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Research Article

# Ecosystem services mapping and assessment for policy- and decision-making: Lessons learned from a comparative analysis of European case studies

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## Abstract

This paper analyses and compares a set of case studies on ecosystem services (ES) mapping and assessment with the purpose of formulating lessons learned and recommendations. Fourteen case studies were selected during the EU Horizon 2020 “Coordination and Support Action” ESMERALDA to represent different policy- and decision-making processes throughout the European Union, across a wide range of themes, biomes and scales. The analysis is based on a framework that addresses the key steps of an ES mapping and assessment process, namely policy questions, stakeholder identification and involvement, application of mapping and assessment methods, dissemination and communication and implementation. The analysis revealed that most case studies were policy-orientated or gave explicit suggestions for policy implementation in different contexts, including urban, rural and natural areas. Amongst the findings, the importance of starting stakeholder engagement early in the process was confirmed in order to generate interest and confidence in the project and to increase their willingness to cooperate. Concerning mapping and assessment methods, it was found that the integration of methods and results is essential for providing a comprehensive overview from different perspectives (e.g. social, economic). Finally, lessons learned for effective implementation of ES mapping and assessment results are presented and discussed.

Graphical Abstarcat in Fig 1.

## Keywords

biodiversity, EU Biodiversity Strategy, comparative analysis, ecosystem services, MAES, case studies

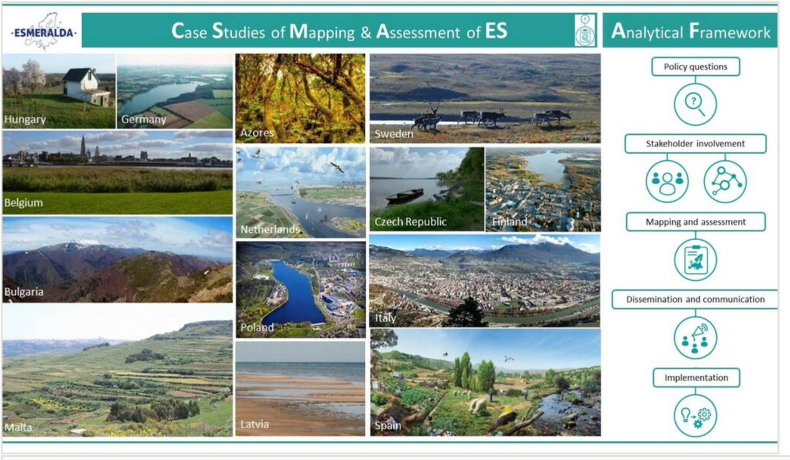


Figure 1.

Graphical Abstract

## 1. Introduction

Mapping and assessment of ecosystems and their services is recognised as a crucial step towards sustainable policy- and decision-making that accounts for both ecological processes and human activities (Maes et al. 2012, Maes et al. 2016). The EU Biodiversity Strategy to 2020 and related targets require all EU Member States to proceed with "Mapping and Assessment of Ecosystems and their Services" (MAES*1) as a key implementing step. In particular, Action 5 of the Strategy's second target sets the requirements for an EU-wide knowledge-base that should serve as a primary resource for developing Europe's green infrastructure, by identifying areas for complementary protection and ecological restoration and as a baseline against which the goal of 'no net loss of biodiversity and ecosystem services (ES)' can be evaluated. Reaching these targets is also important for building the knowledge base to achieve the ambitious nature conservation objectives of the recently-approved EU Biodiversity Strategy for 2030 (European Commission 2020). Similarly, at the international level, the acknowledgement of the need to secure a sustainable provision of ES was explicitly mentioned as the basis of the adoption of the *Aichi-targets* by the *Convention on Biological Diversity, CBD* (2010) and the creation of the *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES* (*Koetz et al. 2011, Opgenoorth and Faith 2013*).

Despite the growing scientific literature addressing ES, for example, Costanza et al. (2017), Haines-Young and Potschin (2010), McDonough et al. (2017), enhancing the integration of mapping and assessment of ecosystems and their services in real-life policy- and decision-making still remains a challenge (Grêt-Regamey et al. 2017, Maes et al. 2012, Geneletti et al. 2020, Stępniewska et al. 2018, Geneletti and Zardo 2016). There is a need for systematic studies that compare a large number of empirical cases and reflect on how ES mapping and assessment have been applied to support decision-making processes and summarise and reflect upon such experiences (Spyra et al. 2018, Dick et al. 2018, Dunford et al. 2018).

This paper compares practical experiences of mapping and assessment of ecosystems and their services in different EU contexts. Particularly, the paper analyses fourteen case studies selected during the EU Horizon 2020 "Coordination and Support Action" ESMERALDA - Enhancing ecosystem services mapping for policy- and decision-making (Burkhard et al. 2018b) to represent different policy- and decision-making processes, across a wide range of themes, biomes and scales (Geneletti et al. 2018a). It thus aims to enhance the understanding of options for and implications of applying ES mapping and assessment for policy- and decision-making, building on lessons learned from real-life case study applications. More specifically, the objectives were:

1. to characterise and critically analyse the main steps of the process of ES mapping and assessment in each case study;
2. to formulate recommendations for each step of the ES mapping and assessment process, based on identified knowledge gaps, as well as on lessons learned from the set of case studies.

For the comparative analysis of the case studies, an analytical framework was adopted, based on a generalised process of ES mapping and assessment that had been conceptualised during the ESMERALDA project. The analytical framework considers the key stages of the ES mapping and assessment process, from the identification of relevant questions from policy, society and business to the actual implementation in policy- and decision-making.

## 2. Methods

### 2.1 Selection of case studies

The case studies were selected to be representative of:

1. the variety of existing conditions across the EU, including data availability, expertise and experience;
2. the geographical regions and biomes of the entire EU (including islands);
3. the variety of policy domains and themes that can benefit from ES mapping and assessment.

To this end, six selection criteria were defined - namely, (A) Levels of progress in ES mapping and assessment; (B) Geographic regions; (C) Biomes; (D) Spatial scales; (E) Themes; and (F) Ecosystem types. These criteria were used to select fourteen case studies, located in Belgium, Bulgaria, Czechia, Finland, Germany, Hungary, Italy, Latvia, Malta, Netherlands, Poland, Portugal (Azores Islands), Spain and Sweden (see Fig. 2). Overall, the selected case studies represent a good coverage of the selection criteria (Fig.

3). A detailed account of the selection process, which took place under the umbrella of the ESMERALDA project, is presented in Geneletti et al. (2018a).

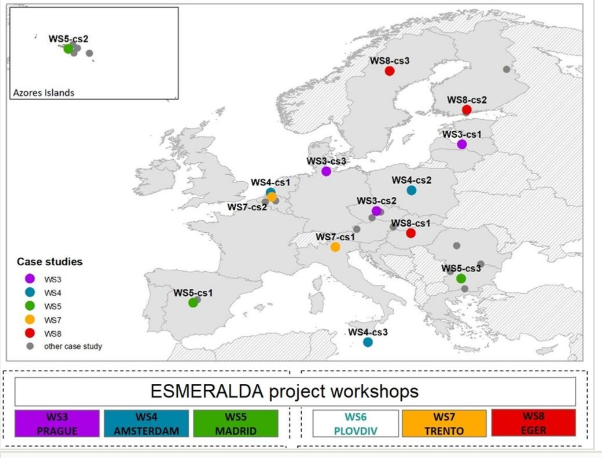


Figure 2.

Locations of the fourteen selected case studies throughout the European Union (case studies at the national scale are represented by a dot placed on the capital city of the country). Overview of ESMERALDA project workshops **WS3** - September 2016, Prague (Czech Republic); **WS4** - January 2017, Amsterdam (Netherlands); **WS5** - March 2017, Madrid (Spain); **WS7**- January 2018, Trento (Italy); **WS8** - March 2018, Eger (Hungary).

| Country | Case Study | Scale* | Area (Km$^2$) |
|---|---|---|---|
| Belgium | Mapping green infrastructures and their ES in Antwerp | L | 205 |
| Bulgaria | Mapping and assessment of ES in Central Balkan area at multiple scales | L/SN | 2,999 |
| Czechia | Pilot National Assessment of ES | N | 78,000 |
| Finland | Green infrastructure and urban planning in the City of Järvenpää | L | 40 |
| Germany | Mapping ES dynamics in an agricultural landscape | L/SN | 60 |
| Hungary | ES mapping and assessment for developing pro-biodiversity businesses in the Bükk National Park | L | 432 |
| Italy | ES mapping and assessment for urban planning in Trento | L | 156 |
| Latvia | Mapping marine ES in Latvia | N | 28,518 |
| Malta | Assessing and mapping ES in the mosaic landscapes of the Maltese Islands | SN/N | 316 |
| Netherlands | ES-based coastal defense | L | 810 |
| Poland | ES in the biggest 10 Polish urban areas | L/SN | 2-6,000 |
| Portugal (Azores) | BALA - Biodiversity of Arthropods from the Laurisilva of Azores (Terceira island) | SN | 400 |
| Spain | Spanish National Ecosystem Assessment | N | 505,990 |
| Sweden | ES mapping and assessment in the Vindelälven-Juhtatdahka river valley | SN | 13,300 |

Figure 3.

The selected set of case studies of ES mapping and assessment to support policy- and decision-making.

* **Scale: L.** Local; **SN.** Sub-national; **N.** National.

Operationally, for each case study, a principal coordinator, typically a researcher who had been involved in the ES mapping and assessment process, performed analysis of his/her case study using the analytical framework described in the following section and drew key lessons learned from it. A further step consisted of classifying and grouping the lessons learned from all the case studies to outline the key recommendations for enhancing ES mapping and assessment for policy- and decision-making synthesised in this article. Noteworthy, the analysis was built on a previous harmonisation and in-depth analysis of the case studies conducted during five dedicated ESMERALDA project workshops, held in between September 2016 and March 2018. Each workshop lasted four days, including a field visit to a study area, was attended by 60 to 90 participants and provided an opportunity to analyse two to three case studies, amongst other activities (see Fig. 2). The analysis and discussions, held both in plenary and breakout sessions, involved the case study coordinator, at least two stakeholders for each case study and a group of experts from the consortium and were focused on the different stages of the ES mapping and assessment process. Overall, the five workshops were conceived as an interactive process of co-learning that involves project partners and stakeholders, to gain a good understanding of the main challenges in ES mapping and assessment for policy- and decision-making and to refine related methods.

### 2.2 Framework for comparative analysis of case studies

For the analysis, we rely on the "ESMERALDA MAES Explorer"*2, which is a framework and a tool that provides overall guidance explaining the process of how to map and assess ES as required by Action 5 of the EU Biodiversity Strategy to 2020 (Burkhard et al. 2018b). To this end, the ESMERALDA MAES Explorer is structured according to seven main stages that characterise the ES mapping and assessment process, entitled as follows:

1. What kind of questions do stakeholders have?,
2. Identification of relevant stakeholders,
3. Network creation/Involvement of stakeholders,
4. Mapping and assessment process,
5. Mapping & assessment case study applications,
6. Dissemination and Communication and
7. Implementation.

In this paper, we focus on case studies of mapping and assessment (stage 5) and analyse and compare them according to the six stages (we joined stages 2 and 3) shown in Fig. 4 and described in details hereafter.

#### 2.2.1 What kind of questions do stakeholders have?

For the comparative analysis of the questions addressed in the case studies, we identified nine policy domains ranging from nature conservation to marine policy, to health (See Fig. 4). Those nine domains were selected because they were considered representative of the main current policy and decision-making challenges in EU. Together, they cover the variety of cross-EU themes relevant for ES, such as the Common Agricultural Policy, Green Infrastructure, Natura2000 network, forestry strategy, water policy, energy, business and industry sectors and health. Moreover, they encompass the variety of policy and planning processes that can be used to mainstream ES in real-life decisions, such as spatial and land use planning, water resource management, climate adaptation planning, energy policy, strategic environmental assessment and protected area planning.

| Stages of ES mapping assessment process | Description |
|---|---|
| What kind of questions do stakeholders have? | **1. Domains and themes** |
| | (a) Nature Conservation |
| | (b) Climate, Water and Energy |
| | (c) Marine and Maritime Policy |
| | (d) Natural Risk |
| | (e) Urban and Spatial Planning |
| | (f) Green Infrastructure |
| | (g) Agriculture and Forestry |
| | (h) Business, Industry and Tourism |
| | (i) Health |
| Identification of relevant stakeholders and network creation and involvement | **2. Categories of stakeholders** |
| | (a) Competent authorities |
| | (b) Other experts |
| | (c) Business |
| | (d) General Public |
| | **3. Level of involvement** |
| | (a) Inform |
| | (b) Consult |
| | (c) Involve |
| | (d) Collaborate / Partnership |
| | (e) Empower |
| Mapping and assessment process | **4a. Ecosystem types** |
| | (a) Urban |
| | (b) Cropland |
| | (c) Grassland |
| | (d) Woodland and forest |
| | (e) Heathland and shrub |
| | (f) Sparsely vegetated land |
| | (g) Wetlands |
| | (h) Rivers and lakes |
| | (i) Marine inlets and transitional waters |
| | (j) Coastal |
| | (k) Shelf |
| | **4b. Ecosystem conditions assessment** |
| | Yes (How?) |
| | No |
| | **4c. Selection of ES** |
| | (a) Scientist-driven |
| | (b) Stakeholders'-driven |
| | **4d. Selected ES & Applied method** |
| | (a) Biophysical methods |
| | (b) Economic methods |
| | (c) Socio-cultural methods |
| Dissemination and communication (D&C) | **5. Target of the D&C activities** |
| | (a) Scientific publication |
| | (b) D&C to Competent Authorities |
| | (c) D&C to General Public |
| Implementation | **6. Increasing level of Impact** |
| | (a) People aware of, understand and discuss ES |
| | (b) Stakeholders focus on ES and articulate different positions |
| | (c) Alternative choices based on ES mapping and assessment |
| | (d) Plans & policies consider ES mapping and assessment |
| | (e) New policy and finance mechanism established |

Figure 4.

The framework used to analyse the case studies.

## 2.2.2 Identification of relevant stakeholders and network creation and involvement

According to the most accepted definition in the participatory literature, a stakeholder in a decision-making process is defined as someone who may either influence or be influenced by the decision (Reed et al. 2009). In a participatory process, stakeholders have the opportunity to engage in decision-making and express their views to be incorporated into the decisions. In particular, the importance of stakeholder involvement in the assessment of ecosystems and their services is widely emphasised (including by international initiatives, such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services IPBES*3 and EU MAES), highlighting that such involvement promotes the policy uptake of the ES concept and is essential for the adoption and implementation of the results of the mapping and assessment (Dick et al. 2018, Drakou et al. 2018). Besides, from an ethical perspective, different actors of society have a fundamental right to participate in issues that affect them. Potential conflicts between individual stakeholders can be more predictable and easier to resolve in a dialogue where participants can express their opinion. By incorporating a diversity of knowledge and values, operational results can be achieved that are more likely to be relevant for the specific situation, as well as legitimate, hence accepted and trusted by many actors, thus significantly increasing their chances of actual implementation (Cash et al. 2003, Clark et al. 2011, Adem Esmail et al. 2017).

Our framework allows gathering information on the type of stakeholders involved in the process (competent authorities for the specific policy area, ES experts and specialists, business sector and general public) and the level of engagement. For the latter, the framework refers to Arnstein's seminal ladder of participation (Arnstein 1969) and recent developments, for example, Lieberherr and Green (2018), Rau et al. (2012). Particularly, it distinguishes between five simplified levels of participation, i.e. Inform, Consult, Involve, Collaborate/Partnership and Empower, representing the "Spectrum of Public Participation" as defined by the International Association for Public Participation (IAP2)*4. In the first level of participation, citizens are informed, but have "no voice". In the second, "consult", stakeholders can also "have voice", for example, through public hearings. However, in both cases, their decision-making power is rather limited. In contrast, on the next levels, "involve" and "collaborate/partnership", citizens receive increasing decision power, up to being able to co-decide (e.g. having authority over a specific plan, programme or subcontracts). Finally, on the highest level of participation, "empower", citizens have full decision rights by gaining "the majority of decision-making seats, or full managerial power" (Arnstein 1969).

### 2.2.3 ES mapping and assessment process

***Assessment of ecosystem condition and selection of ES***

This initial stage of the process includes the identification of ecosystems considered in the study, whether ecosystem condition was assessed together with the ES (and if yes, how) and the selection of the ES to be analysed. Ecosystem condition refers to the "state of the ecosystem", i.e. "the physical, chemical and biological condition of an ecosystem at a particular point in time" (Burkhard et al. 2018a, MAES 2018). Accordingly, ecosystem condition embraces legal concepts (e.g. conservation status under the EU Birds and Habitats Directives, ecological status under the EU Water Framework Directive and environmental status under the EU Marine Strategy Framework Directive), as well as other descriptors related to state, pressures and biodiversity. It is indeed a very important operational concept for assessing trends and setting targets related to the improvement of ecosystem conditions, also in the light of the increasing scientific evidence of the close relationship between biodiversity, favourable ecosystem state and long-term delivery of multiple ES (e.g. IPBES) (MAES 2018). Amongst others, the assessment of the condition of each single ecosystem in the study area is an important step that can provide additional information for the assessment (Burkhard et al. 2018a, Gilliland and Laffoley 2008), including the identification of the ecosystems with critical shortages in the delivery of ES.

***Methods for ES mapping and assessment***

A range of different approaches and methods for mapping and assessment of ES has been tested and explored, which can be applied at various geographical scales and levels of detail and complexity. Tiered approaches have been developed in order to integrate methods and data of these different levels (Weibel et al. 2018). The framework distinguishes between three different types of methods to map and assess ecosystems and their services originating from different scientific domains: biophysical, socio-cultural and economic. Biophysical methods describe how ecosystems contribute to the supply of ES to society through the natural processes and operate on the left side of the "ES cascade", while economic and social methods both reflect on the relative importance and the direct and indirect benefits of ES to people, thus revealing the demand-side corresponding to the right side of the ES cascade (Haines-Young and Potschin 2010). More in detail, biophysical methods rely on quantification of different parameters of biotic and abiotic configurations, which determine the provision of ES (Vihervaara et al. 2018). Socio-cultural methods principally involve measures of individual and collective benefits (e.g. to health and safety) and preferences, demonstrating the multi-dimensional nature of human well-being to support the implementation and further development of the ES concept (Santos-Martín et al. 2018). Economic methods involve quantification of the economic value of ES, including its spatial variation and structuring this information to support decision-making and the design of policy instruments (Brander et al. 2018).

Yet, there is not always a clear distinction between methods and different types of methods are often linked or combined (Vihervaara et al. 2019). By "linked", we here refer to situations where the output of one method is used as input for another method. For example, the biophysical assessment of carbon sequestration can be used as input to estimate the associated economic value. By "combined", we refer to situations where the outcomes of different ES assessments are integrated. For example, an overall ES index can be generated by aggregating the assessment of individual ES.

### 2.2.4 Dissemination and communication

An appropriate and efficient dissemination and communication of (often complex) scientific findings to potential users from policy- and decision-making is at the core of every successful science-policy-society interface. This includes a rigorous plan for dissemination and exploitation of results, based on strong stakeholder engagement and networking. Operationally, for the comparative analysis of the case studies, three main types of Dissemination and Communication can be distinguished, based on the targeted audience: communications targeting specialised audiences (e.g. through scientific publications and presentations in conferences), competent authorities (e.g. through policy briefs, reports and meetings) and the public in general (e.g. through newspaper articles, social media and documentaries) (see Fig. 4).

### 2.2.5 Implementation

In Fig. 4, five different levels of impact were considered in order to compare the degree of implementation of the ES mapping and assessment results in the case studies, building on the framework proposed by Ruckelshaus et al. (2015). In the first level, people are aware of, understand and discuss ES. In the second level, stakeholders focus on specific ES and articulate different positions. The third level of impact is achieved when alternatives to address a specific decision problem are formulated, based on ES mapping and assessment. In the fourth level, considerations of ES mapping and assessment are included into actual plans and policies. Finally, the highest level of impact is achieved, for example, when new policies and finance mechanisms are established, based on ES mapping and assessment. Accordingly, each case study coordinator assigned the level of impact that best represented the specific situation in the case study.

## 3. Results

### 3.1 What kind of questions do stakeholders have?

The selected case studies covered a large variety of themes (see Fig. 5). Most of the cases were either policy-orientated or gave suggestions for policy implementation in different contexts, including urban, rural and natural areas. All the case studies addressed more than one theme, highlighting the potential for multi-functionality. In particular, about half of the 14 case studies combined nature conservation issues with green infrastructure in urban areas, attempting to establish a win-win situation between green infrastructure and environmental or biodiversity issues (e.g. Finland; Tiitu et al. 2018). Rural case studies, on the other hand, generally dealt with issues on larger scales. The German case, for instance, investigated how the land cover pattern in an area could stay rather constant, regardless of significant changes in agricultural land use. The Swedish case analysed the indigenous Sámi groups who keep on following their local natural and cultural identity, combining natural and social aspects of economy and education to improve human livelihoods and the equitable sharing of goods and benefits from natural and managed ecosystems. The case studies that focused on nature areas gave examples of how protecting nature and ES could improve the local economy, social welfare and risk protection or used economic valuation to illustrate the importance of ecosystem services for society. The Hungarian case, for instance, showed how the natural heritage of protected areas can serve as an economic development factor in supporting local development, based on awareness raising and sustainable management (Volles et al. 2019). Finally, even case studies that were more science-orientated still provided support to the local administrations, for instance, via supporting the design and assessment of alternative planning actions ensuring that impacts on ES are included and providing information about decisions aimed at their equal provision for all citizens.

| Case Study | EU-relevant Policy Domains | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Nature Conservation | Climate, Water, Energy | Marine and Maritime Policy | Natural Risks | Urban and Spatial Planning | Green Infrastructure | Agriculture and Forestry | Business, Industry and Tourism | Health |
| Belgium | | X | | X | X | X | | | |
| Bulgaria | X | | | X | X | X | X | X | |
| Czechia | X | | | X | | | | | |
| Finland | X | | | | X | X | | | X |
| Germany | | X | | | | | X | | |
| Hungary | X | | | | | | X | X | |
| Italy | | X | | | X | X | | | X |
| Latvia | X | X | X | | X | | | X | |
| Malta | | | | | | X | X | | |
| Netherlands | X | X | | X | | X | X | X | |
| Poland | X | X | | X | X | X | X | X | |
| Portugal (Azores) | X | | | | | X | X | | |
| Spain | X | | | | | | | | |
| Sweden | X | | | | X | X | X | X | |

Figure 5.

An overview of the policy domains (themes) addressed in the selected case studies.

## 3.2 Identification of relevant stakeholders and network creation and involvement

Different categories of stakeholders were involved in the ES mapping and assessment processes. Fig. 6 presents an overview of the categories of stakeholders involved: competent authorities (for instance, decision-makers and people working for governmental agencies), experts other than those directly conducting the investigation, people from the business sector and the public in general. The level of involvement varied from consultation and request for stakeholder opinions to a level of collaboration in which decision-making power is shared and understanding, commitment and responsibilities are mutual. Taken together, the case studies included all identified types of stakeholders on all levels of involvement.

| Case Study | Involved stakeholders | | | | Level of involvement | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Competent authorities | Other experts | Business sector | General Public | Inform | Consult | Involve | Collaborate | Empower |
| Belgium | X | X | | | | | X | X | |
| Bulgaria | X | X | | | X | X | X | X | |
| Czechia | X | | | | X | | | X | |
| Finland | X | X | | X | X | X | X | X | |
| Germany | X | | | X | X | | | | |
| Hungary | X | X | X | X | X | X | X | X | |
| Italy | X | X | | | X | X | X | X | |
| Latvia | X | X | X | X | X | X | X | X | X |
| Malta | X | X | | | X | X | | | |
| Netherlands | X | X | X | | X | X | X | X | |
| Poland | X | | | | X | X | | | |
| Portugal (Azores) | X | X | X | | X | X | | X | |
| Spain | X | X | X | X | X | X | X | | |
| Sweden | X | X | | | X | X | X | | |

Figure 6.

An overview of the categories of stakeholders and their level of involvement in the ES mapping and assessment process in the case studies.

## 3.3 ES mapping and assessment process

### 3.3.1 Assessment of ecosystem conditions

Fig. 7 provides an overview of what ecosystem types, ecosystem conditions and ES were examined (or not) in the fourteen case studies. The first part of the table shows the ecosystem types identified in the study areas. The fourteen case studies covered all ecosystem types previously identified, with grassland and woodland and forest being the most commonly assessed ones (present in 11 cases) and marine ecosystems being the least covered (in four case studies only). Fig. 7 also specifies whether the condition of the identified ecosystems was assessed. In twelve cases, the assessment of ecosystem condition was carried out explicitly in nine and implicitly in three. The last columns provide an overview of the identification and selection of the ES, specifying the type of ES classification adopted in the case studies. Noteworthy, in all the case studies, the selection of ES was driven mainly by scientists, with only six cases actively involving stakeholders as well. More specifically, table S1 in Suppl. material 1, details how the assessment of ecosystem condition was actually carried out, specifying the applied data and/or method (e.g. Art. 17 assessment under the Habitats Directive (HD), WFD assessment, MSFD assessment, data including air pollutant concentration, habitat connectivity, land use change, soil degradation), as well as reporting some exemplary indicators that were used.

| | Ecosystem type* | | | | | | | | | | | Ecosystem Conditions | Selection of ES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Case Study | a | b | c | d | r | f | g | h | i | j | k | Assessed | Scientist-driven | Stakeholders-driven | Classification** |
| Belgium | X | | X | X | | | X | | | | | Yes | X | X | CICES 4.3 |
| Bulgaria | X | X | X | X | X | X | | X | | | | Yes | X | | CICES 4.3 |
| Czechia | X | X | X | X | X | X | X | X | | | | No | X | | MA (2005) |
| Finland | X | X | X | X | | X | | X | | | | Yes (indirectly) | X | X | CICES 4.3 |
| Germany | | X | X | X | | | | X | | | | Yes | X | | "KIEL" |
| Hungary | X | X | X | X | X | | X | | | | | Yes | X | X | CICES V5.1 |
| Italy | X | | | | | | | | | | | Yes (indirectly) | X | X | |
| Latvia | | | | | | | | | X | X | X | Yes | X | | CICES 4.3 |
| Malta | X | X | X | X | X | X | X | | | X | | Yes (indirectly) | X | | CICES 4.3 |
| Netherlands | | X | | | | | X | X | X | X | | No | X | X | MA (2005) |
| Poland | X | X | X | X | | X | X | X | | | | Yes | X | | CICES 4.3 |
| Portugal (Azores) | | X | X | X | X | X | | | | | | Yes | X | | CICES 4.3 |
| Spain | X | X | X | X | X | X | X | X | X | X | | Yes | X | | MA (2005) |
| Sweden | | | X | X | X | X | X | X | X | X | | Yes | X | X | CICES 4.3 |

Figure 7.

An overview of ecosystems condition assessment and ES selection in the fourteen case studies.

* **ECOSYSTEM TYPES:** **a.** Urban; **b.** Cropland; **c.** Grassland; **d.** Woodland & forest; **e.** Heathland and shrub; **f.** Sparsely-vegetated land; **g.** Wetlands; **h.** Rivers and lakes; **i.** Marine inlets and transitional waters; **j.** Coastal; **k.** Shelf.

**ES CLASSIFICATION: CICES 4.3** and **5.1.** Common International Classification of ES (version 4.3 and 5.1); **MA.** Millennium Ecosystem Assessment; **KIEL.** Kiel own classification of ES.

### 3.3.2 Methods applied for ES mapping and assessment

An overview of the methods that were applied to map and assess selected ES is given in Fig. 8. Specifically, 29 illustrative ES and related mapping and assessment methods were reported. The mapped ES are almost equally distributed amongst the three main CICES categories: provisioning (9), regulating (10) and cultural ES (11). The methods applied in the case studies are mainly biophysical (75.9%), followed by social (17.2%) and economic (6.9%). Noteworthy, eight case studies adopted integrated modelling framework methods, which are counted in the biophysical group, but contain also elements from social and economic methods.

| Case Study | ES | CICES CLASS | APPLIED METHOD* | TYPE |
|---|---|---|---|---|
| Belgium | Filtration/sequestration/storage/accumulation by ecosystems | (2.1.2.1) | Spatial proxy method (expert scoring) | Biophysical |
| | Physical use of land- /seascapes in different environmental settings | (3.1.1.2) | Spatial proxy method (expert scoring) | Biophysical |
| Bulgaria | Surface water for drinking | (1.1.2.1) | Process-based models (swat) | Biophysical |
| | Aesthetics | (3.1.2.5) | Photo elicitation surveys | Social |
| Czechia | Surface water for drinking | (1.1.2.1) | Value (benefit) transfer | Economical |
| | Global climate regulation by reduction of greenhouse gas concentrations | (2.3.5.1) | Integrated modeling frameworks (invest) | Biophysical |
| | Entertainment | (3.1.2.4) | Integrated modeling frameworks (estimap) | Biophysical |
| Finland | Educational | (3.1.2.2) | Participatory GIS | Social |
| | *Multiple ES* | *Multiple ES* | Integrated modelling framework (spatial multi-criteria decision analysis) | Biophysical |
| Germany | Plant-based [energy] resources | (1.3.1.1) | Spatial proxy methods | Biophysical |
| | Buffering and attenuation of mass flows | (2.2.1.2) | Integrated modeling frameworks (Giscame) | Biophysical |
| | Educational | (3.1.2.2) | Narrative assessment | Social |
| Hungary | Animals reared to provide nutrition, fibres and other materials | (1.1.1.2, 1.2.1.2) | Spatial proxy methods (rule-based matrix model) | Biophysical |
| | Touristic attractiveness of nature | (3.1.1.1, 3.1.1.2) | Spatial proxy methods (rule-based matrix model) | Biophysical |
| Italy | Micro and regional climate regulation | (2.3.5.2) | Process-based models | Biophysical |
| | Physical use of land- /seascapes in different environmental settings | (3.1.1.2) | Integrated modeling frameworks (ESTIMAP recreation model) | Biophysical |
| Latvia | Wild plants, algae and their outputs | (1.1.1.3) | Spatial proxy methods | Biophysical |
| | Maintaining nursery populations and habitats | (2.3.1.2) | Spatial proxy methods (spreadsheet method) | Biophysical |
| | Experiential interactions + Physical use of landscapes /seascapes in different environmental settings | (3.1.1.1+3.1.1.2) | Integrated modeling frameworks (Multi-criteria ES assessment model) | Biophysical |
| Malta | Reared animals and their outputs | (1.1.1.2) | Preference assessment | Social |
| | Pollination and seed dispersal | (2.3.1.1) | Spatial proxy methods + field data | Biophysical |
| Poland | Filtration/sequestration/ storage/accumulation by ecosystems | (2.1.2.1) | Spatial proxy methods | Biophysical |
| | Physical use of land / seascapes in different environmental settings | (3.1.1.2 ) | Spatial proxy methods | Biophysical |
| Portugal (Azores) | Pollination and seed dispersal | (2.3.1.1) | Macro-ecological models | Biophysical |
| | Maintaining nursery populations and habitats | (2.3.1.2) | Macro-ecological models | Biophysical |
| Spain | Cultivated crop | (1.1.1.1) | Market price methods | Economical |
| | Surface water for drinking | (1.1.2.1) | Integrated modeling frameworks (invest) | Biophysical |
| Sweden | Reared animals and their outputs | (1.1.1.2) | Participatory GIS | Social |
| | Experiential (physical) use of plants, animals and landscapes | (3.1.1.1 & 3.1.1.2) | Integrated modelling framework (integrated monitoring data gam-modelling framework) | Biophysical |

Figure 8.

An overview of selected ES analysed in the case studies and related methods (B: Biophysical, S: Social, E: Economical). The methods are described in the ESMERALDA MAES Explorer*2

In almost all of the case studies, the methods and related results were linked or combined with each other, although for different purposes and premises. For example, in the Bulgarian case, the results of different ES assessments were combined by normalisation to a common qualitative scale. Similarly, in Finland, Italy and Latvia, multicriteria analysis was used to spatially combine the results of the ES assessments obtained by applying a range of different methods. In the Belgian case study, an interactive web-tool was developed in collaboration with the city administration to summarise expert-based assessments and possible green measures.

### 3.4 Dissemination and communication

Fig. 9 provides an overview of the dissemination and communication of the ES mapping and assessment results to different categories of stakeholders. In most of the case studies, the results were published in scientific articles (78.9%) and/or disseminated and communicated to competent authorities, such as decision-makers, people working in agencies etc. (92.9%). On the other hand, in less than half of the cases (42.9%), results were disseminated and communicated by targeting the public in general. Indeed, the fourteen case studies show different degrees of dissemination and communication of the results.

| Case Studies | Dissemination and communication activities | | |
|---|---|---|---|
| | Scientific publication | D&C to competent authorities | D&C to general public |
| Belgium | | X | X |
| Bulgaria | X | X | |
| Czechia | X | X | |
| Finland | X | X | X |
| Germany | X | | |
| Hungary | | X | X |
| Italy | X | X | |
| Latvia | X | X | |
| Malta | X | X | X |
| Netherlands | X | X | |
| Poland | X | X | (Partially yes) |
| Portugal (Azores) | X | X | |
| Spain | X | X | X |
| Sweden | | X | (Partially yes) |

Figure 9.

An overview of the Dissemination and communication activities in the selected case studies.

## 3.5 Implementation

Fig. 10 indicates the level of impact on policy and decisions of the case studies, assuming that the level of impact is indicative of the level of implementation of the ES mapping and assessment results. The level of impact was evaluated ex-post by the case study coordinators using a scale adapted from Ruckelshaus et al. (2015). Indeed, some of the case studies represent good working examples of the implementation of ES mapping and assessment in different policy- and decision-making contexts. As illustrated in detail in Cortinovis and Geneletti (2018), the Italian case study, dealing with ES mapping and assessment for urban planning in Trento, is a good working example. Initially scientifically driven, the aim of the study gradually shifted towards producing relevant knowledge to support the local administration in drafting the new Urban Plan for the city of Trento. Amongst others, the study produced a spatial analysis of key urban ES and tested the use of this information to prioritise brownfields redevelopment, by comparing the benefits of alternative greening scenarios. The continuous interaction with stakeholders in the public administration during the process of ES mapping and assessment facilitated the consideration of the results into ongoing urban planning processes. Another example is the case study from Latvia, which took place within the development of the national Maritime Spatial Plan (MSP) for Latvian territorial waters and Exclusive Economic Zone, described in detail in Veidemane et al. (2017). In this case, the results were used to assess the possible impacts of different sea-use scenarios and to identify the optimum sea-use solution from ecological and socio-economic perspectives, including suitable areas for locations of new uses - offshore wind farms and marine aquaculture farms. Moreover, the results are included in the strategic environmental assessment (SEA) of the proposed MSP solutions.

| Case Studies | Increasing Level of Impact | | | | |
|---|---|---|---|---|---|
| | (i) People aware of, understand and discuss ES | (ii) Stakeholders focus on ES and articulate different positions | (iii) Alternative choices based on ES mapping and assessment | (iv) Plans & policies consider ES mapping and assessment | (v) New policy and finance mechanism established |
| Belgium | X | X | X | X | X |
| Bulgaria | | X | X | | X |
| Czechia | | | | X | |
| Finland | X | X | X | X | |
| Germany | | | | | |
| Hungary | X | X | X | | |
| Italy | X | X | X | X | |
| Latvia | | | X | X | |
| Malta | X | X | | | |
| Netherlands | | | | | |
| Poland | | | | X | |
| Portugal (Azores) | | X | | X | |
| Spain | | | X | X | |
| Sweden | | | X | X | |

Figure 10.

An overview of the impact on policies and decisions of the ES mapping and assessment process in the case studies (based on the evaluation by the coordinators).

# 4. Lessons learned and recommendations

## 4.1 What kind of questions do stakeholders have?

Policy-makers increasingly acknowledge ES as an important concept in supporting decision-making, due to its holistic understanding of interactions between nature and humans and its ability to reveal synergies and trade-offs between environmental and socio-economic goals. ES provide a comprehensive framework for trade-off analysis, addressing compromises between competing land uses and assisting to facilitate planning and development decisions across sectors, scales and administrative boundaries (Fürst et al. 2017). The application of the ES concept is strongly related to implementation of other related policies, including water, marine, climate, biodiversity, agriculture and forestry, as well as regional development (Maes et al. 2016). In the framework of ESMERALDA, for example, a list of relevant questions from policy, society and business that drive ecosystem assessments in the context of the EU Biodiversity Strategy has been finalised (see Maes et al. 2018). Indeed, ES mapping and assessment results can support sustainable management of natural resources, environmental protection, spatial planning and landscape planning; and can be applied to the development of nature-based solutions and environmental education.

In practice, the ES concept can be included within the impact assessment procedures (e.g. Strategic Environmental Assessment of plans and programmes and Environmental Impact Assessments of projects), thus extending the scope of impact assessment from purely environmental considerations to other dimensions of human well-being. The potential contribution of ES information to impact assessment has been described in Geneletti (2011), Geneletti (2016a), Geneletti (2016b). Briefly, ES mapping and assessment can improve the overall outcome of actions, reduce the likelihood of plan or project delays due to unforeseen impacts and reduce reputational risk to public authorities and developers from unintended social impacts. Mapping and assessment of ES can be used in all stages of impact assessment, including scoping (to indicate ES on which action depends as well as the ESit affects), consultations (helping to focus debate and engagement of stakeholders), assessing impacts and trade-offs of development alternatives, as well as proposing mitigation measures (Geneletti and Mandle 2018). Furthermore, the use of the ES concept in spatial planning provides greater opportunities to integrate environmental considerations into decision-making on land use change or management at strategic and practical levels.

Both the agricultural and forestry sector bear high potential for applying the ES concept, for instance, to increase synergies of recreation and carbon sequestration with timber production in forests or pollination and biological control in agricultural environments. These sectors are inextricably linked with the supply of ES and, at the same time, are dependent on supply of other ES (e.g. pollination, pest and disease control, maintaining of soil fertility). At the same time, both sectors have direct impacts on ecosystem condition and the supply of other ES (e.g. maintaining habitats, chemical condition of freshwaters, global climate regulation). The level of supply of these ES and the impacts produced directly depend on the applied management practice. Thus, results of ES mapping and assessment can be used to address the trade-offs within and between sectors, to target policy objectives and required measures for improving ES supply and related payment schemes. Application of ES in spatial planning and policy-making through scenario development, modelling of impacts and trade-off analyses can provide added value by synthesising and organising knowledge from various datasets, as well as facilitate cross-scale and cross-sector planning, thus contributing to integrative resource management (Adem Esmail and Geneletti 2017, Geneletti et al. 2018b, Mandle et al. 2015). Nevertheless, there is still a need to develop guidance and criteria on how to apply ES within different planning contexts, as well as through the decision-making process (Fürst et al. 2017). An attempt in this direction has been made recently by the the European Commission, publishing a guidance document to help planners, policy-makers and businesses solve socio-economic challenges, while also protecting and restoring Europe's nature (European Commission 2019). Furthermore, integration of various ES mapping and assessment methods and tools is required to address the complexity of socio-ecological systems and support the decision-making process across different scales and sectors.

## 4.2 Identification of relevant stakeholders and network creation and involvement

The first step in the identification of stakeholders is to identify the focal issue that influences the range of stakeholders to be included and their basic interests. Therefore, a good identification of the relevant policy, societal or business questions is an important starting point of the assessment (Rosenthal et al. 2014). The most obvious stakeholders can usually be easily identified after that. The less obvious stakeholders can be further identified by, for example, media and document analysis, focus group discussions and key-informant interviews or by performing social network analysis. A national or regional, active network on ES, biodiversity or natural capital formed by scientists, policy-makers and practitioners can considerably enhance the successful implementation of ES mapping and assessment at national and regional level. However, this requires significant existing understanding and application of the ES concept across the science-policy interface, which were not always established in the case studies.

The case studies highlighted the importance of starting stakeholder dialogue early in the process, which can generate interest and confidence in the project and increase the willingness to cooperate. It is also suggested to provide comprehensive information that enables stakeholders to have a good overview of the goals of the project and related activities. Goals and activities, however, have to be flexible and adaptive enough, so that stakeholder needs and requirements can be taken into consideration in an iterative process. By this, the co-creation of new knowledge becomes possible, facilitating uptake and promoting ownership by key stakeholders (Dick et al. 2018). Dialogues not only need to be started early, but also must be maintained all through the process, establishing, if possible, a permanent network or platform for experts. This platform allows better cooperation between stakeholders, which ideally lasts even after the ES assessment has been finished, promoting sustainability of the results. In the case of Belgium, for example, a tool was developed in an iterative process with the stakeholders. After the project, the tool was used to benchmark sites owned by city authorities and support management plans and it was made mandatory in some large urban development plans to ensure that spatial planners take into account environmental challenges and livability.

Furthermore, the lessons learned emphasized the importance of targeted discussion groups on the one hand and comprehension on the other, involving all relevant stakeholders and their diverse views (García-Nieto et al. 2015). In particular, the involvement of local authorities and public institutions was emphasised as they can play significant roles as cooperating partners. Mutual understanding of the ES concept can strengthen cooperation with authorities and institutions, therefore sufficient time and effort must be taken in the communication of recent scientific results. In addition, important groups to work with are sectoral representatives and the representatives of local citizens, especially for the assessment of locally-relevant cultural ES. From all stakeholder groups, it is suggested to involve key individuals such as "bridge people" (or knowledge brokers) who have connections to many local actors and are able to represent their views or have a high ability to influence decisions or information flows. In Hungary, such key people were identified using the Social Network Analysis tool (SNA) and involved in a participatory discussion on how to increase pro-biodiversity business opportunities and engage public and private actors in capacity-building, networking and know-how transfer (Volles et al. 2019).

Involvement of the public is evenly important but requires different ways of dissemination, for instance, social media, schools, NGOs and social movements, building on the growing impact of ES studies on raising public awareness. In the case of Sweden, for example, the stakeholder input benefitted from an ongoing process within the UNESCO biosphere reserve, covering the case study area, with emphasis on the land use and cultural expression of the indigenous Sámi people and their traditional reindeer (*Rangifer tardanus*) husbandry (Gardeström 2018).

## 4.3 ES mapping and assessment process

### 4.3.1 Identification of ecosystem types

Developing an appropriate typology of ecosystem types that is consistent with existing national, EU and/or international typologies is a key first step to initiate ES mapping and assessment. In the context of mapping and assessment carried out to be compliant with the EU Biodiversity Strategy, in particular, such typologies need to be in line with the European ecosystem map developed by the European Environmental Agency (European Environmental Agency 2015) and the MAES definitions of ecosystem types at level 2. This level of detail should be the basis for further, compatible refinements, which depend on the goal of the study and its spatial extension, amongst others. In most cases, it will be suitable to refine the level 2 ecosystem types provided by the EEA to a third level with ecosystem types relevant in the study area. This refinement can be carried out on the basis of supplementary data sources like CORINE land cover maps*5, habitat maps (e.g. in the EUNIS typology*6), the EU urban atlas, remote sensing data (e.g. satellite images from the Copernicus programme) or topographic databases provided by local authorities (Vačkář et al. 2018). An example of combining various data sources is the Consolidated Layer of Ecosystems composed for the national assessment process in the Czechia (Vačkář et al. 2018).

Studies dealing with green and blue infrastructure in an urban planning context require high-resolution maps created using high-resolution remote sensing data, such as aerial photographs and thematic data provided by the municipalities (e.g. in the Finnish case study). In the case of islands with complex orography and rapid changes in the local environment (e.g. many islands in the EU overseas territories; Sieber et al. 2018), a small-scale map of ecosystem types is needed, including detailed land use, key environmental and high-resolution satellite data (Gil et al. 2017). Again, the definition of marine and coastal ecosystem types should reflect the multidimensional character of these and be consistent with relevant classification systems, such as EUNIS or specific classifications for marine regions. For example, in the Latvian case study, the HELCOM HUB classification of the Baltic Sea (HELCOM-VASAB MSP WG 2015) was applied to identify and map the marine habitat types using, as a basis, marine geology and bathymetry maps, as well as field survey results.

Besides the general consistency with existing typologies and an appropriate level of detail, the typology should reflect the relevant ecosystem types frequently present in the study area, as well as address priority habitats according to European, national and regional schemes. Therefore, the close interaction of experts and the co-identification of relevant ecosystem types together with stakeholders is useful. This procedure allows the creation of a common understanding of the typology, which can assist in the following ES mapping and assessment process. The identification of relevant ecosystem types is a time-consuming, but critical process, in ES mapping and assessment. Thus, enough time should be allocated for this step. To benefit of the work carried out, the developed method to create the typology should allow future continuation, based on changed input data and thereby time-series analysis, while possibly being reproducible in other study areas.

### 4.3.2 Assessment of ecosystem condition

Generally, the 14 ESMERALDA case studies highlight the need for concise and precise indicators for different ecosystem types relevant for the study area, possibly defined by involving stakeholders and using local knowledge. In particular, indicators on ecosystem condition must:

1. be relevant for the targeted ecosystems,
2. be understandable and widely accepted amongst the involved stakeholders,
3. have the ability to express information and
4. be temporally explicit to allow the analysis of trends in time.

Indeed, the availability of relevant data sources is crucial for a robust assessment. In this regard, the second (MAES 2014) and the fifth MAES reports (MAES 2018) list additional indicators and Europe-wide data sources that could be taken into account. The assessment of ecosystem condition can build on existing data sources like the Habitats Directive reporting data (Article 17 reporting)*7, data obtained for the Birds Directive (Article 12 reporting) and assessment of the environmental status of marine waters according to the requirements of the Marine Strategy Framework Directive, amongst others. Furthermore, indirect methods for the assessment can incorporate the structural analysis of soil cover, tree coverage, information on management and an analysis of landscape indicators, based on the composition and configuration of patches. In the urban case studies, for example, data for pollution, noise and flood risk can be used for assessments on smaller scales. In hinterland areas, such as the westernmost part of the Swedish case study, natural resources, extensive wilderness and high conservation values are emphasised (Jonsson et al. 2019, Svensson et al. 2018). As a final note, to allow time-series analysis, data recorded in systematic monitoring schemes should be used and, if not existing, long-term monitoring schemes on parameters needed for the assessment of ecosystem condition should be developed.

### 4.3.3 Selecting ecosystem services

The selection of ES should follow the identified policy, societal or business questions relevant for the study area. In this regard, the analysed case studies underpin the relevance of the involvement of stakeholders and local experts in the selection process. This ensures the relevance of the selected ES for stakeholders, policy- and decision-making and the study area and, at the same time, it may require some capacity-building activities to foster an active involvement of stakeholders involved in the selection process (Rosenthal et al. 2014). As a rule of thumb, the selection should cover the common ES categories (provisioning, regulating and cultural ES), in order to enable the analysis of trade-offs, synergies and interactions amongst the different ES. Therefore, a context-specific selection of ES that are, for example, sensitive to identified pressures is needed. For instance, the indigenous Sámi people in Sweden with their long-lasting, traditional land use, have contributed specific cultural ES to the landscape (Blicharska et al. 2017). Furthermore, even when not required by specific assessment purposes, such as ES accounting, linking the selected ES to common classifications, for example, CICES*8 (Haines-Young and Potschin-Young 2018) or the Millennium Ecosystem Assessment MA (Millennium Ecosystem Assessment) 2005, can be a useful entry point to retrieve scientific information, data and similar case studies. Nevertheless, the selection of ES can be impacted by availability of data, resources and knowledge, to carry out the appropriate assessment. This aspect is particularly important in the case of marine ecosystems, where ES assessment is often hampered by data scarcity, as well as poor understanding of the quantitative relationships amongst the structures, processes, functions and ES (Rivero and Villasante 2016).

### 4.3.4 Methods for ES mapping and assessment

In general, it was found that the integration of methods and results is essential for providing a comprehensive overview integrating different perspectives (e.g. social, economic). For example, focusing on social methods alone may underestimate the value of some more ‘unknown’ ES, such as water purification or infiltration. On the other hand, focusing on biophysical methods only would overlook some important intangible values or conflicts between ES. The development of a simple illustration (e.g. in the form of a flow diagram) presenting the implemented form of integration and its effects in the ES mapping and assessment process, is recommended in order to ensure transparency and to increase replicability. The Integrated Ecosystem Service Assessment Framework, developed within ESMERALDA, can provide a useful conceptual framework for designing such individual workflows (Nikolova et al. 2018). Furthermore, it is very important to identify appropriate spatial resolutions and physical units when integrating results from different methods. Using grid cells can be a suitable approach to visualise an assessment of ecosystem services. It allows integrating results from different assessment methods and physical units, as was demonstrated by the Latvian case study (Veidemane et al. 2017). Amongst others, both the spreadsheet method and Multi-Criteria Analysis emerged as suitable methods/techniques for integration, with different levels of complexity. More information could be found in the "ESMERALDA MAES Methods Explorer" *9, a web-based tool for exploring the Database of Methods for ES Mapping and Assessment (Santos-Martin et al. 2018). A great share of analyses aiming for economic valuation (e.g. market price analysis) requires data on social and biophysical aspects. Thus, in these cases, an integration of results was mandatory for the implementation. Generally, the integration of different methods has the potential to increase the credibility of the ES mapping and assessment results. For example, the use of national-scale monitoring data and forests and biodiversity in Sweden (Fridman et al. 2014, Ståhl et al. 2010) clearly provides assessment opportunities, in particular, in combination with spatial modelling.

## 4.4 Dissemination and communication

The interface between science and decision-making in policy, business and society is crucial for evidence-based environmental governance. An appropriate and efficient dissemination and communication of (often complex) scientific findings to potential users from policy- and decision-making is at the core of a successful science-policy-society interface. Connecting ES mapping and assessment-related research and relevant, competent authorities is thus key to ensure effective use of monitoring, research and science in policy-making. This dialogue is needed, as it was found that policy-makers do not always effectively provide information on their needs for scientific knowledge, especially in the spatial planning and land use realm.

Accordingly, in the case of scientists, the results of the ES mapping and assessment should be made available as (open access) publications, the main instrument for a comprehensive exchange of knowledge, in order to support the reproduction of the assessment in other study areas. When it comes to competent authorities, it is important to provide strong arguments by using strong visualisation and inspiring examples, including references to more commonly-known strategies, such as the Sustainable Development Goals (SDGs) and especially human well-being issues including health, security and employment (Wood et al. 2018). For example, informing stakeholders about ES potentials on the background of land use can provide new perspectives on their activities. Generally, it is important to tailor the final message as a possible input for regional and local landscape planning and management strategies or other relevant ongoing processes. Finally, for the public, dissemination and communication should be informative and, at the same time, attractive and easily understandable with an appropriate language. This is especially important for relevant management and assessments on the local scale, where dissemination and communication should serve to share information about the importance of ecosystems for ES delivery and to promote individual choices favouring the sustainable use of ecosystems.

Involvement of stakeholders is an important part of the dissemination and communication process. Wide participation by experts is strongly suggested throughout the process of assessment of ecosystems and their services (Müller et al. 2020, Jacobs et al. 2015). The development of a network that brings together researchers and policy-makers is crucial to favour knowledge exchange and to lead to the co-production of an adaptive approach for ES assessment, which ultimately increases acceptance of the results and supports their further dissemination and implementation (Burkhard et al. 2018b). Particularly, it is important to bring the attention of stakeholders and to listen to the needs and contributions of the different actors involved in or dependent on ES, to ensure that the results will be useful to them (Geneletti et al. 2018b, Cord et al. 2017, Zoderer et al. 2019). However, the involvement of stakeholders should not be limited only to the initial stages of the ES mapping and assessment process; rather it is important to keep their involvement throughout the process, for example, by organising feedback workshops with practitioners and stakeholders.

Communicating the complexity of the ES concept in an understandable way is challenging. To start with, scientists should not assume that everyone knows and easily understands ES. Quite often, the ES concept is misunderstood by policy-makers and practitioners, thus there is a need of a targeted communication to “get the concept right” in the first place. Following, the results of an ES assessment may not be comprehensible enough for the public in general; there is, thus, a need to “translate” the results in a way that more people could understand them. A crucial step towards getting the message across is to build capacity of the stakeholders who are often aware of environmental issues in their activities (e.g. spatial planning or other decision-making processes), but rarely use the ES approach as such. In fact, there is the need for training technicians and civil servants – a tailored programme, with different levels of complexity (e.g. starting, advanced), for different stakeholders, to demonstrate the benefits of applying the ES approach and to build institutional capacity. Finally, there is a need for local ‘champions’ that defend and promote the application of ES mapping and assessment (Rosenthal et al. 2014).

## 4.5 Implementation

ES mapping and assessment results have great relevance and potential to support decision-making and action planning. Accordingly, researchers or, generally, anyone conducting ES mapping and assessment studies should be open and proactive for co-operation with decision-makers. When involving decision-makers, it is important to display what potential the results have in showing the consequences of decisions on ES potential and to promote innovation in decision-making processes. In some policy fields, integration of the ES concept is becoming a common practice, for instance, through the principles of the ecosystem-based approach in maritime spatial planning promoted by the the Marine Strategy Framework Directive (2008/56/EC). This was demonstrated in practice by the Latvian case study, which involved ES mapping and assessment as a part of the official national MSP process (Veidemane et al. 2017, Ruskule et al. 2018). Implementing local case studies, for example, can demonstrate the effectiveness of ES mapping and assessment to support policy- and decision-making at the local level, proving its potential for upscaling to regional or national level. For example, in the Hungarian case study, ES maps were used as basis for the preparation of participatory local action plans and development of pro-biodiversity business ideas at the local level. Such exercise can highlight criteria for generating financial returns without compromising the natural environments that can be upscaled to higher level planning.

Bringing together researchers, decision-makers and stakeholders is a crucial step to co-produce credible and relevant results that support policies and decisions for sustainable development (Carlsson et al. 2017). As discussed in the previous section, it is important to develop initiatives to promote knowledge and understanding of the importance of biodiversity, including its effects on human well-being, to promote changes in attitudes toward it, (see, for example, Sandifer et al. (2015)). The development of a more effective science-policy interface that involves a wider community of researchers and decision-makers from various fields is critical for the co-production of new approaches that are suitable for ES assessments. It is also important for the development of a continuous cycle of innovation and improvement, rather than the implementation of ES assessments that are static and carried out only at one point in time. Some operational steps that can promote effective networking and mainstreaming include making an effort to represent results in a spatially-explicit way. For instance, participatory GIS methods that are typically used to obtain knowledge on people's values, opinions and experiences can also be applied to raise awareness and strengthen understanding of the ES concept amongst the public and to gain a quick feedback on identification of the pressures in the selected area (Rall et al. 2019).

The barriers for implementation can be beyond the process of ES mapping and assessment. Lack of data and research-based evidence, often mentioned as key barriers mainly by scientists (e.g. Balzan et al. (2018)), should, however, not be an obstacle for introducing an ES approach in policy- and decision-making. Ways forward include applying a tiered approach and an iterative process (Weibel et al. 2018) and updating the assessment results when better knowledge and data become available. On the other hand, land ownership can be a key barrier, which may limit the implementation of planning actions, based on the results of ES mapping and assessment in a real-life context. Similarly, integrating the results in formal decision-making processes (such as planning) requires understanding the (highly regulated) procedures of the administration.

## 5. Conclusions

The fourteen case studies, presented in this research, provided insights into current experiences with the application of ES mapping and assessment for policy and decision-making, which are still rarely described in peer-reviewed literature. However, the selection of cases that was investigated has some limitations, since the breadth of cases clearly influences the results. To start with, the number of case studies, mainly representing the EU context, cannot be considered representative of the whole set of real-life experiences in which ES mapping and assessment have been used to support policy- and decision-making. The *ex-post* comparative analysis using the analytical tool reflects the views and considerations of the case study coordinators, supported by the group discussion involving stakeholders and other researchers from the ESMERALDA Consortium. In general, the risk of subjective answers and misunderstandings involving questions coming from the analytical tool has been addressed during the five dedicated workshops through careful discussions amongst the case study coordinators concerning the research methodology and the content of the analytical framework itself.

In conclusion, this work highlighted and discussed some of the advantages and challenges in the application of ES mapping and assessment for policy- and decision-making, distilling key recommendations for the main steps of the implementation process. Amongst others, emerging specific recommendations are that, first, ES mapping and assessment studies should focus on the specific policy issues or decision-making challenges. This has an impact on theselection of the ecosystems and services to be assessed, as well as on methods to be applied. Second, stakholders involvement should be ensured through an iterative process to increase awareness and acceptance of the ES mapping and assessment results, as well as to support their implemetation, in particular decision-making contexts. More in general, this paper argues that downscaling the EU objectives to the national level, hence integrating national priorities, is a good strategy to use MAES for addressing national challenges. Again, the importance of demonstrating the benefits of MAES, i.e. what advantages can be derived from its application, also providing good case study examples of application. Last, the use of success stories to communicate how ES mapping and assessment can make a difference in the decision-making process.

Despite the complexity in the process of ES mapping and assessment, including the high diversity of contexts of application, which makes generalisations of findings difficult, the analysis has shown that mapping and assessment of ecosystems and their services have a very high potential to support policy- and decision-making in a wide range of domains in policy, business and society across the EU.

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## Supplementary material

**Suppl. material 1: An overview of the assessment of ecosystem condition in the selected case studies.** doi

**Authors:** Geneletti et al.
**Data type:** Table
**Brief description:** Table S1: An overview of the assessment of ecosystem condition in the selected case studies.
SUPPLEMENTARY FILE TO: Ecosystem services mapping and assessment for policy and decision-making: Lessons learned from a comparative analysis of European case studies (Geneletti et al.).
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## Endnotes

*1 https://biodiversity.europa.eu/maes
*2 http://www.maes-explorer.eu/
*3 https://ipbes.net
*4 https://www.epa.gov/sites/production/files/2015-09/documents/spectrum508.pdf
*5 https://land.copernicus.eu/pan-european/corine-land-cover
*6 https://eunis.eea.europa.eu/habitats-code-browser.jsp
*7 https://ec.europa.eu/environment/nature/knowledge/rep_habitats/index_en.htm
*8 https://cices.eu/
*9 http://database.esmeralda-project.eu/#/home.