and assessment results can be integrated within different impact assessment procedures (e.g. Strategic Environmental Assessment of planning documents as well as in the Environmental Impact assessment of development projects), thus extending the scope of impact assessment from purely environmental considerations to other dimensions of human well-being.

ES can be related to various stages of the impact assessment *(Geneletti &Mandle, 2017)*, including:

- ***Scoping and baseline analysis:*** ES mapping results can be used for selection the priority ES that are most relevant for the action under analysis (i.e. services on which action depends as well as services it affects). This stage also requires understanding of the spatial relationship between the area affected by the action, the area where ES are produced and the area where they are used.

- ***Consultations:*** ES maps helps in focusing debate and engagement of stakeholders, including also participatory mapping exercise to understand how ES are perceived and valued by different beneficiary groups. Results of consultation phase can be used in development of alternatives, identification of "no-go" areas for specific activities or suggesting priority locations.
- ***Assessing impacts of development alternatives:*** spatial analysis of ES supply allows tracking impacts to specific beneficiaries and performing of trade-off analysis.
- ***Proposing mitigation measure***: ES maps enables identification of more efficient mitigation options by bringing together environmental and social aspects.

5.2.4. Integrated approaches for applying ecosystem services in decision making

Probably, the most valuable contribution of ES concept to policy and decision making is related to its holistic understanding of interaction between humans and nature, addressing the compromises between competing land uses and resource demands as well as conflicts between nature conservation socio-economic interests. Thus, ES can be used not only in a single policy or planning context, but also for exploring and overcoming trade-offs between different and competing planning or policy objectives. Such integrative approach requires systematic thinking and understanding of the complex linkages and feedback mechanisms in social-ecological systems for delivering integrated solutions *(Liu et al., 2015).*

A conceptual framework - '***Nexus thinking***', suggested by Fürst et al. (2017), demonstrates how ES concepts and practices can contribute balancing integrative resource management by facilitating cross-scale and cross-sectoral planning. It also addresses a crucial question in planning and policy-making – how to define meaningful system boundaries, that address the relevant decision makers to ensure that ecosystem processes and their multiple temporal and spatial scales are sufficiently taken into account. This relates to a common problem or limitation of existing planning systems – plans and policies mostly refer to administrative boundaries, while ES supply capacities and demand are connected to biophysical or social aspects.

The described ES nexus framework offers a common ground for connecting policies, spatial planning and land uses by means of their specific instruments and measures (Fig. 5.3)

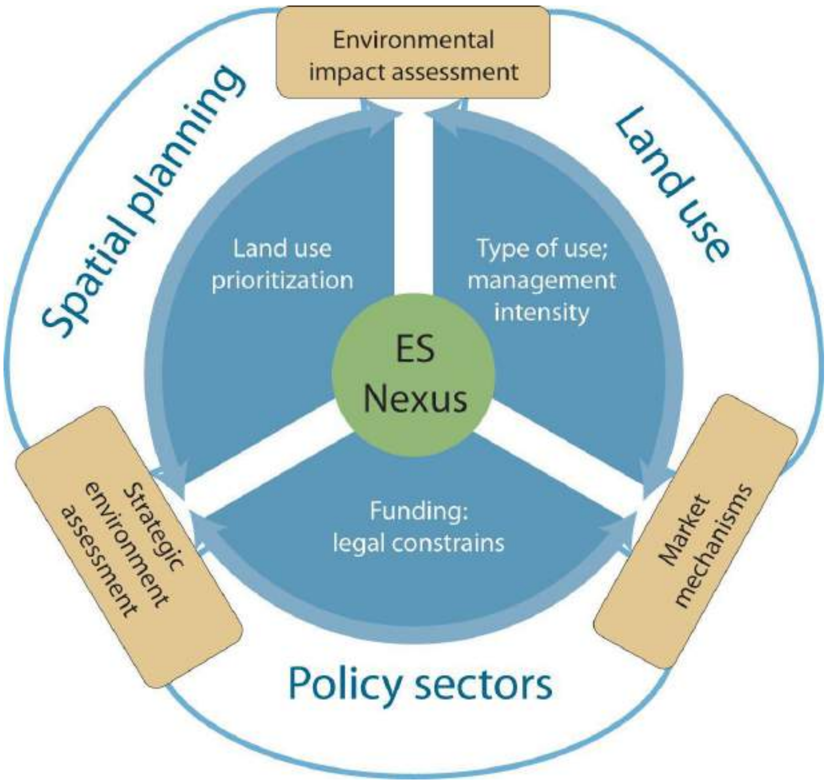

Figure 5.3. ES nexus or interaction between policy sectors, spatial planning, land use and ecosystem services (Source: adopted from Fürst et al., 2017).

The existing instruments for implementation ES nexus approach through interconnection of policy sectors, spatial planning and land use include: i) policy impact assessment implemented before approval of EU policies for different sectors (e.g. agriculture, forestry, climate, environment, etc.); ii) Strategic Impact Assessment (SEA) of national/local plans or programmes; iii) Environmental Impact Assessment of particular development projects as well as iv) various market mechanisms (e.g. certification, ecolabeling). The application of ES approach in impact assessment procedures is described before. The market mechanisms are used as governance instruments for establishment of coherence between policy and societal goals on the one hand and interests of the land owners on the other. Market mechanisms could be used, for example for enhancing regulating or cultural services by including those as addended value in marketing of the products. Furthermore, market mechanisms could strengthen collaboration between different land-use actors (Fürst et.al 2017).

The direct measures, that can be used to impact ES supply capacity, at the policy level includes funding schemes, like direct or indirect payments within CAP, resulting in adjustment of management intensities in land use or development of ecological (green) infrastructure as interface to spatial planning. Furthermore, legal constraints (imposed, for example, by the Habitats Directive, the Water Framework Directive, the Marine Strategy Framework Directive) urge spatial planning to consider EU biodiversity and ES targets. The spatial planning implements these legal requirements by defining priority areas either for particular ecosystem functions (e.g. flood protection) or land use types. A paradigm shift in spatial planning by delineating areas for ensuring particular ES supply or ecosystem connectivity would lead spatial planning towards more integrative way to developing of the land use patterns, that would enhance ES potential as well as provide a common ground for decision making to policy makers, planners and land managers (Fürst et.al 2017).

Suggested reading:

Albert, C., Geneletti, D., Kopperoinen, L., 2017. Application of ecosystem services in spatial planning. In: Burkhard B, Maes J (eds.). Mapping Ecosystem Services. Pensoft Publishers, Sofia, 374 pp.

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6.APPLICATION OF ES FRAMEWORK IN INTEGRATED PLANNING: LIFE VIVA GRASS TOOL EXAMPLE

6.1. Introduction on integrated planning approaches and tools

During the past decade, many tools and frameworks offering integrated planning approaches incorporating the concept of ES have been developed (REF Esmeralda integrated). Before exploring the details of these type of planning tools, and particularly the tools developed within the LIFE Viva Grass Project, it is necessary to establish a common understanding of the concept of „integration“. Integration may refer to the inclusion of several disciplines and approaches in one single assessment (i.e the incorporation of socioeconomic information in ecosystem condition and ES assessments). Integration can also be understood as the structured combination of several ES mapping and assessment methodologies in one single Toolset (i.e. the combination of biophysical, social and economic mapping and assessment methods).

The inclusion of ES in spatial, landscape and environmental planning is recently increasing. Although this process is challenging due to the rigid structure of national spatial and landscape planning frameworks, many benefits arise from the integration of ES in planning processes. The communicative strength of ES enhances the inclusion of public stakeholders into planning processes and improves the understanding of public benefits of certain planning approaches. Moreover, ES help visualize the full spectrum of impacts and benefits of different (and often contrasting) planning scenarios.

Many of the existing spatial, landscape and environmental planning frameworks do not easily accommodate the concept of ES. For this reason, it is often necessary to develop tools that help instrumentalize the above mentioned integration. Many of these tools are flexible in terms of area, ES analyzed and data needs, but often require the end user to provide the base data and maps (i.e. InVEST). Other tools have a stronger focus in a specific area or particular planning issue and already contain pre-defined datasets (i.e. Nature Value Explorer: https://www.natuurwaardeverkenner.be/#/).

The following sections outline the design, content and functionalities of the Integrated Planning Tool developed within the LIFE Viva Grass project.

6.2. LIFE Viva Grass

The LIFE Viva Grass project was launched in 2014, involving researchers and practitioners from the Baltic countries – Lithuania, Latvia and Estonia, and aiming to support the maintenance of biodiversity and ES provided by grasslands, through encouraging ecosystem-based planning and economically viable grassland management. The major task of the project was to develop an Integrated Planning Tool (hereinafter called the Viva Grass Tool), which would provide spatially explicit decision support for landscape and spatial planning and sustainable grassland management.

The Viva Grass Tool is operationalizing the ecosystem service concept into decision making by linking biophysical data on agroecosystems (e.g. soil quality, relief, land use/habitat types) with estimates on the ES supply as well as socio-economic context. The tool is integrated into an online GIS working environment which allows users:

- to assess the supply potential and trade-offs of grassland ES in user-defined areas, as well as
- to develop ecosystem-based grassland management and planning scenarios.

The Viva Grass tool is tested in eight case study areas across the three Baltic States (two farms, four municipalities, two protected areas and one county), each of them having spatial and thematic scale, as well as different data availability.

Thus the Viva Grass tool demonstrates the applicability of ES related information at different planning scales and contexts, which requires a consistent but flexible approach.

One of the challenges integrated planning commonly meets is the need to adapt to different planning scenarios and contexts, as well as meeting the needs of different stakeholder groups Dunford et al. (2017). In this regard, the Integrated Planning Tool developed in LIFE Viva Grass faces the same challenges. In order to overcome the aforementioned problems, the structure of the Viva Grass Integrated Planning Tool follows the framework of the **tiered approach** (see Chapter 3). In a tiered system, methods and tools are combined in a sequential way, so that each consecutive tier entails an increase in data requirements, methodological complexity or both (Grêt-Regamey et al., 2015). In the Viva Grass tool, each tier encompasses different methods and answers different policy questions (Fig. 6.1).

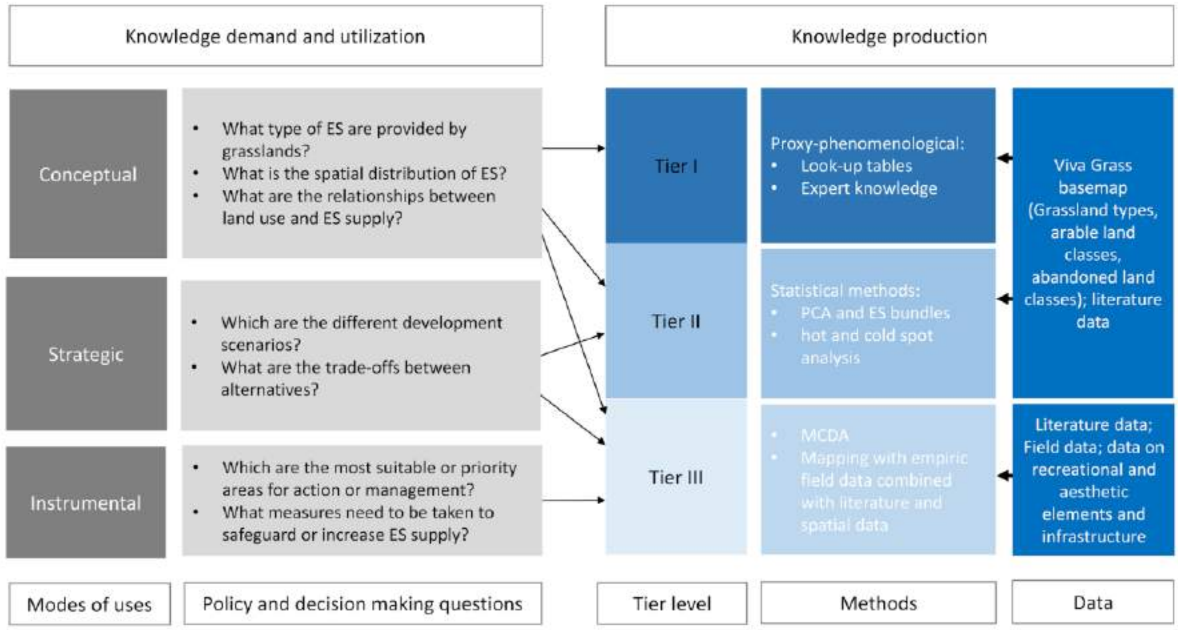

Figure 6.1. The tiered approach for grassland ES mapping and assessment in the Baltic States within the Viva Grass project.

Following the tiered approach the Viva Grass tool offers the three applications or Modules: "VivaGrass Viewer", "VivaGrass Bio-Energy" and " VivaGrass Planner", each designed for different user groups and context of decision making. The "VivaGrass Viewer" is targeted to general public and farmers, providing an overview on ES supply within a selected area, depending on selected management practice. By using this Module farmers can decide on most suitable management model, which would increase the ES supply. The "VivaGrass Bio-Energy" demonstrates the potential for using the grass biomass as source for energy (e.g. heating), thus highlighting the value of one particular ES. The "VivaGrass Planner" module has restricted access - it is targeted to professional users, who could apply the ES information in the spatial planning process.

All the Modules are operating by using: i) basemap of land use and supporting natural conditions; ii) look-up table (matrix) of ES assessment and iii) resulting ES distribution maps. Furthermore the Viva Grass tool offers the spatial visualisation ES bundles and trade-

offs as well as hotspot and coldspot areas, which provides an added value in the land-use planning.
In the sections below, each tool component is explained in details.

6.2.1. Viva Grass basemap

6.2.1.1. Basemap methodology

As outlined in Chapter 3, ES maps constitute the essential basis for ES assessments. With the help of ES maps, we can spatially locate the flow of ES, we can detect mismatches between ES supply and demand or locate factors exerting pressure on the supply of ES. ES supply maps can be built on the basis of landuse/landcover maps (LULC) that define the spatial units that provide ES (i.e. forest, crop, grassland). The first step in any ES mapping analysis is therefore the definition of a LULC that contains the Service Providing Areas (SPAs) (see Chapter 3).

LIFE Viva Grass project encompasses the three Baltic States and nine case study areas and consequently,the construction of a basemap faced large differences in data availability. European-scale maps such as CORINE land cover (Soukup et al., 2016) do not offer the level of spatial and thematic detail required to link, in a spatially explicit way, grassland classes with the ES they provide. On the other hand, the basic national LULC maps differ substantially from one country to the other in terms of their thematic scales. Therefore a common grassland typology was created in order to provide the basis for the ES mapping and assessment in LIFE Viva Grass Project.
Keeping in mind that the potential delivery of ES is determined by the interaction of natural attributes, comprising both biotic and abiotic components, and human inputs and management strategies (Smith et al., 2017), the grassland classes that constitute the Vivagrass basemap were defined according to two main factors:
1. The underlying natural conditions: Two factors were selected as descriptors of the environmental conditions that underpin the provision of ES in the grasslands of the Baltic States: **Land quality** and **slope**. The concept of land quality is an integrated evaluation of fertility of soils used in the Baltic States land evaluation systems and is composed of several factors, e.g. soil texture, soil type, topography, stoniness, and level of cultivation. Land quality was subdivided in four groups:
1. Low quality soils, are associated poor soils with sandy soil texture, high risk of erosion, low capacity of nutrients supply and exchangeable elements and biological activity, very low estimated yields.
2. Medium land quality soils, are associated with loamy sand soil texture, relatively low organic matter, low fertility, moderate capacity to accumulate nutrients and exchangeable elements.
3. High land quality soils, are associated with loam and clay soil texture, moderate soil fertility, a high percentage of organic matter and capacity to accumulate nutrients and exchangeable elements.
4. Hydromorphic soils, are soils developed on organogenic deposits, characterized by various soil fertility and relatively high rate of biological activity.
Slope was also included in underlying natural conditions: steeper slopes are associated with shallower soils with less water retention capacity due to gravity and with a higher risk for soil erosion and consequently affects the delivery of ES. The slope data was aggregated in three categories:
1. plain surface ($0^o – 4^o$): no soil erosion

2. gentle steepness ($4^o – 10^o$): minimal soil erosion
3. steep slope ($>10^o$): noteworthy soil erosion potential

2. The management regime of the grasslands: One of the main driving factors for different supply potential of ES in grasslands is the intensity of management or level of interference in topsoil. Therefore, three types of grassland management regimes and one type of cropland were considered in the analysis as the foundation for creating the ES supply potential base-map:

1. Cultivated grassland: Cultivated grasslands are seeded (often a monoculture – Festuca sp., Phleum sp., Dactylis sp.) and plowed, usually included in crop rotation and less than five years of age. Cutting of grass is done several (up to four) times a season. Fertilization is also a common practice to maintain high yields. Cultivated grasslands are associated with intensive farming systems.
2. Permanent grassland: Permanent grasslands are generally defined as land used to grow grasses naturally or through cultivation which is older than five years. This type of grasslands are rarely seeded, contain both natural vegetation and cultivated species. Permanent grasslands are excluded from crop rotation, mostly used as hay fields and cut not more than two times a season or used as pastures. Permanent grasslands are associated with low input farming systems.
3. Semi-natural grasslands: Semi-natural grasslands are the result of decades or centuries of low-intensity management and are currently not seeded or plowed. Semi-natural grasslands contain high levels of biodiversity (Bullock et al. 2011; Dengler and Rūsiņa 2012) and are used as low-intensity pastures or hay fields (one late cut per season), or solely managed to receive agri-environmental payments (Vinogradovs et al. 2018).
4. Arable/cropland: Arable/cropland is defined as intensively managed farmland used for crop production, plowed at least one time in the season and usually fertilized.

The grassland classes alone do not account for the spatial dimension of ES. As pointed out by Walz et al. (2017), Service Providing Areas (SPAs) (see Chapter 3) constitute the best way to spatially capture the complex ecological systems that underlie the delivery of ecosystem services. SPAs can be defined as spatially delineated units that encompass entire ecosystems, their integral populations, and the underlying natural attributes. The unit used to define SPAs and map the potential delivery of grassland ES was the "basic agro-ecological unit" or field, which comprises the grasslands spatial configuration and boundaries. The basic agro-ecological unit is the smallest relevant unit to apply a management decision, defined as a continuous area with identical land-use.

Each of the abovementioned factors is represented by one spatial layer and were combined in a GIS environment through map algebra and GIS processing operations. Fig. 6.2 shows the classification of input variables and the data sources. As a result of this process, 30 grassland classes were obtained (Table 6.1). In addition to those, 10 arable land classes and 10 abandoned land classes were included in order to allow for the assessment of different LULC change scenarios. The SPAs generated in this process were used in the assessment of *provisioning* and *regulating and maintenance* ES.

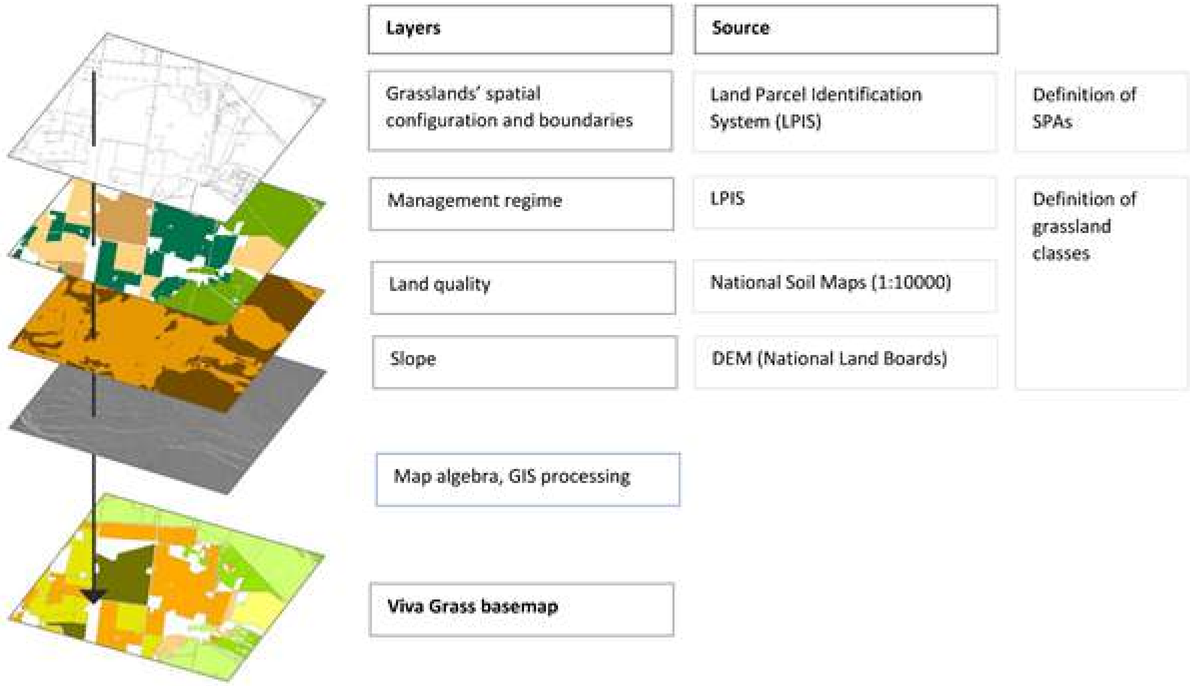

Figure 6.2. LIFE Viva Grass basemap workflow.

6.2.1.2. Look-up table based on expert knowledge (Tier 1)

The common grassland typology and map constitute the basis for the mapping and assessment of ES. Regarding the assessment of ES, at the most basic level, look-up tables based on expert estimates are used in Tier 1. Look-up tables provide the Viva Grass Tool with a qualitative assessment of ES supply, which is subsequently linked to the Viva Grass basemap and presented in an interactive way to the users of the Viva Grass viewer (see section 6.2.2). In addition, the ES scores contained in the look-up table are the basis for more complex analyses such as trade-offs, bundles and hot and coldspots (see following sections).
Within LIFE Viva Grass, the look-up table with expert-based scores was used exclusively to assess the supply of 13 ES belonging to the *provisioning* and *regulating and maintenance* categories. The ES supply assessment was organized in a three-step process:

1. In the first step, the international experts panel selected a relevant set of ES provided by grasslands and one indicator per ES.
2. In the second step experts individually score the provision of ES by the grassland classes based on a qualitative scale ranging from 0 (no relevant supply of the selected ES) to 5 (very high supply of the selected ES).
3. In the third step, experts come to an agreement on the ES supply values in a series of focus group discussions (FGD). In each round of FGD, each expert contrasted his answers with the rest of the group and had the opportunity to re-score the ES.

A subset of the results of the ES assessment process are shown in Table 6.1**.**

Grassland classes	Provisioning					Regulation & Maintenance							
	Cultivated crops	Reared animals and their outputs	Fodder	Biomass-based energy sources	Herbs for medicine	Bio-remediation by micro-organisms, plants and animals	Filtration/storage/accumulation by ecosystems	Control of (water) erosion rates	Pollination and seed dispersal	Maintaining habitats for plant and animal nursery and reproduction	Weathering processes/soil fertility	Chemical condition of freshwaters	Global climate regulation
21. Semi-natural grassland on plain relief, low soil fertility	0	1	1	1	5	4	2	0	5	5	2	3	4
22. Semi-natural grassland on plain relief, medium soil fertilty	0	2	2	2	4	5	3	0	5	4	3	4	4
23. Semi-natural grassland on plain relief, high soil fertility	0	3	3	3	3	5	4	0	5	3	4	5	4
24. Semi-natural grassland on plain relief, organic soils	0	3	3	3	4	5	4	0	5	4	0	3	5
25. Semi-natural grassland on gentle slope, low soil fertility	0	1	1	1	5	4	2	4	5	5	2	3	4
26. Semi-natural grassland on gentle slope, medium soil fertilty	0	2	2	2	4	5	3	4	5	4	3	4	4
27. Semi-natural grassland on gentle slope, high soil fertilty	0	3	3	3	3	5	4	4	5	3	4	5	4
28. Semi-natural grassland on gentle slope, organic soils	0	3	3	3	4	5	4	0	5	4	0	3	5
29. Semi-natural grassland on steep slope , low soil fertility	0	1	1	1	5	4	2	5	5	5	2	3	4
30. Semi-natural grassland on steep slope , medium soil fertility	0	2	2	2	4	5	3	5	5	4	2	4	4

Table 6.1. Extract of the look-up table based on expert estimates including grassland classes 21 to 30. A total of 30 grassland classes plus 10 arable land classes and 10 abandoned land classes were evaluated.

In order to visualize the supply of ES in a spatially explicit manner in the Viva Grass Tool, the results of the look-up table assessment are connected to the grassland classes defined in the basemap.

6.2.1.3. Trade-offs, bundles and hotspots (Tier 2)

A detailed explanation of the concepts of trade-offs, bundles and hotspots is provided in Chapter 4. In LIFE Viva Grass, the trade-offs, bundles and hotspots analyses constitute the core of Tier 2 and allow for a holistic evaluation of the impacts of management decisions and policies in multiple ES provided by grasslands. The results of these analyses are displayed in the Viva Grass viewer (section 6.2.2). The aim of displaying ES bundles in the Viva Grass viewer is to help the tool users to identify specific locations where several ES (bundles) are likely to respond similarly to different management options.

To find out how ES bundle together, a Principal Components Analysis was applied to the ES matrix. Similar analyses have been carried out by Depellegrin et al. (2016), Nikolaidou et al. (2017) and Zhang et al. (2017) among others.

The PCA revealed 3 main components which correspond to three bundles:

Habitats bundle: 4 ecosystem services interact in this bundle: *Herbs for medicine, pollination and seed dispersal, maintaining habitats* and *global climate regulation.* The increase in one of the services in this bundle usually means an increase in the other two services. For example, in species rich grasslands, we are also likely to find a wide range of herbs with a medicinal value. Moreover, grassland management practices that aim to increase biodiversity, such us the reduction or complete elimination of plowing, and fertilization, also increase the carbon sequestration capacity of soils, which is a key service for the regulation of climate.

Production bundle: This bundle is formed by 4 ecosystem services closely related to the productivity of ecosystems: *Reared animals and their outputs, fodder, biomass for energy* and *cultivated crops.* In this particular bundle, the underlying ecosystem function that drives the production of the four ES is the net primary production, or biomass production. Therefore, the increase in one of the services in this bundle usually means an increase in the other two services. However, *biomass for energy* not only depends on the productivity of grasslands, but also on the calorific potential of grassland species. *At the same time, it shall be noted, that even the potential of the four services is based on the same underlying function - productivity, the actual use of ES can exclude each other (i.e. biomass for energy* and *cultivated crop production can exclude grazing or fodder production)*

Soils bundle: The 5 ecosystem services that form this bundle are related with the role of soil functions in ecosystem processes: *Control of erosion rates, chemical condition of fresh waters, bio-remediation, filtration/storage/accumulation by ecosystems and weathering processes-soil fertility*. The increase in one of the services in this bundle usually means an increase in the other two services.

Beyond simply identifying ES bundles, it is important to visualise their spatial configuration in order to incorporate the concept into planning processes. In LIFE Viva Grass, a grassland was mapped as belonging to a certain bundle if all ES in the bundle in that particular grassland scored above average (2.5) (Fig. 6.3). The analysis of bundle overlap reveals certain tradeoffs, for instance, intensification of agriculture, i.e. changing grassland maintenance practice in the same underlying biophysical conditions, will alter services in the “production” bundle and decrease ES in the “habitat” bundle. The direct driver behind tradeoff in grasslands is the management regime, that is, the human factor, the only factor that can be affected through planning decisions.

Results of cold/hot spot analysis are provided in the Viva Grass Viewer and can give the user distinctive information on accountancy of ES supply potential in selected agro-ecosystems. Cold spot is a spatial unit that provides a great number of ecosystem services at low or very low values. Hotspot is a spatial unit that provides ES at high or very high values. The number of services with particular values of interest (low/high) were derived from the ES assessment matrix. Cold/hot spot analysis is strongly complementary to the analysis of tradeoffs. For example, the “coldest” areas did not contain any tradeoff, as both production associated ES and regulating ES displayed low values. Landscape planners should address cold spots as areas with conflicts between two or more landscape functions, which in agro-ecosystems can be described as inappropriate management practice in given natural conditions. Moderate cold spots mostly displayed one of the tradeoffs, and planning decisions should be based on these. “Hotspot” areas should draw attention of decision makers as well, because of high conservation value and high vulnerability. The “hottest” according to assessment presented in

Viva Grass Tool also did not contain tradeoffs because of high values in both competing bundles of ES. The high vulnerability of these agro-ecosystems is associated with their capacity to deliver even higher production under intensive agriculture.

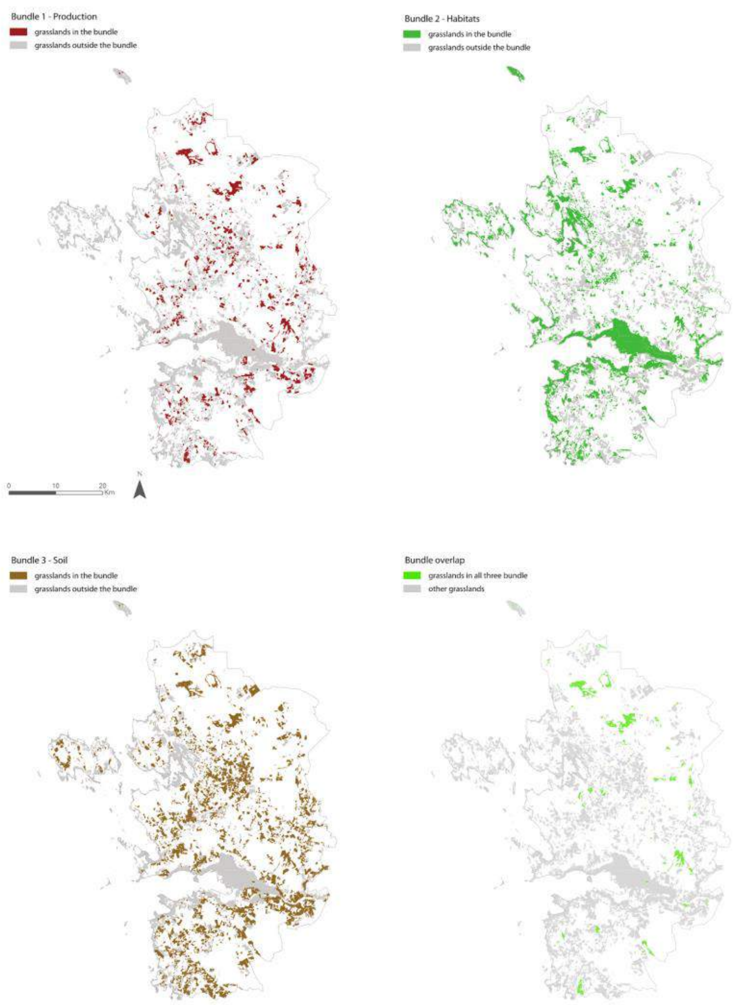

Figure 6.3. Grassland ES bundles in a Viva Grass pilot area: Lääne County (West Estonia).

6.2.2. Viva Grass viewer

Viva Grass Viewer is basic module of the Viva Grass Tool accessible to general public, that aims to visualise the results of mapping and assessment of ES supply potential, as well the grouping of ES in bundles and interaction of ES in agro-ecosystems. Viva Grass viewer intents to serve informative and educational purposes, where user is able to get acquainted with ES approach, spatial distribution of the ES supply depending on underlying natural conditions and management practices. The Viewer is organized in representing exclusionary (one in the time) data layer or by using "swipe" or "double screen" options to simultaneously represent two contextual data layers. Contextual data layers available in Viva Grass Viewer

are farmland land use, supply potential of selected ES, bundles and tradeoffs of ES supply potential, cold/hot spots of ES supply potential.
Default view (Fig. 6.4) of the Viewer is background map with land use data composed from IACS database, representing main classes of land use in agro-ecosystems: grasslands – semi-natural, permanent, cultivated and arable land. Additionally, where there is available data, abandoned farmland is shown.

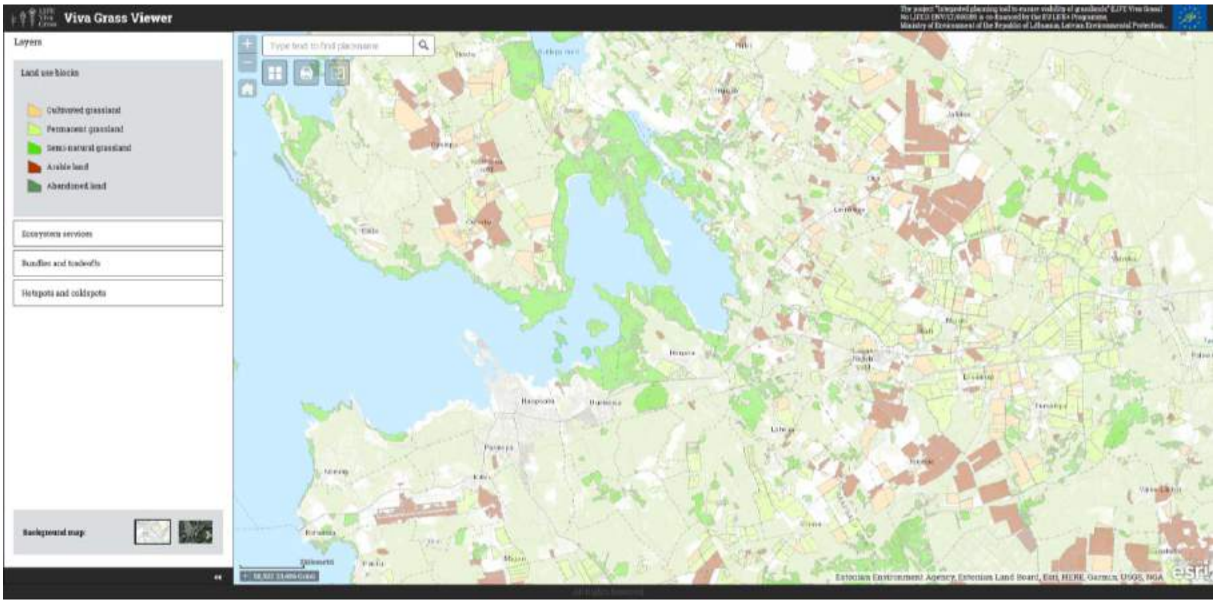

Figure 6.4. Default view Viva Grass Viewer – land use.

By clicking on land block of interest, user can view supply potential of ES in selected field. For informative and educational purposes user can change land use type to view changes in supply potential in case of land use change. Short descriptions and recommended maintenance practices where available are provided (Fig. 6.5).

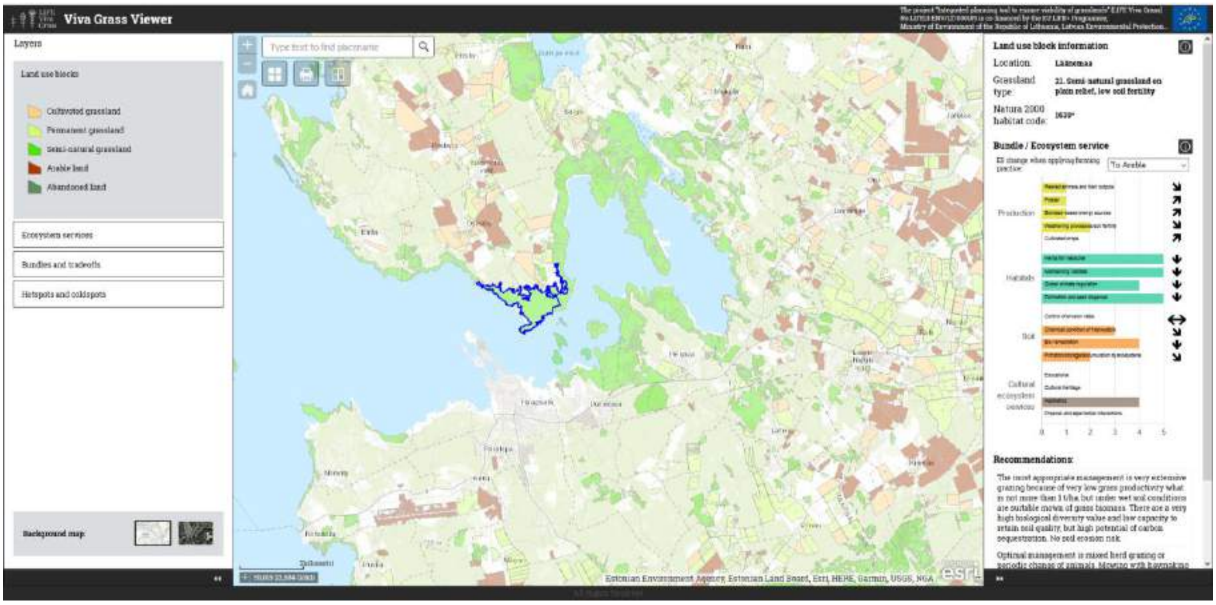

Figure 6.5. Land use change options.

Supply potential of ES is the contextual data layer that allows user to explore mapping and assessment results of selected ES by choosing one in drop-down menu (Fig. 6.6). The theory and methodology of mapping and assessing ES supply potential is described in Chapter 3.

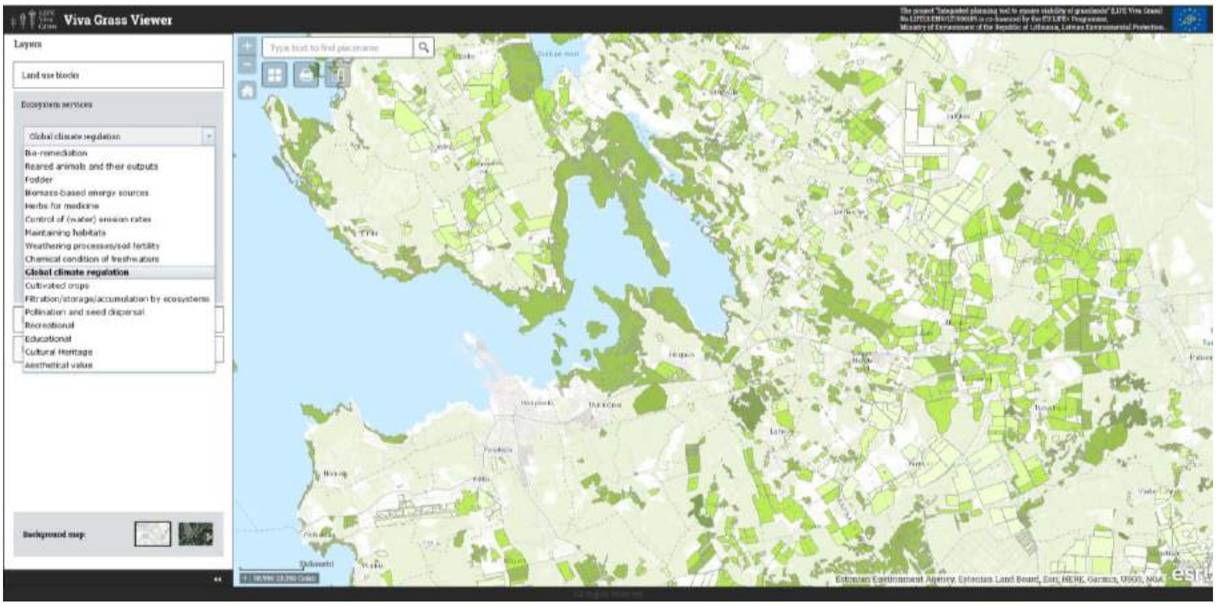

Figure 6.6. Supply potential of selected ES view and drop-down menu.

Bundles and tradeoffs of ES supply potential is contextual data layer that represent spatial grouping and interactions of ES. User is able to explore those groupings and interactions by choosing one of them in drop-down menu (Fig. 6.7). Available selections are linked either to belonging to certain bundle or to having one of two possible tradeoffs. The theory and methodology of mapping and assessing ES supply potential is described in Chapter 4.

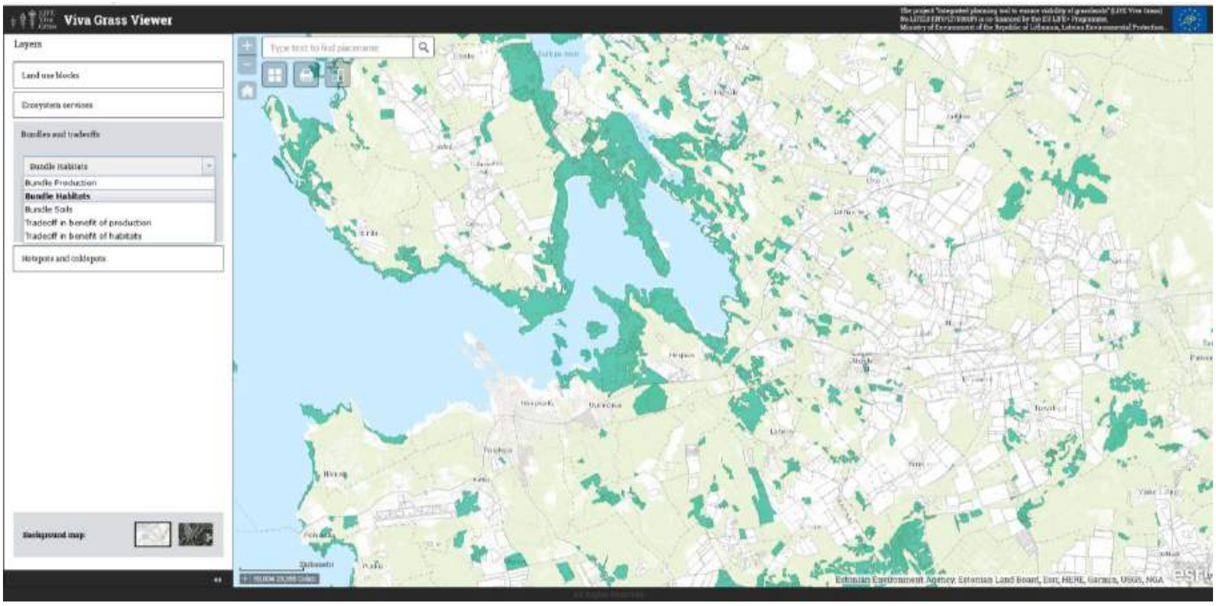

Figure 6.7. Bundles and tradeoff view and drop-down menu.

Cold/hot spots of ES supply potential is contextual layer that represent the number of ES with either low or high values. User is able to explore different representations of cold/hot spots of ES supply potential by choosing one of it from drop-down menu (Fig. 6.8). Default choice is "cold/hot spots" - combined value from "number of ES with high values" and "number of ES with low values". This selection gives general overview of territory in the context of its current potentiality to deliver ES. To get specific view on character of territory in context of shortages or abundance of ES supply potential, user can choose between additional selections – "Hotspots" or "Coldspots" – to view ranked ((1-5) values) combination of ES supply potential.

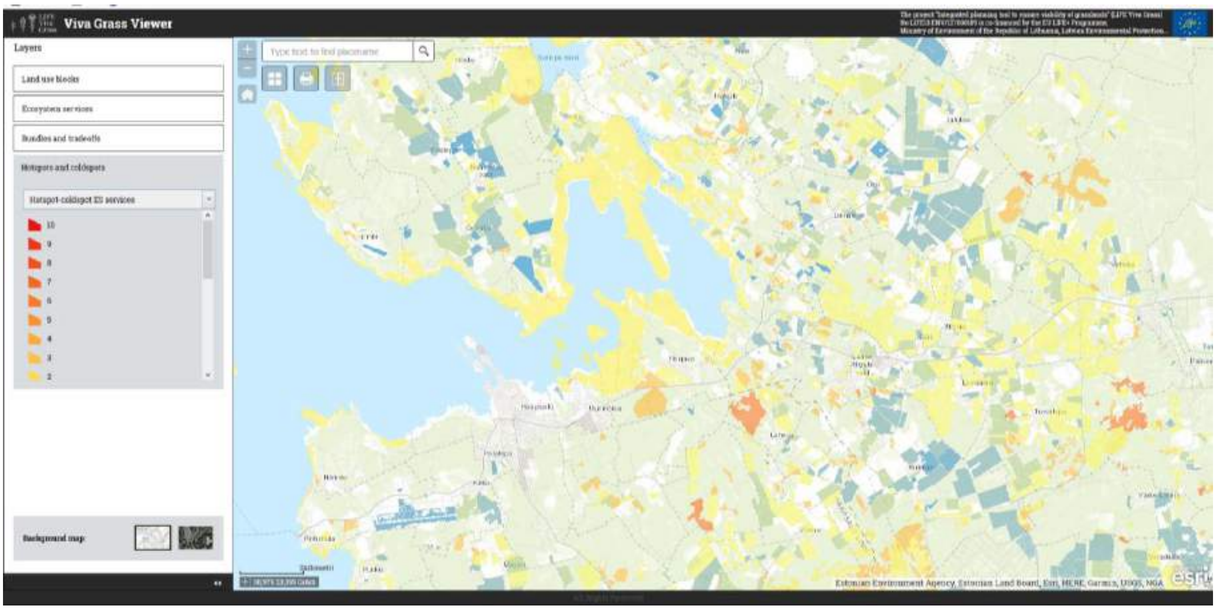

Figure 6.8. Cold/hotspots of ES supply potential and drop-down menu.

To be able to simultaneously explore two contextual layers and view their spatial interactions on screen, user can choose either "swipe" tool, where it is possible to swipe between two layers on the same map extent (Fig. 6.9).

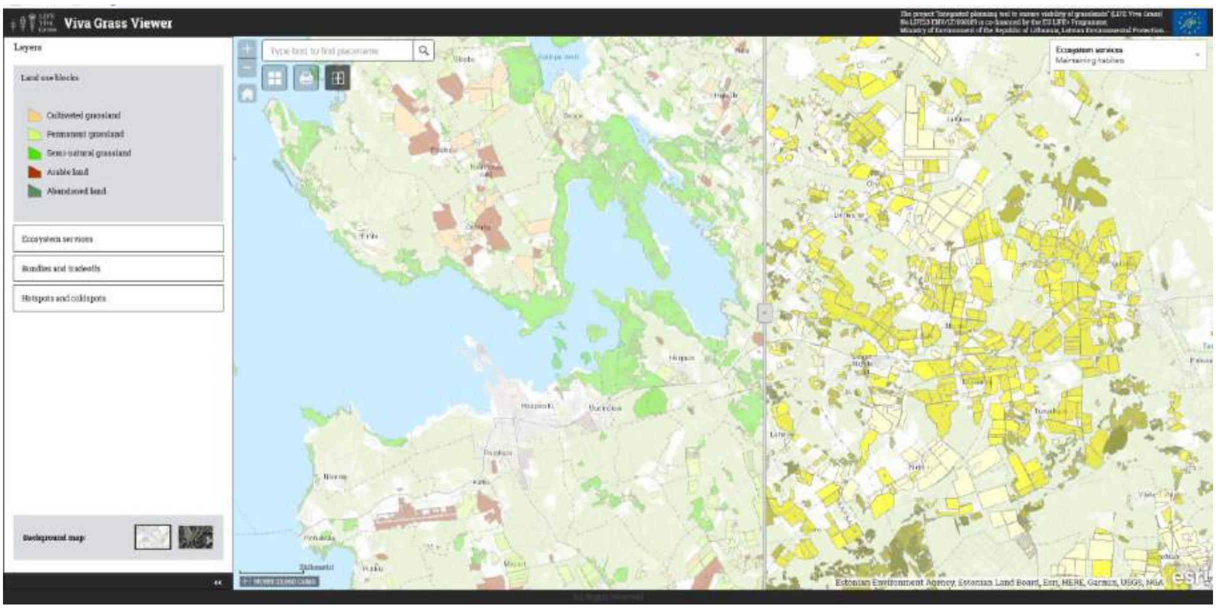

Figure 6.9. Swipe tool.

6.2.3 Viva Grass Bioenergy

The LIFE Viva Grass BioEnergy Module is developed as a tool for assessing grass-based energy resources (area, production, calorific potential for district heating) and informing relevant planners/stakeholders about areas with the highest potential for grass for energy (prioritizing).
Grasslands have a potential for energy production as solid biomass heating fuels. Whether grasslands are specifically cultivated for this purpose, or the grass mown from permanent and semi-natural meadows is used, grass can be burnt in co-fired plants for heat generation. In many cases, the use of grass bales for heating is a feasible alternative to regular biomass-based resources such as woodchips. Unused biomass resources resulting from semi-natural grassland management in some nature protection areas are left in the field and “wasted”.
The Viva Grass bioenergy Module uses additional sources of information to enrich both the basemap and the ES assessment. The 10 semi-natural grassland classes (table 1) are updated with information about the Annex I habitat type they belong to. Subsequently, quantitative data collected from scientific literature sources is linked to the Annex I habitat types. The tool is therefore able to provide detailed information to the user about the average biomass production and average grass calorific power per semi-natural grassland type.
The tool is accessible for registered users and allows to select and summarize bioenergy potential from several grasslands. Additionally, the tool provides information on the current management status of the selected grasslands, as well as information about presence of reed encroachment and recommended grazing pressures per habitat type.

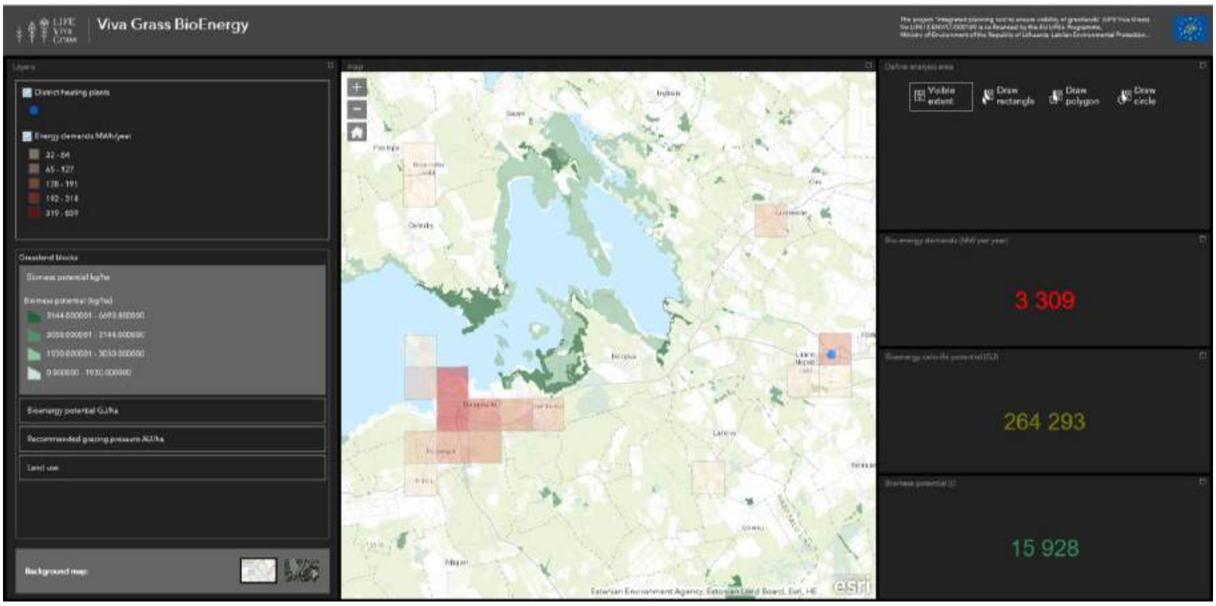

Figure 6.10. The Viva Grass BioEnergy

6.2.4. Viva Grass Planner

Viva Grass Planner is decision support system designed to operationalize ES concept for spatial planning. Viva Grass Planer is accessible for registered user; registration is carried out by system administrator.

Viva Grass Planner consists of two basic sub-modules, designed to carry out prioritization and classification functions and following representation of the results in map, as well possibility to export processed data.
Prioritization is performed in following steps: choosing the criteria, weighting the criteria and displaying the results. Criteria can be selected out of available attributes consisting of the results of ES assessment (see Chapter 3) or from additional data added by user containing case specific attributes. To indicate relative importance of chosen criteria Tool user can assign weight ranging from 0-100%, so that the sum of all percentage would be equal 100% (Fig. 6.11). Weight of one component is calculated by calculating average value of normalized values and multiplying by user defined weight. Total weight of components should be 100%. Total weight index is sum of selected components.
The resulting total weighted index can be further divided in priority categories. To create final prioritization of alternatives additional classification can be performed by employing supplementary data specified by the objective of enquiry.

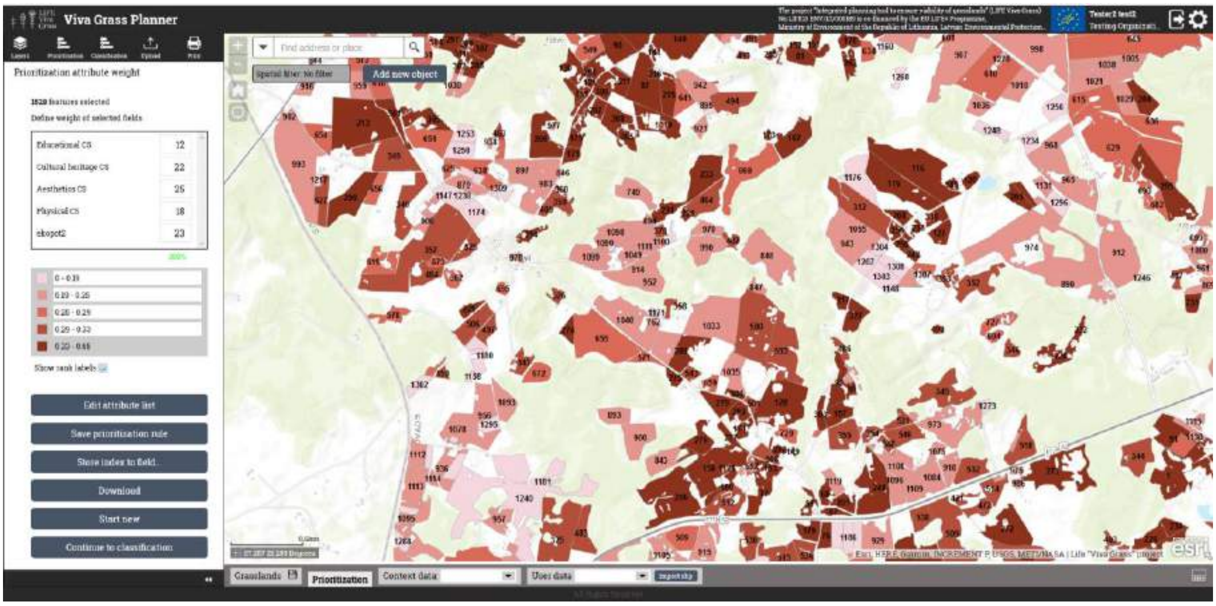

Figure 6.11. Weighting the criteria in Viva Grass Planner.

Classification is an arrangement of data based on selected attributes and can be done both based on performed prioritization and stand alone. To perform classification certain level GIS skills are needed, as it is defined by writing an expression in SQL syntax (Fig.6.12). User have to know the data structure as well.

Figure 6.12. Classification in Viva Grass Planner.

To present how to use Viva Grass Planner we have developed several applications of its full functionality addressed at certain objectives of LIFE Viva Grass project. One example is Landscape planning decision support, where according to certain expert developed criteria (Table 6. 1) prioritization and classification of farmland is calculated, subsequent order and intensity of landscape management practices are suggested. The workflow of Landscape management decision support is presented in Figure 6.13.

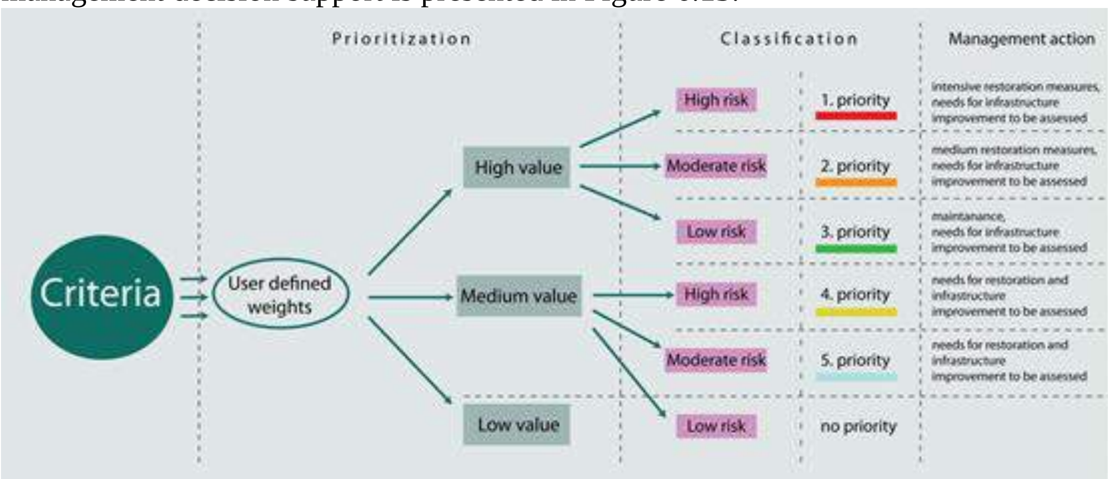

Figure 6.13. Workflow of Landscape management decision support.

To ensure quality of performed analysis data editing and additional data upload is provided. User are able to edit and store underlying natural conditions of selected field in case there are more precise information available. The calculations of ES supply potential and interactions among ES are recalculated and updated by the Viva Grass Tool and further stored in user account.

Default features of place search to navigate map and choosing of defined background maps as well possibility to use custom background map and upload custom data as context layer using WMS are available in Viva Grass Planner.

Table 6.2.4.1. Criteria identified and mapped for Landscape planning module

Criteria	Type	Description
Physical and experiential interactions	Cultural ES	Vicinity to recreational objects and territories
Educational value	Cultural ES	Vicinity to educational objects and territories
Cultural heritage value	Cultural ES	Vicinity to cultural heritage objects and territories
Landscape aesthetics value	Cultural ES	Selected landscape features (openness of landscape, relief undulation, vicinity to water bodies and streams, character of land use and character of surrounding land use
Ecological value	Aggregated ES values	Average value of ES in “Habitats” bundle
Risk of farmland abandonment	Composite indicator	Agro-ecological qualities of farmland, vicinity to farms, roads and settlements
Risk of Hogweed Sosnowsky invasion	Composite indicator	Vicinity to invaded sites

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LIFE Viva Grass Glossary

Based on ESMERALDA Deliverable D1.4.1:
Potschin-Young, M., Burkhard, B., Czúcz, B. and F. Santos Martín (2018). *Glossary for Ecosystem Service mapping and assessment terminology*. Deliverable D1.4 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, 49 pp.
Including additional terms used in the LIFE Viva Grass project.

Term	Definition	Source
Abiotic	Referring to the physical (non-living) environment, for example, temperature, moisture and light, or natural mineral substances.	ESMERALDA (2018) Modified from Lincoln et al. (1998:1)
Adaptive Management	A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for purposes of learning and achieving a desired goal.	ESMERALDA (2018) Adapted from the MA (2005)
Additional (system) Inputs	Non-ecosystem-based anthropogenic contributions to ecosystem services, referring for example to fertiliser, energy, pesticide, technique, labour or knowledge use in human-influenced land use systems.	ESMERALDA (2018) Maes et al. (2014) Burkhard et al. (2014)
Afforestation	Planting of forests on land that has historically not contained forests (as opposed to Reforestation).	ESMERALDA (2018) MA (2005)
Agro- biodiversity (or agricultural biodiversity)	The biodiversity in agricultural ecosystems (including domestic animals and cultivated plants, e.g. crop plants).	ESMERALDA (2018) MA (2005)
Agro-ecosystem	An ecosystem, in which usually domesticated plants and animals and other life forms are managed for the production of food, fibre and other materials that support human life while often also providing non-material benefits. Besides providing ecosystem services, agro-ecosystems are also users of other ecosystem services (e.g. nutrient regulation, erosion control, water supply, natural pest control).	ESMERALDA (2018) Burkhard and Maes (2017)
Alien Species	A plant or animal whose distribution is outside its natural range; alien species are frequently introduced by human activity.	ESMERALDA (2018) Common usage, consistent with MA (2005)
Analytical Framework	An analytical framework consists of a conceptual framework complemented with the main definitions and classifications needed for its operational use.	ESMERALDA (2018) based on OECD (2016); Maes et al. (2018)

Assessment	The analysis and review of information derived from research for the purpose of helping someone in a position of responsibility to evaluate possible actions or think about a problem. Assessment means assembling, summarising, organising, interpreting, and possibly reconciling pieces of existing knowledge and communicating them so that they are relevant and helpful to an intelligent but inexpert decision-maker.	ESMERALDA (2018) Based on Maes et al. (2014, 2018) (Parson, 1995).
Basic Spatial Unit (BSU)	The smallest spatial unit of a mapping project for which the elements of its conceptual framework are estimated. The typical size of BSUs is called spatial resolution.	ESMERALDA (2018) based on SEEA- EEA (2012), modified; as used in Czúcz and Condé (2017)
Benefit Transfer	Estimates economic values by transferring existing benefit estimates from studies already completed for another location or issue	ESMERALDA (2018)
Benefits	Positive change in wellbeing from the fulfilment of needs and wants.	ESMERALDA (2018) TEEB (2010) Maes et al. (2014, 2018)
Biodiversity	The variability among living organisms from all sources, including inter alia terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species, and of ecosystems.	ESMERALDA (2018) (cf. Article 2 of the Convention on Biological Diversity, 1992). Maes et al. (2014, 2018)
Bioenergy	This is energy that is derived from biological matter (i.e. from plants and animals) but which as not undergone a geological process (cf. fossil fuels). Carriers of bioenergy may be solid (e.g.wood, straw), liquid (e.g.biodiesel, bioethanol) or gaseous (e.g.methane)	European Commission (2015)
Biofuel	A fuel that contains energy from geologically recent carbon fixation, produced from living organisms, usually plants.	ESMERALDA (2018)
Biologically Valuable Grassland	Term used within the context of the Rural Development Programme of Latvia, which includes the EU protected grassland habitats (all semi-natural grasslands in Latvia) and grassland habitats significant for birds.	Rūsiņa S. (Eds.) (2017)
Biomass	The mass of tissues in living organisms in a population, ecosystem, or spatial unit derived by the fixation of energy though organic processes.	ESMERALDA (2018) MA (2005)

Biophysical Structure	The architecture of an ecosystem as a result of the interaction between the abiotic, physical environment and the biotic communities, in particular vegetation.	ESMERALDA (2018) Maes et al. (2014)
Biophysical Valuation	A method that derives values from measurements of the physical costs (e.g., in terms of labour, surface requirements, energy and material inputs) of producing a given good or service.	ESMERALDA (2018) TEEB (2010) Maes et al. (2014)
Biotic	Living or recently living, used here to refer to the biological components of ecosystems, that is, plants, animals, soil microorganisms, leaf litter and dead wood.	ESMERALDA (2018) Maes et al. (2014) Czúcz and Condé (2017)
Capacity	(for an ecosystem service): The ability of a given ecosystem to generate a specific ecosystem service in a sustainable way.	ESMERALDA (2018) based on SEEA- EEA (2012) Maes et al. (2018)
Carbon Sequestration	The process of increasing the carbon content of a reservoir other than the atmosphere.	ESMERALDA (2018) MA (2005)
Community (Ecological)	An assemblage of species occurring in the same space or time, often linked by biotic interactions such as competition or predation.	ESMERALDA (2018) UK NEA (2011),
Community (Human, Local)	A group of people who have something in common. A local community is a fairly small group of people who share a common place of residence and a set of institutions based on this fact, but the word 'community' is also used to refer to larger collections of people who have something else in common (e.g., national community, donor community).	ESMERALDA (2018) Adapted from MA (2005) and UK NEA (2011)
Conceptual Model	Conceptual models of ecosystem services describe systemic interactions between nature and people. They are, for instance, illustrations of ecosystem structures and functions, or impact of drivers and pressures on state variables. Conceptual models can also describe complexity of various approaches in the quantification of ecosystem services.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.3
Conservation	The protections, improvement and sustainable use of natural resources for present and future generations.	ESMERALDA (2018) Burkhard and Maes (2017)
Corporate Ecosystem Service Review	A structured methodology that helps private sector decision-makers to develop strategies to manage business risks and opportunities arising from their company's dependence and impact on ecosystems.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2

Cost-Benefit Analysis (CBA)	An evaluation method that involves summing up the value of the costs and benefits of an investment/policy/project and comparing options in terms of their net benefits (the extent to which benefits exceed costs).	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2
Cost- Effectiveness Analysis (CEA)	An evaluation method that involves identifying the least cost option that achieves a specified goal.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2
Cultural Landscape	Cultural properties (that) represent the combined works of nature and of man	ESMERALDA (2018) World Heritage Committee
Cultural Ecosystem Service (CES)	All the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people. CES are primarily regarded as the physical settings, locations or situations that give rise to changes in the physical or mental states of people, and whose character are fundamentally dependent on living processes; they can involve individual species, habitats and whole ecosystems. The settings can be semi-natural as well as natural settings (i.e. can include cultural landscapes) providing they are dependent on *in situ* living processes. In CICES, a distinction between settings that support interactions that are used for physical activities such as hiking and angling, and intellectual or mental interactions involving analytical, symbolic and representational activities is made. Spiritual and religious settings are also recognised. The classification also covers the 'existence' and 'bequest' constructs that may arise from people's beliefs or understandings.	ESMERALDA (2018) As defined in CICES
Decision-maker	A person, group or an organisation that has the authority or ability to decide about actions of interest.	ESMERALDA (2018) MA (2005)
Degradation of an Ecosystem Service	Reduction in the contribution that an ecosystem service, or bundles of services, makes to human well-being as a result of loss of a stock of natural capital or its condition (capacity) to generate service output.	ESMERALDA (2018) OpenNESS
Deliberative Assessment	Deliberative methods are an umbrella term for various tools and techniques engaging and empowering non-scientist participants. These methods ask stakeholders and citizens to form their preferences to ecosystem services together in a transparent way through an open discourse.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliv.3.1

Direct Measurement (of ES)	A measurement of a state, a quantity or a process from ecosystem observations, monitoring, surveys or questionnaires which cover the entire study area in a representative manner	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.3
Direct Use Value (of Ecosystems)	The economic or social value of the goods or benefits derived from the services provided by an ecosystem that are used directly by an agent. These include consumptive uses (e.g., harvesting goods) and non-consumptive uses (e.g., enjoyment of scenic beauty). Agents are often physically present in an ecosystem to receive direct use value	ESMERALDA (2018) adapted from MA (2005) and Rubicode (2010)
Drivers of Change [Direct & Indirect]	Any natural or human-induced factor that directly or indirectly causes a change in an ecosystem. A direct driver of change unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy, an indirect driver of change operates by altering the level or rate of change of 1 or more direct drivers.	ESMERALDA (2018) MA (2005) Maes et al. (2014, 2018)
Ecological Process	An interaction among organisms, and/or their abiotic environment.	ESMERALDA (2018) shortened from Mace et al. (2012)
Economic Valuation	The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making) in monetary terms.	ESMERALDA (2018) TEEB (2010) Maes et al. (2014, 2018)
Ecosystem	1. [in a general context] Dynamic complex of plant, animal, and microorganisms communities and their non-living environment inter-acting as a functional unit. Humans may be an integral part of an ecosystem, although 'socio-ecological system' is sometimes used to denote situations in which people play a significant role, or where the character of the ecosystem is heavily influenced by human action. [in the MAES context] An ecosystem type	ESMERALDA (2018) Modified MA (2005) Maes et al. (2014, 2018)
Ecosystem Accounting	Ecosystem accounting is a coherent and integrated approach to the measurement of ecosystem assets and the flows of services from them into economic and other human activity.	ESMERALDA (2018) (SEEA-EEA, 2012) Maes (2018)
Ecosystem Approach	A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use. An ecosystem approach is based on the application of appropriate scientific methods focused on levels of biological organisation, which encompass the essential structure, processes, functions, and interactions among organisms and their	ESMERALDA (2018) MA (2005)

	environment. It recognises that humans, with their cultural diversity, are an integral component of many ecosystems.	
Ecosystem Assessment	A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers.	ESMERALDA (2018) UK NEA (2011) Maes et al. (2014, 2018)
Ecosystem Characteristic	Key attributes of an ecosystem unit describing its components, structure, processes, and functionality, frequently closely related to biodiversity. The term characteristics is intended to be able to encompass all of the various perspectives taken to describe an ecosystem.	based on SEEA- EEA (2012), simplified
Ecosystem Condition	1. The physical, chemical and biological condition or quality of an ecosystem at a particular point in time (definition used in MAES). 2. The overall quality of an ecosystem unit, in terms of its main characteristics underpinning its capacity to generate ecosystem services. 3. The capacity of an ecosystem to yield services, relative to its potential capacity.	Maes et al. (2018) Czúcz & Condé (2018) MA (2005)
Ecosystem Degradation	A persistent reduction in the condition of an ecosystem.	ESMERALDA (2018) Maes et al. (2018) Modified from MA (2005)
Ecosystem Function	Subset of the interactions between biophysical structures, biodiversity and ecosystem processes that underpin the capacity of an ecosystem to provide ecosystem services. (See also ecosystem capacity and ecosystem condition)	ESMERALDA (2018) TEEB (2010) Maes et al. (2014)
Ecosystem Functioning	The operating of an ecosystem. Very often, there is a normative component involved, insofar as ecosystem functioning not only refers to (any) functioning/performance of the system but to 'proper functioning' and thus implies a normative choice on what is considered as a properly functioning ecosystem (operating within certain limits).	ESMERALDA (2018) Based on Jax (2010)
Ecosystem Health	A state of nature (whether managed or pristine) that is characterized by systems integrity: that is, a healthy nature is a largely self-organized system.	ESMERALDA (2018) Rapport (1992: 145)
Ecosystem Integrity	Integrity is often defined as an environmental condition that exhibits little or no human influence, maintaining the structure, function, and species composition present, prior to, and	ESMERALDA (2018) Hull et al. (2003: 2)

	independent of human intervention [i.e., integrity is closely associated with ideas of naturalness, particularly the notion of pristine wilderness (Angermeier & Karr 1994, Callicott et al. 1999)]	
Ecosystem Management	4. A direct and conscious intervention (or agreement to refrain from interventions) in an ecosystem by people that is intended to change its structure or functioning for some benefit.	ESMERALDA (2018) Adapted from MA (2005)
Ecosystem Process	Any change or reaction, which occurs within ecosystems, physical, chemical or biological. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy.	ESMERALDA (2018) MA (2005) Maes et al. (2014, 2018)
Ecosystem Properties	Attributes which characterize an ecosystem, such as its size, biodiversity, stability, degree of organization, as well as its functions and processes (i.e., the internal exchanges of materials, energy and information among different pools).	ESMERALDA (2018) MA (2005) and UK NEA (2011)
Ecosystem Services	1. The contributions of ecosystems to benefits obtained in economic, social, cultural and other human activity. 2. The contributions of ecosystem structure and function (in combination with other inputs) to human well-being (Comment: The concepts of 'ecosystem goods and services', 'final ecosystem services', and 'nature's contributions to people' are considered to be synonymous with ES in the MAES context.)	ESMERALDA (2018) based on TEEB, (2010) & SEEA-EEA (2012) Burkhard et al. (2012) Maes et al. (2018).
Ecosystem Service Accounting	A structured way of measuring the economic significance of nature that is consistent with existing macro-economic accounts. Ecosystem service accounting involves organising information about natural capital stocks and ecosystem service flows, so that the contributions that ecosystems make to human well-being can be understood by decision makers and any changes tracked over time. Accounts can be organised in either physical or monetary terms.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2
Ecosystem Service Assessment	An appraisal of the status and trends in the provision of ecosystem services in a specified geographic area. The general aim of an ecosystem service assessment is to highlight and quantify the importance of ecosystem services to society. Ecosystem service assessments are multidisciplinary in nature, applying and combining biophysical, social and economic	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2

	methods	
Ecosystem Service Bundle (supply side)	A set of associated ecosystem services that are linked to a given ecosystem and that usually appear together repeatedly in time and space.	ESMERALDA (2018) From OpenNESS
Ecosystem Service Bundle (demand side)	A set of associated ecosystem services that are demanded by humans from ecosystem(s).	ESMERALDA (2018) From OpenNESS
Ecosystem Service Classification	ecosystem service classification: A classification of ecosystem services according to the ecological processes they rely on, and the benefits they contribute to"	ESMERALDA (2018) Czúcz & Condé (2017)
Ecosystem Service Demand	The need for specific ecosystem services by society, particular stakeholder groups or individuals. It depends on several factors such as culturally-dependent desires and needs, availability of alternatives, or means to fulfil these needs. It also covers preferences for specific attributes of a service and relates to risk awareness.	ESMERALDA (2018) Burkhard and Maes (2017)
Ecosystem Service Flow	The amount of an ecosystem service that is actually mobilized in a specific area and time	ESMERALDA (2018) Modified from OpenNESS Maes et al. (2018)
Ecosystem Service Mapping	The process of creating a cartographic representation of (quantified) ecosystem service indicators in geographic space and time.	ESMERALDA (2018) Burkhard and Maes (2017)
Ecosystem Service Model	A scientific (usually computer-based) for quantifying various socio-ecological indicators of an ecosystem service.	ESMERALDA (2018) Burkhard and Maes (2017)
Ecosystem Service Potential	This describes the natural contributions to ES generation. It measures the amount of ES that can be provided or used in a sustainable way in a certain region. This potential should be assessed over a sufficiently long period of time.	ESMERALDA (2018) Burkhard and Maes (2017)
Ecosystem Service Provider	The ecosystems, component populations, communities, functional groups, etc. as well as abiotic components such as habitat type, that are the main contributors to ES output.	ESMERALDA (2018) Modified from Harrington et al. (2010) after Kremen (2005)

Ecosystem Service Supply	The provision of a service by a particular ecosystem, irrespective of its actual use. It can be determined for a specified period of time (such as a year) in the present, past or future	ESMERALDA (2018) Burkhard and Maes (2017)
Ecosystem State	The physical, chemical and biological condition of an ecosystem at a particular point of time.	ESMERALDA (2018) Maes et al. (2014)
Ecosystem Status	Ecosystem condition defined among several well- defined categories with a legal status. It is usually measured against time and can be compared to agreed policy targets, e.g. in EU environmental directives (e.g. Habitats Directive, Water Framework Directive, Marine Strategy Framework Directive), e.g. "conservation status".	ESMERALDA (2018) Maes et al. (2018)
Ecosystem Structure	A static characteristic of an ecosystem that is measured as a stock or volume of material or energy, or the composition and distribution of biophysical elements. Examples include standing crop, leaf area, % ground cover, species composition (cf. ecosystem process).	ESMERALDA (2018)
Ecosystem Typology	A classification of ecosystem units according to their relevant ecosystem characteristics, usually linked to specific objectives and spatial scales.	ESMERALDA (2018) Maes et al. (2018)
Ecosystem Unit	An instance of an ecosystem type within a basic spatial unit. In cases when the spatial resolution is relatively fine, it is a meaningful simplification to assume that each basic spatial unit is occupied by just a single ecosystem unit, in which case these two concepts (BSU, EcU) will coincide."	ESMERALDA (2018 Czúcz & Condé (2017)
Environmental Policy Integration	The incorporation of environmental objectives into all stages of policy making in non-environmental policy sectors, with a specific recognition of this goal as a guiding principle for the planning and execution of policy, accompanied by an attempt to aggregate presumed environmental consequences into an overall evaluation of policy, and a commitment to minimize contradictions between environmental and sectoral policies by giving principled priority to the former over the latter.	ESMERALDA (2018) Lafferty and Hovden (2003)
Excludability	Occurs if institutions or technologies exist that prevent other individuals or groups from using a good or service.	ESMERALDA (2018) Costanza (2008)
Existence Value	The value that individuals place on knowing that a resource exists, even if they never use that resource (also sometimes known as conservation	ESMERALDA (2018) MA (2005)

	value or passive use value).	
Explorative/ Exploratory Scenario	The projection of the state and condition of an ecosystem into the future, based on the anticipated impacts of the direct and indirect drivers of change, designed to help people understand the consequences of different sets of assumptions. See 'normative scenarios'.	ESMERALDA (2018) OpenNESS
Extrapolation	A projection, extension, or expansion of information from what is known into an area not known or experienced, providing conjectural knowledge of the unknown area.	ESMERALDA (2018) OpenNESS
Framework	A structure that includes the relationship amongst a set of assumptions, concepts, and practices that establish an approach for accomplishing a stated objective or objectives.	ESMERALDA (2018) Nahlik et al. (2012)
Functional Diversity	The value, range, and relative abundance of traits present in the organisms in an ecological community.	ESMERALDA (2018) UK NEA (2011)
Functional Group	A collection of organisms with similar functional trait attributes. Some authors use ‘Functional Type’ in the same way. Groups can be associated with similar responses to pressures and/or effects on ecosystem processes. A functional group is often referred to as a guild, especially when referring to animals, e.g. the feeding types of aquatic organisms having the same function within the trophic chain, e.g. the group (guild) of shredders or grazers.	ESMERALDA (2018) Harrington et al. (2010)
Functional Traits	A feature of an organism that has demonstrable links to the organism’s function. Those characteristics (e.g. morphological, physiological etc.) of organisms that either are related to the effect of organisms on community and ecosystem processes or their response to these processes and the physical environment.	ESMERALDA (2018) Maes et al. (2014)
Geographic Information System (GIS)	A computer-based system for the Input, Management, Analysis and Presentation (IMAP) of spatially referenced data.	ESMERALDA (2018) Burkhard and Maes (2017)

Goods	The objects from ecosystems that people value through experience, use or consumption, whether that value is expressed in economic, social or personal terms. Note that the use of this term here goes well beyond a narrow definition of goods simply as physical items bought and sold in markets, and includes objects that have no market price (e.g. outdoor recreation). Comment: The term is synonymous with benefit (as proposed by the UK NEA), & not with service (as propo- sed by MA).	ESMERALDA (2018) UK NEA (2011)
Governance	The process of formulating decisions and guiding the behaviour of humans, groups and organisa- tions in formally, often hierarchically organised decision-making systems or in networks that cross decision-making levels & sector boundaries.	ESMERALDA (2018) Adapted from Rhodes (1991) and Saarikoski et al. (2013)
Green Infrastructure (GI)	A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (ES). It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.	ESMERALDA (2018) EC (2013: 3)
Group / Participatory Valuation	A stated preference method that asks groups of stakeholders to state their willingness to pay for specified changes in the provision of ES through group discussion.	ESMERALDA (2018)
Habitat	1. [in a general context]: The physical location or type of environment in which an organism or biological population lives or occurs, defined by the sum of the abiotic and biotic factors of the environment, whether natural or modified, which are essential to the life and reproduction of the species. 2. [in a MAES context]: A synonym for ‘ecosystem type’ [Note the Council of Europe definition is more specific: the habitat of a species, or population of a species, is the sum of the abiotic and biotic factors of the environment, whether natural or modified, which are essential to the life and reproduction of the species within its natural geographic range.]	ESMERALDA (2018) based on EEC, (1992) Maes et al. (2018)

Health (Human)	A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity. The health of a whole community or population is reflected in measurements of disease incidence and prevalence, age-specific death rates, and life expectancy.	ESMERALDA (2018) UK NEA (2011)
Heritage [Cultural and Natural]	Our legacy from the past, what we live with today, and what we pass on to future generations. Physical objects produced and used by past generations, ranging from small-scale domestic utensils to large-scale buildings, monuments, places and landscapes, may become valued as cultural heritage by their descendants. Equally, symbolic products of human creativity and imagination such as music, visual arts, poetry and prose, knowledge and know-how contribute to a society or group's understanding of its cultural heritage.	ESMERALDA (2018) UK NEA (2011)
Hydromorphic soils	Formed under conditions of poor drainage in marshes, swamps, seepage areas or flats.	JRC (2018)
Hotspots	Areas that provide large components of particular services in a comparably small area/spot (opposite to ES coldspots).	ESMERALDA (2018) García-Nieto et al. (2013); Egoh et al. (2008); Gimona & van der Horst (2007)
Human Inputs	Encompass all anthropogenic contributions to ES generation such as land use and management (including system inputs such as energy, water, fertiliser, pesticides, labour, technology, knowledge), human pressures on the system (e.g. eutrophication, biodiversity loss) and protection measures that modify ecosystems and ES supply.	ESMERALDA (2018) Burkhard and Maes (2017)
Human Well- Being	A state that is intrinsically (and not just instrumentally) valuable or good for a person or a societal group, comprising access to basic materials for a good life, health, security, good physical and mental state, and good social relations.	ESMERALDA (2018) Modified from MA (2005) Maes et al. (2018)
Impact	Negative or positive effect on individuals, society and/or environmental resources resulting from environmental change.	ESMERALDA (2018) Modified after Harrington et al. (2010)

Indicator	An indicator is a number or qualitative descriptor generated with a well-defined method which reflects a phenomenon of interest (the indicandum). Indicators are frequently used by policy-makers to set environmental goals and evaluate their fulfilment.	ESMERALDA (2018) Modified from Heink & Kowarik (2010) Maes et al. (2018)
Integrated Modelling Framework	This group includes modelling tools designed specifically for ecosystem services modelling and mapping that can assess trade-offs and scenarios for multiple services. They integrate various methods for different services which are usually organized in modules each of them designed for particular service. The integrated modelling frameworks utilize GIS software as a mean to operate with spatial data and produce maps. They can work as extensions of commercial or open-source software packages, stand-alone tools or web-based application. They are designed help researchers in ES assessment and enable decision makers to assess quantified trade-offs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.3
Integration	The level of integration within existing ecosystem assessments varies; but usually falls within i) combining, ii) interpreting and iii) communicating knowledge from diverse disciplines. For example, integration may focus on biophysical elements; integrating ecosystem condition with the services that the ecosystem provides (e.g. MAES assess- ment framework). Others have extended inte- gration to include socioeconomic information and links to human well-being (e.g. MA) and indigenous and local knowledge (e.g. IPBES Assessments). A number of assessment practitioner may use the word integration to refer to the inclusion of stake-holders within the assessment process and the overall governance structure that they are implementing.	ESMERALDA (2018) ESMERALDA Deliverable 4.8

Intensification	Intensification of land use aims at raising ecosystem service outputs (e.g. in agriculture raising crop yields per unit area and per unit time), in other words to increase productivity. To achieve this goal, usually the inputs (see term “additional inputs”) are increased. To raise crop yields, a broad range of methods is being applied, often in combinations, including breeding, irrigation, organic and inorganic fertilization, green manure and cover crops, pest and weed management, multi-cropping, crop rotation and the reduction of fallow periods.	ESMERALDA (2018) Modified after Geist (2006)
Intermediate Ecosystem Service	An ecological function or process not used directly by a beneficiary, but which underpins those final ecosystem services which are used directly. Note: 'Intermediate ES' should not be considered a subtype of 'ecosystem services': in fact, these are mutually exclusive categories, and this distinction is sometimes emphasized by using the term 'final ES' as a synonym of ES. Nevertheless, the ‘boundary’ between intermediate and final ecosystem services (sometimes called 'production boundary') is context dependent and should be set clearly and consistently for any ecosystem assessment work. This means that there can be contexts in which an 'intermediate ES' would actually be a (final) service through a direct use by a certain beneficiary or through the avoidance of societal costs if the service is degraded.	ESMERALDA (2018) OpenNESS Note from Czúcz and Condé (2017)
Intrinsic Value	Intrinsic value is the value something has independent of any interests attached to it by an observer or potential user. This does not necessarily mean that such values are independent of a valuer (i.e. values which exist 'as such'), they may also require a (human) valuer (but this is a matter of disagreement among philosophers).	ESMERALDA (2018) OpenNESS, adapted from various sources.
Land Cover (LC)	The physical coverage of land usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, land use.	ESMERALDA (2018) UK NEA (2011)

Land parcel identification system (LPIS)	GIS database, which contains all agricultural areas that are eligible for a direct payment under the Common Agricultural Policy. It is used to cross - check the parcels for which payments have been claimed by the farmer. The land parcel identification system ensures that the farmer is paid for the correct area and that overpayment is avoided.	European Commission (2015)
Landscape	An area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors. The term "landscape" is thus defined as a zone or area as perceived by local people or visitors, whose visual features and character are the result of the action of natural and/or cultural factors. Recognition is given to the fact that landscapes evolve through time and are the result of natural and human activities. Landscape should be considered as a whole – natural and cultural components are taken together, not separately.	ESMERALDA (2018) Burkhard and Maes (2017) [European Landscape Convention Article 1]
Landscape Metrics	Landscape metrics capture composition and configuration of landscape structure in mathematical terms. Not only spatial but also temporal properties of processes can be characterised by a quantifying landscape pattern.	ESMERALDA (2018) Burkhard and Maes (2017)
Land Use (LU)	The human use of a piece of land for a certain purpose such as irrigated agriculture or recreation. Influenced by, but not synonymous with, land cover.	ESMERALDA (2018) UK NEA (2011)
Land Quality Evaluation	Land evaluation in grades, taking into account the productivity of the soil . (note: In Latvia land quality is assessed taking into account soil type, soil texture class and land improvement).	Boruks et al. (2001)
Mapping	Graphical representation of a procedure, process, structure, or system that depicts arrangement of and relationships among its different components, and traces flows of energy, goods, information, materials, money, personnel, etc.	ESMERALDA (2018)
Mitigation	The action of making the consequence of an impact less severe.	ESMERALDA (2018)

		OpenNESS
Model (scientific)	A simplified representation of a complex system or process including elements that are considered to be essential parts of what is represented. Models aim to make it easier to understand and/or quantify by referring to existing and usually commonly accepted knowledge.	ESMERALDA (2018) OpenNESS Burkhard and Maes (2017)
Monetary Valuation	The process whereby people express the importance or preference they have for the service or benefits that ecosystems provides in monetary terms. See 'Economic valuation'.	ESMERALDA (2018) Defined for OpenNESS from TEEB (2010)
Multi-Criteria Decision Analysis (MCDA)	Multi-criteria decision analysis (MCDA) is a decision-support method that help to systematically explore the pros and cons of different alternatives, by comparing them against a set of explicitly defined criteria. These criteria account for the most relevant aspects in a given decision-making process. Operationally, MCDA supports structuring decision problems, assessing the performance of alternatives across criteria, exploring trade-offs, formulating a decision and testing its robustness.	ESMERALDA (2018) Adem Esmail and Geneletti (2018)
Multifunctionality	The characteristic of ecosystems to simultaneously perform multiple functions which may be able to provide a particular ES bundle or bundles.	ESMERALDA (2018) OpenNESS
Narrative assessment	Narrative methods aim to understand and describe the importance of nature and its benefits to people with their own words. By using narrative methods, we allow the research participants (residents of a certain place, users of a certain resource, or stakeholders of an issue) to articulate the plural and heterogeneous values of ecosystem services through their own stories and direct actions (both verbally and visually).	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.1
Natural Capital	The elements of nature that directly or indirectly produce value for people, including ecosystems, species, freshwater, land, minerals, air and oceans, as well as natural processes and functions. The term is often used synonymously with natural asset, but in general implies a specific component.	ESMERALDA (2018) Modified after MA (2005)

	Note: ecosystem capital and ecosystem assets are sometimes used to refer to the parts of nature that produce benefits for people.	
Natural Capital Accounting	A way of organising information about natural capital so that the state and trends in natural assets can be documented and assessed in a systematic way by decision makers.	ESMERALDA (2018) OpenNESS
Nature-based Solutions	Living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits.	ESMERALDA (2018) EU 2015
Natural Grassland	Grassland, the existence of which is completely ensured by natural conditions (precipitation, fire, wild herbivores, soil conditions) and no human activity (mowing or grazing) is required. This type of grassland most commonly occurs in steppe and savannah zones.	Rūsiņa S. (Ed.) 2017.
Net Primary Production	See 'production, biological'	
Non-Monetary Valuation	The process whereby people express the importance or preference they have for the service or benefits that ecosystems provide in terms other than money. See monetary or economic valuation.	ESMERALDA (2018) OpenNESS
Organic soil	A soil in which the sum of the thicknesses of layers comprising organic soil materials is generally greater than the sum of the thicknesses of mineral layers.	JRS (2018)
Operationalization	The process by which concepts are made usable by decision makers.	ESMERALDA (2018) OpenNESS
Participatory Approach	Family of approaches and methods to enable people to share, enhance, and analyse their knowledge of life and conditions, to plan and to act, to monitor and evaluate.	ESMERALDA (2018) Chambers (1997)
Participatory GIS	Evaluates the spatial distribution of ecosystem services according to the perceptions and knowledge of stakeholders via workshops and/or surveys. PGIS allows for the participation of	ESMERALDA (2018) ESMERALDA compendium

	various stakeholders in the creation of an ES map in the identification of ES ‘hotspots’ on a map, and integrates their perceptions, knowledge and values in the final maps of ecosystem services.	ESMERALDA Deliverable 3.1
Participatory Scenario Planning	Participatory scenario planning applies various tools and techniques (e.g. brainstorming or visioning exercises in workshops, often complemented with modelling) to develop plausible and internally consistent descriptions of alternative future options.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.1
Payments for Ecosystem Services (PES)	Conditional payments offered to providers (e.g., farmers or landowners) in exchange for employing management practices that enhance ES provision	ESMERALDA (2018) Modified from Tacconi (2012)
Permanent grassland	Natural (mainly steppe areas) or agricultural soils with grass cover not normally ploughed.	JRC (2018)
Phenomenological Models	The phenomenological models describe empirical relationships between biodiversity or ecosystem components and ecosystem services. They are based on the understanding that biological mechanisms underpinning ES supply.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliv. 3.3
Policy Maker	A person with the authority to influence or determine policies and practices at an international, national, regional or local level.	ESMERALDA (2018) Modified UK NEA (2011)
Population (Biological)	A group of organisms, all of the same species, which occupies a particular area (geographic population), is genetically distinct (genetic population) or fluctuates synchronously (demographic population).	ESMERALDA (2018) Harrington et al. (2010)
Preference Assessment	Preference assessment is a direct and quantitative method to demonstrate the social importance of ecosystem services by analysing social motivations, perceptions, knowledge and associated values of ecosystem services demand or use	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.1
Pressure	Human induced process that alters the condition of ecosystems.	ESMERALDA (2018) Maes et al. (2018)

Process-based Models (includes: landscape function models)	Process-based models rely on the explicit representation of ecological and physical processes that determine the functioning of ecosystems. They provide functional means of plant and ecosystem processes that are universal rather than specific to one biome or region. One purpose of such models is to explore the impact of perturbations caused by climatic changes and anthropogenic activity on ecosystems and their biogeochemical feedbacks. Many process-based models allow the net effects of these processes to be estimated for the recent past and for future scenarios. In terms of ecosystem services, these types of models are most widely applied to quantify climate regulation, water supply from catchments, food provision but also in the wider frame of habitat characterisation.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.3
Production (biological)	Rate of biomass produced by an ecosystem, generally expressed as biomass produced per unit of time per unit of surface or volume. Net primary productivity is defined as the energy fixed by plants minus their respiration.	ESMERALDA (2018) UK NEA (2011)
Provisioning Ecosystem Services	Those material and energetic outputs from ecosystems that contribute to human well-being.	ESMERALDA (2018) Shortened from CICES
Regulating Ecosystem Services	All the ways in which ecosystems and living organisms can mediate or moderate the ambient environment so that human well-being is en-hanced. It therefore covers the degradation of wastes and toxic substances by exploiting living processes.	ESMERALDA (2018) Modified after CICES
Resilience	A measure of an (eco)system's ability to recover and retain its structure and processes following an exogenous change or disturbance event. If a stress or disturbance does alter the ecosystem, then it should be able to bounce back quickly to resume its former ability to yield a service or utility rather than transform into a qualitatively different state that is con-trolled by a different set of processes. In order for ecosystem resilience to be defined, the ecosystem must have a degree of stability prior to the perturbation. Resilience relates to return to stability following a specified perturbation.	ESMERALDA (2018) Modified from Holling (1973); Dawson et al. (2010) Harrington et al. (2010) Brand & Jax (2007)

Restoration	The process of actively managing an ecosystem unit in order to improve ecosystem condition.	ESMERALDA (2018) based on MAES, modified [CBD, 2012] Czúcz and Condé (2017)
Rivalry	The degree to which the use of one ecosystem service prevents other beneficiaries from using it. Non-rival ecosystem services in return provide benefits to one person that do not reduce the amount of benefits available for others.	ESMERALDA (2018) Schröter et al. (2014) Kemkes et al. (2010) Costanza (2008);
Scale (spatial and temporal)	The physical dimensions, in either space or time, of phenomena or observations. Regarding temporal aspects of ES supply and demand, hot moments are equally as important as spatially relevant hotspots.	ESMERALDA (2018) After Burkhard et al. (2013) Reid et al. (2006) Burkhard and Maes (2017)
Scale (on a map)	Represents the ratio of the distance between two points on the map to the corresponding distance on the ground.	ESMERALDA (2018) Burkhard and Maes (2017)
Scenario	Plausible, but simplified descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces and relationships. Scenarios are no predictions of what will happen, but ore projections on what might happen or could happen given certain assumptions about which there might be great uncertainty.	ESMERALDA (2018) OpenNESS, modified from UK NEA (2011)
Security	Access to resources, safety, and the ability to live in a predictable and controllable environment.	ESMERALDA (2018) UK NEA (2011)
Seminatural Grassland	Grassland, the existence of which is supported by human agricultural activity (mowing or livestock grazing), but the environmental conditions and the composition of species is provided by natural processes.	Rūsiņa S. (Ed.) 2017.
Service- Benefitting Area (SBA)	Spatial unit to which an ecosystem service flow is delivered to beneficiaries. SBAs spatially delineate groups of people who knowingly or unknowingly benefit from the ecosystem service of interest	ESMERALDA (2018) Burkhard and Maes (2017)

Service-Connecting Area (SCA)	Connecting space between non-adjacent ecosystem service-providing and service-benefiting areas. The properties of the connecting space influence the transfer of the benefit.	ESMERALDA (2018) Burkhard and Maes (2017)
Service Providing Area (SPA)	Spatial unit within which an ecosystem service is provided. This area can include animal and plant populations, abiotic components as well as human actors.	ESMERALDA (2018) Burkhard and Maes (2017)
Service- Providing Unit	see 'Service Providing Area'	ESMERALDA (2018)
Socio-cultural Valuation	The process whereby the perceived importance or preference people have for a specific element of the MAES framework is estimated in terms other than money. Note: Preferred over term 'non- monetary valuation'	ESMERALDA (2018) based on OpenNESS, simplified Czúcz & Condé (2017)
Socio-Economic System	Our society (which includes institutions that manage ecosystems, users that use their services and stake-holders that influence ecosystems).	ESMERALDA (2018) Maes et al. (2014, 2018)
Social– Ecological System (or Socio-Ecological System)	Interwoven and interdependent ecological and social structures and their associated relationships.	ESMERALDA (2018) OpenNESS
Soil Degradation	Negative process often accelerated by human activities (improper soil use and cultivation practices, building areas) that leads to deterioration of soil properties and functions or destruction of soil as a whole, e.g. compaction, erosion, salinization.	JRC (2018)
Soil Erodibility (K-factor)	Expresses the susceptibility of a soil to erode.	ESMERALDA (2018) Maes et al. (2018)
Soil erosion	Soil erosion is the movement and transport of soil by various agents, particularly water, wind, and mass movement; hence climate is a key factor.	Bullock (2005)
Soil Properties	Chemical, physical, or biological characteristics of soil which can indicate its level of function of ecosystem services.	NRSC (2011)
Soil Productivity	The output of a specified plant or group of plants under a defined set of management practices	Soil Science Society of America (2008)
Soil Sorption	Selective process, which occurs on soil particles smaller than 0.002mm (<2µm); these small particles have colloidal properties, are able to hold and exchange ions, water or gases.	JRC (2018)

Soil Texture:	Numerical proportion (% by wt.) of sand, silt and clay in a soil. Sand, silt and clay content are estimated in the field, and/or quantitatively in the laboratory, and then placed within the texture triangle to determine soil texture class. Texture can be coarse (sand particles predominate), medium (silt particles predominate), or fine (clay particles predominate).	JRC (2018)
Spatial Proxy Methods	Spatial proxy methods are derived from indirect measurements which deliver a biophysical value in physical units, but this value needs further interpretation, certain assumptions or data processing, or it needs to be combined in a model with other sources of environmental information before it can be used to measure an ecosystem service. In many cases, variables that are collected through remote sensing qualify as indirect measurement. Examples for terrestrial ecosystems are land surface temperature, NDVI, land cover, water layers, leaf area index and primary production.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.3
Species Diversity	Biodiversity at the species level, often combining aspects of species richness, their relative abundance, and their dissimilarity.	ESMERALDA (2018) UK NEA (2011)
Species Richness	The number of species within a given sample, community, or area.	ESMERALDA (2018) MA (2005), UK NEA (2011)
Stakeholder	Any group, organisation or individual who can affect or is affected by the ecosystem's services".	ESMERALDA (2018) OpenNESS
State [of a social-ecological system]	Collection of variables that describe the overall physical condition of a social ecological system, including attributes of both ecosystem service providers and ecosystem service beneficiaries.	ESMERALDA (2018) Modified from Harrington et al. (2010)
Statistical Models	Statistical models are mathematical models that measures the attributes of certain population using a representative sample as measuring the whole population is usually not possible. In statistical models ecosystem services are estimated based on explanatory variables such as soils, climate, etc., using a statistical relation.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.3
Storyline	A narrative description of a scenario, which highlights its main features and the relationships between the scenario's driving forces and its main features.	ESMERALDA (2018) UK NEA (2011)
Structure [of an Ecosystem, Habitat, Community]	The aggregate of elements of an entity in their relationships to each other. The component parts of an ecosystem; see 'natural capital asset' or	ESMERALDA (2018)

	'natural capital stock'.	
Supporting Services	Ecological processes and functions that are necessary for the production of final ecosystem services. See also 'intermediate services' and ‘ecosystem functions’.	ESMERALDA (2018)
Sustainable Use of ES	Human use of an ecosystem so that it may yield a continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.	ESMERALDA (2018) UK NEA (2011)
Sustainability	A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs. Weak sustainability assumes that needs can be met by the substitution of different forms of capital (i.e. through trade-offs); strong sustainability posits that substitution of different forms of capital is seriously limited.	ESMERALDA (2018) UK NEA (2011)
Synergies	Ecosystem service synergies arise when multiple services are enhanced simultaneously.	ESMERALDA (2018) Raudsepp-Harne et al. (2010)
System	A construct for a reporting unit at a level of aggregation generally above that which is applied to an ecosystem. Systems may include many ecosystems with varying degrees of inter-action and spatial connectivity, in addition to their associated social and economic components. Systems are not mutually exclusive and can over- lap both spatially and conceptually.	ESMERALDA (2018) Modified from MA (2005)
Threshold, ecological	A point at which an ecological system experiences a qualitative change, mostly in an abrupt and discontinuous way. In the context of OpenNESS ecological threshold and tipping points were used as synonyms. See also ‘regime shift’ and the distinction with ‘limit’.	ESMERALDA (2018) OpenNESS
Tiered Approach	A classification of available methods according to level of detail and complexity with the aim of providing advice on method choice. The provision and integration of different tiers enables ES assessments to use methods consistent with their needs and resources.	ESMERALDA (2018) Burkhard and Maes (2017) ESMERALDA Deliverables. 3.1-3.3

Time-use Assessment	This method estimates the value of ecosystem services by directly asking people how much time they are willing to invest (WTT) for a change in the quantity or quality of a given ecosystem service or conservation plan.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliv. 3.3
Total Economic Value (TEV)	A widely used framework to disaggregate the components of utilitarian value in monetary terms, including direct use value, indirect use value, option value, quasi-option value, and existence value.	ESMERALDA (2018) OpenNESS
Trade-off	ES trade-offs arise from management choices made by humans. Such choices can change the type, magnitude, and relative mix of ES provided by an ecosystem. Trade-offs occur when the provision of one ES is reduced as a consequence of increased use of another ES. Note: In some cases, a trade- off may be an explicit choice, in others, trade- offs arise with-out awareness that they are taking place.	ESMERALDA (2018) Rodriguez et al. (2006)
Travel Cost	A revealed preference method that estimates a demand function for recreational use of a natural area using data on the observed costs and frequency of travel to that destination.	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2
Uncertainty	An expression of the degree to which a condition or trend (e.g. of an ecosystem) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined terminology or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a range of values calculated by various models) or by qualitative statements (e.g. reflecting the judgment of a team of experts).	ESMERALDA (2018) Modified from UK NEA (2011)
Urban	Environmental condition linked to high population density, extent of land transformation, or a large energy flow from surrounding area.	ESMERALDA (2018) OpenNESS, (after McIntyre 2000)
Valuation	The process whereby people express the importance or preference they have for the service or benefits that ecosystems provide. Importance Value can be expressed in monetary or non-monetary terms. See 'monetary valuation' and 'non-monetary valuation'.	ESMERALDA (2018)

Value	The contribution of an action or object to user-specified goals, objectives, or conditions. The worth, usefulness, importance of something. Thus, value can be measured by the size of the well-being improvement delivered to humans through the provision of good(s). In economics, value is always associated with trade-offs, i.e. something only has (economic) value if we are willing to give up something to get or enjoy it.	ESMERALDA (2018) MA (2005) After UK NEA (2011), Mace et al. (2012), De Groot, (2010) Maes et al. (2014, 20 18)
Value Transfer (Benefit Transfer)	The use of research results from existing primary studies at one or more sites or policy contexts ("study sites") to predict welfare estimates or related information for other sites or policy contexts ("policy sites").	ESMERALDA (2018) ESMERALDA compendium ESMERALDA Deliverable 3.2
Weathering	The breakdown and changes in rocks and sediments at or near the Earth's surface produced by biological, chemical, and physical agents or combinations of them.	JRC (2018)

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