USE AND USER REQUIREMENTS OF ECOSYSTEM SERVICE MAPS

ANALYZING DECISION MAKERS NEEDS WITHIN THE CONTEXT OF TARGET 2 (ACTION 5) OF THE EU BIO-DIVERSITY STRATEGY FOR 2020

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September, 2018

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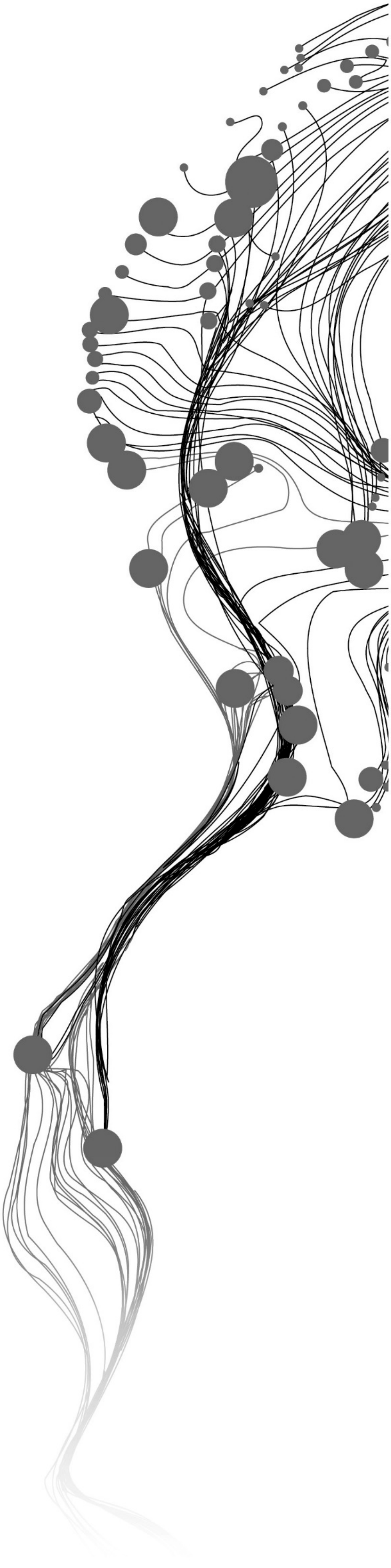

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Enschede, The Netherlands, September, 2018

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-Information Science and Earth Observation.
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ABSTRACT

Mapping ecosystem services presents a key component of the EU Biodiversity Strategy for 2020. Ecosystem service maps aim to inform and support decision- and policy-making by functioning as a bridge between science producing and decision-makers using those maps. Yet, past analysis showed, that the uptake of the provided information by the end-user is very low, which, amongst others, is caused by missing assessment of the users' needs and requirements. This fact highlights the need of exploring the use and user requirements of ecosystem service maps.

This thesis research addresses this issue by proposing and applying exploratory use and user requirement analysis with the intention of deriving user profiles with sample use cases and recommendations for future map design. To achieve this goal mixed user research methods, namely interviews, thinking-aloud and observation were applied. In doing so, both the end-users' and the map-makers' perspectives are taken into consideration, as both play a key role in the cartographic communication process. To derive and compare scale-specific requirements, their aims and intentions at EU-level, national- and sub-national level, with the example of Greece as a case study are assessed. In doing so, this research provides insights into the current mapping processes for the map-makers' perspective, the uses of ecosystem service maps by the users and usability issues of existing ecosystem service maps. Based on those findings user profiles, use scenarios for each administrative level and recommendations for future mapping are derived.

The research explores the intended use purpose by the map-maker and the actual use purpose by the user, concluding that those two perspectives do not strongly differ from each other. Yet, the results indicate, that there are issues in the cartographic communication process. To increase the uptake of ecosystem service maps in decision-making processes, it is recommended to apply cartographic design principles and to increase the communication between map-makers and users by actively involving the user in the map creation process.

Keywords: *Ecosystem services, ecosystem service maps, user requirements, user-centred design*

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LIST OF ABBREVIATIONS

CICES	Common International Classification of Ecosystem Services
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
DG	Directorate General
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
NCP	Nature’s Contributions to People
TEEB	The Economics of Ecosystems and Biodiversity
UCD	user-centred design

1 INTRODUCTION

1.1. Context of research

An ecosystem is "*a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit*" (Mace, Norris, & Fitter, 2012: 19). A distinction between terrestrial, freshwater and marine ecosystems can be made (Maes et al., 2013). In the past 50 years the use of ecosystems by society has changed drastically, driven by increasing demands of the human population, such as the demand for fresh water or food. The majority ecosystems are not being used in a sustainably, thus increasing the pressure on them and resulting in their degradation and loss (Millennium Ecosystem Assessment, 2005). As humans benefit from ecosystems and their well-being is positively impacted by them (TEEB, 2010), mankind draws a number of advantages from preserving and protecting ecosystems. These interactions of human and ecological factors is referred to as social-ecological system (Gallopín, 2006). Ecosystem service measurements should "*capture the consequences of changes in social and ecological factors for multiple services, their benefit flows to different beneficiaries, and corresponding feedbacks*" (Reyers et al., 2013: 268). There are differing definitions of ecosystem services, such as "*the benefits people obtain from ecosystems*" (Millennium Ecosystem Assessment, 2005: 40) or "*the nature's contributions to people*" (Díaz et al., 2018: 270).

The concept of ecosystem services plays a critical key role in making ecosystems and their value more explicit and visible to mankind. In doing so, this concept aims to improve the management and decision-making of natural resources e.g. by capturing how changes of ecological or human factors do impact the social-ecological system (Guerry et al., 2015; Reyers et al., 2013). The function or value of ecosystems can be expressed through variety of indicators such as pollination potential or amount of biomass (Maes et al., 2016). Due to the strong spatial component of ecosystems and human presence, maps are a very frequently chosen means to communicate information about ecosystem services (Drakou et al., 2015; Maes, Egoh, et al., 2012). The medium to display ecosystem service maps are either static (e.g. Ding, Chiabai, Silvestri, & Nunes, 2016; Polce et al., 2016) or online interactive (e.g. Drakou et al., 2015) maps.

In the last two decades the assessment and mapping of ecosystems and their services have gained increasing attention in research (Costanza et al., 2017; Gómez-Baggethun, de Groot, Lomas, & Montes, 2010) and have been included in policy agendas in Europe (European Union 2013). A specific policy application of ecosystem services and ecosystem service maps is the Action 5 under Target 2 of the EU Biodiversity Strategy for 2020 (Maes et al., 2013). This target aims "*to maintain and enhance ecosystems and their services by establishing green infrastructure and restoring at least 15% of degraded ecosystems*" (Maes et al., 2016: 15). The mapping and assessment of ecosystems and their services (MAES) takes place at EU-, national and sub-national level (Maes et al., 2013) This target requires all Member States of the European Union to map and assess their ecosystem services. However, to achieve policy goals like this, the efficiency and usefulness of ecosystem service information and ecosystem service maps must be guaranteed (Maes et al., 2013, 2016). A major challenge accompanying such an international target are different administrative levels of management of ecosystems and their services. On the one hand mapping and assessment of ecosystem services at national, regional or local scale has different requirements than the EU scale. On the other hand, every administrative level includes different users, such as practitioners, decision- or policy-makers who have different uses for ecosystem service maps (Drakou et al., 2017; Hauck et al., 2013).

Within this research, the approach from Gulliksen, Lantz and Boivie (1999) will be applied, defining end-users of ecosystem service maps as people, who use ecosystem service maps to perform tasks within their job.

1.2. Problem statement and research identification

Ecosystem service assessments and maps aim to inform decision-making processes (Guerry et al., 2015). A remaining challenge for ecosystem mapping is the implementation gap between the output of the research and the use in practice (Ruckelshaus et al., 2015; Westgate et al., 2018; Willcock et al., 2016). There is little evidence indicating that the produced ecosystem service maps were used in decision-making or influenced the outcome of a decision-making process (Drakou et al., 2017; Laurans, Rankovic, Billé, Pirard, & Mermet, 2013; Ruckelshaus et al., 2015). While many mapping techniques and frameworks have been developed which claim to support decision-making, the level of acceptance by the end-users (Hauck et al., 2013) or the usability of the output has rarely been assessed. Palomo et al. (2018) identified the lacking understanding and assessment of use and user requirements to be one of the major challenges in the ecosystem service mapping. This is a critical research gap (Hauck et al., 2013; Maes, Egoh, et al., 2012; Willcock et al., 2016), which was addressed by this thesis research.

The hypothesis guiding this thesis research is, that there may be a mismatch between the map-makers intentions and the needs or use purposes of the user. This research addressed the issues discussed above and the research hypothesis by proposing a user-centred design approach to ecosystem service maps, starting at the beginning of the user-centred design cycle (van Elzakker & Ooms, 2018) through the conduction of a use and user requirement analysis.

This analysis did tackle the named problems in various ways. This analysis was conducted at EU, national and sub-national level, with the example of Greece as a case study, to gain insight into the diversity of requirements at different administrative levels. On the one hand, the users, their use intentions and use requirements were explored. On the other hand, this thesis did also focus on the map-makers' perspective and their intended use purpose of ecosystem service maps, in order to identify potential mismatches between the intended and the actual use.

1.3. Research objectives and questions

1.3.1. Research objectives

The main objective of this thesis was to provide a detailed description of the use and user requirements of ecosystem service maps leading to recommendations for future map design. This research focused on the maps for decision makers, that are created under the policy requirements of Action 5 of the Biodiversity Strategy 2020 at EU, national and subnational level. The main objective consists of four sub-objectives and related research questions:

1) Create a profile of the decision makers who use ecosystem service maps at EU, national and sub-national level.
2) Identify the intended map use purposes of the map-maker.
3) Identify usability issues with current ecosystem service maps at EU, national and sub-national level.
4) Derive recommendations for future ecosystem service map design at EU, national and sub-national level.

1.3.2. Research questions

RQ1: What is the profile of the decision makers who use ecosystem service maps at EU, national and sub-national level?

a) What are the characteristics, needs and requirements of decision makers using ecosystem service maps?
b) At which stages of the decision-making process do the decision makers use ecosystem service maps?
c) What purposes do the decision makers use ecosystem service maps for?
d) What are the use contexts of decision makers using ecosystem service maps?

RQ2: What are the intended map use purposes of the map-maker at EU, national and sub-national level?

a) For which purposes are the ecosystem service maps designed by the map-maker?

RQ3: What usability issues with current ecosystem service maps can be identified at EU, national and sub-national level?

a) Do the intended purpose and the actual purpose of ecosystem service maps differ? If yes, how?
b) What map attributes do the decision makers find supportive for decision-making?
c) What types of difficulties are encountered by the decision makers when working with ecosystem service maps?

RQ4: What recommendations for future ecosystem service map design at EU, national and sub-national level can be derived?

a) How do user profiles and use case scenarios at EU, national and sub-national level look like?
b) How do the encountered use and user requirements vary at EU, national and sub-national level?
c) What can be improved in future map design to increase the uptake of ecosystem service maps by decision makers?

1.4. Thesis structure

This thesis is divided into 5 chapters.

- **Chapter 1** provides the context of research and outlines problems, questions and objectives that will be addressed by this research.
- **Chapter 2** aims to provide the scientific background on ecosystem services and ecosystem service maps. Different typologies, definitions and measurement approaches will be discussed, outlining both the complexity and the opportunities of the field. In addition, the cartographic foundations for ecosystem service maps will be presented. This chapter also introduces the users and map-makers of ecosystem service maps, relevant policy requirements and examples of user research in ecosystem service mapping will be presented. The required information for this chapter was gathered through the review of literature.
- **Chapter 3** outlines the methodology applied for this research. The theoretical foundations of UCD and requirement analysis and the implemented research design and steps will be discussed.
- **Chapter 4** presents the results of the conducted user research. Following the order of the formulated research questions, the chapter will firstly analyse the users' perspective and then analyse the map-makers' perspective, usability issues with existing ecosystem service maps and concluding in recommendation for future map design. The outcome of the research will be discussed and together with information from literature. Finally, this chapter discusses its limitations and future research opportunities.
- **Chapter 5** briefly concludes the most relevant findings of the research.

2 SCIENTIFIC BACKGROUND

This chapter provides background knowledge on ecosystems services and their application in decision-making. Chapter 2.1 discusses different definitions of ecosystem services, frameworks which were developed to express their flow and indicators and mapping goals of ecosystem services. Chapter 2.2 focusses on ecosystem service maps, discussing map types and cartographic mapping techniques, spatial levels, relevant policies, the users and map-makers of ecosystem service maps and user research in ecosystem service mapping. Chapter 2.3 briefly summarizes the content of this chapter.

2.1. Ecosystems and ecosystem services

2.1.1. History and definitions of ecosystem services

The history of the term 'ecosystem services' goes back almost 40 years, having its origin in 1981. At that time, the concept was strongly being influenced by economics and for that reason ecosystems and their services were expressed as economic services (Braat & de Groot, 2012). Since then the concept gained further attention from scientific research (Costanza et al., 2017). An important milestone in the history of ecosystem services was the Millennium Ecosystem Assessment (2005), which contributed in making ecosystem services more present in policy agendas. After the Millennium Ecosystem Assessment, the number of publications from different domains such as ecology or economy dealing with ecosystem services grew exponentially (Gómez-Baggethun et al., 2010). Until today many definitions of ecosystem services have been formulated and published. A very frequently cited definition is based on the Millennium Ecosystem Assessment, describing ecosystem services as "*the benefits people obtain from ecosystems*" (Millennium Ecosystem Assessment, 2005: 40). In 2010 a report about the economic of ecosystems and biodiversity defined ecosystem services to be "*the direct and indirect contributions of ecosystems to human well-being*" (TEEB, 2010: 33). The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which is a joint global initiative of governments, society and academia proposed defining ecosystem services as "*nature's contributions to people*" (NCP) (Díaz et al., 2018: 270).

Those definitions include different background assumptions and foci. The Millennium Ecosystem Assessment was mainly an ecological project (Costanza et al., 2017), whereas the TEEB report approaches the ecosystem service concept from an economic perspective for instance by expressing the flow of ecosystem services from nature to society as dividends or by assessing the monetary value of preservation or loss of biodiversity (TEEB, 2010). The NCP-approach emphasizes, that the strong focus on economical aspect fails to include other perspectives, such as those derived from social sciences. NCP sees ecosystem services as an inclusive concept, which takes social sciences into account and puts a strong focus on local, contextual knowledge (Díaz et al., 2018; Pascual et al., 2017). Within this thesis the NCP approach is adapted as working-definition.

2.1.2. Ecosystem service frameworks

Ecosystem services originate from the interrelations of social-ecological systems (Reyers et al., 2013). In the past various frameworks have been developed to model those interactions. A well-known framework is the Cascade model (Haines-Young & Potschin, 2018b). Partly based on the Cascade model, the MAES working group developed a conceptual framework specifically tailored to the assessment of ecosystems and their services within the context of the EU Biodiversity Strategy for 2020. This concept did consider the foci of different Member States, as well as the policy questions that must be addressed by the mapping and assessment of ecosystem services within the European Union. In addition, the MAES model is aligned with existing obligations from legally binding EU Directives which the Member States have to follow (Maes et al., 2016). As this thesis research analyses ecosystem services within the context of the EU Biodiversity Strategy, this conceptual framework will be discussed in more detail.

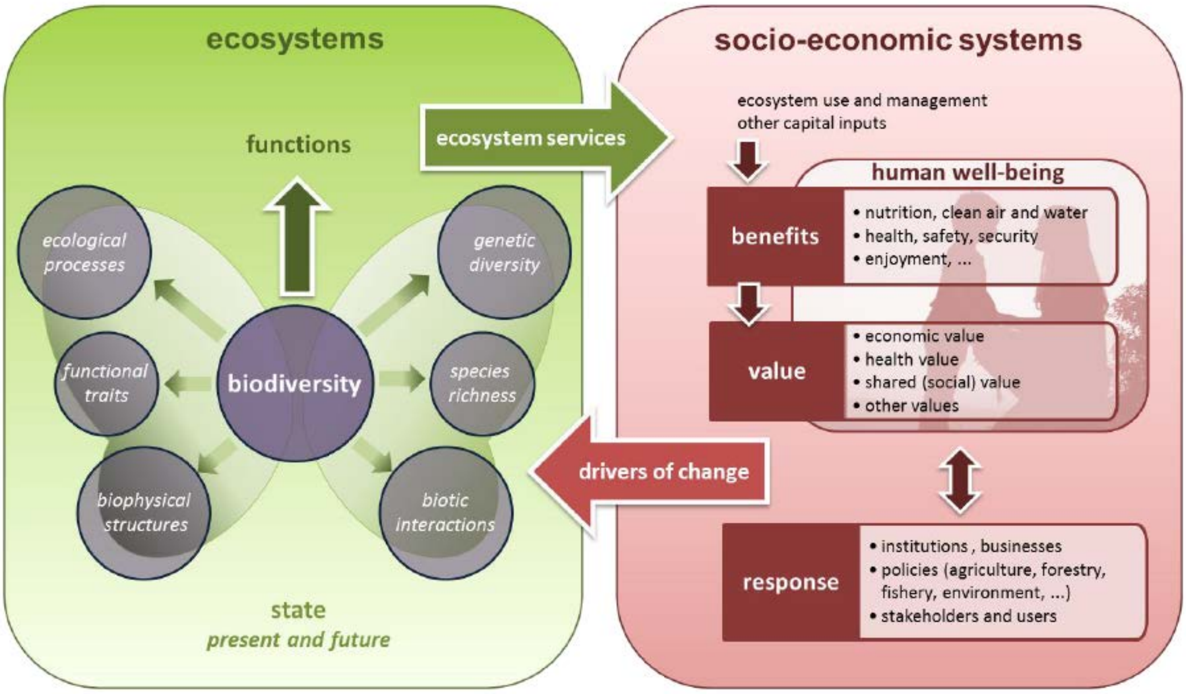


Figure 1: Conceptual framework for assessing ecosystems
(Maes et al., 2013)

Simply put, this framework, which is shown in Figure 1, depicts ecosystem services as the flows from ecosystems to socio-economic systems and socio-economic systems as the drivers of change impacting the ecosystem.

Biodiversity is a key component in a functioning ecosystem. The conceptual framework depicts six elements of biodiversity, which on the one hand contribute to the functioning of ecosystems. The different aspects of biodiversity result in functions of ecosystems are the goods and service provision capacity of ecosystems (de Groot, 1992) and the functions that flow to the socio-economic systems are ecosystem services. Those services contribute to human well-being through their benefits and their values. Benefits obtained from ecosystem could be for example clean water, provision of food or improvement of one's health. The value of those benefits can be measured as monetary value, but in some cases other valuation methods, such as health value, are more appropriate. Another key component of this conceptual framework is how the socio-economic system responds or reacts to ecosystems and the way they affect human well-being. Important actors in this respect are institutions, stakeholders and users or different policies e.g. environmental policies, which directly and indirectly affect ecosystems. These drivers of change may have an impact on the current and future state of the ecosystem (Maes et al., 2013, 2016), which is the "*physical, chemical and biological condition of an ecosystem […] which can also be referred to as its quality*" (Maes et al., 2013: 49).

2.1.3. Ecosystem service typologies

In order to specify and structure the large number of ecosystem services, typologies were required (Costanza et al., 2017). Maes et al. (2013) identified three international typologies for ecosystem services: Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB) and the Common International Classification of Ecosystem Services (CICES). CICES is being used for the mapping and assessment of ecosystems and their services within the implementation of the EU Biodiversity Strategy (Czúcz et al., 2018). For its relevance to the EU Biodiversity Strategy, the classification proposed by CICES will be used as reference in this thesis research. In the following chapter the CICES typology and its differences to the MA and the TEEB system will be explained.

The CICES typology was firstly created in 2009, building on the MA and the TEEB typologies. The aim of this hierarchical classification is to facilitate ecosystem accounting, mapping and assessment (Haines-Young & Potschin, 2018b). CICES defines ecosystem services as *"the contributions that ecosystems make to human well-being […] in terms of 'what ecosystems do' for people"* (Haines-Young & Potschin, 2018b: iii). The typology of Haines-Young & Potschin (2018b) distinguishes three ecosystem service types:

1. Provisioning services include "*all nutritional, non-nutritional material and energetic outputs from living systems as well as abiotic outputs (including water)*" (Haines-Young & Potschin, 2018b: 10). For example, the provision of biomass, water or non-aqueous natural abiotic ecosystem outputs such as minerals are classified as provisioning services.
2. Regulation and maintenance services are provided by the biotic and abiotic environment which "*can mediate or moderate the ambient environment that affects human health, safety or comfort, together with abiotic equivalents*" (Haines-Young & Potschin, 2018b: 10). This service type includes the regulation of physical, chemical, biological conditions such as regulation of atmospheric conditions or water conditions.
3. Cultural services are "*all the non-material, and normally non-rival and non-consumptive, outputs of ecosystems (biotic and abiotic) that affect physical and mental states of people*" (Haines-Young & Potschin, 2018b: 10), such as cultural diversity of ecosystems, educational value and source of inspiration for societies or cultural heritage values.

Since version 5.1 of CICES, which was published in 2018, all ecosystem services are distinguished between biotic (living) or abiotic (non-living) services. For example, the provision of biomass is classified as biotic service, as it is provided by living organisms, while the provision of water can be categorized as abiotic service (Haines-Young & Potschin, 2018b).

A characteristic of this typology is its hierarchical structure. The three main sections may be further specified into division, group, class and class type. An example of this hierarchy is shown in Figure 2. This example illustrates the hierarchy at the example of provision of cereals. The tree structure shows further specification into more detailed class types. In reverse this hierarchical structure also allows aggregation, for example aggregating several classes to a group (cultivated plants) or division (biomass) (Maes et al., 2016).

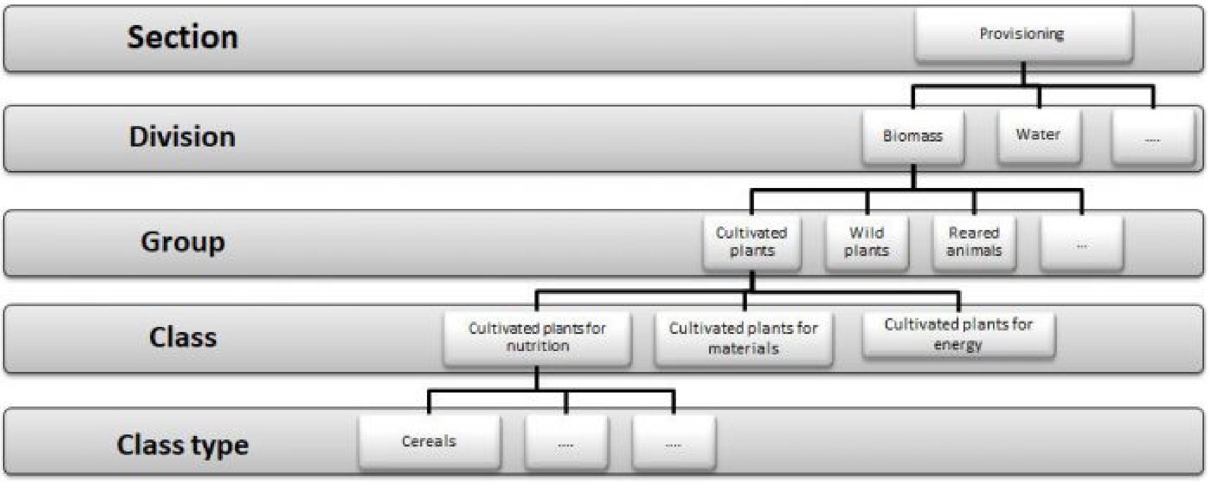


Figure 2: CICES hierarchy (illustrated for the cereals provision service) (Haines-Young & Potschin, 2018a)

Other classifications, differences and challenges

The CICES classification does differ from the MA or the TEEB classification in a few aspects. Firstly, in previous classification system, supporting services, which provide the foundation for the delivery of provisioning, regulating and cultural ecosystem services were included. Examples for supporting services would be photosynthesis, soil formation or nutrient cycling (Millennium Ecosystem Assessment, 2005). Supporting services are not a category of CICES, as the authors argue that supporting services do not deliver a specific service to and do not 'do something' for people (Czúcz et al., 2018; Haines-Young & Potschin, 2018b). CICES does also differ from TEEB by not including 'habitat services' as extra service category. Instead this category was integrated in 'regulation and maintenance services' (Maes et al., 2013). Apart from that, the provisioning, regulating and cultural services in CICES are similar to the services proposed by the MA or TEEB typology (Haines-Young & Potschin, 2017).

In addition to the MA, TEEB and CICES typology other national classification systems, such as the UK National Ecosystem Assessment (Watson et al., 2011), were developed. This variety of typologies still poses a challenge for the ecosystem service research community, as each approach uses different background-assumptions, definitions and scales for its typology (Czúcz et al., 2018; Haines-Young & Potschin, 2017). The CICES addresses this issue by attempting to facilitate the translation between different typologies through its hierarchical approach. This hierarchy provides flexibility as it can be adapted to the needs of the given context of the ecosystem assessment (Maes et al., 2016). Its adaptability to the specifics of the Member States of the European Union is one of the reasons for the applications of the CICES typology within the EU Biodiversity Strategy (Czúcz et al., 2018; Maes et al., 2013).

2.1.4. Measuring ecosystem services

When measuring ecosystem services a large number of aspects play a role (Egoh et al., 2012). As all of those different factettes of measuring ecosystem services do influence the content of ecosystem service maps, they are briefly discussed in this chapter. First, the different indicator types (primary, secondary) will be discussed, followed by an explanation on how ecosystem services can be quantified (e.g. biophysical, monetary quantification) Finally, different concepts (supply, flow, demand) of ecosystem services will be presented.

2.1.4.1. Ecosystem service indicators

There are many different ecosystem services, for example, CICES V5.1 lists 90 different ecosystem service class types (Haines-Young & Potschin, 2018b). In order to quantify and express those services, indicators are being used. Indicators are observed and measured values, that serve to indicate a phenomenon of interest (Egoh et al., 2012; Maes et al., 2013). Indicators can further be classified into secondary and primary. A primary indicator reflects "*the proxy used to measure ES [ecosystem services] […], while secondary indicators provide the necessary information used to compose the primary indicator*" (Egoh et al., 2012: 6).

Table 1: Primary and secondary indicators illustrated by the example of cereal and water provision (Egoh et al., 2012)

Ecosystem service	Primary indicator	Secondary indicator
Cereal provision	Agricultural production	Crop yield
Cereal provision	Agricultural production	Land cover
Provision of surface water for drinking	Water supply	Land cover

This distinction between primary and secondary indicator can be illustrated using the example of cereal provision, as can be seen in Table 1. In the first example crop yield is used as secondary indicator to compose the primary indicator agricultural production. This primary indicator is used to represent the ecosystem service cereal provision. It is also possible to use a different secondary indicator (land cover) to present cereal provision. This example demonstrates, that an ecosystem service (cereal provision) can be represented by various indicators (crop yield, land cover). The variety of indicators used to represent one ecosystem service makes comparing different case studies more difficult (Egoh et al., 2012).

This table also illustrates, that one secondary indicator (land cover) can be used to compose different primary indicators and thus represent different ecosystem services (Egoh et al., 2012). The selection of an appropriate indicator for an assessment is influenced by the purpose of the assessment, scale, data availability or the target group (Viheryaara et al., 2017). In many cases a single indicator is not sufficient to represent the chosen ecosystem service. To solve this issue several indicators, from potentially different data sources, can be combined into a composite indicator, to more accurately present the ecosystem services (Egoh et al., 2012).

2.1.4.2. Ecosystem service valuation

Valuation of ecosystem services deals with assigning importance to them (Jacobs et al., 2016). In general, three dimensions of values of ecosystem services can be identified: ecological, monetary and social value. Those three dimensions of values are interlinked, for example the society being dependent on safe ecological borders to operate within (Boeraeve, Dendoncker, Jacobs, Gómez-Baggethun, & Dufrêne, 2015; Jacobs et al., 2016).

To address the diversity of values of an ecosystem services, efforts of integrated valuation approaches have been made (Jacobs et al., 2016). The following sections will briefly provide an overview over the biophysical, economic and social valuation of ecosystem services.

Biophysical quantification

This approach uses biophysical units to express and measure ecosystem services. Examples for such units would be the area of a wetland (ha) or crop yield (kg/ha/year). The three measurement methods of biophysical valuation are displayed in Figure 3.

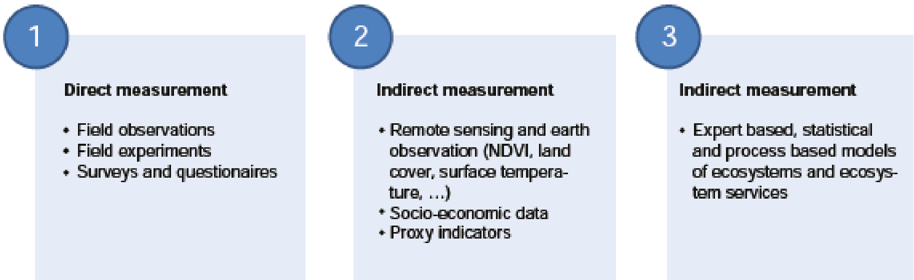


Figure 3: Three measurement methods for biophysical valuation of ecosystem services (Viheryaara et al., 2017)

Some ecosystem services can be directly quantified with the primary data resulting from direct measurements. However, due to lack of data or direct measurability it can be required in certain cases to select an appropriate proxy instead (Egoh et al., 2012) or apply another indirect measurement method (Viheryaara et al., 2017).

It is possible presenting the same ecosystem service with different measurement methods. The ecosystem service cereal provision could be based on crop statistics (direct measurement), satellite images using indices such as the Normalized Difference Vegetation Index (indirect measurement) or models of crop production (Viheryaara et al., 2017). Using primary data from direct measurements has proven to be the most accurate method. However, the required primary data may not always be available or very expensive. Furthermore, the suitability of a method may also vary with the scale. Primary data are mostly available at national or subnational level and retrieving data at national scale or higher is partly very expensive. Model-based approaches on the other hand require sufficient know-how (Egoh et al., 2012).

Economic valuation

Economic valuation expresses the value of a certain ecosystem service for human well-being in monetary terms (TEEB, 2010). This approach measures the value of an ecosystem service in the welfare obtained. The economic value of an ecosystem service can be derived through primary data (primary valuation) or through utilization of existing information (value transfer). Examples for primary valuation would be market prices of the ecosystem services (e.g. timber or crop) or defensive expenditure, which are the costs spent on protecting an ecosystem service/the ecosystem providing the service (Brander & Crossman, 2017). The application of monetary valuation is useful if a service has a direct or indirect market-value or if its loss results in real costs. However, it is important to keep in mind, that not all ecosystem services are suitable to be expressed in monetary values e.g. expressing the value of an endangered species or tourism in a region in monetary terms may only poorly represent the spiritual or cultural value for society or the ecological system (Boeraeve et al., 2015).

Social valuation

Social valuation aims at improving the well-being of generations both in the current time and on the future. This is achieved for example by considering the socio-cultural context or values of an ecosystem service to stakeholders or by inclusion of the affected stakeholders through a participatory approach (Boeraeve et al., 2015). Examples for such social values are the aesthetic or recreational value of a forest or the historic value of a place (Clement & Cheng, 2006).

2.1.4.3. Concepts of ecosystem services

There are several aspects of ecosystem concepts, which play an important role when it comes to the specification of the indicator and consequently its quantification and mapping. Those concepts and their positions in the social-ecological systems are visualized in Figure 4.

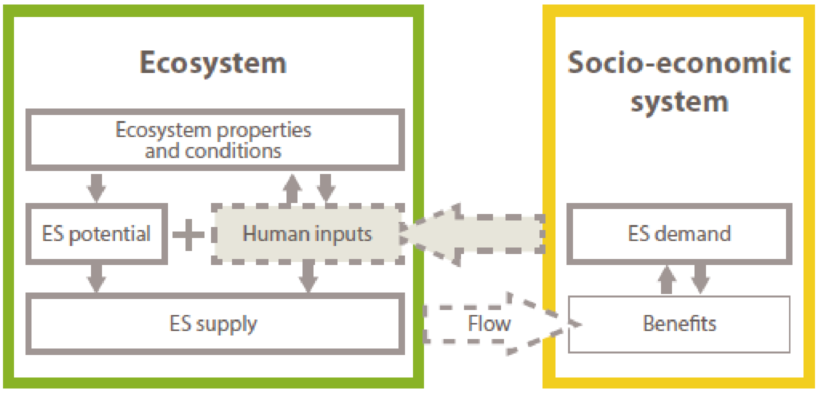


Figure 4: Mapping concepts of ecosystem services (Syrbe et al., 2017)

This model depicts the aspects of ecosystems according to their position in the interaction between ecosystem and the socio-economic system. The ecosystem properties and conditions include the structure, character, status of health and integrity of an ecosystem and ultimately determine the ability of an ecosystem to generate ecosystem services (Syrbe, Schröter, Grunewald, Walz, & Burkhard, 2017). The ecosystem service potential, which is often referred to as ecosystem capacity and describes the potential amount of ecosystem services, that could be sustainably delivered from a certain ecosystem under the current state and properties of the ecosystem (Syrbe et al., 2017). The potential of ecosystem services and human input form the actual supply of ecosystem services, which is the amount of ecosystem services supplied by a certain ecosystem, irrespective of whether those services are actually being used. The supply of an ecosystem service always refers to a given region and period of time (Maes, Paracchini, Zulian, Dunbar, & Alkemade, 2012; Syrbe et al., 2017). The need for ecosystem services within a certain area during a certain period is defined as ecosystem service demand (Crossman et al., 2013). Some demands, such as demand for food, may be well-known, while people may not be aware of their demands for certain services, such as improvement of water quality by soil. The flow of ecosystem services describes the amount of ecosystem services that is actually being consumed by humans (Syrbe et al., 2017).

A practical example illustrating the differences between a supply and flow indicator and the resulting challenges is timber production. It would be possible to choose the annual timber harvest volume as indicator for this service, which would be a flow-indicator. Quantifying this service by measuring the available timber volume, which could be harvested would be a supply indicator (Viheryaara et al., 2017). The indicators suggested for assessing ecosystem services by the MAES working group have a bias towards potential and actual supply indicators due to lacking availability of other indicator type data at an EU and national level (Maes et al., 2016). The latter are more accessible and available at the local level.

2.1.4.4. Conclusion

All of the discussed ecosystem service measurements which have been presented in chapter 2.1.4.1-2.1.4.3 play a role when expressing ecosystem services. Table 2 briefly outlines the connection of those measurements by the example of cereal provision. As discussed in chapter 2.1.4.1, this ecosystem service can be expressed through the primary indicator agricultural production, the underlying secondary indicator being the land cover. The cereal provision could be expressed in the economic value of the annual supply, but also show the demand for cereal provision of a region in kg.

Table 2: Relation between different aspects of mapping ecosystem services

Ecosystem services	Primary indicator	Secondary indicator	Type	Valuation
Cereal provision	Agricultural production	Land cover	Supply	Economic valuation ($/ha/year)
Cereal provision	Agricultural production	Land cover	Demand	Biophysical valuation (kg/ha/year)

2.1.5. End-goal of ecosystem service mapping

The collection of indicators for ecosystem service assessment and mapping is driven by a certain rationale. Those goals do strongly differ between different case studies (Egoh et al., 2012; Maes, Egoh, et al., 2012). A frequently encountered rationale, also relevant for this research, is the valuation of an ecosystem service, whereby the value of a service is estimated either in monetary or in non-monetary indicator units (Boeraeve et al., 2015; Potschin, Haines-Young, Heink, & Jax, 2016; TEEB, 2010). The development of scenarios is another rationale, aiming to display potential future developments of key driving forces under given circumstances (Potschin et al., 2016). Putting an emphasis on potential synergies or trade-offs between different ecosystem services also plays an important role. "*Ecosystem service tradeoffs (sic) arise when the provision of one service is enhanced at the cost of reducing the provision of another service, and ecosystem service synergies arise when multiple services are enhanced simultaneously*" (Raudsepp-Hearne, Peterson, & Bennett, 2010: 5242). Many decisions that are made in the context of ecosystem services are related to trade-offs (TEEB, 2010).

2.1.6. Challenges

As demonstrated in this chapter, a variety of different ecosystem services, ecosystem service definitions, frameworks and indicators exists (Malinga, Gordon, Jewitt, & Lindborg, 2015). The current plurality of definitions brings many challenges (Drakou et al., 2017), one being the limited comparability among different case studies (Egoh et al., 2012). Some steps addressing this challenge have already been taken (Crossman et al., 2013; Grêt-Regamey, Weibel, Kienast, Rabe, & Zulian, 2015), for instance trough the development of a blueprint for mapping ecosystem services, which provides a template that asks for relevant information, such as metadata, the mapped indicator or spatial details by Crossman et al. (2013). However, standardizing classification and mapping of ecosystem services is still an ongoing process for ecosystem service research (Czúcz et al., 2018; Haines-Young & Potschin, 2017). A goal for future research thus is to clearly address this issue by providing additional information about the indicator, scale, methodology, used data and objective (Czúcz et al., 2018; Viheryaara et al., 2017).

2.2. Ecosystem service maps

Maps can be a useful tool to communicate complex spatial situations to stakeholders (Hauck et al., 2013). Ecosystem service maps are "*cartographic representation[s] of (quantified) ecosystem service indicators in geographic space and time*" (Burkhard & Maes, 2017: 370). The mapping of ecosystems and their services by all Member States is a key activity within the Action 5 of the EU Biodiversity Strategy for 2020. A major reason for that is that maps help identifying spatial problems and priority areas in the context of ecosystems services and biodiversity (Maes et al., 2013).

2.2.1. Static and interactive ecosystem service maps

Currently, ecosystem service maps are available either as static maps or interactive systems, with static map being the dominantly encountered map medium during the literature review (e.g. Jónsson, Davíðsdóttir, & Nikolaidis, 2017; Polce et al., 2016; Vlami et al., 2017). The review of literature has shown, that attempts to create interactive, online ecosystem service mapping systems have just started very recently (e.g. Drakou et al. 2015). The analysed online systems (e.g. esp-mapping.net, biodiversity.europa.eu/maes/maes-digital-atlas) are still under development had limited interactivity functions, namely zooming, searching, switching on/off of different layers, displaying of a regions value when clicking on it. Furthermore, the amount of available data was limited, especially for national and sub-national level. A reason for that could be the fact, that the mapping of ecosystems and their services in the context of the EU Biodiversity Strategy is a currently ongoing process. For that reason, I decided to analyse static maps within this thesis research. Thus, the discussion hereafter will focus on static, non-interactive ecosystem service maps.

2.2.2. Cartographic foundations

The following chapter will discuss the foundations of cartographic foundations of ecosystem service mapping, by presenting the model of cartographic communication, different mapping techniques, map elements and colour schemes.

<u>**Cartographic communication**</u>

The interaction between the map-maker, the map and the user of the map is called cartographic communication, which is displayed in Figure 5. The first transmission takes place when the map is created by the map-maker, as during this process much information is lost. By considering the real-world phenomenon, determining the purpose of the map and by collecting source data and visualizing them, the map-maker takes a number of decisions specifying and thus limiting the information displayed in the final outcome (Albert, Brown, & Burkhard, 2017; Slocum, McMaster, Kessler, & Howard, 2014). After the map is finished, it is used by the map user, where a second transmission of information takes place. The user reads and interprets the map throughout processes related to perceiving the displayed information on the map, accessing his/her memory and past experiences (Slocum et al., 2014). At this stage interpretation issues may arise. Ideally those issues and other relevant feedback are communicated by the user to the author (Albert et al., 2017). This feedback loop may be difficult to carry out in practise due to temporal or monetary restrictions, but it is a critical step as it provides valuable information on whether the mapping technique works. Based on the received feedback the map could be redesigned by the map-maker, for example by adjusting the colour scheme (Slocum et al., 2014).

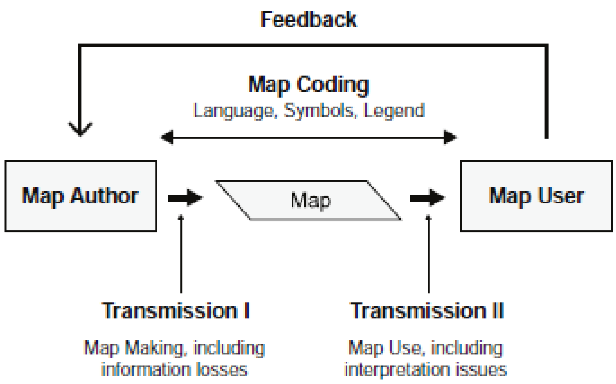


Figure 5: Model of cartographic communication (Albert et al., 2017)

There are several ways, in which the available information can be presented in a map. Depending on the spatial extent of the phenomenon, whether it is a point-, line- or areal-phenomenon a different mapping technique may be the most suitable (Slocum et al., 2014).

Map elements

Maps can and should be complemented with map elements to enhance the users understanding of the map content. Adding a title and/or subtitle, which explain the map theme, information on the map source and a legend are critical elements of map design. Other elements can be added to the map to improve the users understanding, yet the map-maker should avoid visual clutter from having too many unessential map elements (Slocum et al., 2014). Other map elements that can be added are:

- North arrow
- Map labels
- Date
- Scale information
- Page border
- Descriptive text
- Graphs or graphics
- Neat lines
- Inset map
- Copyright
- Map projection (Brewer, 2016; Peterson, 2009; Slocum et al., 2014)

Figure 6 displays a sample map containing some of the map elements that have been discussed. The title and the legend title provide clear information on the questions of the geographic location (upper Ogosta watershed), the time (2000-2005) and the map theme (freshwater supply). The meaning of the colours of the map are explained in the legend. A north arrow and a scale bar provide information in the orientation and spatial extent of the research area. In addition, this map provides metadata such as projection, map author, date and data source.

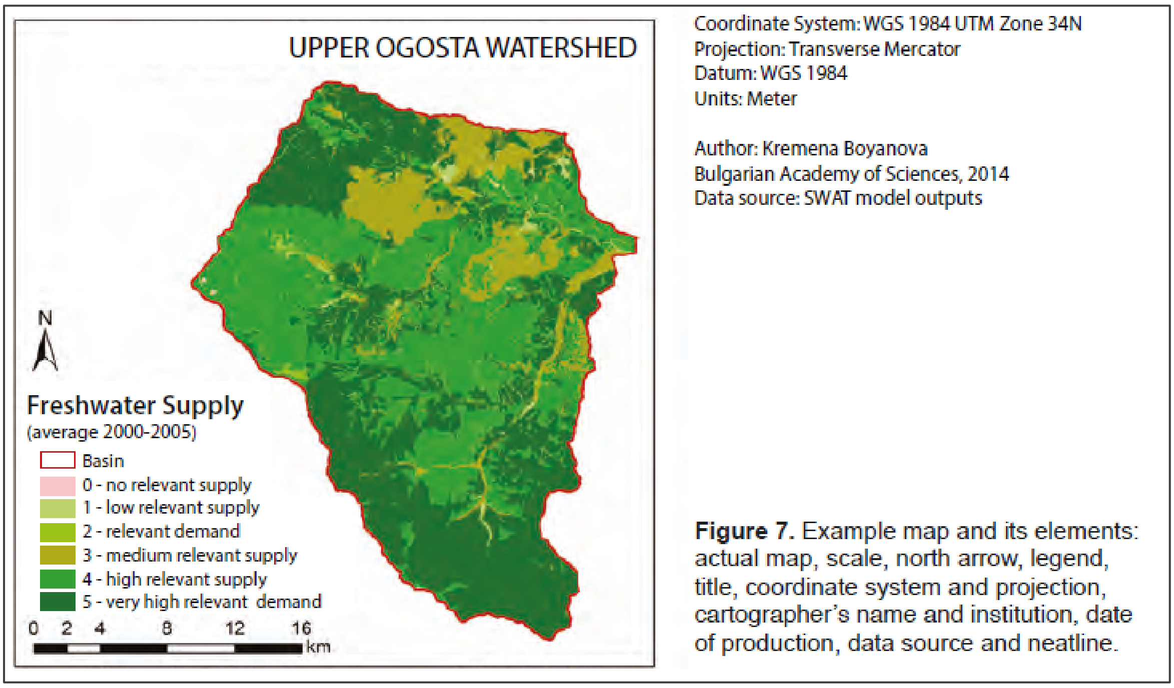


Figure 6: Sample ecosystem service map with map elements (Boyanova & Burkhard, 2017)

Colour scheme

When choosing the colour scheme for a map, it is important that the colours support conveying the maps message (Brewer, 2016; Peterson, 2009). The first step of achieving that is matching the structuring of the colour scheme with the structure of the underlying data. For univariate data, three colour schemes, which are displayed in Figure 7, can be distinguished:

1. **Sequential schemes**: This colour scheme is suitable for ordered data e.g. high-low, 60-10.000 students. To display this ordering, the colour lightness (or the hue) can be altered, with lighter colours generally representing lower values and vice versa (Brewer, 2016).

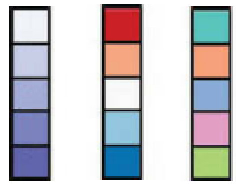


Figure 7: Examples for the different colour schemes (left: sequential, middle: diverging, right: qualitative)

2. **Diverging schemes**: Diverging colour schemes are suitable when differences between high and low values want to be emphasized e.g. cheap-medium-expensive rents income in regions. A break-value (e.g. neutral, medium rent) separates the two sides of the attributes, which are displayed in different colours with extreme values getting darker. Many data can be displayed as sequential or diverging. Diverging schemes should only be applied, if the separation between high and low is meaningful, for example the application of a diverging scheme for temperature data may unintentionally emphasize arbitrary mid-range temperatures (Brewer, 2016; Slocum et al., 2014).
3. **Qualitative schemes**: This colour scheme is used to display unordered data e.g. land cover data. Different classes are displayed with different hues (Brewer, 2016; Slocum et al., 2014).

Mapping techniques

A number of different mapping techniques can be used to map a phenomenon. Different techniques are suitable for different data types and different geographic questions (Kraak & Ormeling, 2010). Hereafter the most common thematic mapping techniques, their advantages and shortcomings are briefly discussed. Examples for the application of those mapping techniques in ecosystem service mapping will be discusses in chapter 2.2.3.

1. **Proportional symbol map**

   Proportional symbol maps present a phenomenon as points, with the size of the point symbol varying on the quantity of the phenomenon at the given location. The position of the point could either be the true geographic location or conceptual e.g. one point presenting the quantity found in an administrative unit. This mapping techniques displays the distribution of quantities. The size of the point symbol presents a challenge of this mapping technique, as the symbols should be big enough to be able to read them, while avoiding symbol overlap (Kraak & Ormeling, 2010; Slocum et al., 2014).
2. **Dot map**

   Dot maps present, like proportional symbol maps, quantities at their most likely geographic position, with the difference that all points present the same amount of the displayed phenomenon.

This mapping technique displays the pattern of a certain phenomenon. Choosing a suitable dot size is of essence in dot maps, as the overlap of the dots should be avoided (Kraak & Ormeling, 2010; Slocum et al., 2014).

3. **Diagram map**

   A diagram map presents diagrams (e.g. bar graphs, line diagrams) at their (representative) geographic location on the map. This mapping technique must be applied with caution, as it can distract from the actual map in the background. It is recommended only to create a diagram map, when the geographic location of the chart is of importance (Kraak & Ormeling, 2010).

4. **Flowline map**

   A flowline map displays the movement of a phenomenon from one geographic position to another making use of arrow symbols. The size of the arrow symbol can vary proportional to the quantity of movement (Kraak & Ormeling, 2010; Slocum et al., 2014).

5. **Chorochromatic map**

   This mapping technique is applied to display nominal values of areas, making use of colours or areal symbols to visualize areas of different values. The chosen colours/symbols should not suggest any ranking among the areas. This map type could lead to the misunderstanding, that bigger areas have a higher importance e.g. a map displaying the languages spoken in a country could be misleading, as the biggest area of one language does not necessarily mean that this language is spoken by most of the population. Adding a diagram displaying the actual numbers of people speaking each language could be a solution for this challenge (Kraak & Ormeling, 2010).

6. **Choropleth map**

   A choropleth map displays discrete, quantitative values of enumeration units by colouring those areas. The differences in quantities are displayed by different colour shadings, darker shadings indicating higher values. The values displayed must be normalized, either area (e.g. students/km^2) and non-area (percentage of students in the total population) specific. In addition, the challenge of the visual dominance of big areas (see chorochromatic maps), non-area specific values may lead to further misleading impressions. This issue can be solved by adding the absolute, non-normalized values either as numbers or as proportional symbol to each unit (Kraak & Ormeling, 2010). Two disadvantages of this map type are, that variations within the units are not displayed and that the unit boundaries are arbitrary and likely do not correspond with discontinuity boundaries of the mapped phenomenon (Slocum et al., 2014).

7. **Dasymetric map**

   Dasymetric maps display, similar to choropleth maps, normalized quantitative values with areal symbols the present uniform regions, but the boundaries of dasymetric maps are data-driven, meaning that the distribution of the phenomenon determines the boundaries of the unit. This mapping technique is suitable if the data boundaries are different from administrative boundaries e.g. natural phenomena. Using a dasymetric map could be a solution for the arbitrary-area problem of choropleth maps (Kraak & Ormeling, 2010; Slocum et al., 2014).

8. **Isoline map**

   Isoline maps connect points of equal value with line symbols, dividing the mapping area in regions of interval values. This mapping type displays continuous phenomena, showing the trend of its distribution and are suitable to compare the distributions of two or more phenomena and assess whether those distributions are correlated or not. For such purposes isoline maps are more suitable than choropleth maps (Kraak & Ormeling, 2010; Slocum et al., 2014).

9. **Cartogram**

   A cartogram displays the size of the enumeration area in proportion to the value they present. This approach could be an approach to solve the problem of non-area related indicators (e.g. students/year), which poses a shortcoming of choropleth maps (Kraak & Ormeling, 2010).

Each of those mapping techniques discussed above is related to some degree of information loss. Choropleth maps, which are easily generated automatically, are a very frequently applied thematic mapping technique. Yet, the discussion above highlighted, that depending on the source data and the questions to be answered, different mapping techniques may be more suitable (Kraak & Ormeling, 2010; Slocum et al., 2014).

2.2.3. Types of ecosystem service maps

The following section briefly displays mapping techniques of ecosystem service maps that were encountered during the literature review. For each technique, one map was selected to demonstrate, how those can be applied in ecosystem service mapping (for presentation of mapping techniques see chapter 2.2.2). This chapter demonstrates, how the different ecosystem service measurements, the different cartographic mapping techniques and the different scales, which have been discussed in the previous chapters, result in a plurality of ecosystem service maps.

Proportional symbol map

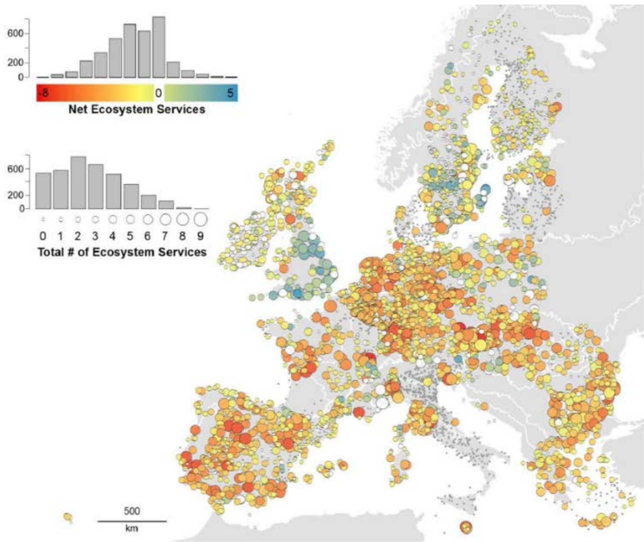


Fig. 1. Distribution of Special Protection Areas (SPAs) for which data on pressures were reported and associated with the use of ecosystem services (ES). The locations represent the centroids of SPA boundaries. Grey dots represent SPAs not used for analyses. Histograms show distribution of SPAs for Net Ecosystem Services (NetES – defined as number of positive minus negative ES; upper histogram) and the total number of ES detected in each site (lower histogram).

Figure 8: Proportional symbol map displaying the number and impact of ecosystem services provided by special protection areas (Ziv et al., 2018)

This proportional symbol map shown in Figure 8 displays the number of ecosystem services provided by special protection areas in Europe. The size of the symbols expresses the quantity of ecosystem services, the colour expresses whether the positive or the negative impacts on species conservation dominate (Ziv et al., 2018). This map has a scale bar, a legend combined with histograms and an explanatory subtitle in the publication.

Dot map

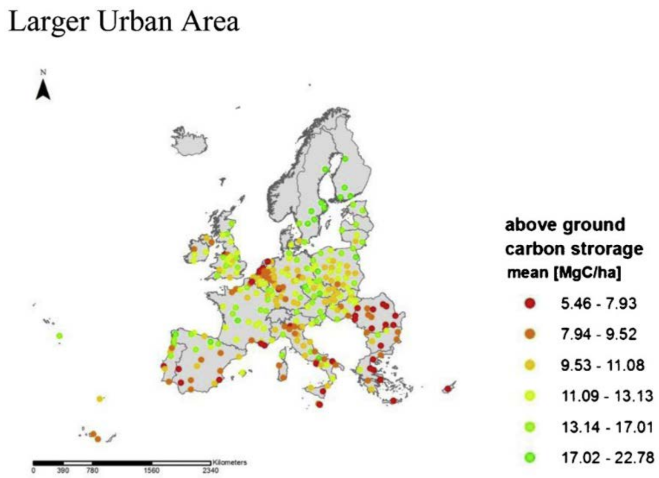


Figure 9: Dot map displaying the supply of carbon storage in European cities (Larondelle, Haase, & Kabisch, 2014)

The map in Figure 9 presents the supply of above ground carbon storage (climate regulation) in the larger urban area of European cities as a dot map (Larondelle et al., 2014). In addition to the actual map, a legend, scale bar, north arrow and a title are included.

Diagram map

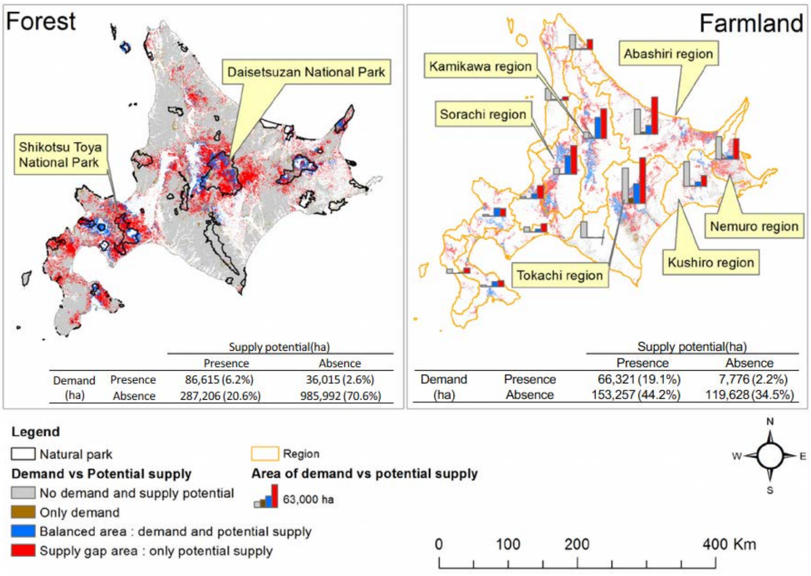


Fig. 7. Distribution of demand and potential supply area in forest and farmland. The bar chart shows the area of gap area in farmland.

Figure 10: Diagram map displaying the supply and demand of cultural services in research region (Yoshimura & Hiura, 2017)

Figure 10 presents bar chart map (right) visualizes the distribution of demand and supply of cultural ecosystem services in the sub-national research area (Yoshimura & Hiura, 2017). The actual map is complemented with map labels, a legend, a scale bar and north arrow, a map description and additional statistical data.

Flowline map

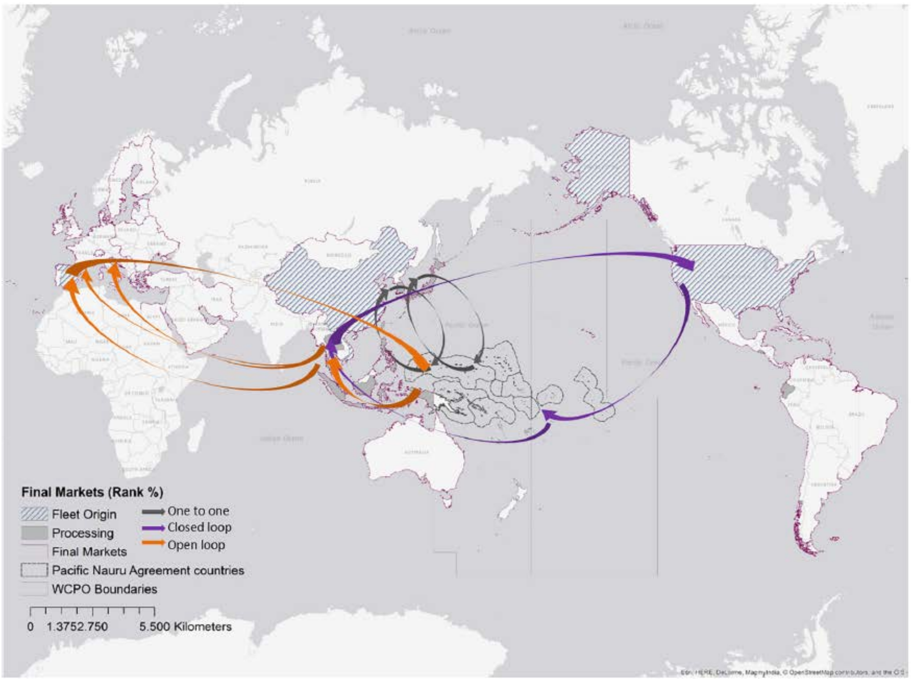


Fig. 7. The global distribution and flow of economic costs and benefits generated by the purse seine tuna fishery in the WCPO region. The different colors in arrows represent the three different types of flows observed.

Figure 11: Flow map displaying the flow of benefits and costs of tuna fishery (Drakou, Virdin, & Pendleton, 2018)

This global map shown in Figure 11 presents an economic valuation of the flows of benefits and costs generated by tuna fishery (Drakou et al., 2018). The colour of the arrows indicates different flow types. This map includes a legend, a legend title, a scale and a short descriptive text.

Chorochromatic map

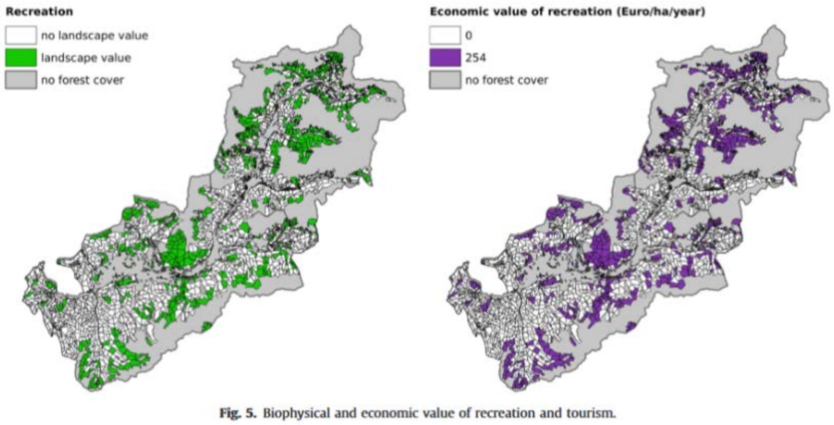


Figure 12: Chorochromatic map (left) displaying the recreational value of the research region (Häyhä, Franzese, Paletto, & Fath, 2015)

This chorochromatic map shown in Figure 12 (left) displays recreation supply, a cultural ecosystem service as qualitative attribute in a sub-national case study (Häyhä et al., 2015). Map elements found in this image are a legend, a legend title and a short title below the image.

Choropleth map

The ecosystem service map shown in Figure 13 (left) displays the mean groundwater withdrawal as index, which represents the demand as well as the supply. This indicator is displayed as choropleth map showing Germany and using NUTS-3 regions as enumeration units (Rabe, Koellner, Marzelli, Schumacher, & Grêt-Regamey, 2016). This map has a legend and a legend title, a north arrow, scale bar, a description (figure description in the publication) and geographic map labels.

Figure 13: Choropleth map displaying the index of groundwater use in Germany (Rabe et al., 2016)

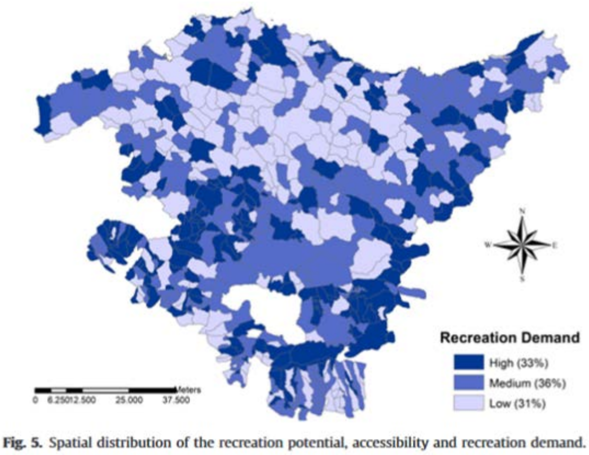


Figure 14: Dasymetric map displaying the demand for recreational ecosystem service in Spanish region (Peña et al., 2015)

Dasymetric map

Figure 14 displays the recreation (cultural service) demand of a sub-national region in Spain. This dasymetric map uses viewsheds as spatial units (Peña, Casado-Arzuaga, & Onaindia, 2015). In addition to the actual map, the authors added a north arrow, a scale bar, a short description and a legend with legend title to the image.

Discussion

The displayed maps demonstrate, that the term ecosystem service map does not refer to a single map type and rather encompasses a variety of different mapping techniques with different mapping backgrounds (e.g. indicators). From a cartographic perspective this means, that all the challenges and pitfalls of the different mapping techniques (see chapter 2.2.2) must be taken into consideration when creating an ecosystem service map. Furthermore, the chosen visualisation technique must maintain the structure of the underlying data, to ensure unbiased information communication and understanding by the user (McInerny et al., 2014).

2.2.4. Mapping ecosystem services at different scales

Ecosystem services can be mapped at different spatial levels. This thesis research focusses on ecosystem service maps at continental, national and sub-national level in Europe. The maps at those different levels do differ in a number of ways, such as the extent that is being mapped, the spatial resolution or the ecosystem services (Crossman et al., 2013). Furthermore the ecosystem services as well as the available data to represent them do also vary with the level (Egoh et al., 2012; Malinga et al., 2015). In the following section the characteristics of those levels and differences between them are discussed.

Sub-national level

Ecosystem service maps at sub-national level comprise for example local or regional level mappings. Those could be maps displaying a single farm or a touristic region, but also administrative units such as municipality or province level maps belong to this category (Malinga et al., 2015). At this level many site-specific ecosystem services, such as pollination or mushroom picking can be found. For such ecosystem services, which can be found in areas of small extent, high spatial resolution of data is required (Crossman et al., 2013; Kruse, 2017). Ecosystem service mapping at this scale often includes participatory approaches, with stakeholders taking part in the mapping process. Data sources such as statistical data or generalized land use or land cover data are suitable for sub-national maps covering a larger spatial extent. The thematic resolution at this level tends to be higher than at the other levels. For instance, a map of cultural ecosystem services may include very detailed information such as points of interests or hiking paths (Kruse, 2017). A literature review carried out by Egoh et al. (2012) found, that 79% of the reviewed ecosystem service mappings were carried out at sub-national level and that most of those case studies dealt with ecosystem service quantification, valuation and the development of scenarios. Regional scales are also suitable for calculating supply-demand budgets (Kruse, 2017). Data availability poses an issue not only for the sub-national, but for all administrative levels (Grêt-Regamey et al., 2015). In data-poor regions this issue can be dealt with by utilizing known information from similar biomes for the case study or by collecting primary data. The latter option is rather work-intensive and cost-expensive, but still most of the available can be found at sub-national or national level (Egoh et al., 2012; Kruse, 2017).

National level

The spatial extent of this level covers the nation, that is subject to the mapping. The spatial resolution of national maps strongly depends on the available primary sources (Anderson et al., 2017). Too high level of detail can be adjusted by spatial or thematic generalisation. Rabe, Koellner, Marzelli, Schumacher and Grêt-Regamey (2016) used the NUTS-3 level as base administrative units for mapping of ecosystem services in Germany and data with higher resolution were aggregated to NUTS-3 regions. Potential data sources for this level could be satellite images, land use and land cover data, population data, data on infrastructure, vegetation or soil maps. High costs of primary data and producing, updating, maintaining and distributing maps are a critical aspect when it comes to ecosystem service mapping at national level (Anderson et al., 2017). National mappings could also provide an overview on which ecosystem services are delivered at which quality, and whether their amount is expected to increase or decrease in the future (Watson et al., 2011). Maps at this level should facilitate the development of policies which aim at protecting and restoring ecosystem services (Anderson et al., 2017).

European level

At European level ecosystem service maps aim to visualize the current state of ecosystems and their services and their distribution. Those maps could support the identification of priority areas and the development of relevant policies (Maes et al., 2013). Potential data sources for mapping at continental scale would be global data sets like carbon storage, agricultural yield, land use or land cover data. Global data sets may have a very coarse spatial resolution, however, for a mapping covering such a large spatial extent that fact is not problematic. Primary data at continental level are usually very costly (Crossman, 2017; Egoh et al., 2012).

2.2.5. Ecosystem services and policies within European Union

There are different policies, which address the mapping and assessment of ecosystems and their services or the protection of ecosystems. Hereafter the policy requirements relevant for the chosen case study will briefly be presented. The EU Biodiversity Strategy for 2020 is the overarching umbrella of mapping and assessment of ecosystem services in Europe. MAES related activities are guided by different policy questions (Maes et al., 2013; Maes, Egoh, et al., 2012), e.g. "*What are the current state and trends of the EU's ecosystems and the services they provide to society? […] What are the economic, social (e.g. employment) and environmental implications of different plausible futures? What policies are needed to achieve desirable future states*?"(Maes et al., 2013). The EU Biodiversity Strategy is not legally binding. Yet, there are other legally binding EU Directives e.g. the Water Framework Directive (2000/60/EC) or the Habitats Directive (92/43/EEC), which address issues related to use of land or natural resources (Bouwma et al., 2018).

At national level in Greece, the Greek Biodiversity Strategy has been implemented since 2014, which aims, in correspondence with global and European initiatives, to halt the loss of biodiversity. This strategy is also not legally binding. Some of the goals of this strategy are corresponding to the goals of Target 2, Action 5 of the EU Biodiversity Strategy for 2020 (Ministry of Environment Energy & Climate Change, 2014). Those goals are displayed in Figure 15.

EU Biodiversity Targets for 2020	National Biodiversity Strategy Targets for 2020
TARGET 2: To maintain and enhance ecosystems and their services **Action 5:** Improve knowledge of ecosystems and their services in the EU (Member States, with the assistance of the Commission, will have mapped and assessed the state of ecosystems and their services in their national territory by 2014, by assessing the economic value of such services, and by promoting the integration of these values into accounting and reporting systems at an EU and national level by 2020)	**General Target 2:** Conservation of national natural capital and ecosystem restoration **General Target 11:** Integration of biodiversity conservation in the value system of the society **General Target 13:** Appreciation of ecosystem services and promotion of the value of Greek biodiversity

Figure 15: Goals of the Greek National Biodiversity Strategy for 2020 and corresponding goals of the EU Biodiversity Strategy for 2020

At sub-national level, different management agencies e.g. management authorities of national parks or wetland areas also have to comply with ministerial decisions, while also complying with other policy requirements e.g. from EU Directives (Apostolopoulou & Pantis, 2009). The listed policy requirements are by far not exhaustive, yet demonstrated, that different administrative levels have to comply with different policy requirements, which adds an additional layer of complexity to the mapping and assessment of ecosystem services.

2.2.6. Users and map-makers of ecosystem service maps

In the cartographic communication process of ecosystem service maps, the users and map-makers present the key actors. Those two roles are introduced in this chapter.

Map-makers and mapping tools of ecosystem service maps

The map-makers task is to create maps that provide information on spatial issues e.g. the attributes of a certain geographic location or the spatial distribution of a topic of interest. In doing so the map-maker translates the distribution of a real-world phenomenon into a visual representation (Slocum et al., 2014). In the mapping process the map-maker decides, which mapping technique or which colour scheme will be used to visualize the geographic data (see chapter 2.2.1). In doing so, map-makers of ecosystem service maps and maps in general exercise power, as they decide what will be included in the map and what will be left out (Hauck et al., 2013).

There are different tools available for creating ecosystem service maps. A widely applied approach is mapping ecosystem services with GIS software (e.g. ArcGIS[1], QGIS[2]) (e.g. Burkhard et al., 2012; Larondelle, Haase, & Kabisch, 2014; Troy & Wilson, 2006). An open GIS tool, which was developed for ecosystem services valuation and mapping is InVEST[3] (= Integrated valuation of ecosystem services and trade-offs) (Guerry et al., 2012). This tool provides different functionalities e.g. biophysical or monetary valuation, spatial correlation or scenario development of ecosystem services (Crossman et al., 2013; Stanford University, 2018). A tool similar to InVEST is ESTIMAP (= Ecosystem Service Mapping Tool). It is also a GIS-based tool aiming to model and quantify ecosystem services, but it was specifically developed for mapping at European scale (Zulian, Paracchini, & Liquete, 2013). Other mapping tools are for example SolIVES[4] (= social values for ecosystem services), which is also a GIS-based tool or ARIES[5] (= artificial intelligence for ecosystem services), which is web-based (Crossman et al., 2013; Villa et al., 2014). Some remote sensing based applications or programming languages like R have also been used for ecosystem service mapping (e.g. Maes, Egoh, et al., 2012; Rabe, Koellner, Marzelli, Schumacher, & Grêt-Regamey, 2016).

Users of ecosystem service maps

The users of maps are the target audience of each mapping process and ideally all steps and decisions during the mapping process are taken having the needs of this audience in mind (Slocum et al., 2014). The users of ecosystem service maps work in many different sectors, such as forestry, agriculture, transportation or tourism. People working in tourism would be interested in example in maps showing recreational benefits of a certain landscape. Agricultural businesses could show an interest in pollination on deriving knowledge on the presence of pollinators or potential crop yields within an area of interest (Tardieu & Crossman, 2017).

[1] https://www.arcgis.com
[2] https://www.qgis.org
[3] https://naturalcapitalproject.stanford.edu/invest/
[4] https://www.usgs.gov/centers/gecsc/science/social-values-ecosystem-services-solves
[5] https://aries.integratedmodelling.org/

The profession of users and the tasks they have to fulfil within this profession do also have an impact on what purposes those maps are used for. A major target group of ecosystem service maps are decision makers, who will use the provided information for decision-making processes (Drakou et al., 2017). Decision makers can be found at all administrative levels, being for instance businesses or NGOs (TEEB, 2010; Willcock et al., 2016) (6.4). An example for a decision maker at the sub-national level would be a landscape planner using ecosystem service maps to choose the most suitable area for a new wind farm, trading off several aspects such as economic interest and interest in renewable sources of energy, landscape aesthetics or the fauna (Albert, Hauck, Buhr, & von Haaren, 2014). Another relevant audience are policy makers at all administrative levels. Their intentions could be the assessment of the achievement of certain policy objectives (Albert et al., 2017) or the development or/and adaptation of suitable policies based on the provided maps (Maes et al., 2013). Ecosystem service maps are also being used within the scientific community, for educational purposes by teachers or students (Albert et al., 2017; Hauck et al., 2013) or/and for raising awareness in the general public.

To sum up, the field and the profession of the target group strongly influences which ecosystem service map is most suitable or which indicators should be selected. It makes a difference if the target group are policy makers or scientists (Viheryaara et al., 2017). Understanding the end-user group may give valuable insights for the map development, such as which degree of precision is suitable for the intended use or which prior knowledge the user has (Albert et al., 2017; Roth, Ross, & MacEachren, 2015).

2.2.7. User research on ecosystem service maps

The lacking assessment of the users' needs and requirements has been identified as a bottleneck in current ecosystem service mapping (Palomo et al., 2018). Until today, there were only a few attempts made to research the users and their use requirements of ecosystem service maps (e.g. Klein, Celio, & Grêt-Regamey, 2015; Klein, Drobnik, & Grêt-Regamey, 2016; Willcock et al., 2016). Willcock et al. (2016) addressed the issue of user requirement analysis within the field of ecosystem service maps by questioning stakeholders from sub-Saharan Africa, analysing why the implementation gap between science and policy still exists. The authors applied purposive sampling to reach potential participants. The conducted survey did include open-ended and closed-ended questions related to their work with ecosystem service maps, their perception of the adequacy of provided data and at what scale or resolution they work with ecosystem service data. Two major findings were that most of the decision makers do not have adequate information to support their decision-making and that trust building between the stakeholders of the mapping process is essential (Willcock et al., 2016). The authors uncovered some unknown needs though their approach and argue, that further "*efforts should be made to understand the barriers preventing engagement for stakeholders not currently using ES [ecosystem service] information*" (Willcock et al., 2016).

The demands of the users towards ecosystem service information have also been researched by Klein et al. (2015). Their approach included testing nine different ecosystem service visualizations such as photorealistic 3D visualizations, 2D thematic maps or charts and asking the users for their preferred visualization in different use cases like support of scenario development or analysis of content. The participants' responses gathered through a survey. The conducted principal component analysis showed that the demands of the users are heterogenous and that the preferred visualization type is situation- and use-dependent (Klein et al., 2015). Klein et al. (2016) took up at this point and integrated some ecosystem service visualization methods introduced by Klein et al. (2015) into a partly interactive decision support system. By conducting cognitive interviews and applying eye-tracking, the researchers aimed to evaluate the usability of those visualization types while the users had to solve given tasks. The results also demonstrated that the use purpose has a significant impact, as the preferred visualization again did depend on the task. Furthermore, this study found that users did rely on their own knowledge, if they considered the provided information not to be helpful (Klein et al., 2016).

2.3. Conclusion

In this chapter the fundamentals of the ecosystem service concept and ecosystem service maps were presented. Ecosystem services, which are natures contribution to people (Díaz et al., 2018), result from the complex interactions between humans and nature within the social ecological system (Reyers et al., 2013). Ecosystem service maps are cartographic representations of those interactions. There are different mapping techniques, such as dasymetric, choropleth or flow maps, which can be used to map ecosystem services (Boyanova & Burkhard, 2017). Those cartographic products aim to visualize the interactions within the social-ecological system and in doing so inform policy and decision makers (Guerry et al., 2015). Yet, in the past, the uptake of the provided ecosystem service information by the user has been very low and the results have not been taken into consideration in decision-making processes (Ruckelshaus et al., 2015). A few attempts in the pasts were done to explore the users of ecosystem service maps, bringing to light unknown preferences and needs (e.g. Klein et al., 2015, 2016; Willcock et al., 2016). It was found, that there is a need of further investigating the users' needs to increase of the use of ecosystem service maps in decision-making processes. This thesis research aims to fill this gap by proposing the application of the first stage of user-centred design, namely a use and user requirement analysis to

3 METHODOLOGY

This thesis research explores the use and user requirements of ecosystem service maps. The requirement analysis presents the first stage of user-centred design cycle. The following chapter will provide an overview of this proposed and applied methodology. Chapter 3.1 will introduce the theoretical foundations of user-centred design and the requirement analysis. The practical conduct of research will be presented in chapter 3.2 and chapter 3.3 presents a brief conclusion.

3.1. Theoretical foundations

This chapter provides the theoretical foundation for the proposed user-centred design approach. Firstly the overarching concept of usability is discussed (chapter 3.1.1), followed by an introduction of the user-centred design cycle in chapter 3.1.2 and more detail on the use and user requirement analysis (chapter 3.1.3).

3.1.1. Usability

Maps should be designed for the users who will make use of those products (Slocum et al., 2014). Ideally the (ecosystem service) map should be easy to learn and use and support the user in the task he or she is fulfilling (Gould & Lewis, 1983; Robbi Sluter, van Elzakker, & Ivánová, 2017; Roth, Ross, Finch, Luo, & MacEachren, 2013). A key concept in this context addressing and measuring this issue is the usability of a system. Usability is the "*extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (International Organization for Standardization, 2018). Focussing on usability of a product can significantly improve the product's success, which is beneficial for the user as well as for the producer of the product (Dumas & Redish, 1999). Integrating a usability-oriented approach means acknowledging the following assumptions:

1. "*Usability means focussing on users.*
2. *People use products to be productive.*
3. *Users are busy people trying to accomplish tasks.*
4. *Users decide when a product is easy to use.*" (Dumas & Redish, 1999: 4)

Usability problems are issues which, if changed, result in better performance of the tested system. The type of encountered problems strongly depends on the tested system (Nielsen & Mack, 1994). This research aims, among others, to encounter usability problems of existing ecosystem service maps.

3.1.2. User-centred design cycle

A methodology developed to address usability problems is user-centred design (UCD). This approach originates from research on Human-Computer-Interaction. It puts the user into the centre of the product development process and aims to have increased usability of a (cartographic) product as output. It gained popularity in the mid-1980s and was adapted in GIS-related research during the 1990s (Haklay & Nivala, 2010). The following three rules are critical for the implementation of a UCD approach:

1. Understanding the users, the tasks they must carry out and their use context should be focussed on early in the development process.
2. Users should use and test prototypes of the product early in the development phase and their performance should be empirically measured.

3. The problems encountered during the prototype testing should be fixed by redesigning the product and then another testing should be carried out. This iterative cycle should be carried out as often as necessary (Gould & Lewis, 1983).

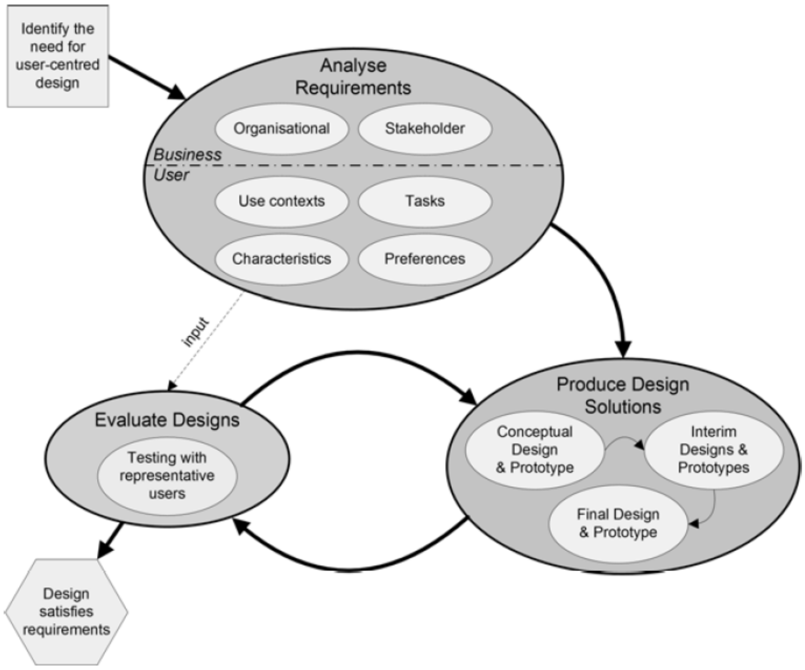


Figure 16: UCD cycle
(van Elzakker & Wealands, 2007)

Van Elzakker and Wealands (2007) proposed a three-stage UCD cycle, which could also be applied in cartography (see Figure 16). This framework identifies three stages within the UCD process: (1) requirement analysis, (2) production of design solutions and (3) evaluation of designs. The identification of the need for UCD initiates this design process. At the beginning of the cycle a user requirement analysis is conducted, capturing the business context of a cartographic product as well as the characteristics, preferences, tasks and use contexts of the users. A more detailed discussion of the elements of the use and user requirements analysis can be found in chapter 3.1.3. Based on the insights gained from this stage a map prototype can be developed. This prototype can be evaluated through user testing and be redesigned based on the input gained from this testing. The output of this cycle is a cartographic product that satisfies all formulated requirements (van Elzakker & Wealands, 2007). Not all decisions and steps in UCD are pre-formulated, it can rather be described as a adaptable, multi-stage process (Roth et al., 2015).

For example Roth et al. (2015) presented a 10-stage UCD approach based on the work of Nielsen (1992). This process further specifies the UCD stages discussed above, containing the requirement analysis, prototype development, evaluation and iteration between the latter two stages.

1. Know the user: Conducting a needs assessment with the target users to derive user profiles and use case scenarios.
2. Competitive analysis: Critical comparison of interfaces, which have been designed for similar use cases.
3. Setting Goals: Use outcome from stage 1 and 2 to derive a requirements document containing desired functionalities which can guide the prototype development.

4. Participatory design: Inclusion of target group members for the conceptual interface design.
5. Coordinated design: Developing a product identity through coordination of the design within the team.
6. Guidelines and heuristic analysis: Recruiting of experts in the design and development phase to evaluate interface.
7. Prototyping: Creation of mock-ups (static or interactive).
8. Empirical testing: Conducting usability evaluation with a representative sample of target groups.
9. Iterative design: Revision of the prototype based on feedback from stage 6 and 8.
10. Feedback from field use: Collect feedback from use in the field to inform other product releases in the future (Roth et al., 2015).

These steps of the UCD approach by Roth et al. (2015) demonstrate the strong and continuous focus on the user throughout all development stages. In map creation processes it sometimes is the case, that the map-makers lose track of their users, considering the map creation as the goal and not the requirements of their users (van Elzakker & Ooms, 2018). Yet, as mentioned in chapter 2.2.2, the user and his/her feedback are an important part of the cartographic communication process (Slocum et al., 2014). UCD could provide guidance on how to actively involve the user in the map-making process. In practice, limitations, such as monetary, temporary or personal constraints may be encountered and used as arguments against UCD (Baxter, Courage, & Caine, 2015; Roth et al., 2015). Yet, implementing UCD reduces costs, as changing for example an interactive cartographic product after its deployment may cost more project resources than implementing UCD already during the development and implementation stages (Delikostidis, 2011; Roth et al., 2015). Several case studies underline, how successfully implemented UCD can help identify unmet needs (Roth et al., 2013) and improve the usability of cartographic products (see e.g. Delikostidis, 2011; Golebiowska, 2015; Haklay & Nivala, 2010; Roth et al., 2015).

3.1.3. Use and user requirement analysis

3.1.3.1. Definition

The use and user requirements of a map comprise a number of influencing factors. On the one hand aspects regarding the use of maps must be considered. Firstly, the purpose of the map, namely the tasks that must be solved with the map and the questions it should answer must be identified. Secondly, the use context of the map, e.g. whether it will be used in an indoor or outdoor environment or whether it is a static or an interactive product, must be established (van Elzakker & Ooms, 2018). The business context of a map, namely any influencing stakeholder or organisational requirements such as policy requirements must also be identified (van Elzakker & Wealands, 2007).

On the other hand, the targeted users of a map must be identified. It is important to distinguish stakeholders, who have an interest in the map, from users of the map, who directly interact with it (Robbi Sluter et al., 2017). Those prospective users can be characterized by their needs, preferences and attributes, such as their job in which they make use of maps. One cartographic product can address different user groups. Having a clear definition of users or different user types can contribute to improving the quality of the final product (van Elzakker & Ooms, 2018).

Methods to capture the use and user requirements of maps can be adapted from other fields, like Ethnography or Geography. Methods such as questionnaires, interviews, focus group discussions or think-aloud have been adapted in the past for cartographic purposes (Suchan & Brewer, 2000). The methods utilized in this thesis research will be further discussed in chapter 3.1.3.4.

3.1.3.2. Use and user requirements in cartography and ecosystem service mapping

In addition to the user requirement research in ecosystem service mapping, which has been discussed in 2.2.7, briefly presents other requirement analysis, which have been conducted in cartographic research.

Capturing the use and user requirements did often receive little attention in the cartographic domain in the past (van Elzakker & Ooms, 2018). Yet, conducting a use and user requirement analysis of a product is beneficial for the producer, as the gathered information is invaluable for a high quality (cartographic) product (Baxter et al., 2015).

Roth et al. (2015) successfully applied a user requirement analysis during the development of an online, interactive crime mapping tool for a police bureau. The authors applied UCD to improve the interface of the tool trough an iterative process. The first stage of the process did elicit the use and user requirements of their target group through interviews. Based on those findings the authors identified prospective user groups and use case scenarios, distinguishing between investigators, officers and administrators. Furthermore, it was established, how experienced the users were with geospatial technologies. Those user profiles were complemented with five use case scenarios e.g. a crime investigative analysis, aiming at conducting analyse a crime and identifying suspects. This stage provided insights on poorly known user expectations and significantly contributed to uncovering unmet needs from the different user groups and the findings of this stage then informed the consequent UCD stages. The prototype was adapted based on the findings and the results were evaluated trough an expert-based think-aloud study, which led to further refinement of the requirements and informed the development of the second prototype (Roth et al., 2015).

Another example of how user requirement analysis can contribute to more usable interfaces was demonstrated by Delikostidis (2011). This research focussed on the development of a mobile geographic application for pedestrian navigation purposes and issues with navigation and usability. Among others, the aim was to derive insights on the usability of mobile interfaces and to implement those findings in the final application. To achieve this goal all three stages of UCD were implemented, starting with a user requirement analysis. At this stage the use context of the application was defined, which is different from a desktop environment. Pedestrian navigation applications are used on mobile devices with a limited screen size in an outdoor environment. The tasks the user wants to solve with the use of the map relate to geographic questions such as "Where am I?". The requirement analysis consisted of user profiling, e.g. in terms of age, prior knowledge or familiarity with the area, field navigation and think-aloud experiments. Those methods served as input for use case modelling and design of requirements, which served as guidelines for the application development. Based on those guidelines a prototype was developed, which was evaluated and redesigned based on those findings in an iterative process. The final interface resulting from this iterative process did satisfy the formulated requirements (Delikostidis, 2011).

Those examples and the case studies of user requirement analysis in ecosystem service mapping, which were discussed in chapter 2.2.7, underline the importance of use and user requirement analysis. Even though the findings are specific to the participants and case studies, the results clearly demonstrate that use and user requirement analysis contributes to bringing unknown user preferences to light (Klein et al., 2015; Willcock et al., 2016). Delikostidis (2011) and Roth et al. (2015) demonstrate how involving the user in the development process can be beneficial and how actively considering requirements like the use context or tasks of the prospective target groups and usability concerns support the development of more usable interfaces (Delikostidis, 2011; Nielsen, 1992; van Elzakker & Ooms, 2018).

3.1.3.3. Adapted use and user requirement framework

This research adapted stages 1-3 (know the user, competitive analysis, setting goals) of the framework proposed by Roth et al. (2015) for the use and user requirement analysis. These steps were expanded with one additional stage, the consideration of the larger context, which was proposed by Nielsen (1992), and adapted in accordance to the research questions of this research (see chapter 1.3.2):

1. Consider the larger context: Consider the policy requirements of the map creation and the intentions and use purposed of the map-makers.
2. Know the user: Gather the individual characteristics and the tasks of the target users to derive use case scenarios and user profiles.
3. Competitive analysis: Empirically analyse existing maps by having users perform real tasks with them.
4. Setting goals: Use the findings from the first three stages to create a requirements document, comprising the user profiles, use case scenarios and recommendations for future mapping.

The latter steps of the framework, which deal with prototype development, evaluation and user feedback, were not considered in this research.

3.1.3.4. Use and user requirement analysis methods

Delikostidis (2011) identified different methods, which can be applied in UCD approaches. A list of these methods, which can be applied throughout all stages of the UCD are displayed in Figure 17. As this thesis focusses on the first stage of UCD, the methods listed for the use and user requirement analysis of relevance.

Analyse Requirements	Produce Design Solutions	Evaluate Designs
Survey / interview of existing users	Usability goal setting	Usability Inspections
User requirements interviews	Design guidelines and standards	Usability testing in the lab
User profiling		
Contextual Observations / interviews	Scenario-based design	Usability testing in the field
Diary keeping	Parallel design	Post-experience interviews
Task analysis	(paper- or working interface-) Prototyping	Heuristic evaluation
Competitive analysis	Card sorting	Focus groups
Card sorting	Focus groups	Satisfaction questionnaires
Personas	Individual interviews	Expert reviews
Scenarios of use	Surveys (online)	Surveys (online)
User / task models	Usability testing	Diagnostic evaluation
Interaction modelling		
Heuristic evaluation	Use cases	Performance testing
Usability testing	Style guide	Critical incidence technique
Evaluating existing system(s)	Wizard of Oz	Remote evaluation
Brainstorming	Heuristic evaluation	Logging
Affinity diagramming	Interface design patterns	
Requirements meeting	Rapid prototyping	

Figure 17: Possible user research methods for the different stages of UCD (Delikostidis, 2011)

In the following chapters the research approach and methods that were selected for this research are justified and discussed in more detail.

3.2. Conduct of the research

This chapter present the chosen research approach and methods (chapter 3.2.1), followed by a discussion on the research sample and the conduction of the research (chapter 3.2.2). Chapter 3.2.3 will present how the data gathered from this research were analysed.

3.2.1. Chosen research approach

Scientific research methods can be divided into quantitative (e.g. survey) and qualitative (e.g. interview) approaches. A main distinction between those two approaches is the role of theory. Quantitative research aims to confirm hypothesis to prove or contradict an existing theory. On the contrary, the intention of qualitative research is to generate assumptions and lead to development of research theories (Suchan & Brewer, 2000). The application of qualitative methods in cartography offers "*the advantage of bringing research closer to the problem-solving realms of mapmakers (sic) and map users*" (Suchan & Brewer, 2000: 145). Due to the exploratory nature of this research and the research goal to uncover unknown issues related to map-makers and users, I chose to apply qualitative methods in this thesis research.

Table 3: Conducted research stages and applied research methods

Research stage	Applied method
1. Consider the larger context	Focused semi-structured map-maker interview
2. Know the user	Focused semi-structured user interview
3. Competitive analysis	Task execution (think-aloud and video observation)
4. Setting goals	User profile, use case scenario

The methods that were applied in the defined research stages (see chapter 3.1.3.3) are presented in Table 3. The selection of those methods will be justified in this chapter. Chapter 3.2.1.1 addresses the selection of the interview method, chapter 3.2.1.2 discusses the application of a task execution within this research and finally, chapter 3.2.1.4 discusses the user profiles and use case scenarios.

3.2.1.1. Focused semi-structured interview

Method

In a focused interview the interviewees are chosen due to their expertise in the researched field (Suchan & Brewer, 2000). The application of this method in user research is suitable if the needs and expectations of the target users are poorly known and the participants are representative for the target group (Roth et al., 2015). Another user-based research method would be a survey. A survey would be good when the researcher cannot be physically present during the research sessions, but applying this method is not suitable if the expectations or tasks of the test persons are unknown (Roth et al., 2015) and, as this was the very purpose of this thesis research, I decided that an interview would be the best approach to achieve this goal.

Interview questions can either be structured, providing only pre-defined answers or unstructured, where all the questions are open-ended. The interview within this thesis research was semi-structured, as some questions were open- and some questions were closed-ended. This interview type provides both quantitative and qualitative data. Qualitative data retrieved from interviews are very rich. Open-ended questions allow follow-up questions and can be useful when it is not clear in advance what answers the participants will give. A shortcoming is that the data from unstructured questions are time-consuming to analyse and the answers of the participants may not be consistent. Data resulting from closed-ended questions can be analysed faster and the answers of the participants are consistent, however, the reasoning behind the participants' choice stays unknown (Baxter et al., 2015). For that reason, I decided to make use of a semi-structured interview. Questions, where the reasoning of the participants behind their answer was of interest, were formulated as open-ended questions and the questions about the personal background of the participants were closed-ended.

Within this research people producing, using or willing to use or produce ecosystem service maps were interviewed. I chose to include not only users but also map-makers in the research, as their perspectives are complementary and including both allowed gaining a broad understanding and analysis of current practices and cartographic communication processes in the field of ecosystem service mapping. Two different sets of questions were developed for users and map-makers, which are briefly explained in the following sections.

Application: User interviews

The interview questions for the map users are displayed in Appendix 3 The participants were asked in the interview about their job, their motivation to use ecosystem service maps, practical examples of the use of ecosystem service maps, their decision-making process, difficulties during the map use and the communication with the map-makers. The sample of users consisted of people who did already use ecosystem service maps within their job and those who did not use them yet but would be willing to. In accordance to that the asked questions did vary according to the prior knowledge of the participants. The interview design for people with experience did include more detailed questions. All participants were also asked closed-ended questions about their background, such as age, education, map use experience, familiarity with the ecosystem service concept, administrative level and use context.

Application: Map-maker interviews

The interview included questions on the job, steps, tools and data of a map creation process, influencing factors on the map creation, intended target groups and involvement of the users in the mapping process. Finally, they were asked closed-ended questions about their background like age, education, map use familiarity, cartographic training, familiarity with the ecosystem service concept, frequency of ecosystem service map production and administrative level. Appendix 4 shows the complete list of questions used in the map-maker interviews.

3.2.1.2. Task execution: think-aloud and observation

Method

One goal of this research was to identify usability issues of existing maps. Interviews or surveys could be used to identify such issues. A survey would be a poor method, when the researches is not familiar with the expectations or tasks of the users and thus do not know which questions should be asked (Roth et al., 2015). Another shortcoming of both survey and interviews is, that the answers of the test persons may be steered in the predicted direction of the researcher (van Elzakker, 2004). However, the focus of this research was to uncover unknown unmet needs rather than verifying assumptions.

A method suitable for this purpose is the think-aloud method, which asks the test person to voice their inner thoughts while solving the given tasks (stimulus) with the help of a provided map and without interruption of the investigator (Suchan & Brewer, 2000; van Elzakker, 2004). A broad range of usability issues can be discovered with this method in a relatively short amount of time and resources. In order to achieve good results, the participants should be representative for the target group (Roth et al., 2015), as was the case in this research (see chapter 3.2.1.4). Applying this method provides insight on what the users are doing, why users take an action, what their underlying thoughts are or what problems they encounter. For that reasons I decided to apply this method in thesis research. However, this method has well-known limitations, such as the fact that the process of thinking-aloud may distract the users from the task they are solving. Furthermore think-aloud does not provide insight on whether the test person will make use of the tested map in practice (Baxter et al., 2015; Dumas & Redish, 1999; van Elzakker, 2004). The latter issue did not present a problem for this research, as the insights on whether the users make use of ecosystem service maps was derived from the user interviews.

The think-aloud method was combined with the observation method to get insight in the users interactions with the maps (van Elzakker & Ooms, 2018). The observation method should complement the data gathered from the audio recording of the think-aloud (Dumas & Redish, 1999). The users were observed during the task execution either via video and/or in person.

Application

The research sessions with the map users included a task execution exercise using the think-aloud method. The users and potential users of ecosystem service maps were shown four maps according to the administrative level they were working at.

The image shown to them contained the actual map, the caption of the map and a description of the displayed content derived from the publication the map was taken from, the source and three geographic tasks. Doing think-aloud the participants were asked to solve the tasks, which had an increasing level of difficulty. Van Elzakker (2004) distinguishes between elementary, intermediate, temporal and overall geographic questions and tasks. Table 4 shows one example for each difficulty level and how this task was applied in the think-aloud exercise in this thesis research. Temporal questions were only asked when the maps did display future scenarios.

Table 4: Different difficulty levels of geographic questions and map use tasks and their application in the task execution exercise (van Elzakker, 2004)

Difficulty level	Geographic question	Task	Example question
Elementary	At a given place, how much is there?	Estimation of amounts	What is the biomass production of the most eastern region?
Intermediate	Where is the least/most?	Quantification of spatial anomalies	Where are the regions with the lowest regulating service supply value?
Temporal	Have the spatial distribution patterns changed?	Establishing trends	What is the trend of the Nitrate concentration under the "Techno World" scenario?
Overall	What relevant patterns are there?	Recapitulating the patterns	Which regions have very high and very low potential for 'convenience and education recreationist'?

Each test person was presented with four maps of ecosystem services. In addition to the maps, the pages shown to the participants contained the sub-title of the map as shown in the publication, the ecosystem service type, a description of the displayed ecosystem service, as derived from the source, the source of the map and three tasks which the user was asked to solve with the provided information. The two layout formats that were used for the task execution can be seen below (Figure 18). The chosen format did depend on the map proportions. All tested maps and theirs tasks can be found in Appendix 5, 6 and 7.

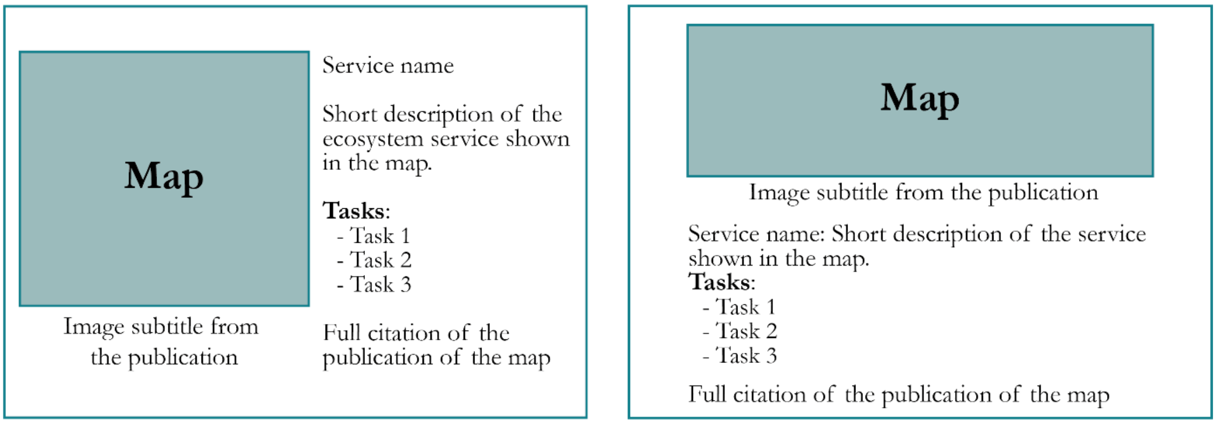


Figure 18: Layout formats used in the think-aloud exercise

The difficulty of the exercise was designed to increase in two ways. On the one hand the difficulty of the geographic tasks increased within every image through increasing difficult of the map use tasks. On the other hand, the maps themselves had different levels of difficulty: *Map 1* and *2* had a low level of difficulty, as they were single maps with one thematic layer, whereas *map 3* and *4* had a higher level of difficulty and contained either two or more maps showing scenarios or an additional layer of information such as pie charts.

3.2.1.3. Map selection

Twelve ecosystem service maps were included in a usability testing in the form of a task execution exercise. The participants of each administrative level were presented with four ecosystem service maps from their level. The maps tested in the task execution exercise were static (e.g. jpg or png format), allowing zooming in and out as only possible interaction with the content of the map. A justification on why only static maps were included in this thesis research can be found in chapter 2.2.1.

The map selection was based on cartographic and geographic criteria and criteria regarding ecosystem services. At EU-level maps that showed at least all Member States of the European Union were chosen. One of the selected European maps did also display data for non-Member States in Europe such as Switzerland or Norway. At national and sub-national level, it was decided to exclusively use maps displaying Greece, as all participants were Greek and past research has highlighted the importance of local knowledge in the context of ecosystem services (Díaz et al., 2018). As most of the maps found in literature were either choropleth, chorochromatic or dasymetric maps, it was decided to focus the usability evaluation on those three map types.

Due to limited data availability at national and sub-national level the selection of maps was limited to maps showing the supply of ecosystem services. I also decided to focus on ecosystem services provided by terrestrial and freshwater ecosystems. Marine ecosystem service maps were not included in this research, as due to their dynamic they bring up new cartographic challenges, which were not addressed by this research. Another selection criterion was having all three ecosystem service types (regulating, provisioning, cultural) present in the maps at each administrative level.

3.2.1.4. User profile and use case

Based on the analysis of the research user profiles and use case scenarios were developed. User profiles and use cases are two methods, which can support the developer of a product (map) to learn about their users (Baxter et al., 2015). Usually these methods are intended to be applied at the start of a mapping process (Baxter et al., 2015; Roth et al., 2015). In this research those user profiles and scenarios were developed of output of the analysis, aiming to serve as starting point for future mapping e.g. by informing the development of a prototype (Roth et al., 2015).

User profile

A user profile contains a detailed description on the attributes of the prospective users and user types. Applying a user profile helps understanding who the final product is built for. Attributes in the user profile contain factors like age, education or knowledge (Baxter et al., 2015; Nielsen & Mack, 1994). A sample user profile, portraying the characteristics of a travel agent can be found in Figure 19. This profile contains socio-economic data such as income or family status, which were not relevant in the conducted thesis research. Yet, this example demonstrates how the characteristics relevant for a certain user type can be presented in a user profile. The information gathered from the user interviews was used to build the user profiles.

Travel Agent (primary) Characteristic Ranges	
Age:	25-40 years (Average: 32 years)
Gender:	80% female
Job Titles:	Travel agent, Travel specialist, Travel associate
Experience Level:	0-10 years (Typical: 3 years)
Work Hours:	40 hours per week; days and times depend on the company
Education:	High school to Bachelor's degree (Typical: some college)
Location:	Anywhere in the U.S. (Predominantly mid-west)
Income:	$25,000-$50,000/year; depends on experience level and location (Average: $35,000/year)
Technology:	Some computer experience; high-speed Internet connection
Disabilities:	No specific limitations
Family:	Single or married (Predominantly married with one child)

Figure 19: User profile - travel agent
(Baxter et al., 2015)

The user profiles were complemented with a sample use case, describing a sample case of application (Nielsen & Mack, 1994) of an ecosystem service maps in practice. Use case scenarios can be useful to provide understanding of the potential user (Nielsen, 2002). Those profiles and sample use cases are presented in chapter 4.5.1.

3.2.2. Research sample and conduction

3.2.2.1. Research sample

When conducting a use and user requirement analysis, it is important to know about the characteristics of the prospective target group and participants should be selected based on those anticipated characteristics (van Elzakker & Ooms, 2018). This research thus applied purposive sampling (as was done by Willcock et al. (2016)), by only considering people whose background and expertise is relevant to the study objectives. This sampling technique ruled out students, university staff or other easily accessible populations (Roth et al., 2015). The sampling of this exploratory research followed four steps proposed for qualitative sampling by Robinson (2014):

1. Defining the research sample,
2. deciding on an appropriate sample size,
3. choosing a suitable sampling strategy and
4. recruiting participants.

Defining research sample

Table 5: Selection criteria of the research sample, specifying the test persons age, education, gender, expertise on the ecosystem service concept, administrative level and profession and role

Category	Specification
Age	21+
Education	Any
Gender	Male and female
Expertise on ecosystem service concept	(Basic) knowledge of ecosystem service concept
Administrative level and profession	EU level: Working for an European Commission National and sub-national level: Working in Greece
Role	(Potential) map-maker or user of ecosystem service maps

The inclusion criteria of the potential research sample are displayed in Table 5. Regarding the attributes age, education or gender no specific assumptions were made. It was however required for the participants to have at least very basic knowledge of the ecosystem service concept. The mapping and assessment of ecosystem services is currently being carried out within the European Union at EU, national and sub-national level (Maes et al., 2013). As ecosystem service maps are relevant for all those levels and different levels have different uses for ecosystem service maps (Hauck et al., 2013) I decided to include test persons from all three administrative levels in the research sample to analyse differences and similarities between those levels.

At European level the research sample was limited to people who work for the European Commission. At national and sub-national level it was decided to limit the research sample to one country to ensure homogeneity among this part of the sample. I decided to use Greece as a case study, because the country is currently in the process of MAES-related activities (Dimopoulos et al., 2017) and the results of the research may potentially have a positive influence on the ongoing mapping processes. The last research sample specification did define the role of the targeted people, namely people using/producing or willing to use/produce ecosystem service maps within their job. As the mapping and assessment of ecosystem services is a currently ongoing process in Greece and trainings related to that are being held, it can be the case that potential users/producers may have heard of the concept in workshops, but do not apply the concept in practice in their work yet, but they would be willing to do so. As this test person group presents soon-to-be users/producers of ecosystem service maps, it was considered imperative to include their perspectives in the research process.

Deciding on sample size

Nielsen (1994) conducted research on the required number of test subjects for a think-aloud test. It was found, that only a few test persons are required to uncover those problems. Two test persons can already find 49% of the existing problems, five test persons participating in a thing-aloud test already helped uncover 77-85% of the usability issues of a system. Due to the exploratory nature of this research and the richness of the qualitative data gathered from the interviews and the task execution exercises, a sample size from 4-5 participants per administrative level and role was considered to be desirable and sufficient for the purposes of this research.

Choosing sampling method

As past user research has demonstrated the advantages of applying purposive sampling (e.g. Roth et al., 2015; Willcock et al., 2016), it was decided to apply this sapling method in this research, selecting the test-persons because of their characteristics of interest. One sampling method applied was the gatekeeper sampling, meaning that the access to the research field was provided by key persons of the community (Oppong, 2013). Access to participants of this study was granted through key persons in Greek and in the European Commission. In addition to the contact details provided by the gatekeepers, snowball sampling was applied, in which a test person suggests further potential participants (Baxter et al., 2015).

Recruiting participants

The recruitment and interviewing of the participants took place from the 15th of July until the 2nd of August 2018. In total 115 potential test persons were contacted two times via e-mail, trough personalized invitation e-mail and a reminder e-mail 6-10 days later. The invitation to the European users was sent in English, the invitation e-mail sent to the Greek participants was English and Greek. In total 23 people replied and took part in this research. All interviews were conducted in English.

Table 6: Number of actual and potential map-makers and users that participated in the research

	map-maker	user

	actual	potential	total	actual	potential	total
EU	2	0	**2**	3	0	**3**
national	4	1	**5**	2	1	**3**
Sub-national	4	1	**5**	1	4 (+1 TAL)*	**6**

*One sub-national map-maker, who also identified as potential user and thus did also do the think-aloud (TAL) exercise

Further details regarding their administrative level and role can be found in Table 6. The research sample was subdivided into smaller test person groups according to their administrative level and role (for the analysis the roles will only be distinguished between user and map-maker).

In total 11 users or potential users of ecosystem service maps were interviewed. As can be seen in Table 6, one additional think-aloud exercise was conducted at sub-national level. This came from a test person who was interviewed as map-maker but also identified as potential user of ecosystem service maps.

In total 23 research sessions were conducted, 12 on the map-maker and 11 on the user side. As mentioned above, the number of conducted interviews did depend on the response rate of the contacted persons. Problems with the internet connection or the phone signal did influence the sampling. The goal of having 4-5 people in each interview category was achieved for the map-makers at national and sub-national level and for the users at sub-national level. Even though the aspired number of think-aloud participants was not met at two administrative levels, it can be argued that with 3 or 4 participants already 63% or 73% of the usability issues can be discovered (Nielsen, 1994). As this research is of exploratory nature and the interview data gathered from those test persons were very rich in information, three interviews were considered to be enough to draw meaningful conclusions from them.

The research was conducted either face-to-face, with video and audio or only with audio. Within the research setting it was of interest to visually observe the participants and, in case of the user interviews, to show the participants some maps. Baxter et al. (2015) concluded, that a face-to-face or a video and audio interview would be the most suitable approach to meet these criteria. As the participants were located in several European countries, a face-to-face interview was not always possible. For that reason, the majority of the interviews (N = 21) were conducted remotely. Two interviews were conducted face-to-face at the place of employment of the interviewee. In eight out of eleven sessions with users, the research was conducted using only audio transmission, as the participants preferred to be contacted via telephone or because of the poor internet connection the video transmission did not work. In all remote user research sessions, the maps were shown to the participants trough screen sharing. During the two user research sessions, that were conducted in person, the maps was shown to the participants on the instructors' laptop. The research sessions were recorded trough audio recording and, if applicable, trough screen recording during the task execution. The user interviews were estimated to take around 50 minutes and the map-maker interviews were planned to take 30-35 minutes.

3.2.2.2. Pilot tests

In order to ensure that research set-up worked as planned and that the formulated questions of the task execution were understandable, two pilot tests were conducted on 12th of June and 15th of June. The test persons were an university staff member and a student. With the test-persons a complete task execution exercise was conducted. Regarding their background and prior knowledge, the two test persons did not represent the intended target group, yet, valuable insights were gained regarding the research set-up. Based on the feedback from the participants the research design and think-aloud tasks formulations were adapted and improved.

All the steps and tools needed for the practical set-up of the research were summarized in a pre-research checklist for map-maker and for user session. Those two checklists are shown in Appendix 1 and Appendix 2.

3.2.3. Analysis

The acquired data from the interview and think-aloud sessions were transcribed and coded. The transcripts did also include non-verbal phenomena such as strong emphasis of a word or laughter. Transcribing is a time-consuming process. Yet, this approach was purposefully chosen, as this enables taking a careful look in retrospective at the conversation (Przyborski & Wohlrab-Sahr, 2014).

The transcripts of the think-aloud exercises are so-called verbal protocols (Suchan & Brewer, 2000). One sample verbal protocol resulting from this thesis research is presented in Appendix 8. The verbal protocols of this research were processed in two ways. On the one hand the data was coded with a coding scheme. This scheme was drafted before the research sessions and refined afterwards. On the other hand, the usability of existing maps was quantified using usability measures. The usability of a product can be measured through its efficiency, effectiveness and satisfaction. Within this research it was decided to analyse the first two measures. It was chosen not to include the satisfaction of the participants, as measuring this parameter unambiguously was challenging as most of the task executions were carried out only through voice transmission and other factors like language barriers or bad signals did influence the conversations. Those factors made it difficult to unambiguously derive the user's satisfaction.

Efficiency describes the amount of resources needed to fulfil a given task. This analysis quantified efficiency by measuring the time the participant took to solve a task. The effectiveness of a map expressed how complete and accurate a certain goal was achieved (International Organization for Standardization, 2018). The effectiveness in this research was measured by 4 categories:

1) Correct – The participant did answer the question correctly
2) Incorrect – The participant did answer the question incorrectly
3) Not answered – The participant knowingly did not answer the question
4) Help required – The participant required help from the instructor to answer the question

The efficiency of the test participants was derived by measuring the number of seconds they took to answer the question, measuring the time from when they started to read the question until they finished giving their answer. The effectiveness was derived by analysing the verbal protocol and classifying the answer into one of the four categories mentioned above. Both of those measures were derived after the task execution exercise. As both only required the verbal protocol and the audio recording of the session, it was possible to derive those usability measures for the interviews that were conducted in person as well as for those, that were conducted remotely.

3.3. Conclusion

This chapter presented the theoretical foundations of UCD user requirement analysis. Furthermore, it was outlined, which methods were applied in this research and how it was conducted. The results from the map-maker and user interviews and task execution exercises will be presented in the following chapter 4.

4 RESULTS AND DISCUSSION

The following chapter will discuss the findings of this user research and connect the findings to scientific literature and in doing so answer the formulated research questions, which were formulated in chapter 1.3. For that reason, the structure of this chapter will follow the structure of the formulated questions. The structure of this chapter and the analysis is presented in Figure 20. The headings in the sub-chapters indicate the research question that is being answered (e.g. RQ1a). Firstly, chapter 4.1 presents the profile, characteristics, use purposes and use contexts of the users at EU-, national and sub-national level. Secondly, the results of the map-maker interviews will be presented in chapter 4.2. Those two perspectives will be brought together and discussed in chapter 4.3. Usability issues of existing ecosystem service maps at EU-, national and sub-national level will be discussed in chapter 4.4. Chapter 4.5 concludes by presenting recommendations for future map design. Finally, chapter 4.6 concludes with a discussion on the limitations of this research and outlines opportunities for future research.

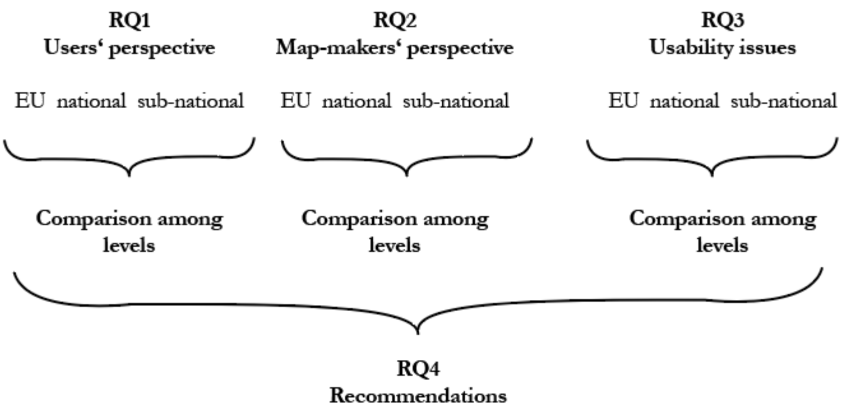


Figure 20: Structure of the research analysis and the "results and discussion" chapter

4.1. The users' perspective

This chapter will discuss the findings of the ecosystem service map user interviews, while outlining their characteristics across different administrative levels. For this research 11 users were interviewed, three at EU, three at national and five at sub-national level. The interview questions are shown in Appendix 3.

The following chapters discuss the results of the interviews of the users at EU- (chapter 4.1.1), national (chapter 4.1.2) and sub-national (chapter 4.1.3) level. Chapter 4.1.4 presents a brief comparison among the administrative levels. The findings are complemented with quotes from the test participants (TP) and compared with information of the literature review to answer research questions RQ1a – RQ1d and RQ4b.

- RQ1a: What are the characteristics, needs and requirements of decision makers potentially using ecosystem service maps?
- RQ1b: At which stages of the decision-making process do the decision makers use ecosystem service maps?
- RQ1c: What are the use contexts of decision makers using ecosystem service maps?

- RQ1d: What purposes do the decision makers use ecosystem service maps for?
- RQ4b: How do the encountered use and user requirements vary at EU, national and sub-national level?

It was chosen to include RQ4b in this chapter already, as it did fit better in the logical structure of this analysis chapter. The aspects related to the usability issues comparted among administrative levels will be discussed in chapter 4.4.4.

In some instances, the interview results brought up interesting findings, which were not included in the formulated research questions. If that was the case the sections discussing those results were labelled as "further findings". One part of the interview were closed-ended questions about personal attributes (see Appendix 3), whose outcomes listed in Table 7 (see next page). Those outcomes will be included in the discussion in the consequent chapters.

Table 7: Results of the questionnaire on the personal background of the users. Table shows the number of the test person (TP), the administrative level, the gender, the highest educational level and field of education, the participants map use familiarity in his/her daily life (leisure and work), since when he/she knows the ecosystem service concept, the use frequency of ecosystem service maps in his/her profession and whether he/she also identifies as (potential) map-maker of ecosystem service maps (hybrid).

TP	Adminis-trative level	Gen der	Age	Highest level of ed-ucation	Field of education	Map use familiarity in daily life	Familiarity with ecosystem ser-vice concept	Use frequency of ecosystem service maps in profession	Hy-brid
23	EU	M	41-50	PhD	Molecular Biology	a bit familiar	4-6y	a few times/y	No
5	EU	F	31-40	PhD	Marine Sciences	very familiar	> 6y	a few times/y (used to be every week)	Yes
3	EU	M	41-50	PhD	Natural Sciences	very familiar	> 6y	once a week	No
12	national	F	41-50	PhD	Forest Management	a bit familiar	1-3y	once a week	No
18	national	F	41-50	M	Agricultural Economics	not familiar	1-3y	almost never	No
8	national	F	31-40	n/a	n/a	very familiar	4-6y	Not yet	No
9	sub-national	F	31-40	M	Management of pro-tected areas	a bit familiar	< 1y	Not yet	Yes
10	sub-national	F	31-40	M	Biodiversity	very familiar	< 1y	Not yet	Yes
16	sub-national	F	31-40	M	Environmental Studies	very familiar	< 1y	Not yet	No
6	sub-national	M	51-60	B	Forestry and Botany	very familiar	1-3y	Not yet	Yes
4	sub-national	M	41-50	PhD	Vegetation Science	very familiar	4-6y	Not yet	Yes

4.1.1. Users' perspective at EU- level

RQ1a: What are the characteristics and needs of decision makers potentially using ecosystem service maps? (EU)

The user interviews at EU-level did include participants from the Directorate General (DG) Environment (DG-ENV) and the DG International Cooperation and Development (DG-DEVCO) of the European Commission. The users interviewed at this level work or used to work with ecosystem services in relation to European policies. Two participants explained that the duties of their profession as policy maker include developing and supporting policies related to conservation of the nature and biodiversity. Another participant was working in the management of projects related to protected areas and biodiversity. TP5 has been creating ecosystem service maps in her prior experience as scientist.

All users at EU-level were very or a bit familiar with using maps in their daily lives and very familiar with the concept of ecosystem services, with all participants knowing the concept for 4 or more years. Furthermore, they make use of those maps more often than those at the other levels, using them once a week or a few times per year. All three participants mentioned, that maps can be useful to show and communicate spatial information to others. Using a map "*it is clearer to show a map than to give a ten minutes speech*" (TP23).

Those findings may underlie limitations in terms of representativeness, due to the fact, that the sample size consisted of three people. However, past analysis, which dealt with the questions of policy-makers did include policy makers from different DGs of the European Commission (e.g. Hauck et al., 2013; Maes, Liekens, & Brown, 2018), which shows, that the policy makers working for the European Commission are a key target group of ecosystem service maps. Some of the guiding policy questions of the EU Biodiversity Strategy (see chapter 2.2.6) have been formulated by policy makers of the DG Environment (Maes, Egoh, et al., 2012; Maes et al., 2018). This fact and the characteristics discussed above could lead to the assumption, that policy officers at EU-level are well informed on activities related to the EU Biodiversity Strategy and very experienced with the ecosystem service concept and the use ecosystem service maps.

RQ1b: At which stages of the decision-making process do the decision makers use ecosystem service maps? (EU)

Currently, ecosystem service maps are not or only partly used in decision-making processes by the interviewed users. Two participants use those maps for communication purposes to communicate the existence and value of ecosystem service to others but did not base any decision on those maps. Another participant sometimes uses ecosystem service maps during policy development processes, as they are useful to "t*o get a general story or picture of what's happening with ecosystems and services and their relationships"* (TP3), but emphasized, that the maps are not the only arguments, that are taken into consideration. Sometimes this participant preferably considers short key messages or other information visualizations like charts or graphs, as they also convey the needed information.

These findings could be an indication, at EU-level other use purposes for ecosystem service maps than decision- or policy making can be encountered (further discussion see RQ1c below). If an ecosystem service map is included in a policy development or decision-process, it is done so during the process, while taking other pieces of evidence into consideration. In the literature review no information specifically addressing the decision-making process of policy makers was found, which would present an opportunity for future research.

Q1c: What purposes do the decision makers use ecosystem service maps for? (EU)

The participants presented two ways in which ecosystem service maps are used on their level. On the one hand those maps can be used to inform decision and policy development processes of the policy officer and on the other hand the user can make use of the map to communicate its content to other people.

TP3 pointed out that, with the information shown in ecosystem service maps should show the "*interlinked roles between the services and conservation of interest. Then you can have winning arguments and you can swing policies*" (TP3). Ecosystem service maps at European level could also be used to advertise and communicate the existence of protected areas or biodiversity to relevant stakeholders. It was emphasized by two participants, that using maps in their job does not always have an impact on peoples' opinion (TP3) and that motivating people by showing the maps can be difficult (TP23).

These purposes match the findings of Hauck et al. (2013). Another use purpose identified by literature was policy impact assessment (Diehl, Burkhard, & Jacob, 2016). The fact, that this purpose was not mentioned in the user interviews could be explained by the sample size. Table 8 presents the use purposes and examples that were identified by the users at EU-level.

Table 8: Identified use purposes and examples identified by users at EU-level

Identified use purpose	Example
Policy development	Identifying areas where the provision of water regulating services should be enhanced
Policy impact assessment	Assessing if a policy measure would improve the provision of an ecosystem service
Communication and raising awareness	Raising awareness among fellow stakeholders for the existence of ecosystem services

Further findings

TP5 elaborated, that the concept of ecosystem services is more powerful than for instance just habitat map. For example, ecosystem service maps could be used to identify areas where actions should be taken to enhance water provisioning or water regulating services. This participant also acknowledged, that on their opinion "*in ecosystem services, several things have to be shown together, like the natural capacity or the benefits*" (TP5). In order to be useful for policy makers in policy making, an ecosystem service map must tell a clear story, be simple and contain a few, but precise messages. "*Very clear, very simple, with a legend - clear legend and some kind of text narrative or somebody explaining the narrative to me*" (TP3). A map should be "*clear in the sense of that the information is all shown together, there are titles, there is a clear legend at two points in time and a trend. It is fully I mean the information is full*" (TP5). Complex ecosystem service maps, which are not self-explanatory, take a long time to read, have a counter intuitive content or are too complex and technical can cause a high level of frustration by the user. One participant pointed out, that creating a good map takes time and many current ecosystem service maps, which are automatically generated, do not effectively convey the intended message.

When asked about how much they trust the provided ecosystem service map, all test persons indicated that the trust in a map is strongly related to the underlying data. One test person highlighted the importance of having a trustworthy source in order to trust the map. TP5 and TP3 pointed out, that is important to know about the uncertainties and assumptions behind the displayed values or the used simulations and models. The test persons had clear images in mind on what a useful map should look like and did critically reflect on the map content and the underlying data. Those findings support the assumptions made while answering RQ1a, that the users at European level are very experienced with using ecosystem service maps.

RQ1d: What are the use contexts of decision makers potentially using ecosystem service maps? (EU)

Until now all three participants have been using ecosystem service maps in form of static screen maps. TP3 has also been rarely using dynamic screen maps and printed ecosystem service maps. None of the participants has been working with interactive ecosystem service maps in their past work experience.

This shows that the use context of ecosystem service maps so far dominantly was the use in a desktop environment and that interactive cartographic systems have not been used yet by the interviewed European users. These findings are in line with the conclusions drawn from the conducted literature review on ecosystem service maps (see chapter 2.2.1).

Business context

The EU Biodiversity Strategy for 2020, especially the actions of MAES, does influence the work of TP3 and TP5, who do or did work frequently with ecosystem service maps in their profession. According to one user, this strategy "*was a huge motivation in Europe to start doing all these marketing on ecosystem mapping services*" (TP5). One test person pointed out, that policies are being promoted in accordance to the Biodiversity Strategy. Yet, it was pointed out by TP3, that the strategy is not legally binding unlike a directive and that there is still a lot of effort needed to ensure a successful application in all EU Member States. The work of TP23, whose profession was dealing with regional development, was not influenced by the EU Biodiversity Strategy.

These findings are in line with the assumptions made in RQ1a, leading to the hypothesis, that policy makers who frequently work with ecosystem service are generally also very familiar with the EU Biodiversity Strategy, yet keeping in mind, that it is not legally binding.

4.1.2. Users' perspective at national level

RQ1a: What are the characteristics and needs of decision makers potentially using ecosystem service maps? (national)

At national level one user (TP12) and two potential users (TP8, TP18) were interviewed, all of whom were working in Greek ministries, which presents a limitation for the generalizability of the results. The test persons had mixed map use familiarity and knew the concept of ecosystem services for one year or more. Only TP12 uses ecosystem service maps on a weekly basis, the other two participants do not use those maps (yet).

A plausible reason for that could be the fact, that the mapping and assessment of ecosystem services is currently taking place in Greece (Dimopoulos et al., 2017) and those type of maps do not exist yet.

Two test persons were working in professions related to forestry, the third was working in the field of agriculture. TP12 is currently working in management of forest areas and her duties include monitoring the development of biodiversity and habitats in those areas. One test persons profession includes the development of laws or guidelines. TP18 is active in the field of designing and implementing national agricultural policies.

The fact, that all participants were working for Greek ministries complements the findings of Willcock et al. (2016), who identified governmental organisations to be one of the stakeholders of ecosystem service maps. Yet, for the context of this research this fact presents a limitation for the generalizability of the results. Keeping this in mind, the results discussed above could lead to the conclusion, that due to the novelty of MAES activities in Greece, the ecosystem service concept is not fully integrated yet in the work of ministry employees.

RQ1b: At which stages of the decision-making process do the decision makers use ecosystem service maps? (national)

TP8, who does not use ecosystem service maps in her current profession yet, but emphasized, that the information provided by ecosystem service maps should ideally be used during the entire decision-making process: "*I think it should have two directions: taking and giving. I don't think it's going to be [at] the end or the beginning. It should be all-over the process. It's a starting point and it's an ending point*" (TP8).

TP12 who uses ecosystem service maps on a weekly basis pointed out, that the maps are only being used to get an overview over the managed forested areas, but that no decisions that are made are based on those maps. Decisions on forest management rather rely on knowledge "*from the previous years: How they managed on the past, how they were managed in the past and how they are now. How they are evolving now*." (TP12). The lacking impact of ecosystem service information on decision-making was also identified by Ruckelshaus et al. (2015).

TP8 also pointed out, the decisions currently are sometimes taken only by relying on expert knowledge and experience. The reliance on expert knowledge could explain why ecosystem service maps are not (yet) applied in decision-making processes in the Greek ministries. That brings up the question, why TP12 rather relies on expert knowledge than information provided by the map, even though she stated, that she completely trusts the provided maps.

It could be, that the provided information is not relevant to the type of decision that has to be made (Wright, Eppink, & Greenhalgh, 2017) or that training on how to use the information ecosystem service maps would be required. The latter issue was raised by TP8 and TP12. They underlined that training for managers, policy and decision makers would be useful when introducing ecosystem service maps with in their profession. On the one hand, it is important to provide knowledge on what the ecosystem service concept is and how this new way of thinking can contribute to sustainable management of the environment. On the other hand, training on how to use maps and how they can contribute to the policy makers work may be required. "*For us that we don't make extended use of the map it would be definitely important to... to get informed of <u>what</u> information you can find there and then be trained on <u>how</u> this information can contribute to your more efficient work, more efficient policies*" (TP18). Ultimately, TP8 acknowledged, that ecosystem service maps could be useful for policy makers working in Greek ministries to develop new laws and base decisions on. "*when you have a new decision or a ministerial decision or a new law or whatever, you have to base it on something other than your instinct. So I would [be] glad to have something- to have some kind of tools"* (TP8).

RQ1c: What purposes do the decision makers use ecosystem service maps for? (national)

Maps were perceived to be useful or potentially useful for different reasons. TP12 pointed out, that maps provide an overview over the forested area, as they show "*What sort of trees, what sort of the plantation, what else. What sort of the animals that live there. In general, about biodiversity. Also, we are interested about the roads in the forest*" (TP12). Furthermore, ecosystem service maps could be applied in national risk assessment by helping to identify high risk areas for intervening measures against natural disasters and priority areas for investments to improve the delivery of a service.

The work of TP18 is not directly related to ecosystem service maps, as it is more related to the administrative tasks related to national policies. Information about the state of a natural area is currently presented to this test person in form of charts or numbers. Yet, it was acknowledged by the participant, that those maps could potentially be useful for agricultural policy makers under the following condition: "*Only data for example that can contribute to designate better policy is important. I mean... of course to know the habitat what the concentration of all the environmental elements is important but also maybe they should be combined with information regarding other elements of... for example the age of farmers, the sustainability of the farms in those areas*" (TP18). In other words, ecosystem service maps should help the people in the ministry to take care of the resources so that farmers could keep producing in an environmentally friendly way. In order to be useful for this user group, the maps would have to take the concrete expectations of the user into consideration. Table 9 summarizes the use purposes and examples identified by the users at national level.

Table 9: Identified use purposes and examples identified by users at national level

Use purpose	Example
Policy development and support	Development of forest policies
Management decisions	To improve the health of forested areas
Risk assessment	To identify high risk areas for natural disasters
Information	To get an overview over the area

RQ1d: What are the use contexts of decision makers potentially using ecosystem service maps? (national)

TP12 has been using ecosystem service maps in the past as static screen maps and on paper. The other two test persons have not use ecosystem service maps yet in their current profession. None of the test persons indicated that his/her current profession includes field work, which could lead to the assumption, that maps would likely be used in an indoor desktop environment.

Business context

The Greek Biodiversity Strategy or the EU Biodiversity Strategy did influence the work of the participants to different degrees. While one test person is not familiar with the Greek Biodiversity Strategy, two participants stated that this strategy influences their work and that it provides them with strategies and standards on forest management. One participant was critical of this strategy, as it is very exhaustive, which is a good thing but also could lead to loosing priorities on what is important. "*There are so many things inside that actually we are absolutely losing priority. Which is good to have everything, but to have priorities […]you are losing the forest, you know*" (TP8). All three participants have heard of the EU Biodiversity Strategy but have their main focus on other policies. TP12 stated, that this European Biodiversity Strategy is familiar but mainly the Greek Biodiversity Strategy, which is an adaption of the EU Biodiversity Strategy, is considered. The work of TP18 is rather influenced by legally binding EU Directives. This stronger importance of national laws can be explained by the fact, that the participants were working for Greek ministries.

4.1.3. Users' perspective at sub-national level

RQ1a: What are the characteristics and needs of decision makers potentially using ecosystem service maps? (Sub-national)

At sub-national level five potential users were interviewed, none of whom has been using ecosystem service maps in their prior work experience. Yet, most of the users at sub-national level stated to be very familiar with using maps in general and maps related to the supply of biodiversity have been used in the prior work experience. The people interviewed at this level had different levels of expertise on ecosystem services. Ranging from three years or less to one participant knowing the concept for four or more years.

Three test persons are also currently creating maps within their job, one participant expressed his/her interest in creating ecosystem service maps in the future. One test person interviewed at sub-national level is working at a university and also interested in producing maps in the future. The four other test persons were working in the management authorities of national parks in Greece, which does present a limitation to the generalizability of the research results. Three of those are either currently also producing maps or would be interested in producing ecosystem service maps in the future.

Based on the findings it could be assumed, that the prior knowledge regarding the ecosystem service concept of national park employees at sub-national level is mixed and that maps in general are already being used to some degree. Despite the limitations of the research sample, those findings are similar to what Albert, Hauck, et al. (2014) found when investigating the needs and characteristics of landscape and regional planners in Germany.

RQ1b: At which stages of the decision-making process do the decision makers use ecosystem service maps? (sub-national)

None of the participants at sub-national level has been using ecosystem service maps yet. Thus, they could not answer questions related to the stages of use of ecosystem service in decision-making processes. They had different opinions on the potential usefulness of ecosystem service maps in their job and related decision-making processes. On the one hand, TP16 was unsure, how the seemingly very theoretical ecosystem service concept can be applied as tool to a national park area. This participant expressed doubts "*if it would complicate things or make them much more simple […] if it would help make the decision much more easy*" (TP16). On the other hand, participants pointed out that ecosystem service maps could provide guidance for management actions in the park and support argumentations in debates. In other words, ecosystem service maps could be a useful tool that provides insights on "*how to manage the human activities inside the area.*" (TP10).

Even tough maps have been used in the past, they were not the only factor influencing the decision-making process. Other pieces of evidence like the road network, laws or background information has also been taken into consideration for management decisions. One participant pointed out, that the judgment of experts, who rely on experience regarding best or worst practise examples of the national park and the personal knowledge on a certain subject matter is currently the strongest factor in decision-making processes. Research from Albert, Hauck, et al. (2014) came to similar conclusions, finding that different types of informal evidence like expert judgement or discussions with colleagues are used as information source in regional and landscape planning in Germany.

Looking for a more general perspective on decision-making processes, one could assume, that ecosystem service maps would be (potentially) included during the decision-making process in combination with other types of information or laws the users at sub-national level have to comply with.

Another interesting aspect raised in the context of decision processes was the participation of local stakeholders. "*We are an authority which acts like an umbrella for the other services, like forest service, police department, civil engineers' services and something like that. And we try to connect all those services, state and private services. Like, tourist organizations and others, like farmers and others. We take all that to connect and to discuss and to always be together, with all these people to make some real proposals and effective for the local environment […] We always discuss to - not theoretical proposals but we propose matters in reality. That means we think our work is ecology in real life*" (TP6). The relevance and usefulness of stakeholder involvement at this administrative level has been highlighted in the past (e.g. Albert et al., 2014; Kruse, 2017).

RQ1c: What purposes do the decision makers use ecosystem service maps for? (sub-national)

The management authority of a national park "*must play the role between the people that must be here in this protected area and the protection of the same area*" (TP10). The profession of the participants included a variety of duties, which could also be supported by ecosystem service maps. For example, conducting an environmental impact assessment, which evaluates the positive and negative impacts of a planned activity to the national park area. Such activities could range from scientific research, photography, construction to agricultural activities. Based on this assessment, permission for activities is granted or denied. Ecosystem service maps could be useful for such an activity, if "*we can put into the data, what the existing usage of the land is, the permissions according to law, what we want to do, a kind of planning of the area and probably these maps will help us*" (TP16). Another task would be the monitoring of habitat types and species and their development within the national park. "*The other thing is to inform citizens and visitors of the area about the flora, fauna and protected species and also about the activities that are not/allowed in the protected areas*" (TP9). Ecosystem service maps visualizing the distribution of certain indicators could be useful for such educational purposes.

One use purpose of ecosystem service maps could be the support in trade-off decisions (Hauck et al., 2013). An example case study named by one participant would be the placement of a new windmill in the national park area. Trading-off interests of different stakeholders, the new location should ideally minimize the conflicts between biodiversity and societal interests like recreation, ecotourism or farming. In such a situation a map would be "*a concrete argument for everybody*" (TP6). TP4 highlighted the importance of maps showing economic valuation of ecosystem services or future scenarios. The latter issue was also raised by two other participants, which supports the findings of Willcock et al. (2016).

A different use purpose, which can also be encountered at sub-national level is policy development and implementation (Hauck et al., 2013; Ruckelshaus et al., 2015). This was brought up by TP8, who was interviewed as user at national level but pointed out, that in a prior employment ecosystem service maps were used in regional forest policy development processes. The fact, that policy development was not identified as use purpose by the interviewed sub-national users can be explained by the limitations caused by the profession of the test participants. The use purposes and examples identified at sub-national level are presented in Table 10.

Table 10: Identified use purposes and examples identified by users at sub-national level

Use purpose	Example
Impact assessment of future management scenarios	**e.g. assessing impact of planned agricultural or touristic activities**
Trade-off analysis	e.g. trade-off between interests of different stakeholders
Monitoring purposes	e.g. monitoring of development habitat types and species
Educational purposes	e.g. showing the value of ecosystem services to pupils
Public communication and raising awareness	e.g. promote cultural services or national park to its visitors

RQ1d: What are the use contexts of decision makers potentially using ecosystem service maps? (sub-national)

As ecosystem service maps have not been used by the interviewed persons at this level yet, it could not be established, which medium is being used to display ecosystem service maps. Regarding the environment of the map use TP9 pointed out, that her work is mostly taking place in the office, which could support the assumption, that future ecosystem service maps also will be used in such indoor desktop environment.

Business context

One test person mentioned, that no strong weight has been put on the Greek or the European Biodiversity Strategy, as the management rather focusses on learnings from past management activities. On the contrary, two participants TP9 and TP10 make use of the Greek Biodiversity Strategy to support argumentations about activities taking place in the national park. One participant pointed out, that at sub-national level "*governmental decisions of the ministry of environment, which more or less are the same as the European*" (TP16) are being followed. This indicates, that the influence of the EU Biodiversity Strategy is not as strong at this administrative level, as it is at EU-level. This could be explained by the novelty of the implementation of the Biodiversity Strategy in Greece and by the fact, that other policy requirements at sub-national level (see chapter 2.2.5) have more weight (Albert et al., 2014).

4.1.4. Comparison of the users' perspectives among administrative levels

Hereafter the similarities and differences between the end-users on different administrative levels are briefly summarized and in doing so, RQ4b will be answered. The answers of RQ4b, that relate to usability issues of existing ecosystem service maps will be discusses in chapter 4.4.4.

RQ4b: How do the encountered use and user requirements vary at EU, national and sub-national level?

User characteristics and needs

At EU-level the users were more familiar with the ecosystem service concept and ecosystem service maps. than users at national and sub-national level. This can be explained by the fact that European policy makers have been working for a longer time with the ecosystem service concept (Maes, Egoh, et al., 2012) and the novelty of ecosystem service mapping in Greece (Dimopoulos et al., 2017). Interestingly all participants had a background in environmental sciences or management or economics, none had a background in social sciences or engineering. This fact did potentially limit the results to users from this field and background.

Policy requirements

The influence of the EU Biodiversity Strategy did differ between the administrative levels. At EU-level the EU Biodiversity Strategy was identified to be a key driver of the use of ecosystem service maps. At national and sub-national level, the EU Biodiversity Strategy had less impact and national laws or the Greek National Biodiversity Strategy had higher importance. The importance of laws can be explained by the fact, that they are legally binding. Those results may be case study specific, due to the novelty of MAES related activities in Greece (Dimopoulos et al., 2017).

Decision-making process

The provided ecosystem service maps were not always included in decision-making processes. Yet, if maps were used in decision-making processes, users at EU- and sub-national level pointed out, that the provided maps were one argument used in the decision and that the ecosystem service maps are/would be included during the decision-making process. Other factors influencing decisions at all three levels were policy requirements (e.g. laws) or other types of visualized information (e.g. bar chart, text with key messages). The users at national level, who were ministry employees pointed out that laws or expert knowledge do currently guide decision-making processes.

Use purposes

Table 11 shows the use purposes that were identified by the users at EU-, national and sub-national level. The different use purposes encountered by the users at EU-, national and sub-national level support the assumptions of Hauck et al., 2013, that different administrative levels are related with different requirements and use purposes for decision-making.

Table 11: Use purposes of ecosystem service maps identified by (potential) users at EU-, national and sub-national level

EU	National	Sub-national
Policy development Policy impact assessment Communication and raising awareness	Policy development and support Management decisions Risk assessment Information	Impact assessment of future management scenarios Trade-off analysis Monitoring purposes Educational purposes Public communication and raising awareness

4.2. The map-makers' perspective

Hereafter the similarities and differences between the map-makers at different administrative levels are briefly summarized. In chapter 4.2.1 - 4.2.3 the findings for the three administrative levels will be discussed, summarized and used to answer RQ2a:

- RQ2a: For which purposes are the ecosystem service maps designed by the map-maker?

Chapter 4.2.4 briefly outlines the similarities and differences among EU-, national and sub-national level and links the findings to scientific literature. In total 12 map-makers were interviewed at EU-, national and sub-national level. The questions of the map-maker interviews are displayed in Appendix 4. The map-makers were asked about their profession, experience with map-use and the ecosystem service concept, their map creation process and their intended target groups and use purposes. The results of the closed-ended background questions are presented in Table 13.

Table 12: Results of the questionnaire on the personal background of the map-makers. Table shows the number of the test person (TP), the gender, the age group, the highest educational level and field of education, the participants' map use familiarity in his/her daily life (leisure and work), if he/she has ever participated in cartographic training and if yes in which software, which software is used in his/her current profession, since when he/she knows the ecosystem service concept, how frequently he/she produces ecosystem service maps, the administrative level and when the user is involved in the map creation process

TP	Gender	Age	Education	Field of education	Map use familiarity	Cartographic training	Training in	Software used in current profession	Familiarity with ecosystem service concept	Produce frequency of ecosystem service maps	Administrative level	Involvement of user in map creation proves
13	M	41-50	PhD	Biology	very familiar	Yes	ArcGIS, Python	ArcGIS, QGIS, Python, ESTIMAP	>6y	a few times/y	EU	After
19	F	41-50	PhD	Landscape ecology	very familiar	Yes	ArcGIS	ArcGIS, R	4-6y	a few times/y	EU	After
22	F	41-50	PhD	Ecology (Biologist)	very familiar	Yes	ArcGIS, 3D modelling	ArcGIS	>6y	a few times/y	National	No communication
1	M	21-30	PhD	Biology and Ecology	very familiar	Yes	ArcGIS, Remote sensing mapping	ArcGIS, QGIS, InVEST	4-6y	a few times/y	National & sub-national	No communication
17	F	41-50	M	Ecotourism	a bit familiar	No	No training	Google Earth	1-3y	every month	National & sub-national	Beginning
7	M	50-60	PhD	Ecology (Biologist)	very familiar	No	No training	ArcGIS, QGIS	4-6y	a few times/y	National & sub-national	During
2	F	41-50	M	Forestry and Remote sensing	very familiar	Yes	ArcGIS	ArcGIS, QGIS, InVEST	less than 1y	a few times/y	Sub-national	During
14	M	41-50	PhD	Range land management and forestry	very familiar	No	No training	Potentially GIS software	4-6y	Not yet	Sub-national	No maps produced yet
19	F	41-50	M	Geotechnology and Environment	very familiar	Yes	ArcGIS, ERDAS, SWOS toolbox	Tools for data discovery, web map services, tools for creating-processing-analysing-modelling geospatial data, satellite image processing/classification, tools for map compilation	1-3y	a few times/y	Sub-national	Throughout the entire process
21	M	51-60	PhD	Environmental Engineering	very familiar	Yes	ArcGIS	GIS	>6y	a few times/y	Sub-national	During (he said after)
11	M	21-30	M	Forestry	very familiar	Yes	ArcGIS	ArcGIS	>6y	a few times/y	Sub-national	No
15	M	41-50	M	Environmental science	very familiar	Yes	QGIS, AutoCAD-Map	ArcGIS, QGIS	less than 1y	Not yet	Sub-national	No maps produced yet

4.2.1. Map-makers' perspective at EU-level

Job description

At the EU-level two map-makers who were working for the European Commission were interviewed. Both of those map-makers have a PhD (biology, landscape ecology) and are very familiar with map use in general. Furthermore, both of them have a high level of expertise on the ecosystem service concept. Within their profession they have been mapping different ecosystem services such as pollination or flood regulation with the intention of providing scientific and technical advice to policy departments. In doing so, the map-makers have mapped the supply of ecosystem services, as well as the demand and the flow of services.

Policy requirements

The EU Biodiversity Strategy plays a key role at this administrative level. *"It really sets the sort of legal basis to do our work, so it is of course a very important driver to do what we are doing. I mean without a Biodiversity Strategy and targets and action 5, we would not do the work*" (TP13). TP19 stated, that her entire work is framed within the EU Biodiversity Strategy. This strong familiarity the EU Biodiversity Strategy and the mapping experience with different ecosystem service mapping techniques (e.g. flow, demand) indicate, that the map-makers at EU-level are very experienced with ecosystem service mapping.

Table 13: Tools used for map creation, influencing factors on the map creation process and the intended use purpose for the users of ecosystem service maps identified by map-makers at EU-level

Tools	Influencing factors	Intended user	Intended use purpose
ArcGIS QGIS Python R ESTIMAP	Expertise Data availability Missing methodologies Limited manpower Temporal restrictions	Policy officer	Supporting policies with maps Evaluation of project impact Assessment of success of policies

Tools

The map-makers at EU-level use a variety of tools, which are displayed in Table 13. The map-makers used tools for data mining, GIS software as well as ESTIMAP, which was specifically designed to model and map ecosystem services.

Influencing factors

The map-makers identified several factors which influence the map-making process (see Table 13). First of all, expertise on a certain ecosystem service type poses a challenge. If that is not available, it must be acquired through research or through consultations with experts. Another main issue is the availability of data. Limited data availability may also lead to an adaption of the mapping objective, if the data from the original objective is not available. Thirdly, a factor that influences the map-making process at European level is the fact that methodologies at this level are usually not available yet, which requires the map-makers to conduct thorough research and develop suitable procedures. This could lead to limited resource availability in terms of man power or time. "*If you start from zero and you set up a decent mapping approach, then you quickly end up with one person for one ecosystem service. This is a bit our experience. So if you want to make ten, I mean ten credible maps on ecosystem services which, in our case, can be used as a baseline of report and policy making. And you want to produce them in one year ten people or more*" (TP13).

Intended user and use purpose

RQ2a: For which purposes are the ecosystem service maps designed by the map-maker? (EU)

The maps of the interviewed map-makers are intended to be used by the DG Environment (DG-ENV) and the DG of Regional Development (DG-REGIO), with different users having different needs. First of all, those maps at European level could be used by policy makers in their process of making or implementing EU-policies, which do impact natural resources like marine or climate policies. Secondly, ecosystem service maps could be used as arguments for proposals of LIFE projects and to evaluate their success by conducting ecosystem service mapping before and after the project. Furthermore, ecosystem service maps are indirectly used to evaluate the success of the EU Biodiversity Strategy by assessing whether policy targets have been met. "*the European Commission and the DG Environment. They are not really users of the map but we map ecosystems services, we look at trends and the information both spatially the configuration on how ecosystem, services are applied by what type of ecosystems, at which quantities as well as the trend information is an important input into the final evaluation on the Biodiversity Strategy so we will see whether or not the targets have been met, and there is a specific target on maintain or announced in ecosystem services which has to be evaluated against the baseline of 2010. So the commission wants to know in 2020 if we achieved the target, yes or no"* (TP13).

It was emphasized by TP13, that those policy makers of the European Commission are only indirect users of the provided ecosystem service maps, as the maps should rather support policy.

The map-makers at this level were aware of who their users were as they were also meeting them in person in meetings. The interviewed persons pointed out, that their maps consist of a lot of technical details which requires a joint approach, in which scientists explain the map content to the policy makers, meaning that those maps are not designed to be self-explanatory.

A possible solution for this could be consulting the user regarding their preferences and questions in advance as this could contribute to the quality of the map design (van Elzakker & Ooms, 2018). Even though there are certain limitations like data or time limitations, the steps in the map creation process should always have the final user in mind (Slocum et al., 2014)

Involvement of the user

The map-making processes at this level did involve the intended users after the mapping process. "*It's not very common that you will just deliver a set of maps of course to policy-making departments of the Commission […] the maps support policy, but there is always a need to have people, scientists in making the interpretation*" (TP13). When the first draft of the map produced by the European map-makers was available, the map was shown to the policy officers and the technical details of the mapping process were explained to them. Yet, as pointed out by TP19, the users sometimes get lost in those technical details and they have questions which differ from the content displayed in the map.

Further findings

According to TP19, in one project potential communication problems between the map-makers and the policy makers were encountered. "*What is expected from the policy maker is not answered by the maps we produce. And in this case, we have a big problem in misunderstanding each other our role. Or maybe the policy questions for instance they have in mind to answer. […] Sometimes they policy questions are too broad and cannot be answered with a specific map*" (TP19).

This shows, that even though the map-makers have the technical know-how on ecosystem service mapping and the map content is explained to the user, problems are encountered. This fact could support the hypothesis of this research, that there could be a problem in the cartographic communication process.

It must be pointed out, that the two map-makers at EU-level work in the same working division, which does bring a bias to the results. Thus, those results only reflect the current situations of map-makers in the European Commission and whether those results are also encountered in other European institutions would be a potential option for future research.

4.2.2. Map-makers perspective at national level

Job description

At national level four map-makers were interviewed, all of whom were working at Greek universities, thus the following results may only apply to this specific group of map-makers. The participants did have different research foci which resulted in different foci on the ecosystem service maps they produced. For example, TP17 was focussing on cultural ecosystem services maps and the cultural value of landscapes, whereas TP22, having a background in soil ecology, focused more on the relations of biodiversity and ecosystem services provided by soils. TP1 and TP7 did create vegetation and habitat type maps in the past and currently transform those maps to ecosystem type maps, which aim to display the condition of ecosystems in Greece. Those participants were interviewed in their role as national level ma-makers, but three of them have also been involved in sub-national mapping processes.

All participants are familiar with the concept of ecosystem services. TP17 knowing it for 1-3 years and the other three map-makers knowing it for 4 or more years. The mapping of ecosystem services in Greece is currently taking place. "*Since 2017 we started producing maps of ecosystems and ecosystem services*" (TP7). TP22 pointed out, that in his/her area of interest no specific research has been done yet and that "*I´m forced to start with what I have until now*" (TP22).

Policy requirements

All participants did know about the EU Biodiversity Strategy for 2020 or the Greek Biodiversity Strategy to different degrees. One test person did not know about the Greek Biodiversity Strategy, another test person did say, his/her work is indirectly influenced by those strategies. Yet, most of them pointed out, that the information provided by those strategies supports their work: "*It sets actually a framework of points to highlight what is important for conservation. What is important for conservation, influences actually everything.*" (TP22). The steps described in the MAES work are applied by TP1. For TP7 the goals of the Greek Biodiversity Strategy are the main targets, yet it is acknowledged that fulfilling the national targets does also support the targets of the EU Biodiversity Strategy.

Table 14: Tools used for map creation, influencing factors on the map creation process and the intended use purpose for the users of ecosystem service maps identified by map-makers at national level

Tools	Influencing factors	Intended user	Intended use purpose
ArcGIS QGIS InVEST	Data availability Data resolution Missing methodologies	Policy and decision makers in public administration	Monitoring, management of areas Environmental impact assessment Management decisions (e.g. on agricultural areas or on priorities for biodiversity conservation)

Google Earth	(ministry, state services) Scientific community	Educational purposes Scientific research

Tools

The tools used at national level are displayed in Table 14. Two of the participants have received training in ArcGIS, TP17 and TP7 have not received any cartographic training in the past and their mapping skills are self-taught. TP17 uses Google Earth to create ecosystem service maps but showed interest in participating in a training on GIS software. Most of the participants use GIS software or InVEST for creating maps.

Influencing factors

The factors that influence the map creation process at national level are listed in Table 14. Both the resolution and the availability of the data were identified to have a strong influence on the map-making process. TP7 and TP17 pointed out, that data availability is one of the major issues. Furthermore, the data availability may vary depending on the topic. "*In many cases, especially data for water management is very difficult to obtain. Most easily we can obtain data on, let's say, forest productivity, on the extent of forest"* (TP7). Missing methodologies were also identified as challenge: "*there is no specific research done for mine own thinks. But I´m forced to start with what I have until now*" (TP22). One solution for this problem was a cooperation for data exchange with another Greek university. TP22, who uses European data sets raised the issue of spatial and thematic resolution of the data, as those European data sets "*are very coarse and the do not include biological information*".

Involvement of the user

In past mapping processes users have been involved by two map-makers trough questionnaires during the mapping process. For example, TP7 used questionnaires in a local case study on a lake area to gather insights on the needs and attitude of stakeholders towards the research area. Based on those findings potential future scenarios with different trade-offs of human and ecological interests for the management of this area were developed. The map-makers did not indicate, that the users were involved more than one time in the map creation process.

Intended target group and use purpose

RQ2a: For which purposes are the ecosystem service maps designed by the map-maker? (national)

The map-makers at national level identified the scientific community, ministries, state services and decision makers or stakeholders working for administrative units as the intended target groups. TP22 and TP1 elaborated, that different user groups do require different types of maps. "*We have one time made an educational map, a very broad map with some signs on it with describing of the presented service. This was to promote which services in the area. When we are dealing with administrative units or agencies of course we make detailed maps because those maps are going to be handled by topographers or geographers or foresters in the relevant units. So yes. We always think who will use this map that we produce*" (TP1). According to TP22, there are differences between maps for scientists and maps for other stakeholders. When creating a map for a stakeholder the map-maker must "*discard all the details and try to be very, very specific on what you are trying to say*" (TP22).

TP7 identified monitoring, management of areas and environmental impact assessment as the main use purposes of ecosystem service maps at national level. People working for the ministries could use ecosystem service maps to make decisions on agricultural or natural areas and decisions on priorities for biodiversity conservation. Maps on cultural ecosystem services could support stakeholders in better managing and planning of cultural services.

TP22 and TP17 pointed out that their current users are members of the scientific community and that other stakeholders in their field do not make use of ecosystem service maps yet due to knowledge gaps. "*For the time being the user of the map is people that understand what I am talking about, which means that it's not stakeholders, it's not everyday people, it's only the scientific community, right now. We are not at a stage that stakeholders are ready to understand what we are talking about, because it is something new*" (TP17). TP22 pointed out, that stakeholders would require further knowledge on "*how to work with ecosystem services and how to take advantage of the new knowledge*" (TP22). It was highlighted, that a training on ecosystem services that was organized by the Greek ministry of environment and involved map-makers, users and hands-on exercises was a good step in the right direction.

All map-makers acknowledged, that the maps intend to support their users, namely policy or decision makers in their work. However, it was pointed out that there is a science-policy gap (Westgate et al., 2018) and maps are currently not used yet by the users. In addition, knowledge gaps of the users present a potential issue. Furthermore, the involvement of users in ecosystem service mapping processes was low. A main reason for this could be the fact, that the mapping of ecosystem services in Greece has just recently started and that not many maps have been produced yet.

This highlights the need of further producing maps in Greece, which are tailored to the concrete needs of the target user. To achieve that, communication between institutions, namely the universities and the administrations or practitioners must be established. Interactive science-policy processes as well as training of the users on how to use ecosystem service information in decision-making processes could improve this situation (Willcock et al., 2016).

4.2.3. Map-makers perspective at sub-national level

Job description

At sub-national level six map-makers were interviewed. Three of them were working at Greek universities, the other three were working in other institutions, namely in forest services or in an NGO. Four of them have already been producing ecosystem services maps in the past, on average they have been making ecosystem service maps a few times per year. TP14 and TP15 did not produce ecosystem service maps yet. The participants at this administrative level have either a master's degree or a PhD in forestry, environmental science or environmental engineering. All of them describe themselves as very familiar in using maps. The map-makers had different levels of experience with the ecosystem service concept ranging from recently introduced to it (<1 year) to very experienced (<6 years).

Policy requirements

All participants were familiar with the EU or the Greek Biodiversity Strategy. TP2 and TP20 who have been producing ecosystem service maps in the past acknowledged, that those strategies oblige them to present ecosystem service maps. Yet, the work of the other four test participants at sub-national level was only indirectly or not influenced by those strategies. TP14, who is working at a university, is indirectly in contact with the EU Biodiversity Strategy trough research projects. TP11 and TP15 do not apply those strategies in their work. "*Here in Greece the things are not so good about the Biodiversity Strategy. We in forest services we don't have Biodiversity Strategy. Some universities try to put - to say "guys look we must take a Biodiversity Strategy". They make their* *results, they have the totals numbers. Then they are screaming "look here are the numbers you must do this" - the universities. The government always says "ok, keep it" and if I need it I will ask you to give it to me. We don't share connection between the government services and the universities. So, the results on the universities always they take things, they are putting them in the shelf and they keep it there."* (TP11). That is an indication, that there is lacking communication and exchange between science and policy, which could be a reason for the existing research implementation gap (Westgate et al., 2018). One reason for that could be, that the "*the ecosystem services concept is very recently in Greek also in research community and in the more general society discussion*" (TP14).

Table 15: Tools used for map creation, influencing factors on the map creation process and the intended use purpose for the users of ecosystem service maps identified by map-makers at sub-national level

Tools	Influencing factors	Intended user	Intended use purpose
ArcGIS QGIS InVEST	Data availability Data quality	Policy maker management bodies of protected areas & regional managers Public administration public	Management decisions on construction Raising awareness Educational purposes Management decisions (choosing of best management practice and best policy option) Trade-off decisions on future scenarios

Tools

Table 15 presents the tools encountered at sub-national level. Five of the participants have been trained in ArcGIS, TP20 was also trained in ERDAS and the SWOS toolbox. TP14, who has not produced ecosystem service maps yet, did not participate in any cartographic training in the past. Most of the participants use GIS software (ArcGIS, QGIS) in their daily work and TP2 does also apply InVEST, which is a mapping tool for ecosystem services. None of the participants uses graphic design software. "*The representation of that it has not been kind of the focus of our research here. So, I think we are using the simplest that we can to actually show spatially the results*" (TP21).

Influencing factors

All influencing factors are listed in Table 15. At this administrative level, the quality and the availability of data have been identified by three test participants to be major challenges. One interviewee pointed out, that the data availability in Greece strongly depends on the subject matter. "W*e had very limited data regarding non-wood forest products production in, about the Greek forest or the rangeland*" (TP14). A solution for that problem, which is applied by TP2, is conducting field measurements. This type of data acquisition was also conducted by TP21 and TP11 and as those two primarily relied on their own field measurements they did not encounter issues regarding data quality or availability. TP21, who is working on ecosystem service and scenario modelling, named the calibration of the model to be the major challenge.

Intended user and use purpose

RQ2a: For which purposes are the ecosystem service maps designed by the map-maker? (sub-national)

TP2 and TP20 who are both working in fields related to forestry identified different target user groups. Both of them found that the ecosystem services provided by forests and the maps displaying them could be of interest for policy makers, management bodies of protected areas, public administration (e.g. ministry of environment, municipality), the public and researchers.

Ecosystem service maps for policy makers could help them recognize the services provided by an area and thus could be applied in policy making. Maps for the general public could be maps that are displayed on public info days for increasing public awareness on ecosystem services. Public administrations could use ecosystem service maps displaying the vulnerability of ecosystem conditions to take actions to protect natural areas like for example wetlands. TP14, who is working at a university, brought up the potential use of ecosystem service maps for educational purposes in lectures. The facilitation of sustainable management and trade-off between ecosystem services was identified to be a use purpose of ecosystem service maps by TP14 and TP21. According to TP21, who is working on modelling and mapping future scenarios in the field of soil and water management, scenario maps could be of use for local stakeholders like regional managers. Based on the outcomes of this mapping those target users can trade-off between scenarios and ultimately *"choose the best management practises and policies that they need to establish at the local level*" (TP21). TP14 identified the increase of the supply of ecosystem services within a region as a potential sustainable management goal that should be achieved by management actions. TP21 and TP2 highlighted that economic valuation is a useful approach of expressing the value of a service to scientists or base land use decisions on. TP15, who is working for the forest services, identifies this institution to be both the map-maker and user of those maps. While no ecosystem service maps have been used by this participant yet, forest maps are often used. Those maps are used to make decisions about the construction of houses or roads, trading off between protection of forests, plants or water resources and human pressures and economic interests.

TP2 emphasized, that it is important to adapt cartographic elements like the level of detail, scale or colour selection depending on the target users and their background knowledge: "*When we are going to make an info day, we make some maps easy to eye. And to focus to the point that we want. With no scientific definitions or difficult numbers and units. When it is for scientists and other kind of - we present another kind of map. It's more scientific. You have the unit, the appropriate unit, the appropriate classes, more detailed.* […] *For example, on in info day we also call small kids. So, the maps must have colours, right? Not too small, big scales. But the maps for stakeholders, like hunters or hotel owners must be different. To present other things, we use point data - not polygons for example*" (TP2).

Involvement of the user

Three map-makers did involve their intended users in past map-making processes. TP2 and TP21 involved the user during the map-making process. "*In the beginning we have, some presentation of what we are going to do, what we want to present, and they say their opinion what do they need. And we are producing our map and they make some small suggestions and we fix the final map […] For example, the economists, they ask us: 'we want to see that number there, we want to see that unit over there.' They help us make our job better*" (TP2). TP21 includes the opinion on future development options from local stakeholders into existing future scenario models to analyse, how societal factors would affect the local environment and economy in the case study area. The involvement of local stakeholders is a key aspect in this modelling process, as "*you want society to dream that their own future*" (TP21). Yet it was acknowledged by this test participant, that those scenario modelling approaches have not been taken into account by the decision makers yet.

4.2.4. Comparison of map-makers' perspectives among administrative levels

Hereafter the similarities and differences between the map-makers at different administrative levels are briefly summarized.

Policy requirements

The presence of the EU Biodiversity Strategy (or the Greek National Biodiversity Strategy) did noticeably differ among the administrative levels, being a key driver at EU-level and only partly of impact at national and sub-national level. This finding is very likely to be case study specific, as the implementation of MAES related activities has just recently started in Greece and not many ecosystem service maps have been produced yet.

Education and tools

All map-makers had university degrees (master's or PhDs) in fields related to ecology, biology, engineering, remote sensing or management. Interestingly no participant had a background in cartography. Table 16 displays the software that is used for map creation by the participants at all three administrative levels.

Table 16: Tools used for map creation at EU-, national and sub-national level

EU	National	Sub-national
ArcGIS	ArcGIS	ArcGIS
QGIS	QGIS	QGIS
Python	InVEST	InVEST
R	Google Earth	
ESTIMAP		

GIS software has shown to be the most widely applied software among the test participants to create maps. At all administrative levels, software specific to ecosystem service mapping was applied (InVEST, ESTIMAP). Those tools fall into the current standard tools used for ecosystem service mapping, which were presented in chapter 2.2.5.

Those software packages mainly focus on data modelling and do not primarily focus on data visualization. Some participants also received training in certain software tools (see Table 7), but those also were data processing and modelling tools. This could be an indication, that until now the visualization of the mapping results and the relevance of cartographic map design as such was not considered to be an important part of the map creation and map communication process in the past. Also, none of the test persons indicated that expertise from a cartographer is taken into consideration when creating the maps.

Influencing factors

Table 17 presents the influencing factors, that were identified by the test persons. Data availability has been identified as influential factor at all three administrative levels. This is a well-known challenge for ecosystem service mapping (Grêt-Regamey et al., 2015; Palomo et al., 2018), which is a driving factor in ecosystem service map creation (Crossman et al., 2013). At sub-national level this problem was solved by collecting data in the field. One participant at national level used continental data sets to solve this problem, but was confronted with problems regarding the coarse data resolution of those data sets (Crossman, 2017). Using open data repositories, as was brought up by two participants and also found by Westgate et al. (2018), would be a possible solution for removing barriers to data access.

Missing methodologies have been identified to be an issue at EU-level and by one participant at national level. At sub-national level this issue was not brought up explicitly, but it was acknowledged by two sub-national participants, that the method development and calibration play an important role in the map creation process. The mapping processes described by the map-makers at EU-level were very extensive, which could be a reason that limitations of time and manpower were only named at this administrative level to be an influencing factor.

Table 17: Factors influencing the map creation process at EU-, national and sub-national level

EU	National	Sub-national
Data availability Missing methodologies Expertise Limited manpower Temporal restrictions	Data availability Data resolution Missing methodologies	Data availability Data quality

User and use purpose

The map-makers at EU-, national and sub-national level identified different users (see Table 18) and use purposes (see Table 19). The use purposes get more specific and more management related at lower administrative levels, users and use purposes identified at EU-level were only policy related. The research question, whether the intended use purposes and the actual use purposes of the users differ will be answered in the following chapter 4.3.

Table 18: Identified users of the map-makers of ecosystem service maps at EU-, national and sub-national level

EU	National	Sub-national
Policy maker	Policy and decision makers in public administration (ministry, state services) Scientific community	Policy maker management bodies of protected areas Public administration General public

Table 19: Identified use purposes of the map-makers of ecosystem service maps at EU-, national and sub-national level

EU	National	Sub-national
Supporting policies with maps Evaluation of project impact Assessment of success of policies	Management decisions (e.g. on agricultural areas or on priorities for biodiversity conservation) Monitoring, management of areas Environmental impact assessment Educational purposes Scientific research	Management decisions on construction Raising awareness Management decisions (choosing of best management practice and best policy option) Trade-off decisions on future scenarios Educational purposes

At all administrative levels it was acknowledged by some participants, that different user groups do have different needs and background knowledge and the maps should be adapted accordingly. Yet, this was only further specified by one participant. This may indicate, that the map-makers are generally aware of their users and aim for the outcome to be used by the potential users, but that there is lacking knowledge on how this information could inform decisions (Ruckelshaus et al., 2015), how the variety of user requirements can be met (McInerny et al., 2014) or how to translate those different requirements into map design. Consulting the user in the map-making process e.g. through participatory approaches and eliciting their specific geographic questions. like TP2 did, would be one possible approach to do so (Albert et al., 2014; van Elzakker & Ooms, 2018).

Involvement of the user

The stage of the map-making process, at which the user was involved did differ throughout the administrative levels. At EU-level the involvement took place after the map creation process, at national level before or during the process and at sub-national level the user was involved during the process. One thing of those cases had in common is the fact, that the user was only involved once during the map creation process and that the involvement of the user was not an iterative process. Only two map-makers at sub-national level did involve the users throughout the mapping process and implemented the users' needs and feedback into the map design, emphasizing that this feedback supported them at their job. This statement underlines the importance of the feedback from the user to the map-maker in the cartographic communication process, as this step helps understanding if the map is clear to the user (Slocum et al., 2014). The involvement of the user e.g. in form of participatory approaches or UCD can not only increase the usability of the final visualization, but also increase its credibility (McInerny et al., 2014).

Further findings: Science-policy gap

It was identified at all levels, that scientific findings are either not communicated between scientists and researchers or that the insights from scientific findings are not implemented in decision-making processes, which complements the findings of Ruckelshaus et al. (2015). Possible solutions for this issue, that were brought up by the participants, could be training in form of capacity building for stakeholders and researchers (Willcock et al., 2016), to make scientific findings open access (Westgate et al., 2018) or to involve decision makers in mapping processes through participatory approaches (Palomo et al., 2018).

4.3. Comparison of the perspectives of the map-makers and users

This chapter aims to briefly bring together the perspectives from the users and the map-makers. In doing so, research question Q3a will be answered.

- RQ3a: Do the intended purpose and the actual purpose of ecosystem service maps differ? If yes, how?

Business context

One issue that stood out when comparing the users and the map-makers perspective was the business context of the ecosystem service maps. Due to the novelty of the mapping and assessment of ecosystem services in Greece, at national and sub-national level it seemed that the awareness for the EU Biodiversity Strategy or the Greek Biodiversity Strategy was not as strong as at European level.

The use by the user is an often-encountered goal and justification of ecosystem service assessments (Laurans et al., 2013), as was also acknowledged by the map-makers at all administrative levels. At national and sub-national level there was no clear indication on how those produced maps are intended to be brought to the user. The users at national level stated, that they do not have such maps or that they do have such maps, but they do not base their decisions on them. These findings could be an indication for two issues:

On the one hand, it could be an indication, that there are no clear mechanisms in place yet to connect the maps produced by scientific research with the decision- and policy makers who could potentially use those maps. This could originate from the map-makers producing and publishing some maps in publications but not for a specific user and use purpose. Furthermore, as was highlighted by one participant, that governmental institutions often do not actively request information from scientific institutions.

On the other hand, it could be an indication, that the maps do not show yet what the users need (McInerny et al., 2014) (further discussed in the next section) or that there are no mechanisms or knowledge yet, on how to use ecosystem service maps into policy- or decision-making processes (Willcock et al., 2016).

As already mentioned, the novelty of ecosystem service maps in Greece and the small sample size may limit the representativeness of these findings. However, the findings highlight the importance of having concrete mechanisms in place to bring the ecosystem service maps to the decision- and policy makers, cooperation among different institutions.

It is important to point out, that these findings hold for the case of user and map-maker are not being the same person. Yet, as it was encountered at sub-national and at national level, it can be the case that the people who produce ecosystem service maps are also the users of those maps. In that case the assumptions made above regarding the cooperation among different institutions do not apply.

Use purpose

RQ3a: Do the intended purpose and the actual purpose of ecosystem service maps differ? If yes, how?

Generally speaking, the intended use purposes and the actual use purposes of ecosystem service maps did not strongly differ from each other (see Table 11 and Table 19) or from use purposes that have been encountered in literature (e.g. Albert, Hauck, et al., 2014; Guerry et al., 2015; Hauck et al., 2013) and were discussed in chapter 2.2.5. Some use purposes were named on the user side were not identified on the map-maker side and vice versa, which can be explained by the small sample size which resulted in a non-exhaustive list of use purposes.

Yet, it was observed, that the use purposes by the map-makers and the users' needs in some cases were very generic. Those could indicate lacking awareness of the specific application of those maps on the map-making side or lacking knowledge on ecosystem service maps on the user side. As mentioned earlier, these findings may be partly case study specific due to the novelty of ecosystem service mapping in Greece. In addition to that, it was found, that the map did not show what for example some policy makers wanted to see or needed to make decisions based on them.

For future map design it is thus imperative to not create maps based on generic map use purposes or to claim that a map can be used by a large number of users. It is rather beneficial to tailor the produced map to the needs and requirements of the specific target group and to consult the user on what they need from the cartographic product and on what aspects of the subject matter are of relevance for them (van Elzakker & Ooms, 2018). The lacking subject knowledge on ecosystem services and on how to use ecosystem service maps (specifically at national and sub-national level) should be addressed by further training and capacity building (Palomo et al., 2018; Willcock et al., 2016).

4.4. Usability issues

This chapter discusses usability issues of existing ecosystem service maps that were encountered during the task execution exercise. First the coding scheme derived from the verbal protocol analysis is presented. Thereafter, the usability issues of the tested maps at EU- (chapter 4.4.1), national (chapter 4.4.2), and sub-national (chapter 4.4.3) level are presented. Within each of those chapters, the maps included in the task execution exercise and the usability measures will be presented. Furthermore, all issues that were brought up by the participants will be summarized at the end of each chapter (the connection to scientific literature will be made in chapter 1.4.4 to avoid repeating discussions), answering research question Q3b and Q3c.

- Q3b: What types of difficulties are encountered by the decision makers when working with ecosystem service maps?
- Q3c: What map attributes to the decision makers find supportive?

Finally, chapter 4.4.4. will discuss the differences and similarities among the encountered usability issues at EU-, national and sub-national level and will link those findings to scientific literature. In doing to the usability related part of RQ4b will be answered.

- Q4b: How do the encountered use and user requirements vary at EU, national and sub-national level?

Participants

In total 12 participants took part in the task execution exercise, 11 of which were users and one was a sub-national map-maker (TP14), who identifies as a potential user of ecosystem service maps. The maps used in this exercise were selected based on the displayed ecosystem service type, scale and geographic extent (see chapter 3.2.1.3)

Coding scheme

The coding scheme, which was developed based on the verbal protocols consists of 11 categories, which are displayed in Table 20. Each category was assigned a name, according to the issue that was brought up by the participants either explicitly formulated ("*Can we zoom in?*") or implicitly/non-verbally (e.g. participant leaning forward to be closer to the screen). The content of the category is described in the category description and illustrated by sample quotes. It was chosen to include statements addressing usability issues "*you could probably use some different colour*", "*legend is far too detailed*" and neutral statements "*the lowest is red*", "*It gives me t/ha/year*" in the same categories, to understand what aspects of a category could be improved and what works. Passages of reading the map description or the tasks were not included in the coding scheme.

Table 20: Coding scheme categories for think-aloud protocols

Category name	*Category description*	*Sample quote(s)*
Spatial and thematic resolution	Remarks about the spatial and/or thematic resolution of the map	*"these broad units - simplifies the information I get", "it is quite difficult also to recognize the colours because of the scale, it is very fine scale"*
Colours and colour scheme	Reading of and comments about the colours used in the map and the colour scheme	*"The lowest is red", "you could probably use some different colour". "I cannot distinguish some special combination of colours"*
Legend	Remarks about the legend	*"It gives me t/ha/year", "legend is far too detailed"*

Description	Comments on the description and subtitle of the map	*"The text here is good as background information", "I find this is the definition there were beginning of the map which is a bit maybe insufficient"*
Content	Remarks regarding the content of the map	*"I am not agreeing with the map", "The map is telling me something that I can't understand"*
Title	Remarks regarding the title	*"There is not a title so that is not a good sign"*
Zooming	Indication that the participant uses the zooming function	*"Can we zoom in?", "Okaaay if I can see the map – maybe I can, not- I cannot make the map bigger?"*
Personal knowledge	Inclusion of personal knowledge that is not displayed in the map	*"It is very high, of course it is very high it got a moun-tain", "There is desertification in that area that I know."*
Map labels	Remarks about the geographic labels in the map	*"very north west but I cannot see the region to say it by name", "I am not good in Geography I am afraid."*
Level of detail	Remarks regarding the level of detail of map elements	*"It is not easy, it is far too small to recognize this one", "It is a bit tiny"*
Image resolution	Remarks regarding the resolu-tion of the image	*"I quit zoom in for 800%. I find this would not really clarify this"*

4.4.1. Usability issues at EU-level

At this level three test persons participated in the task execution exercise. The sessions of TP5 and TP3 were conducted in person. One participant was observed during the exercise trough video observation, the other one was observed trough note taking. The exercise with the third participant (TP23) took place re-motely and without video transmission. Thus, only the data gathered from the audio recording were used to derive verbal protocols. One test participant (TP5) had a background in making ecosystem service maps from a prior employment.

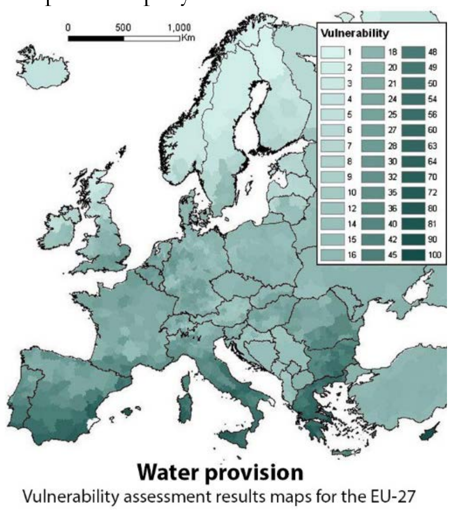


Figure 21: *Map 1* of task execution exercise at EU-level (Tzilivakis, Warner, Green, & Lewis, 2015)

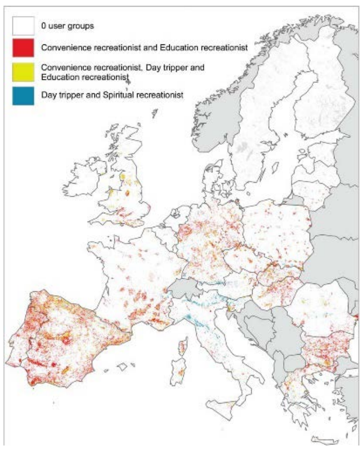
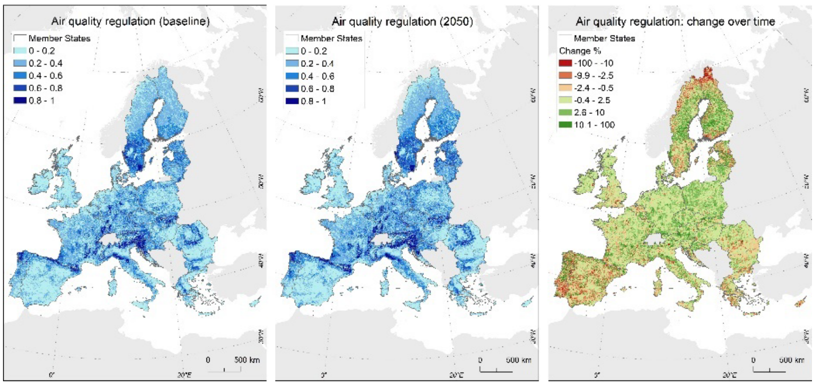
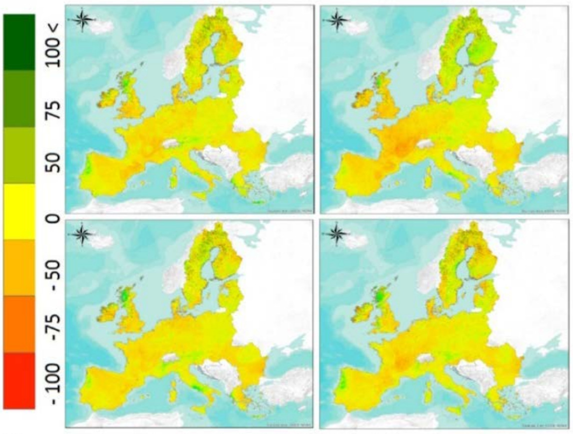


Figure 22: *Map 2* of task execution exercise at EU-level (Komossa, van der Zanden, Schulp, & Verburg, 2018)



Air quality regulation for baseline, 2050 and as a percent change over time (2050 vs. baseline). For the baseline and the 2050 maps, classes represent equal intervals over the range of rendered predictions; for the percent change over time, the visual representation reflects the distribution of the values. Maps are displayed using the Projected Reference System LAEA. See main text for additional details.

Figure 23: *Map 3* of task execution exercise at EU-level (Polce et al., 2016)



Changes in soil organic carbon stocks by 2050 by Climate Scenarios and Representative Concentration Pathways (RCPs). 1st row: MRI-CGCM3 (RCP 2.6, 4.5). 2nd row: MRI-CGCM3 (RCP 6.0 and 8.5). Red areas represent decrease and green areas represent increase in SOC stocks (tonnes·ha−1) compared to present conditions (background map: ESRI, USGS, NOAA)

Figure 24: *Map 4* of task execution exercise at EU-level (Yigini & Panagos, 2016)

Table 21: Characteristics of the maps included in the task execution exercise at EU-level

	Map 1	**Map 2**	**Map 3**	**Map 4**
Ecosystem service type	Provisioning service	Cultural service	Regulating service	Regulating service
Mapping technique	Choropleth map	Dasymetric map	Dasymetric map	Dasymetric map
Mapping goal	Valuation	Valuation	Scenario	Scenario
Level of difficulty	Single map	Single map	Series of 3 maps	Series of 4 maps

The maps that were used in this exercise are displayed in Figure 21, Figure 22, Figure 23 and Figure 24. Table 21 shows an overview of the characteristics of the tested maps, namely the ecosystem service type (discussed in chapter 2.1.3), the mapping technique (discussed in chapter 2.2.2), the mapping goal (discussed in chapter 2.1.5) and the level of difficulty (discussed in chapter 3.2.1.2). The participants were presented with maps of all three ecosystem service types. The first map was a choropleth map displaying a provisioning service at NUTS-3 level, while the other three maps were dasymetric maps with high spatial resolution. The first two maps had a low level of difficulty, displaying only a single map. *Map 3* presented the participant with 3 maps of one future scenario and *map 4* presented the user with 4 different maps displaying different future scenarios.

Table 22: Effectiveness and efficiency of the test persons at EU-level

	Map 1			Map 2			Map 3			Map 4			
	1	2	3	1	2	3	1	2	3	1	2	3	
	Efficiency (s)												Duration (min)
TP3	8	4	24	37	15	66	26	54	x	58	27	x	6,6*
TP5	30	10	22	48	17	34	41	34	43	58	26	44	6,8
TP23	32	22	22	15	11	97	x	x	x	22	24	26	6,5*
Average (s)	23	12	23	33	14	66	34	44	43	46	26	35	**6,2**
	Effectiveness (**C**orrect, **I**ncorrect, **N**ot answered, **H**elp required)												Overall C (%)
TP3	C	C	C	C	C	C	C	I	N	C	C	N	75
TP5	C	C	C	C	C	C	C	C	C	C	C	C	100
TP23	C	C	C	I	C	C	N	N	N	C	C	C	67
Task C (%)	100	100	100	67	100	100	67	33	33	100	100	67	**81**

* When participant did not answer a question, the average duration of the other participants to answer that question was added to the calculation of the duration
x = Question was not answered by the participant
Task C = Percentage of correctly answered questions per task
Overall C = Percentage of correctly answered questions per participant

The effectiveness and efficiency of the test persons at European level is displayed in Table 22 (information on how those usability measures were derived can be found in chapter 3.2.3). With increasing difficulty of the map type, the users spent more time for answering the questions, which was an expected result. The effectiveness shows, the tasks related to *map 1* were solved by all participants. The tasks of *map 2* and *map 4* also show a very high rate of effectiveness in solving the tasks. *Map 3* had a low rate of efficiency. The first task was solved by two participants and tasks 2 and 3 were only correctly answered by one participant. This could be an indication, that the participants encountered challenges while solving the tasks related to this map.

Spatial resolution

A number of usability issues and supportive attributes were mentioned by the test persons. An issue encountered by all three test persons was the spatial resolution of the map. The questions regarding *map 1* were answered by the participants without zooming in or leaning towards the screen, whereas the participants had to do so when working with the other three dasymetric maps. The overall correctness of *map 1* was 100% for all three tasks and after finishing all exercises TP3 pointed out, that using such broad (NUTS-3) units simplifies the information in a way that enables understanding a trend in "*just a snapshot*" (TP5). The average response time for each task in *map 1* was 19 seconds, whereas for *map 2,* which was also a single but a dasymetric map, the participants needed on average 38 seconds to solve a task. That shows, that the participants needed more time to solve tasks related to high resolution dasymetric maps than they needed to solve tasks with maps using NUTS-3 units. A conclusion that could be drawn from those findings is, that spatial resolution at NUTS-3 level could be a useful resolution for taking decisions at EU-level.

Colour scheme

The colour schemes of the maps were either sequential (for data from 0 upwards), diverging (for data from high to low) or qualitative (for different categories). The meaning of those colour schemes (e.g. red meaning low, darker meaning more) was clear to all participants. *Map 2* displayed three different qualitative categories visualizing them with three different colours. All three test persons could identify and distinguish these categories in the map. This may be an indication, that the number of categories and the different colours visualizing them was convenient.

One participant was partially red-green colour blind and thus had difficulties distinguishing red and green. As those colours were used in two maps in a high-low sequential colour scheme the participant had to guess the answer of the tasks related to those maps. This shows that certain colour schemes, which are hard to distinguish for people with visual impairments are not suitable for decision-making purposes.

Legend and thematic resolution

Small font size in legends has been identified as another usability issue, as it required the participants to zoom in or to look closer to the screen than usually to be able to read the text. TP3 pointed out, that having too much text describing a single item in a legend is not optimal.

A problem encountered by all three test persons was confusion caused by missing units, which were neither displayed in the legend nor in the image description. When the participants identified a region of interest in the map, they managed to name the areas value, but expressed uncertainty on the meaning of this value. "*I don´t know what the unit is there*" (TP23). It was also pointed out by two participants, that too many categories in the legend showing the variation of one colour are difficult to distinguish. "*it is going from 1 to 100 and you do not need to see all the 100 boxes because you do not see 100 colours with human eye*" (TP5).

Description and map content

No participant expressed uncertainty or knowledge gaps regarding the concept of cultural, regulating or provisioning service. Yet, in some cases the participants were confused or frustrated about the map content. For example, they expressed their doubts on how an indicator shown in the map was composed or they questioned the underlying data. TP5 pointed out that the map content should be explained by the map description, which is not always the case. Two participants stated that the provided descriptions were insufficient as they did not provide all the information necessary to read and understand the map. Yet, TP5 and TP23 acknowledged, that the information they were missing from the map was probably available in the paper to which the map belonged to.

Furthermore, it was pointed out by TP5, that some map descriptions and subtitles contained a lot of scientific terms and acronyms, which is helpful for people with scientific knowledge in that field but may not be easy to understand for people who do not have such a background. This statement was underlined by the results regarding the effectiveness. TP5, having a background as researcher and map-maker, was familiar with the technical terms and concepts mentioned in the map descriptions. This test person (TP5) was the only one to solve every task correctly, having an overall effectiveness rate of 100%. The other two test persons did answer most of the questions correctly, but gave up on answering some tasks related to the more complex scenario maps, when they felt lost and confused about the map content. "*I don't understand what is the map about*" (TP23) or TP5 was saying: "*I can't answer that question. Not quickly, I would have to really go into it. I find that a bit confusing*". Those two test participants were very experienced with the ecosystem service concept (more than 4 years). TP3 is using ecosystem service maps on average once a week, which suggests, that being confused about a map is independent of the experience with ecosystem service maps of the user.

TP3 and TP5 pointed out, that they cannot quantify the difference between different future scenarios by simply looking at the map, as this provided not all necessary information. "*Ah that is difficult you know! So the Greens are good as always. […] Really depend on the region it is difficult to say without an overall statistics. Roughly speaking it should be an area it should be this one in quantity we cannot know*" (TP5). All three test persons expressed missing knowledge about the underlying assumptions of the different scenario maps, which shows, that scenario explanations are useful for decision-making.

Title

Two of the four maps did not have a title, which was pointed out by one participant. The description of the map content was provided in the image description of the map from the source publication. *Map 3* contained three maps from different time periods, each of which had a short title at the top, describing the topic and the time of the map. "*This is a set of clear maps, clear in the sense of that the information is all shown together, there are titles, there is a clear legend at two points in time and a trend. It is fully I mean the information is full*" (TP5). In this case, the presence of a title did enhance the understanding of the map content.

Personal knowledge

All three test persons included geographic knowledge such as country or region names which were not shown in the map in answering the questions and no participant showed any difficulty in naming countries or regions.

Image resolution

Another issue brought up was the resolution of the images. TP5 and TP23 pointed out, that zooming into a map with high spatial resolution did not improve the situation, as the image resolution was too low, and the image then appeared pixelated. That shows that the image resolution must be high enough to allow the user to zoom.

Summary: Usability issues at EU-level

Q3b: What types of difficulties are encountered by the decision makers when working with eco-system service maps?

The following difficulties were encountered at EU-level:

- Additional information or map description missing
- Difficulty to distinguish red and green colours due to visual impairment
- Small font size
- Missing units in the legend
- Too much text in the legend
- Too many variations of one colour in legend
- Low image resolution
- Uncertainty about the map content
- Uncertainty about scenario assumptions
- Too high spatial resolution in dasymetric maps
- Missing explanation of the map and technical terms in the map description
- Missing title

Q3c: What map attributes to the decision makers find supportive?

The following (potentially) supportive attributes were encountered at EU-level:

- Display information at NUTS-3 level
- Having both a title and legend in a map
- Clearly distinctive colours for visualizing qualitative categories
- Overall statistical value for scenario maps
- Map description tailored to target audience (e.g. only make use of technical terms if the user is known to have this technical expertise)

4.4.2. Usability issues at national level

All users at national level were interviewed remotely with the phone or online voice call, thus no video observation was carried out at this administrative level. In total three users participated at this administrative level. One user (TP12) did participate in the research session, thus also in the think-aloud exercise, together with a colleague who stayed anonymous.

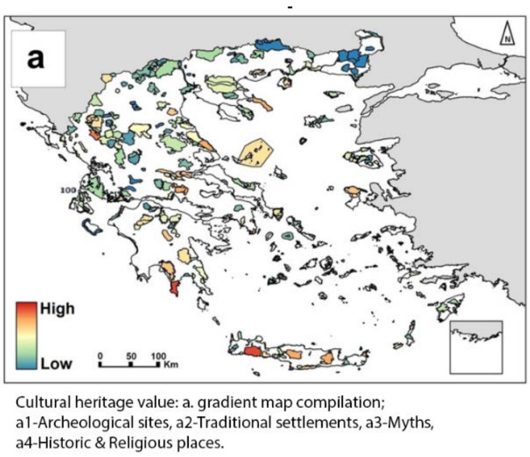


Figure 25: *Map 1* of task execution exercise at national level (Vlami et al., 2017)

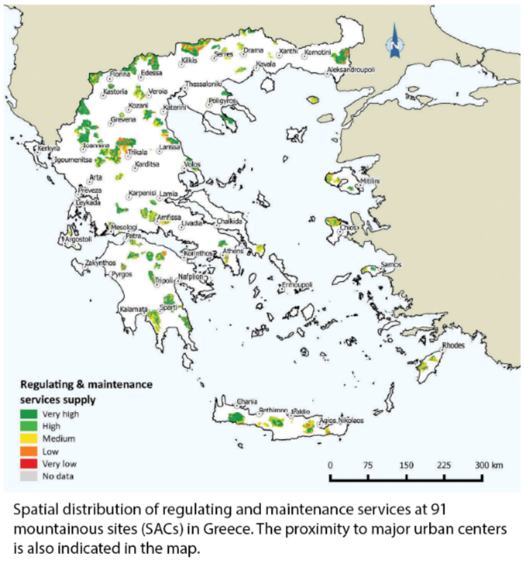


Figure 26: *Map 2* of task execution exercise at national level (Kokkoris, Drakou, Maes, & Dimopoulos, 2018)

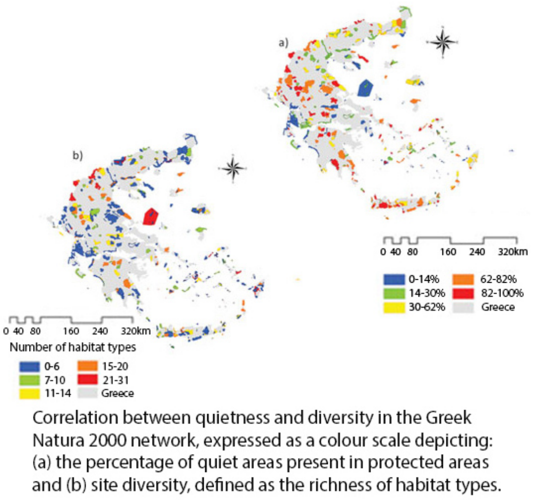


Figure 27: *Map 3* of task execution exercise at national level (Votsi, Kallimanis, Mazaris, & Pantis, 2014)

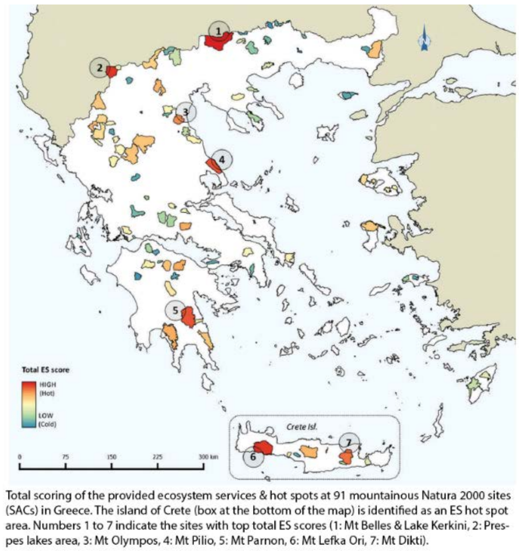


Figure 28: *Map 4* of task execution exercise at national level (Kokkoris et al., 2018)

Table 23: Characteristics of the maps included in the task execution exercise at national level

	Map 1	**Map 2**	**Map 3**	**Map 4**
Ecosystem service type	Cultural service	Regulating service	Cultural service	Total ecosystem service Score
Mapping technique	Choropleth map	Dasymetric map	Choropleth map	Choropleth map
Mapping goal	Valuation	Valuation	Valuation	Valuation
Level of difficulty	Single map	Single map	Series of maps (2)	Single map with additional info in map (Ranking)

Figure 29, Figure 30, Figure 31 and Figure 32 display the maps that were used at national level. The attributes of the maps tested at national level are shown in Table 23. The participants were provided with maps displaying cultural, regulating services and an overall ecosystem service score. *Maps 1, 3* and *4* are choropleth maps displaying values on protected area level. *Map 2* has a higher spatial resolution, the data being displayed on habitat type extent. *Map 1* and *map 2* had a low level of difficulty, displaying a single map with one thematic layer. *Map 3* displayed two maps and *map 4* displayed a single thematic map and ranking-numbers of the areas with the highest values.

Table 24: Effectiveness and efficiency of the test persons in resolving the tasks(?) at national level

	Map 1			**Map 2**			**Map 3**			**Map 4**			
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
	Efficiency (s)												**Duration** (min)
TP8	31	38	x	7	23	54	65	51	54	15	x	29	7,8*
TP12	31	52	72	30	52	133	48	34	121	106	48	91	13,6
TP18	56	27	43	9	41	75	64	83	57	29	36	79	10,0

Average (s)	39	39	58	15	39	87	59	56	77	50	36	66	**10,5**
	Effectiveness (**C**orrect, **I**ncorrect, **N**ot answered, **H**elp required)												Overall C (%)
TP8	C	C	N	C	C	I	I	I	I	C	N	C	50
TP12	H	C	I	C	I	I	C	I	I	I	I	C	33
TP18	C	C	C	C	C	C	C	I	I	C	C	C	83
Task C (%)	67	100	33	100	67	33	67	0	0	67	33	100	

* When participant did not answer a question, the average duration of the other participants to answer that question was added to the calculation of the duration
x = Question was not answered by the participant
Task C = Percentage of correctly answered questions per task
Overall C = Percentage of correctly answered questions per participant

Table 24 displays the effectiveness and efficiency of the test persons at national level. On average this user group took 52 seconds for each task. It must be pointed out, that those values cannot be compared with the values from other administrative levels, as the maps shown to the participants were different. TP12 took in total 3 minutes longer to answer the given tasks. This can be explained by the discussion with the second, anonymous participant.

Maps 1, 2 and *4* were all single maps and had the same average rate of effectiveness (67%). *Map 3*, being a series of 2 single maps, had a low effectiveness rate of 22%, which could indicate, that two maps may be challenging to interpret.

Thematic and spatial resolution

Three of the national maps displayed the data at protected area level, the fourth one (*map 2*) displayed the ecosystem service information at habitat extent. This high thematic resolution resulted in this map having a higher spatial resolution than the other three maps. When using *map 2*, test persons had to use the zooming function to solve the tasks, as the details of the map were not clear to see.

Colour and colour scheme

Three maps did use a diverging colour scheme do display data ranging from "high" to "low". The diverging colour scheme using green for high and red for low values was understood by all participants. One map used a qualitative colour scheme with five different colours for sequential data ranging from 0 upwards. Only 22% of the questions related to this map were answered correctly. This value is lower than the average effectiveness rate of the other three maps (67%). That may be an indication, that a qualitative colour scheme visualizing sequential data may not be intuitive to interpret, which proves the cartographic principle, that the colour scheme should be in line with the data structure (see chapter 2.2.2).

Personal knowledge, map content and description

Including personal knowledge in the map reading process played an important role at this administrative level. This knowledge did include geographic names as well as knowledge on the map content. Two test participants included some degrees of their own knowledge, which was not shown in the map in each of the four exercises to solve the tasks. This knowledge sometimes stood in opposition to the information shown in the map. In such cases, TP12 did rather rely on her own experience and TP8 repeatedly expressed disagreement with every map: "*To be honest this is not a very good map. I am saying I am not agreeing with the map. It is interesting to see that X [geographic name] is blue […] I do not agree with that. I see very few red, that is misrepresenting. I* *would go with more reds, definitely go with more reds*.". This strong reliance on personal knowledge may explain why the average effectiveness rate at national level (56%) is lower than at sub-national (82%) or EU-level (81%).

These observations could be an indication for two issues. On the one hand, the strong disagreement with the colours by TP8 underlines the importance of carefully selecting data categories and data schemes of a map. Secondly, it shows, that not only the design of the map plays a role but also the content. If the user does not agree with the content, there is a chance that he/she will get frustrated or that he/she will not use the content of the map for a decision.

Map labels

Three of the four tested maps did not contain map labels, only *map 2* had labels naming urban centres in Greece. The answers regarding *map 2* were not more specific in terms of number of geographic names mentioned, as the participants did also include geographic names from their own knowledge for answering other tasks as well. Yet, it was observed that the elementary tasks asking about a specific location (average efficiency of *map 2*: 15s) were answered faster than the elementary questions pointing at regions such as "most north-eastern region" of the other three maps (*Map 1*: 39s, *map 3*: 59s, *map 4*: 50s). Furthermore, one participant encountered difficulties in naming locations in the maps and communicating their findings: "*The highest number is within […] the very north west but I cannot see the region to say it by name.*"; "*puh, which area is that, I don't see the name […] I am not good in Geography*" (TP18). That could be an indication, that the presence of map labels may be supportive for users.

Summary: Usability issues at national level

Q3b: What types of difficulties are encountered by the decision makers when working with eco-system service maps?

The following difficulties were encountered at national level:

- Contradiction of map content with personal knowledge
- Red colour for high values counter intuitive
- Difficulties in interpreting a qualitative colour scheme for sequential data
- Missing map labels

Q3c: What map attributes do the decision makers find supportive?

The following (potentially) supportive attributes were encountered at national level:

- Colour scales ranging from high to low
- Geographic labels in a map

4.4.3. Usability issues at sub-national level

In total six people participated in the task execution exercise at sub-national level, five of which participated in this research as users. The sixth test person, TP14, was interviewed as map-maker, but - as this participant also identified as potential map user – also participated in the task execution exercise. TP9 and TP10 were interviewed together and thus did also do the task execution together. The sessions with all people participating in the task execution exercise were conducted remotely. Video observation trough Skype was applied for TP14.

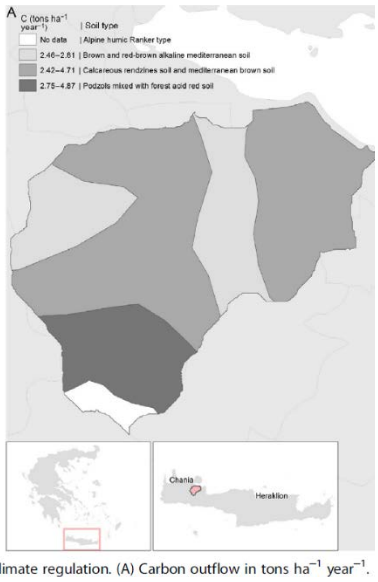


Figure 29: *Map 1* of task execution exercise at sub-national level (Jónsson, Davíðsdóttir, & Nikolaidis, 2017)

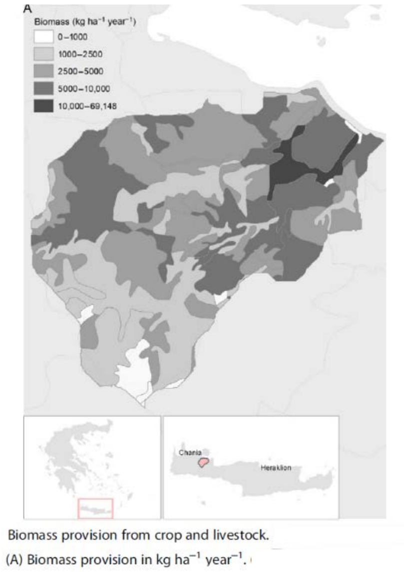


Figure 30: *Map 2* of task execution exercise at sub-national level (Jónsson et al., 2017)

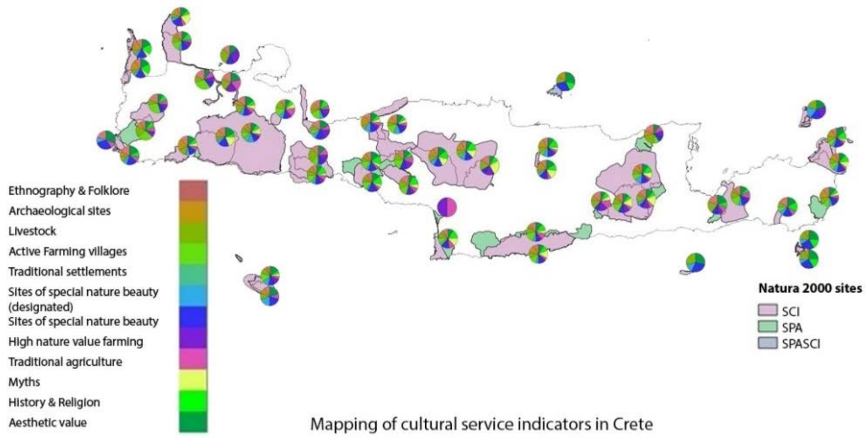


Figure 31: *Map 3* of task execution exercise at sub-national level (Dimopoulos, Vlami, & Kokkoris, 2016)

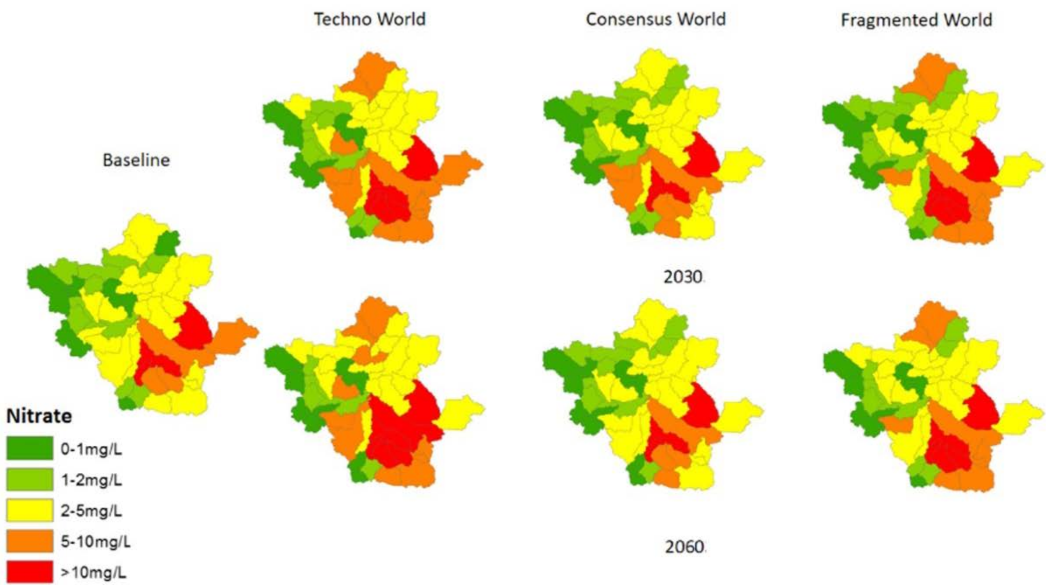


Figure 32: *Map 4* of task execution exercise at sub-national level (Stefanidis, Panagopoulos, & Mimikou, 2018)

The maps used at sub-national for the task execution exercise are shown in Figure 29, Figure 30, Figure 31 and Figure 32. Table 25 displays the characteristics of the maps that were tested at sub-national level. The users were presented with all three ecosystem service types. *Map 1* and *map 2* displayed single chorochromatic maps showing biophysical valuation. The level of difficulty increased with *map 3*, which had two thematic layers and *map 4*, which consisted of a series of 7 scenario maps.

Table 25: Characteristics of the maps included in the task execution exercise at sub-national level

	Map 1	*Map 2*	*Map 3*	*Map 4*
Ecosystem service type	Regulating service	Provisioning service	Cultural service	Regulating service
Mapping technique	Dasymetric map	Dasymetric map	Chorochromatic map	Dasymetric map
Mapping goal	Valuation	Valuation	Valuation	Scenario
Level of difficulty	Single map	Single map	Base map + pie chart	Series of maps (7)

As TP9 and TP10 conducted the task execution exercise together, the efficiency and effectiveness were derived for the two of them together. This fact explains, that this task execution session took longer than those from the other participants.

Table 26: Effectiveness and efficiency of the test persons at sub-national level

	Map 1			**Map 2**			**Map 3**			**Map 4**			
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
	Efficiency (s)												**Duration** (min)
TP4	19	27	44	32	9	38	65	16	53	13	30	21	7,1*
TP6	10	37	23	31	10	27	10	48	87	18	19	17	5,9*

TP9&10	26	30	180	47	25	66	60	118	70	25	78	82	13,5
TP14	36	8	40	31	7	55	21	54	114	17	33	36	7,5
TP16	26	5	36	32	4	13	27	78	66	50	42	29	7,2*
Average	23	26	65	35	11	40	37	75	78	25	40	37	8,2
	Effectiveness (**C**orrect, **I**ncorrect, **N**ot answered, **H**elp required)												**Overall C** (%)
TP4	C	C	C	C	C	C	C	N	C	C	C	C	92
TP6	C	C	C	C	C	C	I	C	C	I	C	C	83
TP9&10	C	I	C	C	C	C	C	C	C	C	I	C	83
TP14	C	C	C	C	C	C	C	C	I	C	C	C	92
TP16	H	H	C	C	C	C	C	I	C	I	C	C	80**
Task C (%)	80	60	100	100	100	100	80	60	80	60	80	100	

* When participant did not answer a question, the average duration of the other participants to answer that question was added to the calculation of the duration
** Percentage of the tasks that were solved without help from the instructor
x = Question was not answered by the participant
Task C = Percentage of correctly answered questions per task
Overall C = Percentage of correctly answered questions per participant

Thematic resolution

A topic that came up was the number of categories in a legend. A map displaying 12 different categories was challenging for several participants. When solving a task asking for one specific item in the legend, one participant could not identify it even though the test person was going through the legend. Two test persons expressed being overwhelmed by the number of different colours and categories they were presented with. The participants were asked to solve two tasks related to those categories and on average they needed 75 and 78 seconds to solve those tasks, which is significantly longer than they needed for other tasks (average 34 seconds). In solving those tasks, the answers were less effective (average 70% effectiveness rate) compared to the effectiveness rate to the other tasks (average 86% effectiveness rate). Yet, TP14 stated that a "*more detailed map is for much interest [as] you can take information by this map with higher level of detail*" and three participants underlined, that having maps with two thematic layers is of interest for them, as those could be useful for their jobs for communicating the distribution of services to the public or for educational purposes (TP9, TP10, TP14). This could indicate, that high thematic resolution in terms of thematic layer can be useful for certain user groups, yet, the map must be designed carefully to avoid difficulties caused by cognitive overload.

Colour and colour scheme

The colour schemes in the maps were sequential, diverging and qualitative. The first two maps did use a grey-white sequential colour scheme for indicating low and high values. No participant brought up any difficulty with this colour scheme, only one participant pointed out, that in their opinion maps using "*colours are more helpful than greyscale*" (TP9). The other maps contained a diverging and a sequential colour scheme with five or more colours. This was challenging for two participants who had a partial visual impairment and had difficulties identifying and distinguishing certain colours. For that reason, those participants had problems identifying areal colours ("*the areas mapped with grey colour, I cannot, or pink colour. But I am not sure*" (TP4)) as well as different colours in pie charts ("*I cannot see the colours in the pies*" (TP4)). Another issue that was brought up is the white colour used for displaying oceans. TP16 had problems identifying those areas and recommended it might be beneficial to "*use some different colour to show the sea.*" (TP16).

Legend

The font size was an issue in some cases. One participant did misread what was written in the legend even though he was referring to the correct legend item: "*The region near the coast has in intermediate carbon from 242 to 200 ehm 2.42 to 4.71.*" (TP14). TP9 and TP10 immediately asked about the zooming function when the first map was shown to them, even though the polygons in the first map were very big and generalized. This may be an indication that the text displayed in the legend and/or map was not clearly legible. Increasing the font size of the legend may be a solution for that problem.

Content

In retrospect some participants pointed out, that different ecosystem service maps are of different relevance to them. TP4 pointed out, that cultural services are not of interest for his profession and expressed doubts of the mapping approach behind it, because of the perceived subjectivity of this service. This participant considered biophysical valuation to be very important for his profession. In the contrary, TP9 and TP10 said, that maps related to cultural services and showing their distribution could be of use for their work in the national park for displaying the services of their area. That shows, that the perceived usefulness of ecosystem service maps may depends on the background and use purposes of the users (as was discussed in chapter 2.2.6).

Description and map labels

Map 4 was presenting the users with 3 different future scenarios. The map displayed the title and year of the scenarios, but not the background of those scenarios. TP16 pointed out, that an additional description explaining the meaning of the difference scenarios would be desirable. Furthermore, it took participants a long time to understand which title belonged to which map, one test person did not find a map when asked for it. This highlights the importance of thoughtful title placement in the map. When asked about the "most favourable" scenario, the participants chose the scenario that showed the least red and the greenest polygons. Knowing about the shortcomings of choropleth maps (see chapter 2.2.2) an estimation like this could be misleading.

Personal knowledge

Some users brought their own knowledge into answering the questions. For example, TP14 or TP6 included geographic names that were not displayed on the map. TP16 has visited or was familiar with all 4 maps and included his knowledge of the terrain or the land use of the area in his answers: "*In general, as I said before, in lower altitudes - because I know the area - and north-eastern area we have and north in general area we have more biomass*" (TP16). In this case the information shown in the map did match the personal knowledge of the test person.

Level of detail

Map elements which had a high level of detail and were very small, were difficult for some participants to read. TP4 pointed out that "*a lot of zooming*" (TP14) was necessary to understand those small elements.

Summary: Usability issues at sub-national level

Q3b: What types of difficulties are encountered by the decision makers when working with ecosystem service maps?

The following supportive attributes were encountered at sub-national level:

- Too many categories and colours in legend
- Difficulty to distinguish colours due to visual impairment
- Too many colours difficult to distinguish
- Small map elements
- Small font size
- Missing titles for scenarios

Q3c: What map attributes do the decision makers find supportive?

The following (potentially) supportive attributes were encountered at sub-national level:

- More thematic layers can be useful
- Colour schemes are more helpful than grey scale
- Description of scenarios

4.4.4. Comparison of the usability issues among administrative levels

Hereafter the similarities and differences between the encountered usability issues by the end-users on different administrative levels are briefly summarized and in doing so, the second part of RQ4b will be answered. The answers of RQ4b, that relate to results from the user interviews can be found in chapter 4.1.4.

RQ4b: How do the encountered use and user requirements vary at EU, national and sub-national level?

4.4.4.1. Usability measures

According the analysis of the think-aloud protocols, the users at national level on average had a lower effectiveness and efficiency rate than the participants at EU- or sub-national level. A reason for that may be the lack of expertise in using maps. The users at national level did have less experience in working with ecosystem service maps or environmental map types (e.g. habitat maps, forest maps) than the users at EU- or sub-national level. The lower effectiveness may be explained by the strong focus on own knowledge by the participants at this level. However, it must be kept in mind that different maps with different content were shown to the participants. Regarding the knowledge of the ecosystem service concept, the results from the task execution exercise indicated that difficulties with ecosystem service maps are equally encountered by people with high or low familiarity with the concept. This could be an indication that the difficulties encountered during the map use originate from the design of the ecosystem service maps. While this statement is based on the average effectiveness and efficiency of a small sample and is thus not statistically representative, this assumption complements the information gained from the qualitative data gathered from the interview data and the think-aloud protocols.

4.4.4.2. Usability issues

This chapter will briefly discuss the usability issues and supportive attributes encountered at EU-, national and sub-national level. As different maps with different attributes and designs were tested at those levels, different issues have been discovered at one or more levels. This chapter will discuss those issues and make assumptions, whether those issues hold for all ecosystem service maps. In doing so it is distinguished between universal issues, which hold for all cases and case specific issues, which may be only valid for one administrative level and may only enhance the usability of a map in a certain case. The recommendations for future map design, that were derived from those findings will be presented in chapter 4.5.2.

Colour and colour scheme

The issue of colour-blindness was brought up by three test participants from EU and sub-national level. Yet, as approximately 4% of the population have some kind of visual impairment (Brewer, 2016), it can be concluded that this usability issue is relevant for all user groups at all administrative levels. A very frequently applied colour scheme is green-red to visualize areas of high or low value. Those two colours are hard to distinguish for people with red-green visual impairment, which is the most common type of colour-blindness (Brewer, 2016). This issue can be solved by applying colour schemes which are not confusing for colour blind people.

Another issue encountered related to colour was the applied colour scheme, namely a diverging colour scheme that was applied for sequential data. The participants took more time to answer questions related to the map with this colour scheme. This supports the findings of Brewer (2016) and Kaye, Hartley, & Hemming (2012), who state that the colour scheme should match the data structure. For that reason, it is assumed, that this issue is not administrative level specific.

Thematic resolution and colour

When presented with legends, containing 42 different variations of one colour (EU-level) or 12 different qualitative categories with different colours (sub-national level), it was expressed by some participants, that they had difficulties distinguishing this amount of colours. This issue was also addressed by cartographic literature, which recommends to limit the number of colours (and thus also the number of categories) in a legend to ensure the user can distinguish the presented colours (Peterson, 2009).

Legend

Users at two administrative levels indicated that the font size in the map legend was too small and they could not read it without zooming in. As the legibility of text in a map is not related to the administrative level of the map, it can be said, that a small font size poses a usability issue for all administrative levels. There is no ideal font size, as it strongly depends on factors like the font type of weight, but it must be considered by the map-maker that the font should be big enough to be legible for users who have difficulties reading small fonts (Brewer, 2016).

Missing units in the legend was a usability issue encountered at European level. At sub-national level, the units were displayed in the legend and as the sub-national test persons referred to those units in their answers, it can be concluded that they used this information in their reasoning about the map content. As legends are a critical element for understanding the map (Slocum et al., 2014), it can be assumed, that having complete information in the legend is a usability issue, that applies to all ecosystem service maps, which display content that has units e.g. maps showing biophysical valuation (kg/ha) or economic valuation ($/year).

Image resolution

Low image resolution has been identified as a usability issue at European level, as the map appeared to be pixelated when zooming in. As this problem can be relevant to any static raster map (e.g. jpg, png), independent from the ecosystem service displayed or the administrative level, it is assumed, that this is a universal prerequisite for static maps. This problem can be solved by increasing the image resolution when exporting the image (Brewer, 2016).

Title

A missing title was found to be a usability issue at EU-level. As in many cases the tested maps were taken from scientific publications, the titles were placed below the map. Having a title in a map is important to improve the understanding of it (Slocum et al., 2014), which was also indirectly confirmed by the participants. For that reason, it is argued, that a title is an essential map element independent of the administrative level.

Personal knowledge and map content

Personal knowledge, that was not shown in the map, was included by users at all three administrative levels. At EU-level that knowledge did only refer to geographic names of regions. At national and sub-national level, the users included their own knowledge on the characteristics of the shown region to answer the map. At all the levels this knowledge was used to underline the information shown in the map but also to express doubts if the personal knowledge was contrary to the map content.

This brought up issues were also encountered by Hauck et al. (2013), who found, that main challenges in ecosystem service mapping originate from doubts on the scientific accuracy of the data and doubts whether the shown information is relevant to the users' needs. The first problem does partly relate to the challenges of data or method availability. The latter problem could indicate, that a map is not perceived as useful if the content in not considered relevant or accurate. Involving the users in the mapping process to consider their needs but also their knowledge, could lead to an improvement (Hauck et al., 2013; McInerny et al., 2014).

This also raises the opportunity of including this personal, specifically local knowledge in the ecosystem service mapping process (Raymond et al., 2010), as past research has shown, that can be of value for ecosystem service mapping, as it is more related to the direct livelihoods of the local people and better grasp the complex implications of decisions on environmental management challenges (Agrawal, 1995; Raymond et al., 2010). Local and indigenous knowledge presents a key factor to "understanding nature's contribution to people"(Díaz et al., 2018: 270)

Scenario maps

Scenario maps were found both by some participants and by literature (Willcock et al., 2016) to be of importance for ecosystem service mapping. At sub-national and EU-level scenario maps were shown to the participants. At EU-level it was a dasymetric map and at sub-national level a choropleth map was shown to the participants and at both levels the participants were asked to choose the environmentally most favourable scenario. At EU-level the participants expressed difficulties quantifying from just looking at the map, which map has the highest values and it was pointed out, that an overall statistical value would be useful. At subnational level, the participants solved this task by counting, which scenario has the highest number of green polygons. Knowing about the shortcomings of choropleth maps (see chapter 2.2.2), such an estimation could be misleading. As this limitation is restricted to the mapping technique and the mapping goal, it is concluded, that this is valid independent from the administrative level.

Description and map content

The map description was read and included in the answer of the participants during the task execution exercise. Difficulties were encountered when the description was too technical and showed terms that were not known by the participants. Furthermore, when the map was showing an indicator, the participants asked for it to be explained in the map description. With respect to maps showing scenarios, the participants expressed the wish of having a short description of the underlying scenarios assumptions.

The fact, that the participants used the map description to answer the questions may have been a result from the research design. In general, a map description is considered to be useful, if it enhances the users understanding of the map content (Peterson, 2009). Due to the complexity and variety of ecosystem service indicators and ecosystem service maps (as discussed in chapter 2), it certainly is useful to have a brief descriptive text explaining what the map shows. This map description should be tailored to the background of the target audience e.g. a non-scientific audience (McInerny et al., 2014).

Spatial resolution

Too detailed spatial resolution was encountered to be a usability issue by users at EU- and national level. At national level a map with high spatial resolution required the user to zoom in, in order to answer the given question. And EU-level the users expressed their confusion about dasymetric maps with high resolution and one user pointed out, that the map showing the data at NUTS-3 level was easier to interpret. That could be an indication, that too high spatial resolution – even though it presents the underlying data more accurately – may not be user friendly. This issue is likely to apply to all administrative levels, yet which spatial resolution is suitable for which level may vary. In the end, it is important, that the spatial resolution matches the map's scale (Brewer, 2016).

Map labels

Missing map labels were identified to be a challenge by one participant at national level. Another map at national level, which did contain labels, was more efficient in terms of faster response time of the participants. The EU maps did not have any map labels, but the participants did not show any difficulties in naming countries or regions. A conclusion drawn from that is, that map labels should be added to a map, if they enhance the understanding of the user (Slocum et al., 2014).

Thematic resolution

In some cases, at sub-national level it was highlighted by participants, that having more than one thematic layer was useful for them. The need for more than one thematic layer was not expressed by the other participants. This requirement seems to be case specific and is thus classified as map element, that could be added if it enhances the understanding of the user. However, it is important to avoid visual clutter when adding an additional thematic layer e.g. diagrams (Kraak & Ormeling, 2010).

4.5. Recommendations

4.5.1. User profiles and use case scenarios

The following tables (Table 27, Table 28and Table 29) present the user profiles, that have been developed based on the findings from the conducted user research. For each user profile a sample use case was developed, which presents a potential future application of ecosystem service map and geographic questions (van Elzakker, 2004), that should be answered with the given map. Those questions do not aim to be a complete selection of all questions that should be addressed by ecosystem service maps and rather aim to be an inspiration for future map-making processes. Those user profiles have been developed on a small sample size and their verification or the exploration of other user profiles of different target groups would be an option for future research.

Table 27: User profile at EU-level showing the characteristics of a user working for the European Commission

EU user profile	
Age group	31-50
Ethnicity	International
Highest education	University degree (PhD)
Educational background	Environmental sciences
Profession	Policy officer working for the European Commission
Map use experience	Very experienced with using maps
Knowledge on ecosystem service maps	Knows the ecosystem service concept for several years and has been using those maps in the past work experience
Sample use case	Identification of current trends of carbon sequestration in the European Union for policy development. Sample geographic questions that seek to be answered: ▪ What is the distribution of the object of interest? ▪ What important patterns are there?

Table 28: User profile at national level showing the characteristics of a user working for a Greek ministry

National user profile	
Age group	31-50
Ethnicity	Greek
Highest education	University degree (bachelor's degree or higher)
Educational background	Forest management, agricultural economics
Profession	Employee of Greek ministry of environment or agriculture
Map use experience	Basic map-use experience
Knowledge on ecosystem service maps	Has known the ecosystem service concept for a few years and does sometimes use ecosystem service maps
Sample use case	Conduction of risk assessment to identify areas of high risk of floods for allocating intervening steps. Sample geographic questions that seek to be answered: ▪ Where is the highest/most? ▪ What are the characteristics of the region?

Table 29: User profile at sub-national level showing the characteristics of a user working for a Greek national park

Sub-national user profile	
Age group	31-60
Ethnicity	Greek
Highest education	University degree (bachelor's degree or higher)
Educational background	Ecology, biology
Profession	Employee of management authority of national park
Map use experience	Very experienced with using maps
Knowledge on ecosystem service maps	Learned about the ecosystem service less than a year ago and did not use such maps yet
Sample use case	Conduction of environmental impact assessment by comparing the impacts of alternative future management actions. Sample geographic questions that seek to be answered: ▪ What important patterns are there? ▪ Will the spatial patterns change over time?

4.5.2. Recommendations for map design

The analysis of the think-aloud protocols let to the conclusion, that the application of basic cartographic principles can notably increase the usefulness of ecosystem service maps for the users. Following the example of Roth, Ross, & MacEachren (2015), the information gathered from the task executions were used to derive recommendations for cartographic map design. Unlike Roth et al. (2015) those recommendations do not refer to the improvement of one specific mapping application but can be understood as general guidelines for map design in future maps. Some of those findings are specific to ecosystem service maps, others apply to cartographic design in general. The recommendations were derived from the issues brought up by the test participants and do also take into consideration findings and design principles mentioned in cartographic literature (e.g. Brewer, 2016; Kraak & Ormeling, 2010; Slocum, McMaster, Kessler, & Howard, 2014).

Recommendations for map design

Issue	Solution
Visual impairment	Use colour combinations, which are distinguishable for the most common variations of colour-blindness: ▪ "*red and blue* ▪ *red and purple* ▪ *orange and blue* ▪ *orange and purple* ▪ *brown and blue* ▪ *brown and purple* ▪ *yellow and blue* ▪ *yellow and purple* ▪ *yellow and gray* ▪ *blue and gray*" (Brewer, 2016: 169).
Colour scheme and data structure	Chose colour scheme that matches the structure of the data (e.g. sequential data should be visualized with a sequential colour scheme) (Brewer, 2016; Kaye et al., 2012).
Number of categories and colours in legend	Diverging/sequential colour scheme: Use maximum five hues of the same colour (Peterson, 2009). Qualitative colour scheme: Use maximum 10-12 different colours (Peterson, 2009).
Legend units	Include the units (if available) in the legend.
Font size	Legible font size of map description, map labels, legend labels and title.
Image resolution	Export raster format (e.g. jpg) with resolution of 300-400 dpi (Brewer, 2016; Peterson, 2009).
Title	Have a title, which describes the intent of the map either on top or bottom of the layout (Peterson, 2009).
Map labels	Add map layer, if they enhance the users understanding (Slocum et al., 2014).
Thematic layers	Add additional thematic layer, if it enhances the users' understanding
Description and map content	Add explanatory description explaining the map content e.g. displayed ecosystem service or type. Adjust the description and map content to the background knowledge of the audience.
Scenario maps	Include numerical summary value (e.g. mean, median) (Slocum et al., 2014).

Spatial resolution	Ensure the spatial resolution matches the map scale, and generalize data e.g. through aggregation, if required (Brewer, 2016).

Map type recommendations

A general recommendation for future ecosystem service map design is critically reflecting on which map type may be suitable for the presented data and the geographic questions the map should answer (van Elzakker & Ooms, 2018). Shortcomings of choropleth maps (see chapter 2.2.2) should be overcome by adding the actual, non-standardized values to the polygons. Even tough choropleth maps are easily generated, other visualization types may be more suitable for the available data. It is also worth considering other map types (e.g. cartograms, proportional symbol maps, dasymetric maps) to overcome the problem of arbitrary units (Kraak & Ormeling, 2010; Slocum et al., 2014).

Further recommendations

The following bullet points were derived from the analysis of the user and map-maker interviews. This list shows recommendations that may contribute to the successful use of ecosystem service maps in decision-making processes.

- Training on cartographic map design principles for map-makers or cooperation with cartographers for the map design
- Application of UCD and inclusion of the users and their geographic questions, needs and expectations in the mapping approach by actively consulting them e.g. by asking about specific geographic questions they need to answer (van Elzakker & Ooms, 2018)
- Iterative, repeated communication between the map-maker and user throughout all stages of the map creation (Roth et al., 2015) to increase the trust in the product and the likelihood of uptake of the information by the decision- or policy maker (Ruckelshaus et al., 2015)
- Capacity building between researchers and stakeholders e.g. collaboration of users and researches throughout the map creation process and application of participatory approaches (Albert et al., 2014; Hauck et al., 2013; Palomo et al., 2018)
- Training and development of guidelines on how to use ecosystem service maps and the ecosystem service concept for prospective users
- Promotion of open data portals (Westgate et al., 2018) and data exchange between institutions

4.6. Limitations and outlook

This research aimed at conducting a thorough analysis of the use and user requirement of ecosystem service maps. The limitations of this research and resulting options for future research are discussed hereafter.

The chosen research sample and the sample size does present a limitation of this research and does limit the representativeness of the outcomes. At EU-level the sample was only restricted to employees of the European Commission. At national and sub-national level only Greek citizens were interviewed. These limitations could make the findings organization or country specific and thus other uses or user requirements of groups outside of this sample may have been missed.

Further in-depth research into the use and user requirements of ecosystem service maps at those three levels or the validation of the developed user profiles could be a potential option for future usability research.

Furthermore, the sample size for each test participant category was between 2 and 6 participants for each test category. The task execution exercises had between 3 and 6 participants in each test group. Findings by Nielsen (1994) show, that with three users already 63% of the potential usability issues of a system can be encountered. Thus, this sample size was considered to be sufficient for the purposes of this research. Even though some of the issues, from encountered during the tasks execution, user and map-maker interviews were supported by findings from other scientific research, this small number of participants does not allow to derive any statistically representative findings. Rather the issues encountered could be used as starting point to generate hypothesis on the use and user requirements of ecosystem service maps in future research.

In this research the following three methods were applied: Interview, task execution exercise and partly video observation. As the findings derived from those methods did answer the formulated research questions, it was chosen not to apply any other methods. As briefly touched upon in the previous paragraph, those findings do not present a statistical validation of the results. On the one hand the application of an online survey to quantitatively assess the use and user requirements could also be a potential option for future research. Future case studies could e.g. select one specific use case and investigate the potential use purposes, geographic questions and needs of the user in more depth. Secondly, future research should address the other steps of the UCD cycle, which are the development of a prototype based on those findings and a usability evaluation of it.

All test persons spoke English as a second language. This sometimes resulted in insecurities during the research process. Also, it is likely, that certain nuances of language and communication were not transported because of that. Insecurities related to the English language sometimes caused (some of) the participants to not feel at ease(/uncomfortable) during the interviews. In addition to the language barrier, communication problems related to bad internet connection and interview interruptions did in some cases, make the communication with the participant difficult.

Prior to the research sessions a pilot test for the task execution exercise was conducted. The findings from this test were very valuable and notably improved the research design. Based on those insights the practical research set-up (e.g. always having paper and pen ready, reformulation of questions) was adapted. It would also have been useful to conduct a pilot test of the interview set-up and questions with a person from the interview context, like a local Greek researcher, as was also recommended by Baxter et al. (2015). During the first interview sessions it was discovered that the purpose of the research or certain questions were not fully clear to the test persons and the explanations that were prepared to be given in such a case did not seem to answer the question of the user.

The maps for the task execution were selected on ecosystem service type and level of difficulty differentiating between single maps and map series. Two of the four tested maps should be map series and two should be single maps. Furthermore, all three service types (provisioning, regulating, cultural) or terrestrial or wetland ecosystems should have been shown to the test persons. Marine ecosystems were excluded as due to their "interactivity" they bring many new methodological and cartographic challenges, which were not addressed by this research. Those restriction criteria were met at sub-national and at EU-level, but at national level this goal was not fully achieved due to limited data availability. The participants were provided with maps showing cultural, regulating services and ecosystem service score on three single maps and one map series. Instead of a second map series the participants were presented with a single map which displayed a ranking of regions. The map selection was further limited by focussing only on maps displaying the supply of ecosystem services. Future research on the usability of ecosystem service maps should take into account the mapping of other relevant concepts like the demand or flow of ecosystem service. Also, spatially expressing the uncertainty of measurements as uncertainty maps, which partly has been addressed by some publications (e.g. Kokkoris, Drakou, Maes, & Dimopoulos, 2018), should receive more attention in the future. In addition, participatory approaches are promising to increase the trust of decision makers in the final map (Hauck et al., 2013) and should be explored further.

Another limitation of this research was the focus on static desktop ecosystem service maps. It was chosen to limit the selection of maps to this display medium, as the interactive systems that exist (see chapter 2.2.1), do not provide a high level of interactivity and there was almost no data available at national or sub-national level for any European country. It would be of relevance for future ecosystem service mapping approaches to explore the implementation and evaluation of interactive maps to support decision-making.

Furthermore, the results encountered by this research, that the application of UCD related to ecosystem service maps, is highly needed and has the potential to improve future map design.

5 CONCLUSION

This study conducted a use and user requirement analysis of ecosystem service maps at EU-, national and sub-national level to gain insights on the perspectives current users and map-makers of ecosystem service maps and identifying usability issues of ecosystem service maps.

To achieve these research goal, exploratory user research methods were applied. Through the conduction of interviews with the map-makers and the users insights on their perspectives were derived. Usability issues with ecosystem service maps were identified through the conduction of a task execution exercise using the think-aloud and video observation method.

It was found, that the participants at EU-, national and sub-national level were different and similar in some respects and that different use purposes were encountered at different administrative levels. Ecosystem service maps were currently not or only partly applied in decision-making processes. The interviews with the map-makers showed, that there are not notable differences between the actual use purpose by the user and the intended use purpose by the map-maker. All map-makers were willing to produce ecosystem service maps that are used by their target group, but the produced ecosystem service maps were not often applied in practise yet. The usability evaluation of current ecosystem service maps identified different usability issues with ecosystem service maps e.g. issues related to the colour scheme, as well as attributes, which were supportive for decision-making. Based on the findings of this research, recommendations for future map design and map creation processes were derived.

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APPENDIX 1: PRE-INTERVIEW CHECKLIST MAP-USER

Remotely	**In person**
Interview: via Skype Think-aloud and observation: Show maps with screen sharing software and observe trough screen and camera recording	Interview: In person Think-aloud and observation: Show maps on laptop and give them printed tasks; observe trough camera recording

Pre-research checklist

Longer before the meeting

Remotely	**In person**
☐ Charge laptop ☐ Charge camera ☐ Charge phone ☐ Check that camera has enough storage space ☐ Bring tripod ☐ Have Skype/phone contact details of participant ready ☐ Print interview structure	☐ Charge camera ☐ Charge laptop ☐ Adapt screen brightness of laptop ☐ Check if SD card is in camera ☐ Check that cameras have enough storage space ☐ Bring tripod ☐ Bring camera ☐ Bring laptop + mouse ☐ Print interview structure ☐ Bring **passport!**

Right before the meeting (15mins)

Remotely	**In person**
☐ Put "Interview in progress, do not interrupt" sign on door ☐ Mute phone ☐ Close all programs on phone ☐ Start phone recording ☐ Start screen recording software ☐ Start screen sharing software ☐ Start Skype ☐ Open maps to be shared ☐ Have Skype/phone contact details of participant ready ☐ Have paper/pen to take notes ready ☐ Have printed interview structure ready	☐ Camera/tripod are in position ☐ Start camera ☐ Start phone recording ☐ Start screen recording software ☐ Have jpg maps opened on laptop ☐ Close all other programs on laptop ☐ Have paper/pen to take notes ready ☐ 2x Have printed think aloud tasks ready ☐ Have printed interview structure ready

APPENDIX 2: PRE-INTERVIEW CHECKLIST MAP-MAKER

Interview: via Skype

<u>Pre-research checklist</u>

Longer before the meeting

- ☐ Charge phone
- ☐ Charge laptop
- ☐ Check that phone has enough storage space
- ☐ Have Skype/phone contact details of participant ready
- ☐ Print interview structure

Right before the meeting (10minutes)

- ☐ Put "Interview in progress, do not interrupt" sign on door
- ☐ Mute phone
- ☐ Start Phone recording
- ☐ Start Screen recoding
- ☐ Start Skype
- ☐ Have Skype/phone contact details of participant ready
- ☐ Have paper/pen to take notes ready
- ☐ Have printed interview structure ready

APPENDIX 3: INTERVIEW QUESTIONS – MAP-USER

1) Tasks, use purposes and goals of ecosystem service maps

1. Can you briefly tell me about your job and how it relates to ecosystems and their services?
2. **If prior knowledge**: Can you tell me a typical example of when you use ecosystem service maps within your job?
3. What do you (potentially) use ecosystem service maps for? So imagine you have a map [Go back to maps], what do you use it for? What tasks do you have to solve?

   If prior knowledge: Follow-up question: When solving those tasks, at what point of a decision-making process do you consider the ecosystem service maps?

   - ☐ In the beginning
   - ☐ During the entire task-fulfilment period
   - ☐ At the end of the task-fulfilment period
   - ☐ Other:
4. What is your personal motivation or personal goals behind (potentially) using ecosystem service maps?
5. **A) If prior knowledge**: What weight do ecosystem service maps have in the decision-making process?

   Probing question: What other factors play a role in the decision making-process? What role does the Biodiversity Strategy 2020/ Greek national Biodiversity Strategy play?

   B) If no prior knowledge:

   - What factors are currently influencing your decision-making processes?
   - Are you familiar with the Biodiversity Strategy 2020/ Greek national Biodiversity Strategy?
     - ☐ Yes
       - o If yes: Can you tell me how this strategy influences your work?
     - ☐ No

2) Task execution exercise

3) Usefulness and requirements

1. Can you elaborate on any difficulties you encountered during the use of ecosystem service maps?
   a. Follow-up question: did the provided spatial and temporal scales match your needs
2. **If prior knowledge** How much do you trust the provided ecosystem service maps?
   a. 1 I completely trust them
   b. 3 Neutral
   c. 5 I do not trust them

3. **If prior knowledge** Have you ever been involved in the mapping-process by the producer of maps?
    - ☐ Yes
    - ☐ No

    If yes:
    Follow-up question: Can you explain me a bit more about this case study? How have you been involved?
    Follow-up question: At which stage(s) of the mapping process have you been involved?
        - ☐ Before the mapping process
        - ☐ During the mapping process
        - ☐ After the mapping process
        - ☐ Throughout the entire process

4) Background (personal, ecosystem service concept and maps)

0. What is your gender?
    - ☐ Male
    - ☐ Female
1. What is your age group?
    - ☐ 21-30
    - ☐ 31-40
    - ☐ 41-50
    - ☐ 51-60
    - ☐ 61-70
2. What is your highest educational level
    - ☐ High school
    - ☐ Bachelor's degree
    - ☐ Master's degree
    - ☐ Doctorate degree
    a. Follow-up question: If participant has education higher than high school: What was the specialization of your studies?
3. How familiar are you with using maps?
    - ☐ Very familiar
    - ☐ A bit familiar
    - ☐ Not familiar
4. How familiar are you with the "ecosystem service" concept in terms of years?
    - ☐ Less than 1 year
    - ☐ 1-3 years
    - ☐ 4-6 years
    - ☐ >6 years
5. How frequently are you working with ecosystem service maps in your daily work?
    - ☐ Every day
    - ☐ 2-4 times per week
    - ☐ Once in a week
    - ☐ Once in a month
    - ☐ A few times per year
    - ☐ Never

6. At which administrative levels do you use (ecosystem service) maps?
    - ☐ EU
    - ☐ National level
    - ☐ Sub-national level
7. On what medium do you display ecosystem service maps?
    - ☐ Screen
        - ☐ Static
        - ☐ Dynamic
        - ☐ Interactive
    - ☐ Paper
    - ☐ Other:

APPENDIX 4: INTERVIEW QUESTIONS – MAP-MAKER

1) Map creation

1. Can you briefly tell me about your job and how it relates to ecosystems and their services?
2. Can you explain your typical map-making process?
    - Which steps do you follow?
    - Which tools do you use for the map creation?
    - Where do you acquire relevant data?
3. What factors do influence the map creation process?
    - <u>Probing question</u>: What role does data availability play?
    - <u>Probing question</u>: Which role does the Biodiversity Strategy/Greek national Biodiversity Strategy for creating maps?
4. Can you explain how/why you decide to map a certain ecosystems service with your data?
    - Explanation: Certain data such as land-use data can be used to display different ecosystem service

Food provision	Agricultural production	Land cover
Climate Regulation	Carbon storage	Land cover

2) End-users

1. What target groups do you have in mind when designing a map?
    - <u>Probing question</u>: Who do you expect to be your end-user? E.g. In terms of job title, …
    - <u>Probing question</u>: For what tasks do you design ecosystem service maps?
2. Does the mapping process involve direct communication with the users?
    - ☐ No
    - ☐ Yes

      Follow-up question: Could you tell me more about that?

      <u>Follow-up question</u>: At which stage of the mapping process were the users involved?

        - ☐ Before the mapping process
        - ☐ During the mapping process
        - ☐ After the mapping process
        - ☐ Throughout the entire process

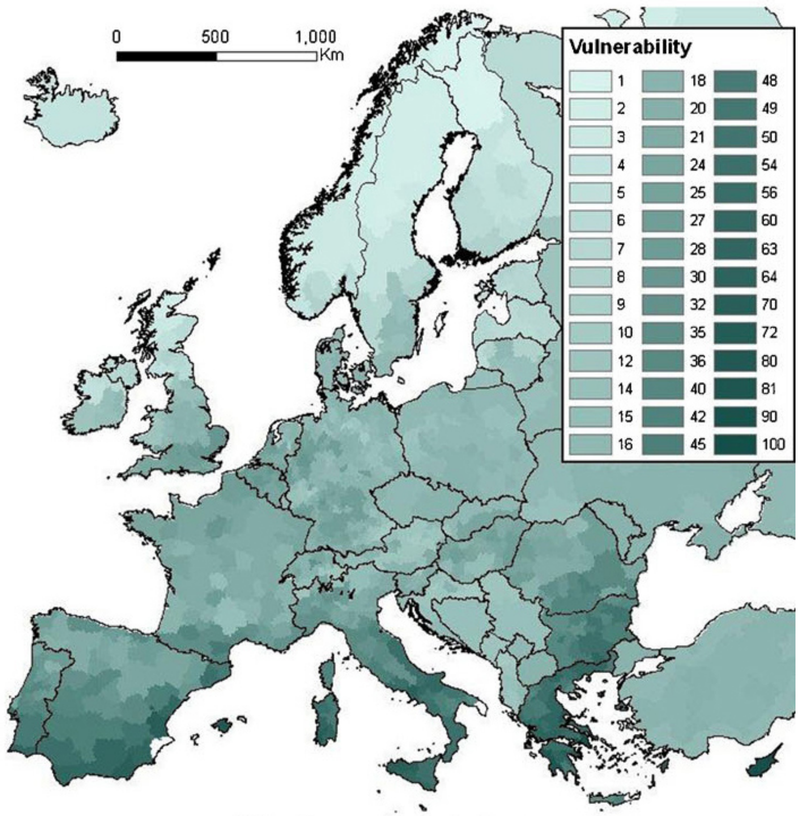
3) Background

1. Gender
    - ☐ Male
    - ☐ Female
1. What is your age group?
    - ☐ 21-30
    - ☐ 31-40
    - ☐ 41-50
    - ☐ 51-60
    - ☐ 61-70

2. What is your highest educational level
   - ☐ High school
   - ☐ Bachelor's degree
   - ☐ Master's degree
   - ☐ Doctorate degree

   Follow-up question: If participant has education higher than high school: What was the specialization of your studies?
3. How familiar are you with using maps?
   - ☐ Very familiar
   - ☐ A bit familiar
   - ☐ Not familiar
4. Have you ever participated in any kind of cartographic training? If yes, please explain.
5. How familiar are you with the "ecosystem service" concept in terms of years?
   - ☐ Less than 1 year
   - ☐ 1-3 years
   - ☐ 4-6 years
   - ☐ >6 years
6. How frequently are you producing ecosystem service maps in your daily work?
   - ☐ Every week
   - ☐ Every month
   - ☐ A few times per year
   - ☐ Almost never
7. At which administrative levels do you create ecosystem service maps?
   - ☐ EU
   - ☐ National level
   - ☐ Sub-national level

Map 1



Water provision

Vulnerability assessment results maps for the EU-27

Source: Tzilivakis, J., Warner, D. J., Green, A., & Lewis, K. A. (2015). Adapting to climate change: assessing the vulnerability of ecosystem services in Europe in the context of rural development. Mitigation and Adaptation Strategies for Global Change, 20(4), 547–572.

Map 1

Service description

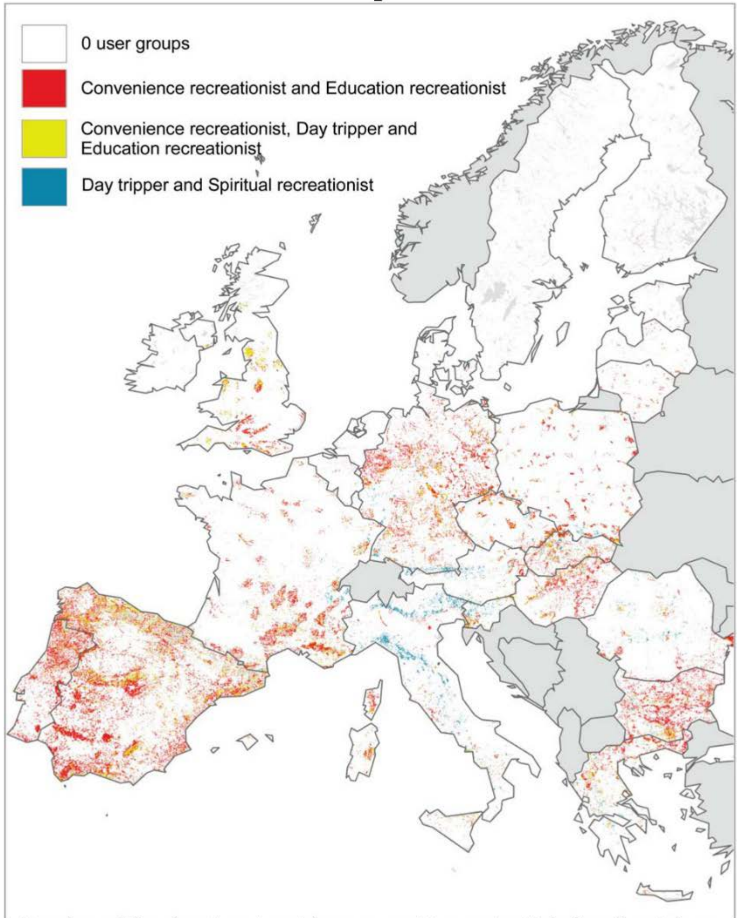
Water provision

Vulnerability assessment of water provision = the provision of water for human use and its reaction to the following 3 stress factors: consumptive water loss & human water stress & agricultural water stress

Tasks:

1. What is the vulnerability of the Czech Republic?
2. Where are regions having the lowest vulnerability of water provision?
3. Which areas would be priority areas for management interventions to reduce vulnerability?

Map 2



Overlay of the dominant outdoor recreation potentials for all outdoor recreation user groups. Map was simplified for visualization purposes by removing small patches.

Map 2

Service description

Dominant outdoor recreation potential (Cultural service)

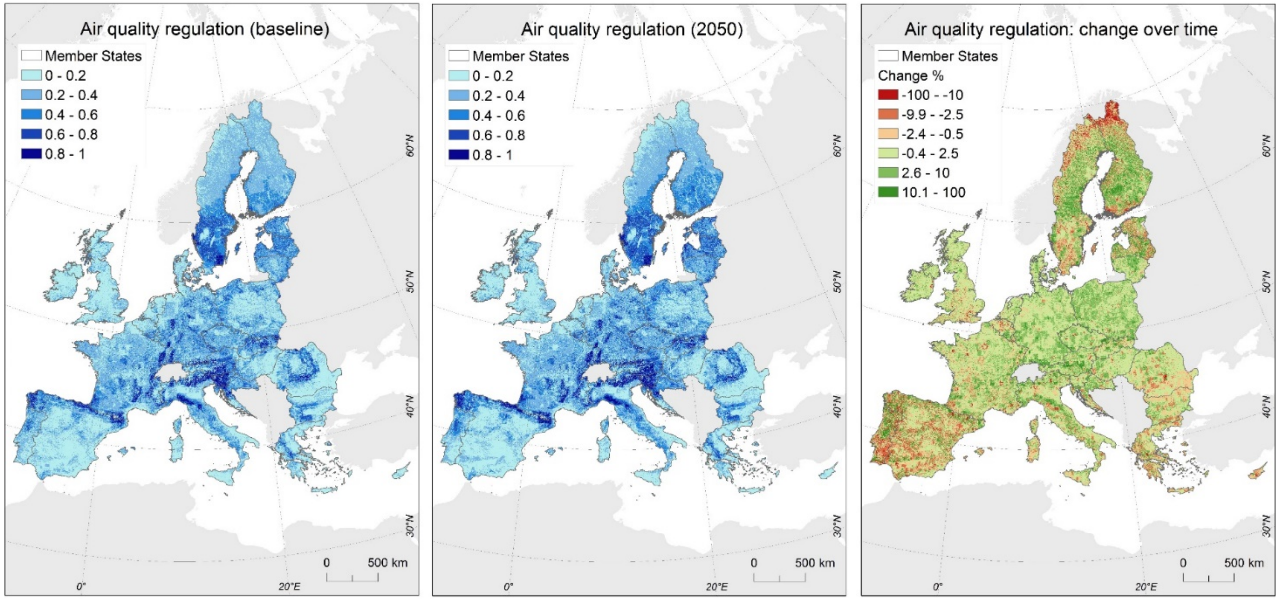
Engagement with the natural environment and public enjoyment of access to farmland and woodland often takes the form of outdoor recreation. Based on their recreation preferences 5 types of people can be distinguished (e.g. the "day trippers" aim is to escape the stressful routine of everyday life)

Tasks:

1. Which outdoor recreation potential user groups can be found in France?
2. Which region has the highest presence of the "day tripper and spiritual recreationist" category?
3. Which regions have very high and very low potential for convenience and education recreationist?

Source: Komossa, F., van der Zanden, E. H., Schulp, C. J. E., & Verburg, P. H. (2018). Mapping landscape potential for outdoor recreation using different archetypical recreation user groups in the European Union. Ecological Indicators, 85(May 2017), 105–116. https://doi.org/10.1016/j.ecolind.2017.10.015

Map 3



Air quality regulation for baseline, 2050 and as a percent change over time (2050 vs. baseline). For the baseline and the 2050 maps, classes represent equal intervals over the range of rendered predictions; for the percent change over time, the visual representation reflects the distribution of the values. Maps are displayed using the Projected Reference System LAEA. See main text for additional details.

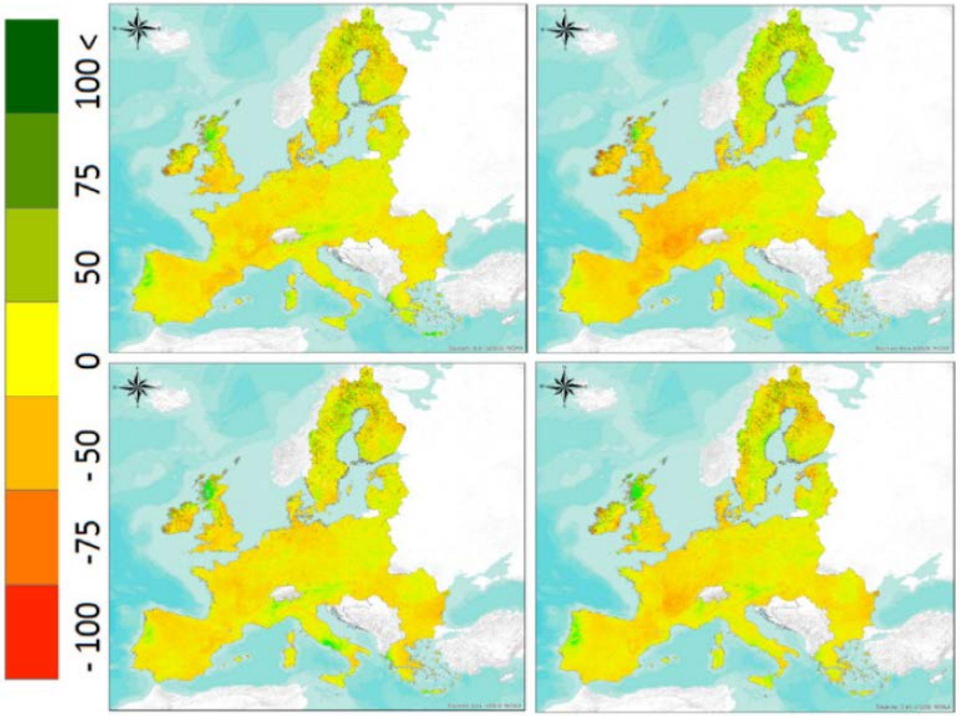
Source: Polce, C., Maes, J., Brander, L., Cescatti, A., Baranzelli, C., Lavalle, C., & Zulian, G. (2016). Global change impacts on ecosystem services: a spatially explicit assessment for Europe. One Ecosystem, 1, e9990.

Service description: Air quality regulation. This model assesses the change of air quality regulation in the EU. It included the contribution of three main elements: vegetation, rainfall and fire.

Tasks:

1. What is the most dominant air quality regulation value in the baseline year in Ireland?
2. What regions will experience the most positive change of air quality regulation until 2050?
3. Which regions would be priority areas for management interventions to mitigate negative change in air quality regulation?

Map 4



Changes in soil organic carbon stocks by 2050 by Climate Scenarios and Representative Concentration Pathways (RCPs). 1st row: MRI-CGCM3 (RCP 2.6, 4.5). 2nd row: MRI-CGCM3 (RCP 6.0 and 8.5). Red areas represent decrease and green areas represent increase in SOC stocks (tonnes·ha–1) compared to present conditions (background map: ESRI, USGS, NOAA)

Map 4

Service description

Soil organic carbon stocks

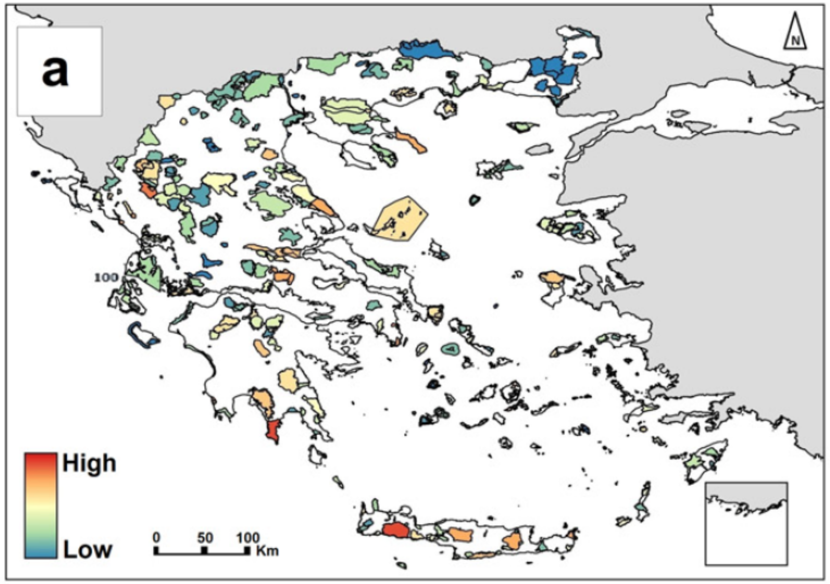
Soil is the largest organic carbon pool of the terrestrial ecosystems on earth. However, C sequestration in terrestrial ecosystems could contribute to the decrease of atmospheric CO_2 rates.

Tasks:

1. What are the changes in soil organic carbon stock of Italy in the bottom left scenario?
2. Where can the highest decrease in organic carbon stocks be observed in the top left scenario?
3. Which is the environmentally most favourable scenario for 2050?

Source: Yigini, Y., & Panagos, P. (2016). Assessment of soil organic carbon stocks under future climate and land cover changes in Europe. Science of The Total Environment, 557–558, 838–850. https://doi.org/10.1016/j.scitotenv.2016.03.085

Map 1



Cultural heritage value: a. gradient map compilation; a1-Archeological sites, a2-Traditional settlements, a3-Myths, a4-Historic & Religious places.

Map 1

Service description: Cultural heritage value

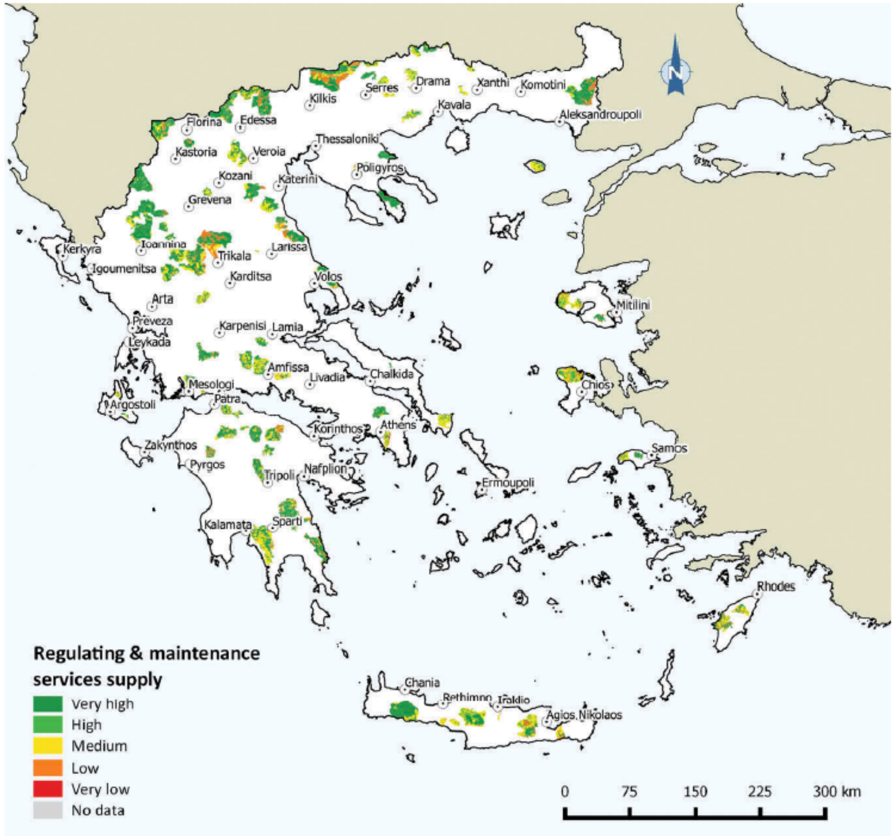
The cultural heritage value is an aggregate from the following indicators: Presence of Archaeological sites, Presence of Traditional settlements, Presence of Historic & Religious places.

Tasks:

4. What is the cultural heritage value of the most north-eastern region?
5. Where are the regions with medium cultural value?
6. Could point out where high and low values of cultural heritage are located within the mainland?

Source: Vlami, V., Kokkoris, I. P., Zogaris, S., Cartalis, C., Kehayias, G., & Dimopoulos, P. (2017). Cultural landscapes and attributes of "culturalness" in protected areas: An exploratory assessment in Greece. Science of the Total Environment. 595. 229–243.

Map 2



Spatial distribution of regulating and maintenance services at 91 mountainous sites (SACs) in Greece. The proximity to major urban centers is also indicated in the map.

Map 2

Service description: Supply of regulating services

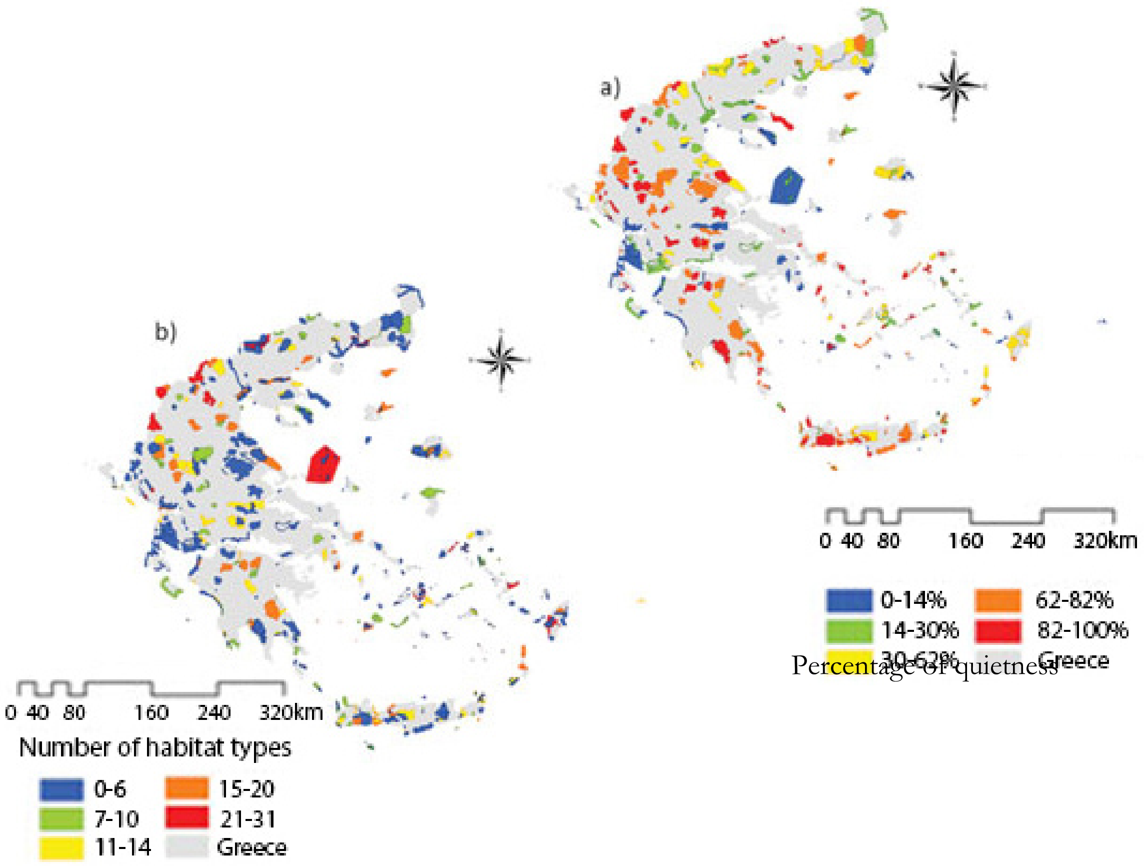
Regulating services are all those ways in which ecosystems and living organisms can mediate the environment to support human well-being.

Tasks:

1. What is the value of regulating services of mountainous protected areas surrounding Ioannina?
2. Where are the regions with the lowest regulating service supply value?
3. Could point out where regions with high and low supply of regulating services are located in Greece?

Source: Kokkoris, I. P., Drakou, E. G., Maes, J., & Dimopoulos, P. (2018). Ecosystem services supply in protected mountains of Greece: setting the baseline for conservation management. International Journal of Biodiversity Science, Ecosystem Services & Management, 14(1), 45–59.

Map 3



Correlation between quietness and diversity in the Greek Natura 2000 network, expressed as a colour scale depicting: (a) the percentage of quiet areas present in protected areas and (b) site diversity, defined as the richness of habitat types.

Map 3

Service description: Quietness (cultural) and diversity

Quietness in protected areas could ensure the preservation of wildlife while the protection of Quiet Areas could contribute to visitors' health and well-being

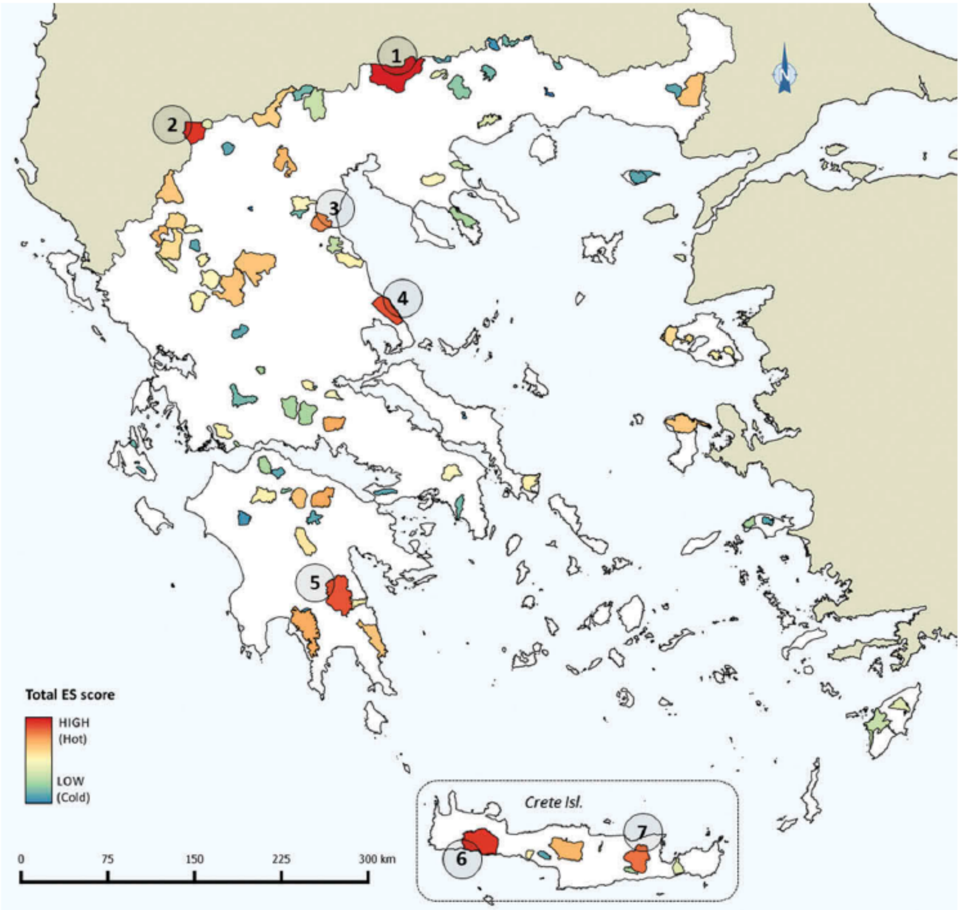
Number of habitat types refers to the 19 conservation priority habitat types

Tasks:

1. Where are regions with the highest number of habitat types?
2. Where are regions that have a low percentage of quiet areas as well as a small number of habitat types?
3. Could you briefly describe the difference of the overall trend of quietness and species diversity?

Source: Votsi, N.-E. P., Kallimanis, A. S., Mazaris, A. D., & Pantis, J. D. (2014). Integrating environmental policies towards a network of protected and quiet areas. Environmental Conservation, 41(04), 321–329.

Map 4



Total scoring of the provided ecosystem services & hot spots at 91 mountainous Natura 2000 sites (SACs) in Greece. The island of Crete (box at the bottom of the map) is identified as an ES hot spot area. Numbers 1 to 7 indicate the sites with top total ES scores (1: Mt Belles & Lake Kerkini, 2: Prespes lakes area, 3: Mt Olympos, 4: Mt Pilio, 5: Mt Parnon, 6: Mt Lefka Ori, 7: Mt Dikti).

Map 1

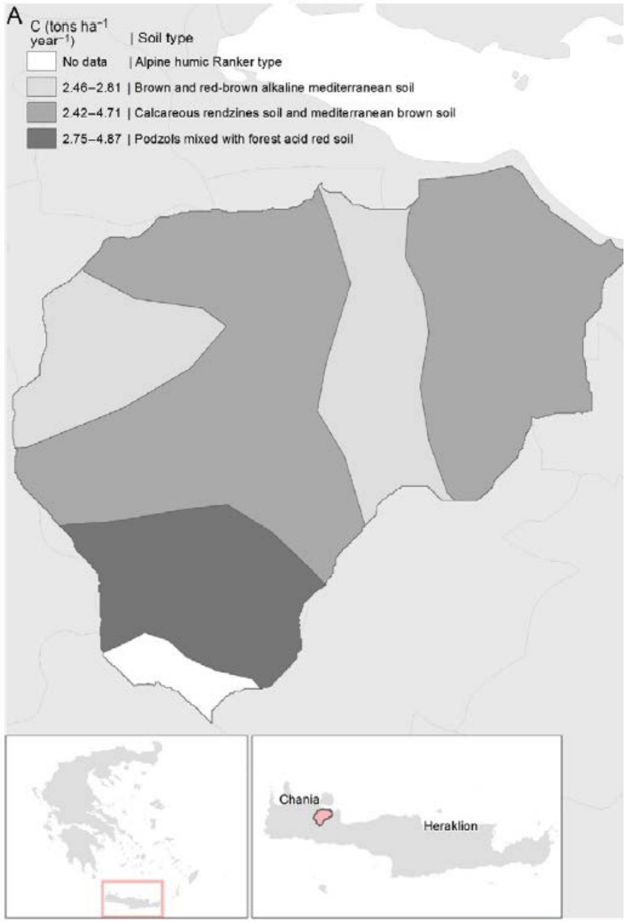
Service description: Total scoring of the provided ecosystem services

Each mountainous region received an ID, which consists of the provided ecosystem service (ES), accompanied by the evaluation of each ES and the total ES score per site at the relevant assessment matrix. Based on the total ES score, a hierarchy of the sites was created. Thus, the ES 'hot-' and 'cold-' spot sites were identified and thematically presented on the total ES supply and hot spot map.

Tasks:

4. What is the total ES score in western Crete?
5. Where is the mountainous sites with the highest ES score?
6. Could you briefly point out where regions with high and low ES scores are?

Map 1



Climate regulation. (A) Carbon outflow in tons ha^{-1} year^{-1}.

Map 1

Service description

Climate regulation by soil type

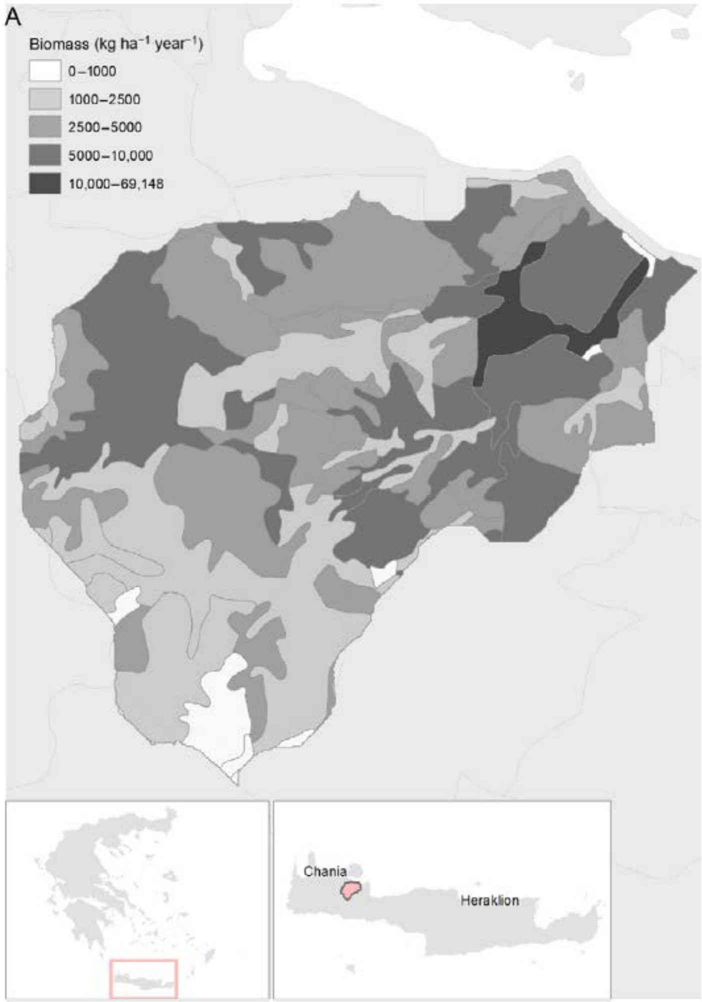
climate regulation of soils, is defined as the role of soils in regulating global temperatures and precipitation through sequestration of C and N compounds and emissions of the related greenhouse gases. Carbon mineralization/carbon outflow can be considered a proxy for CO2 emissions.

Tasks:

7. What is the carbon outflow of the regions near the coast?
8. What is the region with the highest Carbon outflow?
9. Can you briefly describe what the overall carbon outflow distribution in this region is?

Source: Jónsson, J. Ö. G., Davíðsdóttir, B., & Nikolaidis, N. P. (2017). Valuation of Soil Eco-system Services. In Advances in Agronomy (1st ed., Vol. 142, pp. 353–384). Elsevier Inc.

Map 2



Biomass provision from crop and livestock.
(A) Biomass provision in kg ha^{-1} $year^{-1}$.

Map 2

Service description: Biomass production from crop and livestock of different soil types

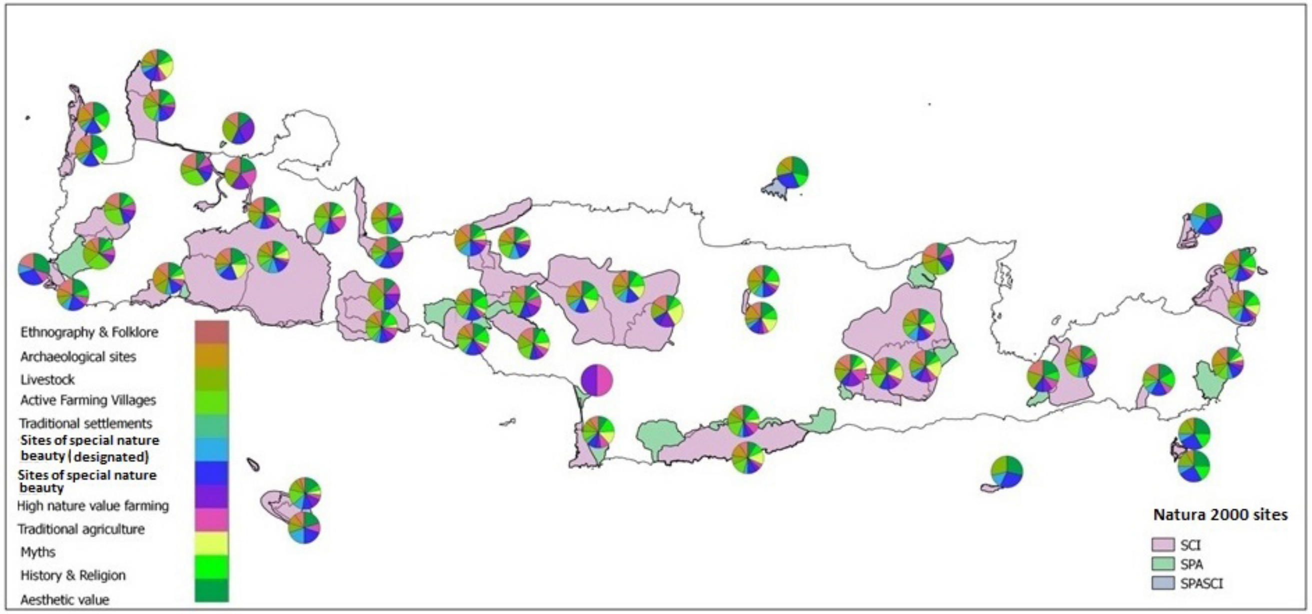
Soils provide nutrients, water, and the physical environment for terrestrial biomass production. Humans use biomass in the form of food, wood, fuel, and fiber

Tasks:

1. What is the biomass production of the most eastern region?
2. Where is the most productive region?
3. Can you briefly describe how biomass provision is distributed in the Chania prefecture?

Source: Jónsson, J. Ö. G., Davíðsdóttir, B., & Nikolaidis, N. P. (2017). Valuation of Soil Ecosystem Services. In Advances in Agronomy (1st ed., Vol. 142, pp. 353–384). Elsevier Inc.

Map 3



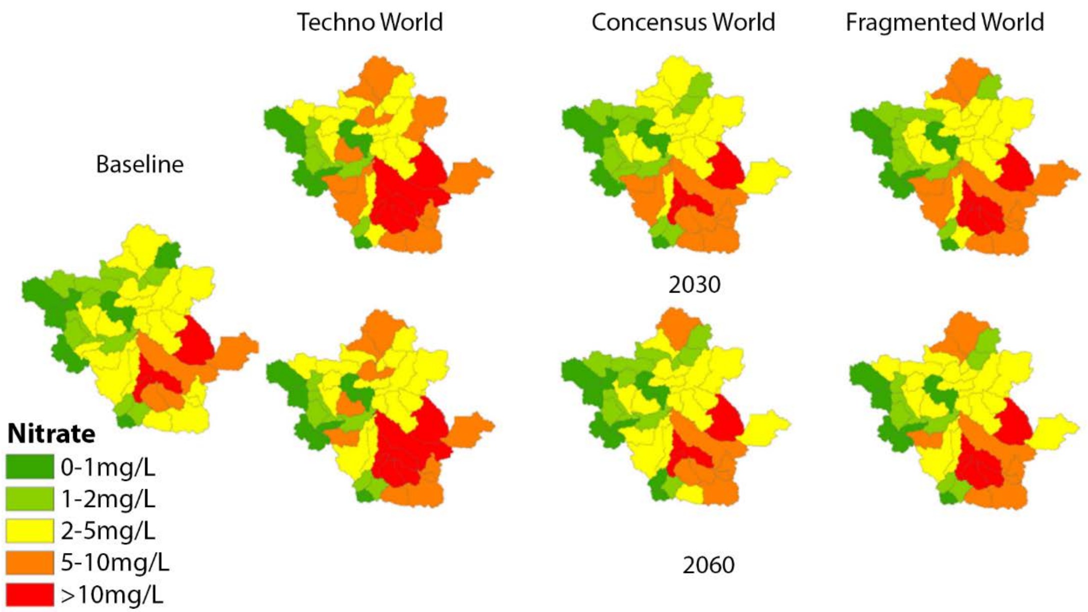
Mapping of cultural service indicators in Crete

Service description: Overview of cultural services
Cultural services are non-material outputs of the ecosystem which positively contribute to people, such as recreation or aesthetic value. Examples would be opportunities for diving or walking paths.
Tasks:

1. Where are special protection areas?
2. Which cultural indicators are present in the most northern Natura 2000 site?
3. Can you briefly describe which regions have a high and low percentage of the map attribute “Myths”?

Source: Dimopoulos, P., Vlami, V., & Kokkoris, I. P. (2016). Inventory, Delineation and Assessment of Cultural Landscapes in the Natura 2000 ecological network [in Greek], 157 pp.

Map 4



Average nitrate concentration in water for the baseline period (1995–2005) and the three future scenarios (2030 and 2060) in the Pinios basin

Service description: Water quality

One service which ecosystems provide is the improvement of the water quality. The water quality can be determined by the amount of nitrate in it. Lower nitrate concentration is an indicator for higher water quality.

Tasks:

1. What is the Nitrate concentration of most western region in the base line period?
2. What is the trend of the Nitrate concentration under the "Techno World" scenario?
3. Which is the environmentally most favourable scenario for 2060?

Source: Stefanidis, K., Panagopoulos, Y., & Mimikou, M. (2018). Response of a multi-stressed Mediterranean river to future climate and socio-economic scenarios. Science of The Total Environment, 627, 756–769.

APPENDIX 8: SAMPLE VERBAL PROTOCOL

Map 1
Task 1 #00:24:07-1#
No, I think. Ok, if I understand the map the first question what is the carbon of the region near the coast. The region near the coast has in intermediate carbon from 242 to 200. 2.42 to 4.71. #00:24:41-1#

Task 2
Second question is what's the region with the highest carbonate use the southest region. #00:24:49-8#

Task 3
And the third question: Can you briefly describe what the overall carbonate use distribution in this region is. The overall means the mean? #00:25:01-3#

I: Or like a pattern. #00:25:02-0#

TP14: But an rough estimation the pattern we can say that the overall carbonate use intermediates the second category from 2.42 to 4.51. #00:25:29-3#

Map 2
Task 2 #00:25:55-1#
Yes. The most eastern region generally is the most productive, is the second question. #00:26:02-4#

Task 1
And regarding the first question the production is relatively high in this region ranges from let's say from 5000 to 69000. I mean in the two, the majority of the areas is in two highest categories. #00:26:33-7#

Task 3 #00:26:37-7#
And then generally for the third question the production is rate is in the whole prefecture in the wide ranges from the lowest category very few kilos per hectare per year to very productive areas. And generally, the most productive areas are in the eastern part of Chania, while the less productive is in the southest part of Chania Ok. #00:27:32-0#

Map 3
Task 1 #00:28:25-3#
TP14: Yes. Special protected areas are those with the light green colour. And they are in various parts of Crete. I don't know if you need some more specific answer….Because I can see it in the map as a SPAs special protection areas. Yes. So they have been coloured in light green so that's why, how I identify it. #00:29:19-1#

Task 2 #00:29:21-3#
TP14: The most northern. The most northern natura site is in the north-western part of Crete. And there is a variety of a cultural services there, including historian religion sites of natural, especial natural beauty, traditional agricultural areas, archaeological areas and others too. #00:30:15-3#

Task 3 #00:30:21-5#
And the third question is? I think that myths are related to Folklore and Ethnography, this means that the red colour. But I can't identify correctly the colours. I think that the most eastern part of Crete has the

lowest percentage of myths. While. Probably central and western part of Crete has highest percentage. Ok. #00:32:15-0#

Map 4
Task 1 #00:33:09-8#
Ok. The first question was the nitrate concentration of most western the region in the baseline? I can see that it is green. So the nitrate concentration there is very limited. #00:33:26-1#

Task 2 #00:33:26-3#
The second question. Under the techno world scenario generally the nitrate concentration remains stable. At both years after the base line ... the 30 and the 60 very limited changes, I can see limited changes. #00:33:59-4#

Task 3 #00:33:59-4#
And ok and the third question: in the 2060s the most environmental friendly scenario I think it is the consensus world, I think it is a consensus world scenario…Because under this scenario generally less changes in nitrate concentrations can be identified in 2060s. And also when comparing the three of the scenarios in the 60s, you can see that most of the areas are having limited nitrate concentration under 2 milligrams per litre #00:35:18-8#