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ECOLOGIES OF COHESION

An ecological perspective on territorial cohesion through the lens of landscapes as social ecological systems

PhD Student

Matteo Giacomelli

Supervisor

Massimo Sargolini

Co-supervisor

Maria Felipe-Lucia

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Summary

Urbanization together with growing human activities is leading to increasing marginalization and regional inequalities. While cities are mostly associated with economic success and power, the inland areas – defined as territories remote from the delivering of services such as health, education, and mobility – are undergoing a process of socio-economic decline. Nevertheless, inland areas are crucial in the delivery of goods and services to society. The multiple ways society benefits from ecosystems is captured by the definition of "Ecosystem Services" (ES), and its integration into regional planning can help researchers and policy-makers to identify trade-offs between ecological and socioeconomic aspects. On that account, this dissertation investigates regional interdependencies through the lens of ES, proposing an ecological perspective on territorial cohesion.

The analysis builds on the concept of landscapes – conceived as the result of the interplay between human and nature through the perception of people – framed in this work as social-ecological systems. The spatial relations within systems are assessed through the concept of ES bundles and developing it in the direction of the supply-demand perspective. Yet, as benefits from nature do not occur independently but often require significant human contributions, the role of social systems is further analyzed though ES co-production.

Within this theoretical framework, the thesis develops three main investigations: i) the critical examination of the applications of the ES framework in planning through a literature review; ii) the characterization of landscapes as social-ecological systems through ES bundles, offering insights for landscape planning and territorial cohesion; iii) the development of a framework to assess the role of social actors within landscapes though the analysis of ES co-production. The empirical work is applied to a regional and a local case study within the Mediterranean region of Le Marche, Italy.

The results of this dissertation prove "ES in planning" to be a promising research area, both for its conceptual and methodological applications. The spatial analysis developed a functional landscape characterization in terms of bundles of ES demand and supply, further characterized though social-economic assets. This allowed the interpretation of the regional landscapes systems along a coastal-mountain gradient drawn by the raising of altitude and decreasing of population density. The analysis of interdependencies highlighted a strong dependency of urban poles on inland systems, concerning nearly the total 12 ES taken into consideration. Results from social analysis showed that rural actors associate great cultural values to local landscapes. The ES were co-produced both physically by actions on the state of ecosystems, and cognitively through users' values.

In relation to the global pressures faced by inland ecosystems, the thesis offers a set of recommendations for sustainable landscape planning, concerning the preservation of the identity of inland systems through the enhancement of local ecosystems management. While incorporating the central role of people in landscape assessment, governance should foster collaboration and social learning, integrating innovative tools for ensuring participation. Overall, the thesis produces a new environmental-based argument toward territorial cohesion where place-based policies should build on local territorial assets, recognizing the central role of inland areas in the provision of ES.

Glossary

Territory: Region or geographical area that includes the social and physical (i.e., morphological, geological, ecological) dimension of the environment. It is the space where communities establish relationships with the land, in clashing and in sharing, driven by cultural, economic, and social trends. *Territorial planning* aims at the governance of both socio-economic processes and the physical environment in which they are located. (Magnaghi, 2010)

Territorial cohesion: Promoting balanced and harmonious territorial development between and within countries, regions, and municipalities, as well as ensuring a future for all people, building on the diversity of places and subsidiarity. It enables more equal opportunities, including access to public services for individuals and enterprises, wherever they are located. Territorial cohesion reduces inequalities between disadvantaged places and those with less prosperous prospects and helps all places to perform as well as possible using their own assets through place-based strategies. (European Union, 2007)

Inland area: Territories characterized by a significant distance from the main centers offering essential services (health, education, mobility), as well as by a high availability of important environmental resources (e.g., water resources, agricultural systems, forests) and cultural resources (e.g., archaeological heritage, historical settlements). (Barca et al., 2014)

Landscape: the result of a continuous interaction between nature and humans, which have transformed the territory creating specific regional patterns associated with local historical and cultural backgrounds. The European Landscape Convention (2000) defines it as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors”. The definition includes both the physical object and its interpretation by human communities. *Landscape planning* aims at strong forward-looking action to enhance, restore or create landscapes. (Sereni, 1961; Gambino, 1996; Council of Europe, 2000; Sargolini, 2013)

Landscape as social-ecological system: anthropic and natural features in a landscape are coupled to the point that they should be conceived as one social-ecological system. Those systems are complex and adaptive, as they are composed of interdependent and interacting entities: social systems adapt to changes in their environment and, as a result, the environment adapts to their changes. (Berkes and Folke, 1992)

Cultural heritage and natural capitals: Defined by Unesco as “both a product and a process, which provides societies with a wealth of resources that are inherited from the past, created in the present and bestowed for the benefit of future generations”, cultural heritage is in this dissertation conceived for its natural capitals, i.e., the stock of natural resources, which includes geology, soils, air, water and all living organisms that combine to provide benefits to people. These capitals are framed recognizing the central and pervasive role that culture plays in defining all links between people and nature. (Calafati, 2015; Díaz et al., 2018)

Ecosystem Services (ES): Benefits society derives from ecosystems, classified as provisioning, i.e., food, water, timber, etc.; regulating, i.e., climate, floods, disease, waste; and cultural, i.e., recreational, experiential, aesthetic, or spiritual benefits; supporting, i.e., including soil formation, nutrient cycling, or photosynthesis. *ES supply* represents the capacity of ecosystems to provide specific goods and services, while the *ES demand* refers to the amount of service desired by a society. *ES Bundles* are a set of positively correlated ES (demand or supply) across space and time. (Villamagna et al., 2013; Raudsepp-Hearne et al., 2010)

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Chapter 1: Introduction and research objectives

1.1 Background and motivation

The exponential growth of human activities has caused an increasing demand for natural resources, raising concern for the consequences on natural ecosystems. Soil degradation, destruction of forest vegetation, and the decrease of natural habitats are triggering environmental changes that would have catastrophic effects for biodiversity and the life of species on planet earth (Sala et al., 2000). The extraction of biomass, fossil fuels and minerals from the soil has increased over the last decades by 80%, urban areas have doubled since 1992, and agriculture has significantly shifted toward intensive management all over the world (IPBES, 2019). The human impact on the Earth's climate, land, oceans and biosphere is now so relevant that the birth of a new geological epoch is debated under the name of Anthropocene (Zalasiewicz et al., 2011). Yet, the impact of human action is not equally distributed over space. Despite the relatively small surface they cover, cities have a massive environmental impact well beyond their borders. To fulfill their needs, urban areas are linked to surrounding territories in the extraction and consumption of natural resources through a real "ecosystem appropriation" (Folke et al., 1997).

Beyond the urban fabric, territories are experiencing an unprecedented demographic and economic decline. Excluded by the urban concentration of capitals, rural areas are undergoing a process of the loss of economic opportunities and the availability of essential services, making living in these territories increasingly difficult (ESPON, 2021). Nevertheless, urban development hardly exists in the absence of a linkage with rural areas (Gebre and Gebremedhin, 2019). For centuries, the agricultural landscapes have provided cities with food, energy, and fresh water. Mountain landscapes covered by woodland support the regulation of water flows, capture air pollutants from the atmosphere and prevent soil erosion. The awareness of this dependency was further amplified during the COVID-19 sanitary crisis, when the rural open spaces ensured recreational opportunities to the urban population constrained in the cities and forced to measures of social distancing (Beckmann-Wübbelt et al., 2021; Derks et al., 2020). The rural area supplies are often considered free gifts of the environment with little human efforts. Yet, the provision of services and benefits from ecosystems require management practices and care to sustain their current and future use (Felipe-Lucia et al., 2020).

To support an equitable prospect for rural areas, several initiatives are underway in Europe aimed at minimizing spatial disparities among regions and avoiding polarization between cities and surrounding territories. The long term vision for European rural areas 2040 is currently animating a debate in the direction of stronger, more connected, resilient and prosperous rural areas (European Commission, 2021). This and the other actions directed towards reducing the disparities among regions are based on the concept of Territorial cohesion, launched in the Green Paper on Territorial Cohesion (EC, 2008), and included in the Lisbon Treaty (2009) as one of the three main pillars of the EU (European Union) Cohesion Policy.

In this frame, the Italian Strategy for Inland Areas (SNAI) represents a major national application of territorial cohesion in Europe (Lucatelli et al., 2022) and aims at reversing the depopulation trend in the "inland areas" of the country. Defined as distant from the delivery of services as health, education and transportation, the concept of inland areas aims at overcoming the urban-rural dichotomy, rejecting any dimension of town recognized by theory, and following a polycentric reading of the territory (Lucatelli et al., 2019). Since it was launched in 2013, the SNAI has held the merit of placing marginal areas at the center of the Italian public debate, putting the focus on their possible future through the use and regeneration of their ancient cultural and natural heritage (Barca, 2022). At a society level, a growing number of grassroots projects are building on this available heritage experimenting with new models of society (Collettivo PRiNT, 2022; Giacomelli and Calcagni, 2022; Osti, 2006). Despite that, inland areas are still described in terms of underdevelopment and marginality. In the context of regional development, planning and governance face the challenge of integrating the ecological value of inland areas in the territorial assessments in order to guarantee a sustainable landscape development (Albert et al., 2014; Bennett et al., 2015).

Aware that the future of inland areas lies in the interplay between human and nature, the motivation of this dissertation relates to the application of the social-ecological framework to the analysis of regional landscapes, to support the "inland areas" discourse with scientific and objective assessments. Through a multidisciplinary perspective, I aim to bridge the gap between cohesion strategies and ecological studies, integrating the role of environmental assets in territorial analysis. To date, a growing number of researchers are approaching the complexity of social-ecological interaction to support sustainable landscape planning to cope with current and global challenges (de Vos et al., 2019; Fischer et al., 2015). Yet, our understanding of how – and to which extent – human patterns influence and are affected by landscapes characteristics remains unclear.

1.2 Research Objectives and structure of the dissertation

Within the motivation described above, the dissertation aims at integrating the social-ecological systems perspective in the territorial analysis, exploring regional landscapes as the result of complex interaction between social and natural components. Links within and between systems are investigated though the concept of Ecosystem Service (ES), defined as the benefits society derives from ecosystems. This functional definition allows the visualization of multisectoral relationships between society and nature enabling their integration in planning and regional governance. The dissertation aims therefore to provide territorial policymakers with a rigorous assessment tool, while advancing the research on the application of the ES concept in landscape planning. This is achieved through specific objectives:

1. Identification of the fields of application of the ES concept in landscape planning, considering the different disciplines at play, and an investigation on how the ES concept can support a multidisciplinary vision of the landscape, particularly considering its social and ecological aspects.
2. Development and testing of an approach to map landscape as social-ecological systems though the application of the ES framework in a Mediterranean regional case study, highlighting spatial interdependencies between local systems and deriving recommendation for sustainable landscape planning and territorial cohesion policies.
3. Development of a framework for the analysis of the role of social actors within social-ecological systems through the concept of ES co-production, integrating the social perspective on ES as well as stakeholders' dependency and benefits, and deriving implications for landscape planning on stakeholders' relationships and access to decision making

The three research objectives are functional and integrated to grasp the complexity of landscapes as social-ecological systems and serve the macro objective of including an ecological perspective in territorial cohesion policies. Figure 1 offers a graphic scheme of the thesis articulation, where the research objectives drive the development of the dissertation along the respective chapters. Namely, after outlining the background and motivation, **Chapter I** describes the theoretical framework related to the concept of landscape, introduces the ES-related concepts utilized in the dissertation, and presents the current debate on cohesion strategies and territorial inequalities. It further includes an explanation of the methods applied within the following research chapters and the description of the case studies. **Chapter II** presents the literature review developed on the topic of the integration of ES in landscape planning. Near the quantitative analysis of published papers, the chapter includes the assessment of co-citation networks to investigate the temporal development of research trends. This is a crucial step for early-stage research, in order to correctly design the following work. Introducing the core part of the dissertation, **Chapter III** illustrates the spatial analysis of ES supply and demand on the regional case study of Le Marche. After explaining the mapping and socio-economic characterization methodology, the study develops in two parallel paths, on the one side testing ES bundles for the visualization of social-ecological systems, on the other applying ES budgeting to highlight interdependencies along the inland-urban gradient. The chapter provides suggestions for sustainable landscape development and territorial cohesion with a social-ecological perspective. The perspective of social actors is further explored in **Chapter IV**, introducing an analytical framework of landscapes as social-ecological systems based on the concept of ES co-production. By means of questionnaires and focus groups, local stakeholders in the Fiastra Valley case study are asked on preferences for local ES and their anthropic contribution in ES co-production. Through the analysis of these data, the chapter investigates on stakeholders' dependency, benefits and access to decision making, and their collaboration across scales. Implications on stakeholders' relations and for sustainable management practices are developed especially regarding the role of local actors in landscape transformation, collaborative planning, and access to decision-making. **Chapter V** summarizes the main points of the dissertation, referring to the research objectives and highlighting key findings for landscape planning as well as the development of cohesion strategies. Finally, supplementary material is included as for appendixes Appendix 3.A – Individual Ecosystem Services, Appendix 3.B – Individual socio-economic indicators, Appendix 3.C – R code chapter 3, Appendix 4.A – Focus group materials, Appendix 4.B – Characterization of questionnaire respondents, Appendix 4.C – Statistical Analysis, Appendix 4.D – R code chapter 4.

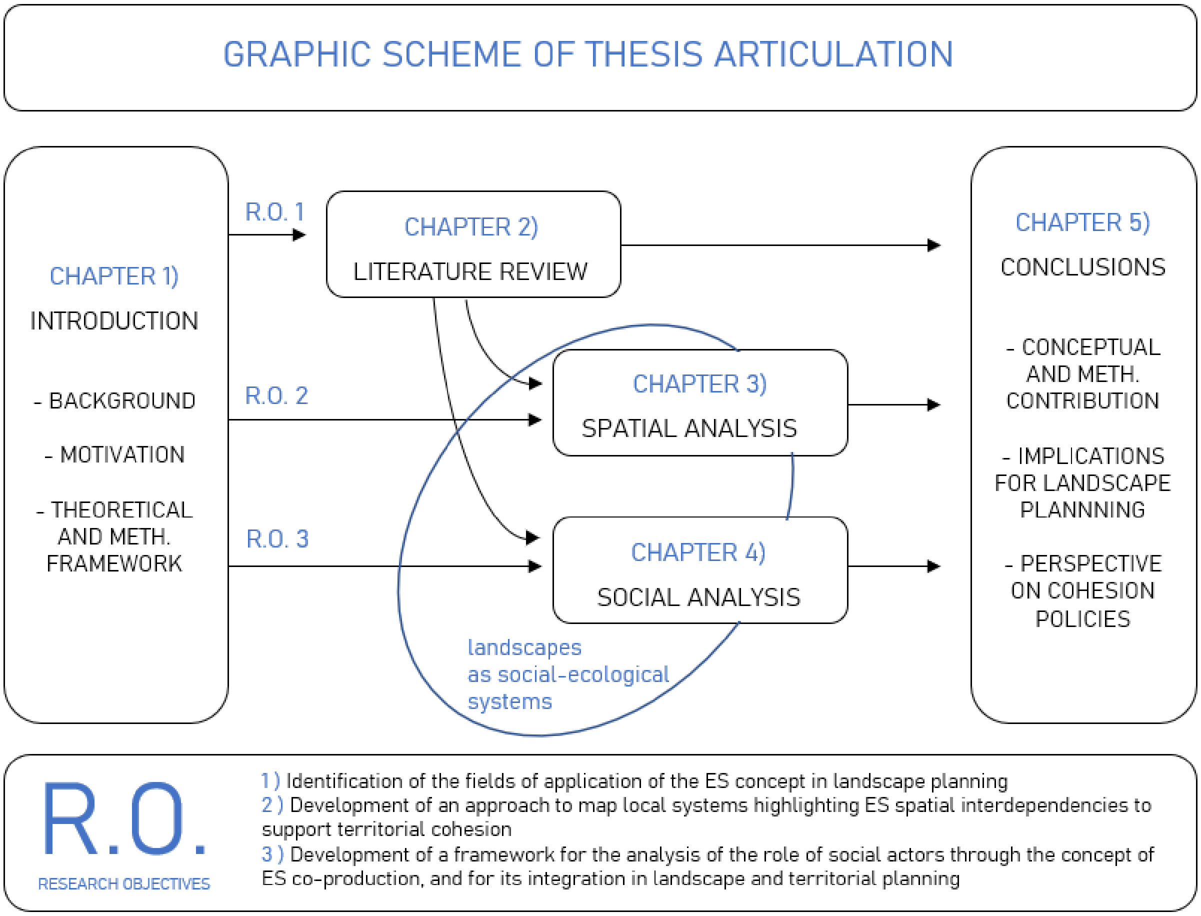

Figure 1: Graphic scheme of thesis articulation. The three research objectives drive the development of the dissertation along the respective chapters and serve to the macro-objective of including an ecological perspective in territorial cohesion policies.

The dissertation contains unpublished research conceived, designed, and developed under my personal lead, without the use of AI or machine learning. My supervisor Massimo Sargolini followed the work through overall confrontations on the topic of research. My co-supervisor Maria Felipe Lucia supported and provided expertise in the methodology definition of Chapter III and Chapter IV as well as the review of the outcomes and discussions. Together with Chapter II, those sections follow the structure of research papers as they are planned to be published as single studies after the submission of the manuscript. For this reason, their content might present a degree of overlapping information concerning the introductions and the case study descriptions within the methodology.

1.3 Theoretical framework

1.3.1 The concept of landscape: from aesthetic conceptions to social-ecological systems

Landscapes are the result of continuous interaction between nature and humans, which has transformed the territory creating distinct regional patterns associated with local historical and cultural contexts. Landscape is the making of a society in a given territory (Sereni, 1961) and by definition brings back the ambiguity between "real country" and its representation. The planning practice experiences the dualism between the objectifying attempts of earth sciences and regressions to the aestheticizing conception of impressionistic and a-scientific subjectivism (Gambino, 1996). The holistic approach necessary for analysis thus suffers from the unresolved tension between the objectivity of ecological reality and the subjectivity linked to the reworkings of the local actors who inhabit and thus modify the landscape.

The term Landscape Ecology was introduced by German bio-geographer Carl Troll in 1939 and originated from the convergence of the spatial approach of the geographer with the functional method of the ecologist (Forman and Godron, 1986). Landscape ecology emphasizes the interaction between the ecological patterns of a process, focusing on the causes and consequences of spatial heterogeneity across different scales. The heterogeneity is approached within and between scales, focusing on how it influences the management of natural and human-dominated landscapes (Turner & Gadner, 2015). Landscape is thus seen as a mosaic of interacting ecosystems, where the landscape ecologist aims to understand their structures, processes, and meanings for society.

The European Landscape Convention (Council of Europe, 2000) attempts to resolve the ambiguity between the objectivity of ecological reality and the subjectivity of perception, proposing a definition that integrates these two components:

> *"Landscape" means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors*

In this way, the convention recognizes the complexity of landscapes, incorporating the central role of people and communities in planning and governance (Sargolini, 2013). The convention brings along new approaches to landscape assessment, and a new idea of environmental quality, based on the systemic view that embraces all of the components into which it can be divided. A major challenge of planning is to apply this complexity in the analysis, combining objective and quantifiable assessments with more subjective ones, capturing the complexity of the landscape and going beyond the limits of sectoral planning (Sargolini and Gambino, 2016). This need is made even more urgent today, when strong global pressures are appearing in regional landscapes, threatening the balance of ecosystems (IPBES, 2019).

The interlinked dynamics of environmental and societal change can be addressed and understood through the concept of social-ecological systems. Fischer et al. (2015) underline the capacity of this framework to support the recognition of the human dependence on ecosystems, improving collaboration across disciplines and between science and society. Despite the growing application in the context of landscape planning, critical open challenges are related to the understanding of social–ecological interactions between regions and the interactions among power relations and access rights, leading to open questions in the field of environmental justice (Felipe-Lucia et al., 2015; Fischer et al., 2015).

This dissertation adopts the lens of landscapes as an ideal frame for reading the interaction between ecological and social systems. Figure 2 shows how anthropogenic and natural contribution co-produce landscape, and how its perception by the population can shape the process of planning and management of the landscape itself. This circle of interactions is read in this thesis through the concept of ES, that allows to structure and visualize the benefits people derive from ecosystems (the issue is explored in more detail in the next chapter). The literature further stresses how the landscape unit is the most suitable for the assessment of impacts and variation in environmental quality and it is furthermore appropriate to land use decisions concerning biodiversity conservation and ES (Nogué and Sala, 2018; Tallis et al., 2015). In this sense, together with the main goal of territorial cohesion, the research aims at supporting landscape planning toward the improvement of environmental conditions and therefore people’s health and quality of life, integrating the perception and role of social systems in maintaining habitat quality and enhancing biodiversity.

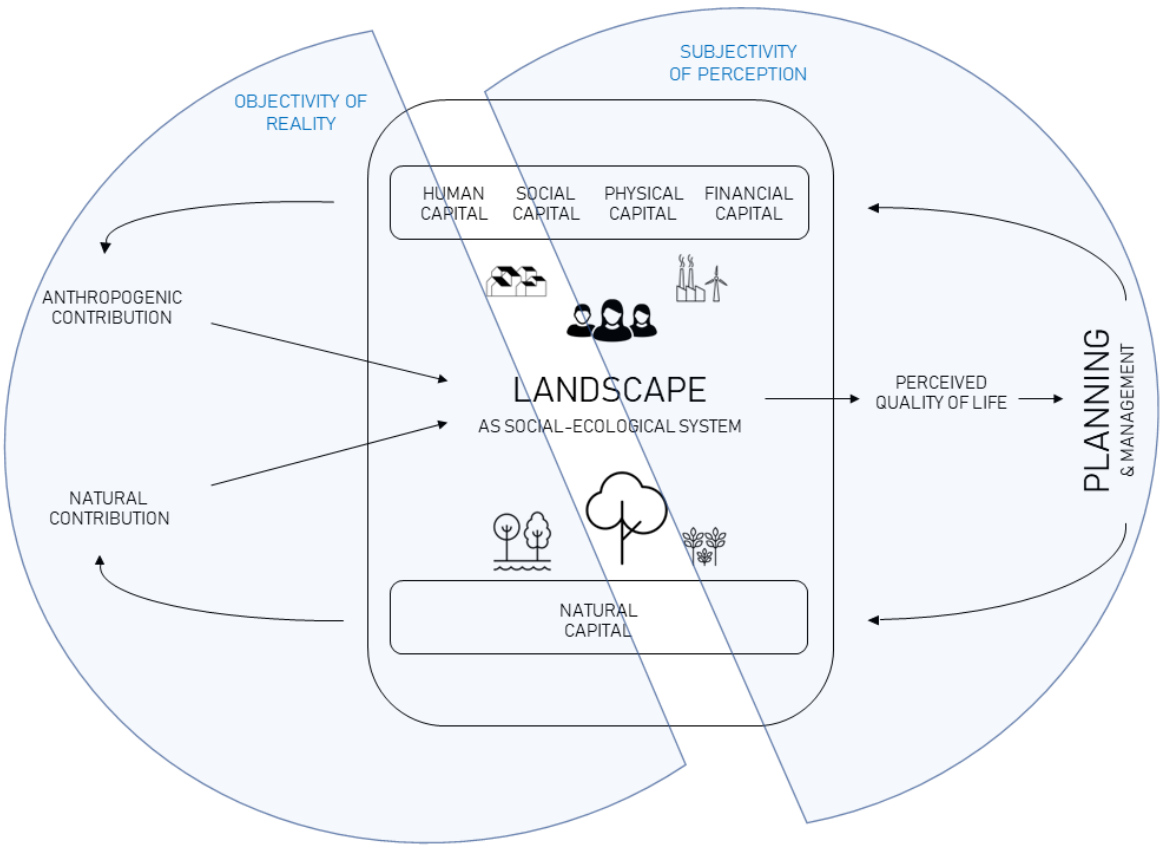

Figure 2: The framing of landscapes as social-ecological systems used in this dissertation.

The structure and flow of this dissertation in based on the dualism of the landscape concept. After the literature review (Chapter 2), providing the instruments for designing the methodology of the analysis, the two following chapters aim to address the dual characteristic of landscape. Chapter 3 reads the socio-ecological elements with biophysical indicators to grasp the 'objectivity of reality', while Chapter 4 applies social science methods to capture the 'subjectivity of perception'. Through a unified and integrative reworking of the components (Chapter 5), the thesis aims to offer an integrated approach for landscape assessment.

1.3.2 Framing the environment through Ecosystem Services

The history of our planet can be analyzed in terms of a series of smaller periods of time, referred to as geological eras. Although it has faced periods of significant environmental change, the planet has experienced a period of stability — known to geologists as the Holocene — where humankind lived in harmony with the rest of nature on earth. During the Holocene, the interaction between human and natural activity have coexisted in regional patterns. The regularity of temperatures, the availability of freshwater and biogeochemical flows enabled human civilizations to emerge, develop and thrive in balance with the environmental assets (Zalasiewicz et al., 2011).

Such stability is now under threat. Since the Industrial Revolution, human actions have become the main driver of global environmental change. In the so-called Anthropocene, human activities push the Earth outside the environmental stability and planetary boundaries, with catastrophic consequences for the whole globe (Rockström et al., 2009). The capitalist development system requires food, energy, and raw materials for allowing the exponential growth we are experiencing, and this is happening increasingly at the expense of the rest of nature (Haraway, 2015). The biosphere, upon which humanity depends, is being altered to an unprecedented degree across all spatial scales. Defined as diversity within species and ecosystems, biodiversity is today declining faster than at any time and human action is proved to threaten more species with global extinction now than ever before (IPBES, 2019).

Aware of the human impact on the life on earth, scientists and decision-makers debate over instrumental or intrinsic value approaches to this "environmental issue" (Lele et al., 2018). Within the landscape and territorial planning, the intrinsic approach has been translated and applied through the establishment of protected areas and ecosystem conservation strategies. It has led to the success of policies to protect species habitats in relation to the spatial changes taking place outside them (Chape et al., 2005). Since the creation of Yellowstone National Park in 1872, the extent of protected areas has grown exponentially over the years, and it is still today one of the major environmental measures in terms of biodiversity conservation (see for example the EU Biodiversity Strategy target of 30% of land in Europe under legal protection by 2030). Nevertheless, while the state of ecosystems has been maintained in parks and protected areas, beyond the fences we assisted to an unprecedented loss of natural surface area.

Overcoming the perception of nature to be preserved with respect to a generically defined "wild" (Cumming and Allen, 2017), this research recognizes the human presence on earth and seeks to analyze the reasons for ongoing injustices and exploitation of nature – in the spatial and social dimension – in order to explore possible ways out. The social-ecological system approach combines the human action on the planet together with the essential role of ecological elements for societal wellbeing (Binder et al., 2013). In this framework, the *Ecosystem Services* lens allows the visualization of how society profits from ecosystems, integrating biophysical, social, and cultural aspects in one assessment. Avoiding the risk of endorsing the reproduction of market logics to environmental goods and services (Gómez-Baggethun et al., 2010), this thesis escapes from monetary evaluations, while keeping the instrumental power of the ES definition to bridge environmental sciences to an intrinsic anthropocentric discipline such as planning and governance. This utilitarian perspective also challenges conventional wisdoms, including the belief that conservation in planning is based on ethics rather than the benefits society derives from ecosystems (Haines-Young and Potschin-Young, 2010). Although the definition of *Nature's Contributions to People (NCP)* might be more suitable for its focus on cultural values and local knowledge (Díaz et al., 2018), the research builds on concepts and frameworks applied within ES research and thus integrates this framework and terminology throughout the dissertation.

The Millennium Ecosystem Assessment (MEA) represents the first attempt to systematize and categorize the benefits society derives from ecosystems – i.e., Ecosystem Services – by grouping them into distinct classes: provisioning, i.e., food, water, timber, etc.; regulating, i.e., climate, floods, disease, waste; and cultural, i.e., recreational, experiential, aesthetic, or spiritual benefits. The supporting class, including soil formation, nutrient cycling or photosynthesis, is classified as basic services, and is required to sustain and maintain all the others (MEA, 2005). Over the years, the concept has attracted increasing interest and met different territorial disciplines, offering a bridge between science and policy (R.S. de Groot et al., 2010). An important operationalization of the concept relies on the cascade model, proposed by Haines-Young and Potschin-Young (2010), which highlights the steps of the flow of contributions from ecosystems to human well-being. The model was further revised through the role of governance in limiting pressures as well as integrating the multiple values ecosystems contribute to human well-being (R. S. de Groot et al., 2010; Martín-López et al., 2014). Figure 3 presents the framework of the dissertation, discerning the supply- from the demand- sides. The ES supply represents the capacity of ecosystems to provide specific goods and services, while the demand refers to the amount of service desired by a society (Villamagna et al., 2013a). The calculation of budgets between ES supply and demand allows the exploration of mismatches and gaps between different areas (Burkhard et al., 2012). As demand is often not dependent from actual supply within a local system but rather from a larger spatial extent, spatial analyses can help visualizing mismatches among local systems.

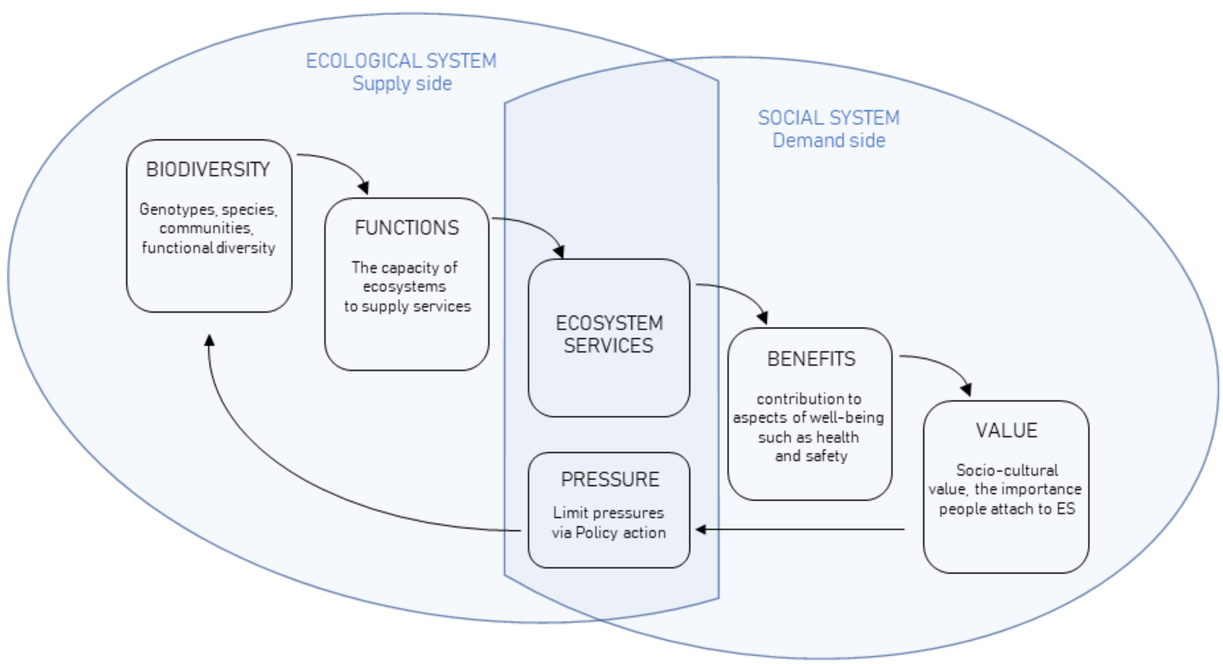

Figure 3: ES cascade model in the social-ecological system. Adapted from Haines-Young and Potschin-Young, (2010)

In order to identify and characterize local social-ecological systems, this dissertation builds on the concept of ES Bundles, defined as set of positively correlated ES across space and time (Saidi and Spray, 2018). This tool is particularly useful for identifying areas of a landscape where ecosystem management has produced exceptional sets of ES and link them to distinct regional socio-economic characteristics (Raudsepp-Hearne et al., 2010). Within Bundles, ES can be positively associated, therefore presenting synergies, or negatively related, representing the case of trade-offs. Trade-offs occur when the provision of one ES is increased at the expenses of another ES. In some cases, this is an explicit choice, but in many others, trade-offs occur without awareness of their taking place. As the role of social actors can shape access to ES and determine which individuals or groups benefit from ecosystems (Felipe-Lucia et al., 2015), the dissertation complements the spatial analysis with a social assessment framed within the concept of ES co-production. This concept stresses how benefits from nature to people do not occur independently but in most of the cases require a significant human contribution. Co-production of ES include several anthropogenic components relating to natural systems, such as motivation or education (human capitals), values and norms (social capitals), machinery and infrastructure (physical capital) and credits or direct payments (financial capitals) (Palomo et al., 2016). Following this rationale, the research includes co-production through the analysis of direct management of service flow (e.g., agricultural activity, forest management) or as users, benefiting and valuing a service (e.g., the preference for a product or a tourist destination, or the ecosystem function toward an environmental risk).

1.3.3 Territorial inequalities and cohesion policies

For the last century until today the world has witnessed a major movement of population towards urban settlements. In the early 1900s the share of population living in cities was less than 13%, in 1950 this proportion reached almost 30% and in 2009 it surpassed the 50% of the total population (United Nations, 2016). This mass exodus from rural territories is expected to continue till 2050 when nearly 70% of the world's population will live in cities. The trend is consistent with shrinking rural regions across Europe, particularly strong in Northern and Mediterranean countries (ESPON, 2021). Driven by industrialization and modernization of societies, the concentration of capital and innovation in cities has pushed people to move to urban areas to seek better economic opportunities and thus a higher quality of life.

However, the urbanization process did not happen at no cost. Besides leading to the discussed unprecedented environmental impacts, the rise of urban settlements carried with it a process of marginalization of the rest of the territory, which have suffered strong social and economic impacts (Sørensen, 2014). The new urban centralization has led to exclusion from innovation processes and labor markets and areas that shaped cultural and social identity in the past are now politically underrepresented and culturally marginalized (Pittau et al., 2010). Quoting the words of the World Bank (WB, 2009), “the concentration of the economic activity is inevitable and usually desiderable for economic growth, but the resulted spatial disparities in welfare are not”. Indeed, such trends are widely believed to be a result of political interest and market forces, privileging the highly productive metropolitan areas to the rest of the territory (Medeiros, 2016). This sense of abandonment, together with a self-perception as “losers” of the global system, tends to a complex social phenomenon that Stenner (2010) defines as "authoritarian dynamic". Intolerance of diversity, desire for closed communities, demand for strong powers as well as distrust of institutions are some of the social consequences of this tendency.

The issue of promoting a more balanced, sustainable territorial development is addressed in Europe through the concept of *Territorial cohesion*, defined by the Lisbon Treaty as the “aim of reducing disparities between the various regions and the backwardness of the least-favoured regions” (European Union, 2007). Integrating and complementing the two pillars of economic and social cohesion (competence of the European Community since the Single European Act, 1986) territorial cohesion brings a new spatial dimension to the debate on the European social model (Faludi, 2007). It is often associated with the environmental sustainability component (Medeiros, 2016) and applies to disparities between and within countries, regions, and municipalities, and designed for achieving “harmonious development”. Derived from France roots[1], the concept reflected a will to counteract the prevailing tendency of market forces to favor the most competitive and populated regions. Faludi (2007) underlines how this new emerging “EU conceptual novelty” was in support of a European Model of Society, in opposition to the liberal Anglo-Saxon model of development, looking at the equity principle behind territorial cohesion as diametrically opposed to the efficiency principle based on free mobility of labor.

However, the adoption of the Europe 2020 strategy, and with it also the EU Cohesion Policy 2014-2020 follows a “growth” rather than a “development” narrative, including the territorial cohesion within the “inclusive growth” priority, “fostering a high-employment economy delivering social and territorial cohesion” (Medeiros, 2016). The undergoing EU political agenda does not place territorial cohesion policy as a main topic of political discussion and the potential for Member States, Regions, and territories to use this tool to increase opportunities for people in remote, mountainous, and the outermost regions is largely unexploited. Barca (2018) stated how cohesion policies are still determined by space-blind decision-making (one-size-fits-all institutional reforms) and public investment driven by corporate decisions. To remedy the inequalities, "compassionate compensations" led to welfarist dynamics toward disadvantaged areas, and this unconditional support is often questioned today as it has not succeeded in addressing structural divergences but often served only to appease anger and potential conflicts (Barca et al., 2012).

The Report for a Reformed Cohesion Policy[2] represented an attempt to lay the theoretical and operational foundations of a new place-based approach that would face the ever-increasing territorial and social inequalities (Lucatelli et al., 2022). The document starts from the assessment of how distant cohesion policy is from the ideal model stated in the Lisbon Treaty and propose a set of pillars for developing a new perspective. This proposal aims at a new EU strategic framework for cohesion policy, which includes the implementation and reporting aimed at results,

[1] It was first discussed by the Assembly of European Regions, under the vice president Robert Savy, and afterwards popularized in the European Commission (EC) by the French commissioner for Regional Policy Michel Barnier, who ensured that territorial cohesion received a mention in the Treaty of Amsterdam, in 1997 (Faludi, 2007)

[2] The report was prepared at the request of Danuta Hübner - EU commissioner for regional policy - by an independent working group, coordinated by Fabrizio Barca, with the aim of drawing up a cohesion policy reform document.

a strengthened governance for the core priorities, the promotion of additional, flexible, and innovative spending as well as experimentalism and the mobilization of local actors (Barca, 2009). Four years later[3] these pillars are implemented at the Italian level, within the *National Inland Areas Strategy* (SNAI). The SNAI applies the concept of territorial cohesion to the local scale (within-regions) and aims to reverse the depopulation trend in the "inland areas" classified on the basis of distance indexes from the supply of main citizenship services – i.e., education, health and (railway) mobility (Figure 4). In this sense, the definition of "inland areas" overcomes the opposition between urban and rural, following the principle of territorial connectivity. The strategy is based on a polycentric reading of the territory, characterized by a network of municipalities (centers of service provision) around which gravitate areas characterized by different levels of spatial peripherality (Lucatelli et al., 2022).

[3] In 2011-2013, during the Monti government in Italy, Fabrizio Barca is Minister for Territorial Cohesion and put in place a new integrated policy called the National Strategy for Inner Areas (SNAI). This policy applies to every region and macro-area in Italy and is directed at recognizing the social and physical fragilities of remote places.

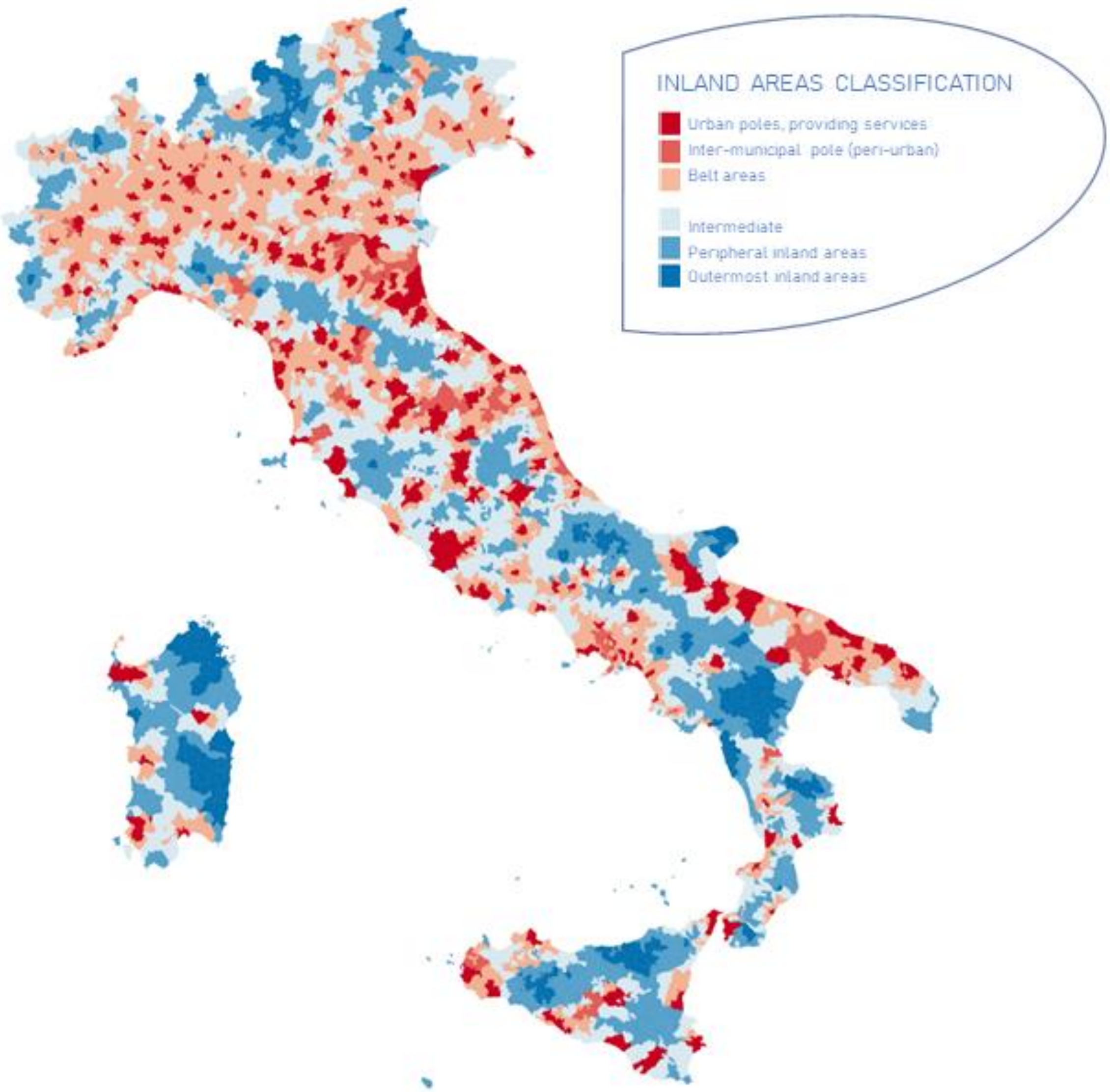

Figure 4: The SNAI inland area municipalities classification. Through the identification of municipal poles delivering services, the SNAI categorize municipalities in relation to travel distance: Urban poles, Inter-municipal poles (peri-urban), Belt areas, Intermediate, Peripheral inland areas, Outermost inland areas. Source: ISTAT, 2018

This dissertation approaches the issue of territorial cohesion through the framework proposed in 2013 by the National Inland Areas Strategy (SNAI), as it is considered to date the main example of effective strategic implementation of the European goal of territorial cohesion (Lucatelli et al., 2022). Through a place-based approach, the strategy activated pilot projects throughout the country, promoting a co-planning and collective learning process between the central, regional, and local administrations as well as stimulating a broader participation of citizens in the local development. At five years from the launch, pilot cases registered innovations in the field of educational services management and the organization of local welfare (Lucatelli et al., 2019). Yet, the omission of the environmental sector in the policy-making – both institutionally due to the exclusion of the Environmental ministry from the SNAI direction, and in practice because of the missed integration of environmental instances in the pilot areas – has led to low implementation of environmental assets in local strategies (Pierantoni and Sargolini, 2021).

To overcome this gap, this research focus on the fourth dimension of territorial cohesion, specified in the framework proposed by (Medeiros, 2016) as the *Environmental and Sustainability dimension* (Figure 5). This dimension acquired growing attention as environmental pressures and sustainability goals began gradually to shape the EU Policy agenda. With the support of the ESPON program (among others TEQUILA, INTERCO), the Territorial Agenda 2030 (2020) defines two overarching objectives, a "Just Europe" and a "Green Europe". In the latter, the report specifies the goal to protect common livelihoods and shapes societal transition, especially supporting the development of nature-based solutions as well as green and blue infrastructure networks linking ecosystems and protected areas in spatial planning, land management and other policies. Reference is made to COVID-19 pandemic, that has changed policy making and future development outlooks. As implications and policy responses vary across territories due to different conditions, the pandemic shows that "territories matter" and are highly interdependent (Territorial Agenda 2030, 2020).

Figure 5: The four dimensions of territorial cohesion. Source : Medeiros (2016)

In the need of producing an ecological perspective on cohesion policies, this dissertation aims of highlighting the role of inland systems in providing benefits to society through the lens of ES. Studies already underlined how the growth of urban settlements is based on the exploitation of natural capitals mostly coming from inland areas (Gebre and Gebremedhin, 2019). Yet, this dependency is not accounted in the neoclassical paradigm, which considers most of environmental benefits as positive externalities or free gifts from nature (Gómez-Baggethun et al., 2010). Through bio-physical and socio-cultural assessments the thesis aims to visualize spatial injustices inherent in the urban development model. In this sense, new elements for spatial cohesion strategies are provided in the direction of enhancing biodiversity and the human practices protecting it.

1.4 Methodological framework

1.4.1 Research approach and methodology

The topic is addressed in this dissertation through a multidisciplinary and multimethodological approach. The research is structured into three main studies: the analysis of the state of the art in the integration of the ES framework in landscape and territorial planning; the spatial analysis through mapping indicators in a regional case study; the social analysis of stakeholders' roles and perceptions in a local case study.

The first study, corresponding to Chapter 2, was approached through a systematic literature review, which aimed to search, select, and critically appraise published papers addressing the topic of ES integration in landscape planning. I focused on the sectors involved, the methodology used and how this concept could support a multidisciplinary vision of landscape. The process followed pre-defined inclusion-exclusion criteria and explicitly stated the review steps. The work was further integrated with a co-citation analysis aimed to detect research fields through their development over time using co-citation networks.

The second study incorporates the core part of the dissertation, applying ES spatial analysis tools and methodologies in the regional case study of Le Marche. Assisted by the regional authorities, a set of 12 representative ES was selected, and the mapping indicators for supply and demand were evaluated. The methodology was based on existing studies and approaches agreed with regional authorities. The mapping results provided the base for two parallel analyses: on the one hand, supply and demand data was clustered to obtain ES bundles, and on the other hand, the budgeting operation allowed to analyze spatial interdependencies. The analysis was run at the municipal scale because of the availability of data and the centrality of the institutional level in the political decision-making process. Nevertheless, the match of ES bundles with socio-economic data resulted in landscape units related to the functional characteristics of social-ecological systems. Simultaneously, ES budgets were characterized using SNAI classification classes along the urban-inland gradient, to visualize interdependencies at the regional scale. In both cases, statistical analyses allowed the assessment of associations between variables, as well as the analysis of trade-offs and synergies between ES. This dual exercise provided regional governance with suggestions for sustainable landscape management and implications for cohesion strategies.

The last study proposes a framework for the analysis of landscapes as social-ecological systems through the concept of ES co-production. It complements the indicators-based research with a bottom-up social perspective related to the local case study of Fiastra Valley. Via focus groups and interviews with local stakeholders, we assessed anthropogenic contribution to ES co-production though stakeholder's role and capitals involved. The data analysis aimed at highlighting stakeholders' dependency, benefits and access to decision making, as well as self-perception and collaboration across scales. Strengths and weaknesses are discussed in terms of the effectiveness of the ES co-production framework to integrate the role of social actors in landscape planning and management.

1.4.3 The case study: Le Marche Region and the Fiastra Valley

The selection of the case studies was linked to the availability of data and the opportunities for engagement with authorities and local stakeholders. The choice of the regional scope is related to my participation in *VAUTERECO* (Italian acronym for *Assessment of Urban and Spatial Assets for Community Resilience*) a research project in support of the definition of Le Marche Regional Sustainable Development Strategy. My involvement in the project allowed for easier exchange of information and collection of nonpublic regional data. The choice of the local case study of Fiastra Valley is linked to the activities of the Borgofuturo Association, of which I am a member, that is promoting a valley-scale regeneration process together with the six local municipalities facing the valley. The selection of this case study not only allowed for easier involvement of local stakeholders but also gave the study a chance of concrete implementation in local planning. The two case studies are shown in Figure 6.

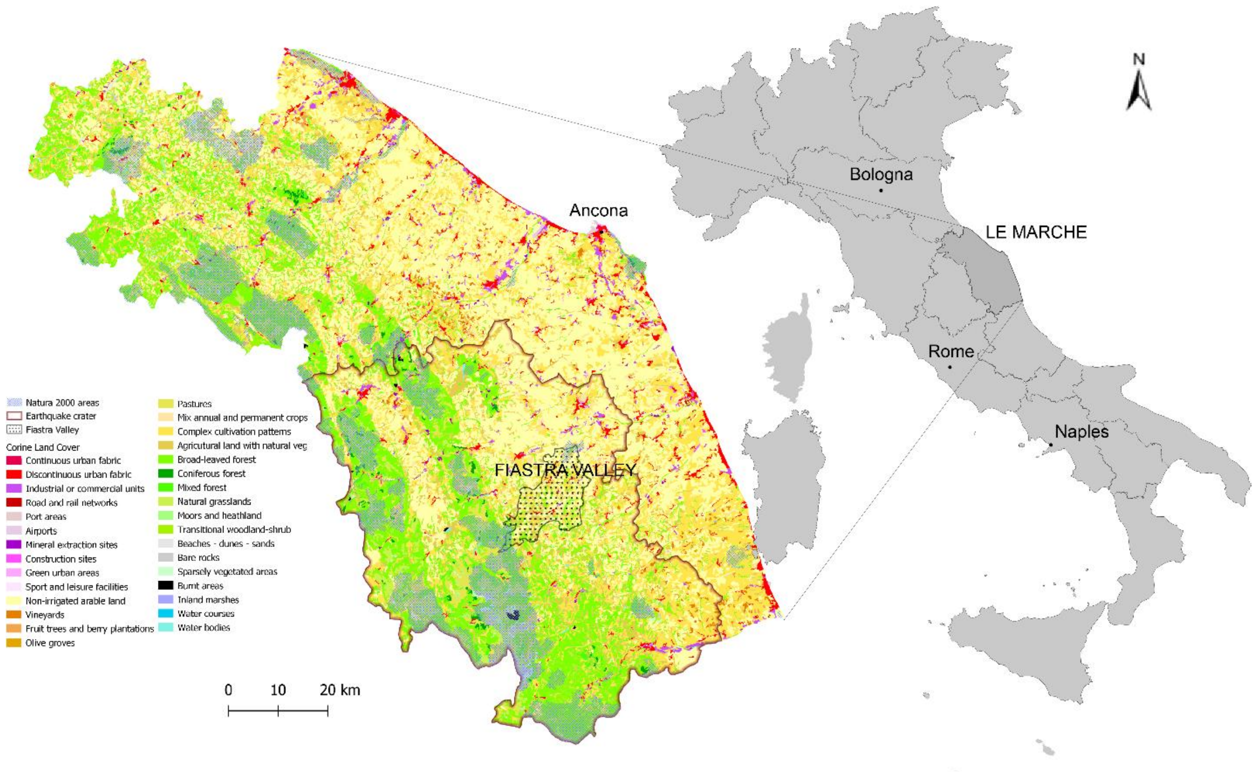

Figure 6: Le Marche regional case study and the Fiastra Valley. Beside the information on land use, the map includes the protected areas of the Natura 2000 network and the limits of the Central-Italy 2016-2017 earthquake crater, i.e., the area affected by the earthquake, with special reference to damage incurred by people and properties.

Le Marche (9.344 km²) is a central-Italy region bounded on the east by the Adriatic Sea and on the west by the Apennine chain. Characterized by a high landscape diversity, it is described as a good example case of the Mediterranean regions (Bevilacqua, 2013). The region comprises a western mountain area, a central hilly belt characterized by rural landscapes and mostly small settlements, and a coastal area consisting in an urban continuum along the Adriatic seaside. From the coastal strip, urbanizations expand along the valleys, where faster road connections penetrate the inner part of the region toward major towns and allow links with the western side of the Apennines. In Le Marche, the Regional Environmental Landscape Plan (*Piano Paesistico Ambientale Regionale* - PPAR) is configured as a territorial plan, and refers to the entire regional territory, including natural areas with cultural value, but also urban or degraded areas. ES information can provide relevant insights for the integration of a Green Infrastructure perspective into future landscape planning tools. In terms of regional cohesion, Le Marche inland areas, as other Mediterranean areas of Europe, have been for years at the center of the international academic and political debate, concerning development strategies against the phenomena of depopulation and economic decline. The phenomena already described in the Theoretical framework are combined here with the effects of the severe earthquake that hit Central-Italy in 2016–2017. Causing 41.000 displaced persons, 388 injured and 303 dead, the event had catastrophic effects on the built heritage but also in exacerbating the dynamics of abandonment. While the physical reconstruction has barely started, regional governance debates today over the best approaches to support life in the area.

The Fiastra Valley (43° 9' N, 13° 50' E) is a sparsely populated rural district, covering a hilly area characterized by ancient settlements and agricultural land crossed by the Fiastra river. It is included in the Earthquake crater, i.e., the area affected by the earthquake, and located in the inner part of Le Marche region, at the foothills of the Apennine mountains. The land cover consists mainly of arable land, with few forests covering mostly riparian and high-inclination areas. Its territory is constituted by six municipalities and counts about 11.764 inhabitants for 181,2 km^2 land. Social actors involved in the study were selected according to 5 stakeholder groups: *Production* includes workers from the agriculture sector, agronomy and local producers; *School and research* includes school teachers, university students, ecology experts and a representative from environmental centers; *Culture and commerce* includes tourist managers, hotel, agritourism and restaurant owners, café and a local shop owner; *Planning and administration* includes members of the municipality, Engineers, architects and planners, and the local water distribution company; *Society* includes members of local associations, artists, family doctors, local recreationists and other inhabitants.

The Fiastra Valley, as well as other areas in the region, can be read with the category of 'local system', conceived by Calafati and Mazzoni (2009). This interpretation addresses and interprets local systems as new poles present in the mental maps of individuals, visible in the spatial patterns of transactions, and in the spatial organization of settlements. The authors further underline how this polycentric territory is today without government and without a strategy, characterized by socio-economic imbalances as well as evolutionary potential (Calafati and Mazzoni, 2009). By adopting this scheme, this dissertation attempts to recognize the design of a new territorial organization, proposing a frame of inter-municipal connection and regulation.

Chapter 2: Ecosystem Services in landscape and territorial planning - evolution of the field and future perspectives

Abstract

The scientific community and policy makers are increasingly concentrating on the application of ES concepts and indicators for sustainable landscape transformation, emphasizing the ability of the ES framework to integrate different planning domains. However, it is not clear how the framework can support landscape and territorial planning adopting a social-ecological perspective, making services explicit and thus facilitating a discussion of trade-offs between ecological and socio-economic aspects. Learning from existing experiences is a fundamental step for developing new analysis but most of literature reviews are confined to individual intervention sectors and an overarching view is still missing. To overcome this gap, I developed a review of all published literature towards the identification of research trends and the application domains of the ES framework, specifically addressing landscape planning through a multidisciplinary perspective. I applied the methodology of systematic literature review for categorizing application fields of published studies and analyzed co-citation networks through the CiteSpace software. The research shows a dense network of collaboration and a variety of research fields developed in time. Several innovative tools and applications open windows of opportunities for the ES integration in the analysis of landscapes as social ecological systems.

2.1. Introduction

Ecosystem Services (ES) have been addressed as a theoretical framework able to visualize and analyze socio-ecological interactions linking biodiversity and human wellbeing with decision-making context (Bennett et al., 2015; R.S. de Groot et al., 2010). A growing interest from both the scientific community and policy makers is focusing on how the application of ES concepts and indicators can support sustainable landscape transformation (Albert et al., 2016; Longato et al., 2021; Ruckelshaus et al., 2015). In this frame, Grêt-Regamey et al. (2017) emphasizes the ability of the ES framework to integrate different planning domains, making services explicit and thus facilitating the discussion of trade-offs between ecological and socio-economic aspects.

The literature stresses how ES could bridge different fields of public sector management and facilitate policy decisions such as land and water use planning, agriculture policies, conservation strategies, and other multi-sectoral contexts of high policy relevance, e.g. planning for resilience from extreme events (Albert et al., 2014; Ruckelshaus et al., 2015; Sargolini, 2013; Sitas et al., 2014). However, most applications are confined to individual interventions such as measuring benefits of afforestation strategies (e.g. Yu et al., 2018), or the compensation for water quality and quantity (e.g. Keeler et al., 2012), through the application of payments, management changes or regulations (Longato et al., 2021; TEEB, 2010). In this context, Benra et al. (2022) demonstrate that the design of sectoral strategies is not sufficient to achieve the challenges of sustainable development and that multi-objective strategies pursuing both environmental and social goals should be promoted.

A growing number of studies are aiming to support sustainable landscape planning to cope with current and global challenges approaching the complexity of social-ecological interaction (de Vos et al., 2019; Fischer et al., 2015). In the Social-ecological systems perspective, landscape is conceived as a complex and adaptive system whose natural and social components are strictly connected and must be addressed together in the assessment. The approach can help to incorporate society's dependence on ecosystems into planning, promote understanding of interactions between regions, and recognize the links among power relations, justice, and ecosystem stewardship (Fischer et al., 2015). In this context, the landscape scale is considered particularly relevant to land use decisions concerning the quality, flow, and distribution of ES (Tallis et al., 2015).

However, landscape and territorial planning processes adopting a social-ecological perspective through an ES framework are still rare (Longato et al., 2021). Most of this “implementation gap” originates from the ineffective interface between ES science and policy (Albert et al., 2014). This comprises, among other elements, the scarcity of knowledge for the practical integration and the poor understanding of the applicability of ES integration models in existing planning structures (Bennett et al., 2015). The process of learning from existing practices in order to develop operational improvements is a key step in ensuring the use of scientific knowledge in decision-making processes (Dick et al., 2018). Nevertheless, systematic explorations of the ES concept in planning are mostly linked to specific sectors through a policy-making perspective (Geneletti et al., 2020; Ruckelshaus et al., 2015), focusing on specific aspects such as participatory planning (Spyra et al., 2019) or governance instruments (Longato et al., 2021). For supporting implementation, this paper aims to develop a comprehensive analysis of theoretical and practical integration of the ES concept as a social-ecological tool for landscape planning and management.

The study aims to identify the fields of application of the ES concept in landscape contexts, considering the different disciplines in the field, and investigate how the ES concept can support a multidisciplinary view of the landscape, particularly considering its social and ecological aspects. Through the tool of systematic literature review the study aims to give a rigorous and scientific reading of all published material, providing a solid basis for the construction of new analyses.

2.2. Methodology

The study is developed through a systematic literature review aimed at identifying and critically evaluating research concerning the application of the ES concept in landscape planning. The work is organized into two main phases, the first related to co-citation networks, and the second corresponding to the selection and quantitative analysis of published papers on the topic. While the first phase aimed at identifying research trends in the field, the second led to the recognition of the main fields of application of the ES frame in landscape planning by defining specific categories.

2.2.1 Analysis of co-citation networks

In order to identify major research trends related to the application of the ES frame in landscape and land use planning we developed a co-citation network analysis through CiteSpace software (Chen, 2006). The software is designed as a tool for progressive visualization of the knowledge domain and is based on co-citation networks between a set of publications. The approach follows the assumption that if two studies are both cited by a third study, then they are likely to have common content. If the number of co-citations is high, the possibility that the studies are related increases. Within the network, a node (article) with a high centrality value corresponds to a publication that connects two or more groups of nodes, i.e., it connects clusters of different topics. This metric, therefore, characterizes articles according to their predominance in the network structure.

As input of the co-citation analysis, we used the result of a search in ISI Web of Science as of May 1, 2020, which consisted in 391 studies. The search query applied three levels of keywords related to (i) Ecosystem Services, (ii) landscape and land use planning, and (iii) concepts of integration and multidisciplinarity. Table 1 shows the final set of keywords defined after several attempts and combinations. CiteSpace allows the visualization of networks of co-citations, together with the clusterization of the studies according to citations. The clusters labelling technique follows titles, keywords and abstracts content in order to explicitly interpret the clusters' research-front concepts.

Table 1: Script of the database search: the keywords were selected to operationalize the three level of search

Topic	Keywords
ECOSYSTEM SERVICES	TS= ("ecosystem service*") AND
LANDSCAPE PLANNING	TS= ("landscape planning" OR "regional planning" OR "land-use planning" OR "spatial planning" OR "territorial planning") AND
INTEGRATION AND MULTIDISCIPLINARITY	TS= ("integrative" OR "interdisciplinar*" OR "multidisciplinar*" OR "multi-sector*" OR "multifunctional*" OR "multi-functional*" OR "multicriteria*" OR "multi-criteria*" OR "bundle*" OR "trade-off*" OR "cluster*" OR "synerg*" OR "social-ecological system*" OR "transdisciplinary*")

2.2.2 Quantitative analysis

The quantitative selection and analysis process aimed to characterize the published studies addressing the topic and then organize them into distinct categories. To include all the scientific products the keyword search (Table 1) was developed both in ISI Web of science and Scopus and resulted in respectively 520 and 391 studies. After merging the total 911 results in Endnote and deleting the duplicates we got a final number of 774 studies.

The selection process was developed in Covidence and consisted in two phases. The *screening* process involved the analysis of titles and abstracts to exclude any publication clearly out-of-scope, e.g. not related to ES at all or publications for which analysis based on the title was inconclusive. This was carried on focusing on the reasons for inclusion. Afterwards, the *eligibility* aimed at selecting the relevant studies based on the paper content and exclusion criteria. The criteria for inclusion and exclusion of studies in the review are explicitly stated and consistently implemented (Table 2). With a multi-sectoral integration perspective, research focused on studies with a multidisciplinary approach, excluding those unrelated to integration in planning, and those considering only a single – or a single class of – ES (e.g., studies on cultural ES were excluded).

Table 2: Inclusion and exclusion criteria applied during the selection process of the literature review

Inclusion Criteria	Exclusion criteria
1 The study focuses on Ecosystem Services (both theoretical and empirical approaches are included).	1 The study is not centered on the Ecosystem Services concept, e.g., ES is named as side topic.
2 The study has a planning prospective or refers to a decision-making process.	2 The study focuses on ecosystem services assessment and does not relate to its integration in planning.
3 The study develops at landscape level or considers multiple Ecosystem Services.	3 The study considers a single (or a single class of) Ecosystem Service

Furthermore, during the *eligibility* phase we developed a tag system related to application categories. By iterative method, we defined 18 application categories related to the main sectoral references contained in each study. In case of papers falling into more than one category (more than one tag), the study would be classified by the tag relating the most with the object of the paper. In order to understand the evolution of the discipline over time and the distribution of case studies in space, we extracted the year of publication, location of case studies, and place of affiliation of the first authors of the studies included in the analysis.

2.3. Results

2.3.1 Emerging trends and research topics

The CiteSpace analysis results in a dense network of co-citations within the papers published in the field of ES in landscape planning. Figure 7 visualizes this network as a central block of interconnected nodes and two smaller clusters that temporally detach one upper part (purple color indicating past) and the lower part (yellow color indicating ongoing activity). The clusters can be clearly seen in the bottom graph, where CiteSpace recognizes 7 main thematic clusters tagged (labeled) according to the titles and keywords of the publications. The clusters are numbered following the number of studies they contain (from largest to smallest) and are organized in a timeline showing the period of activity of each thematic group, highlighting most significant papers (in terms of co-citation).

The analysis of the nodes shows five publications especially having a pivotal role within the network: *Burkhard et al., 2012* and *Crossman et al., 2013* deal with the topic of mapping and modeling the supply and demand of ES, the study published by *Costanza et al., 2014* proposes an estimation of changes in the contributions of natural capitals to human well-being globally, the study by *Plieninger et al., 2013* focuses on cultural ES at the community scale, and finally *de Groot et al., 2010* addresses some important challenges related to integrating the concept of ES into landscape planning and management. According to co-citation networks, these nodes represent turning points in the development of the research field related to the ES integration in landscape planning.

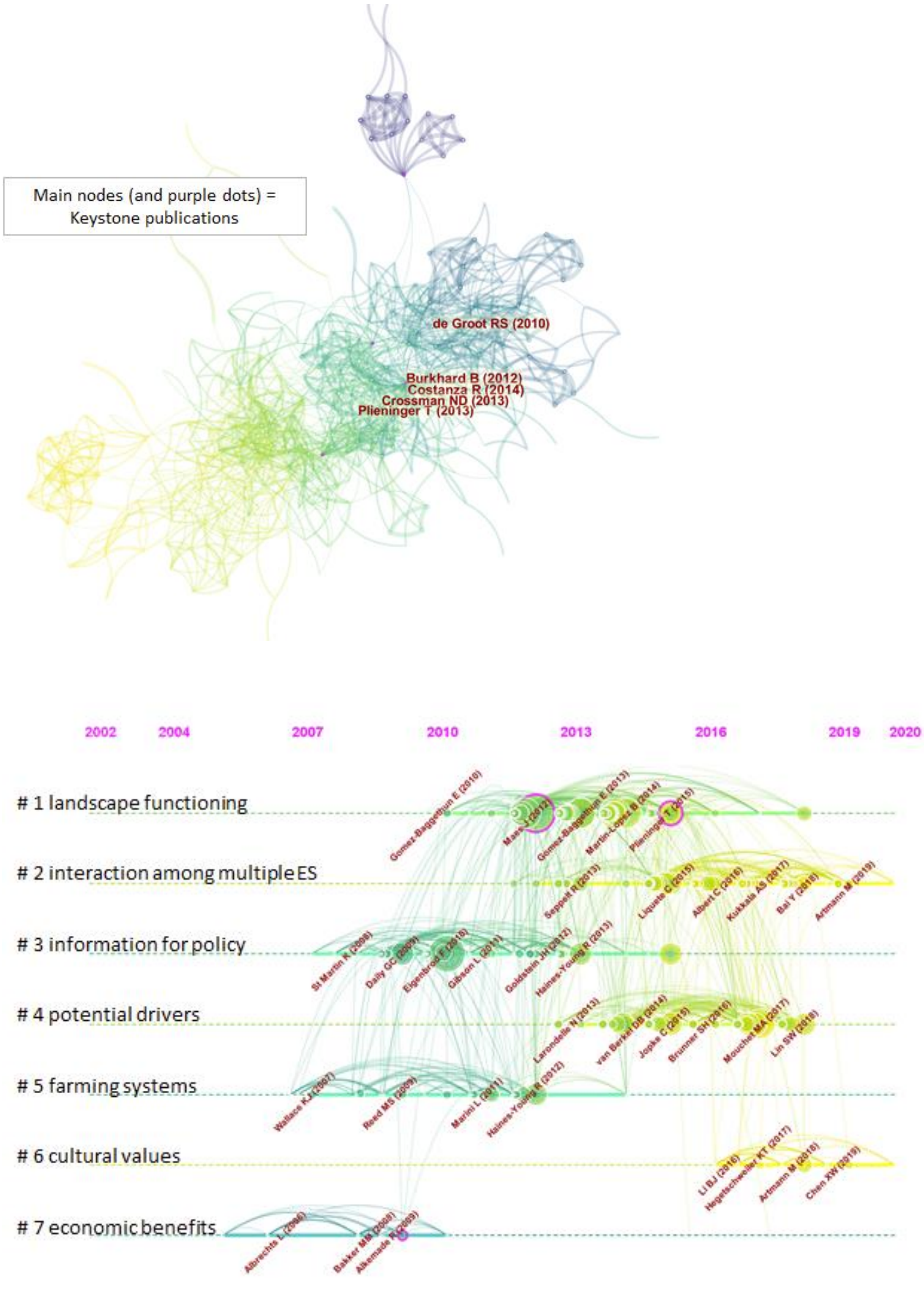

Figure 7: Co-citation networks and clusters of co-citation distributed over time

More interestingly, the clusters' names outline what can be considered research strands within the theme of ES integration in landscape planning, suggesting some important consideration on future perspectives. The *Landscape functioning* cluster is the most populated and contains publications from 2010 to 2018. Within the papers contained in the cluster, CiteSpace recognizes a main focus relating to the analysis of landscape properties in relation to the delivery of ES. The second cluster is tagged as *Interaction among multiple ES* and focuses on multifunctionality and interaction among multiple ES and remains active to this day. *Information for policy* is the label of the third cluster, whose beginning is set in 2007 and continued until 2015. It focuses on integration models related to assessments and applications linked to policy and strategic governance. The *Potential drivers* cluster finds a common thread among studies concerning the drivers of change and pressures related to ES. Cluster #5, *Farming systems*, focuses on applications of the ES concept to agricultural systems. The recent *Cultural Values* cluster is linked to the cultural values of ES and along with cluster #2 is the only one still in operation. Finally, the *Economic benefits* cluster, related to the economic value of ecosystem benefits, characterize an initial group of publication, but it concludes before 2010.

2.3.2 Categories of application

The quantitative analysis reveals the great diversity of categories in which the ES framework is applied in landscape planning. Specifically, Figure 8 shows three macro-categories, and 18 categories in which selected papers were organized. *Proactive Planning* includes studies related to planning for a desired future, actively controlling its outcomes or predicting its effects. Studies in *Management and Risk Reduction* deal with the management of existing processes, the assessment of future trends, and the regulation of processes according to these assessments. Finally, the *Assessment and Information* class groups studies that analyze current phenomena, mitigate or react to changes, and evaluate their effects.

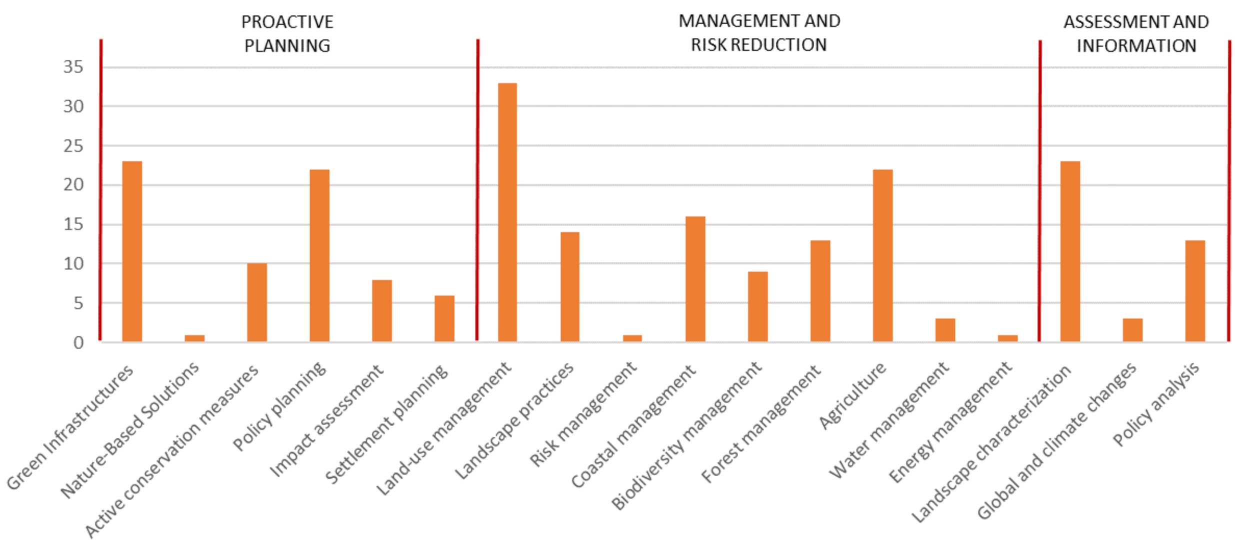

Figure 8: Categories of ES integration in Landscape planning, organized within three macro-categories

Within *Proactive Planning*, an important area of application (23 studies) is related to the design of so-called "Green Infrastructures". Conceived as functional spaces for the provision of ES, studies included in this category refer to natural land use or vegetation layers enhancing the environment through direct or indirect means. The "Policy-making" category apply the ES framework to strategic/policy planning by analyzing tools such as Multiple-Criteria Decision

Analysis (MCDA) to identify monitoring areas, plan afforestation programs, or set targets to achieve. Within the *Management and Risk Reduction* macro-category, "Land-use management" is the most represented and includes 33 studies related to the evaluation of ES provided by specific land-uses, assessment of alternative land-use scenarios and conflicts arising from decision-making. In *Assessment and Information*, the "Landscape characterization" category includes 23 different studies that characterize landscapes according to benefits ecosystems provide to society, through the concept of ES. Examples include notions of landscape multifunctionality, livability, and the intersection of the social and ecological spheres.

2.3.3 Distribution of publications in space and time

The increasing number of publications within the selected keywords demonstrate a growing interest in the application of the ES concept in land use planning. Figure 9 shows a rising number of studies published and an internationally established research field.

In terms of the geographical distribution of case studies, the figure shows that most are located in China (35 studies), followed by Spain (23) and then the United States, Italy and Germany (between 10 and 20). Some Scandinavian countries, England, as well as Canada and some Latin American countries are the subject of three to ten studies. Other states, such as Colombia, France, Turkey, South Africa, India and Australia seem to show less interest in the field (less than three studies each). One research analyzes the topic on a global scale, while five studies consider all of Europe. Eighteen studies are proposals for conceptual or methodological frameworks and do not find application in a specific case study. With respect to the country of affiliation of the first authors, 80 % match that of the case study, while for those that do not match, it was seen that, for the most part (55%), researchers affiliated in institutes in Western countries carry out studies in countries in the Global South.

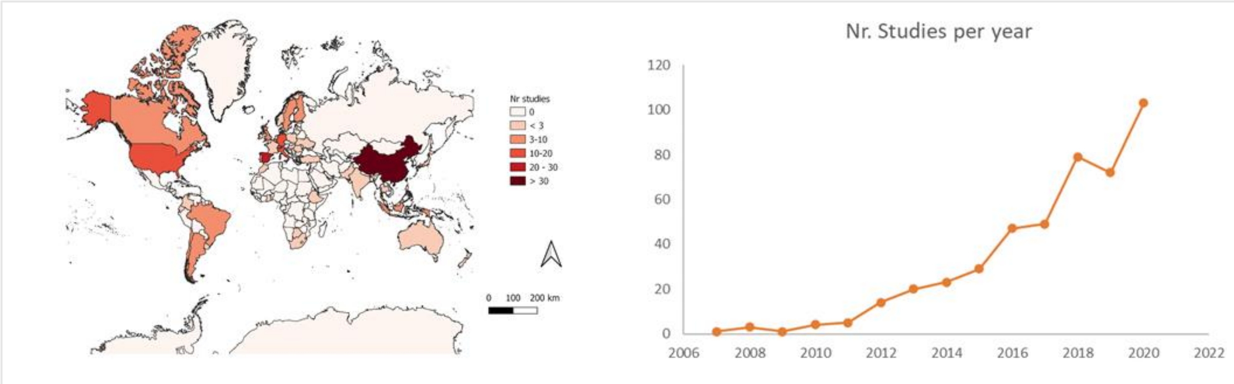

Figure 9: Map of studies localization (case study/study team - first author affiliation) and trend of publications on the topic (number per year)

2.4. Discussion

2.4.1 A thriving research arena

The application of the ES framework in landscape and spatial planning proves to be a thriving and growing area of study. While the distribution in time and space shows an increasing number of studies being published around the world, the network analysis gives interesting hints on the research sub-fields mostly addressed today. First among all, the field of research related to the interactions between ES and cultural values is among the most active today. This confirms the growing interest toward the recognition of the central role that culture plays in defining links between people and nature (Díaz et al., 2018). Indeed, several studies today include in the landscapes analysis anthropogenic components such as motivation or education, values and norms, machinery and infrastructure (Palomo et al., 2016).

On the other hand, the decrease in academic interest toward economic ES assessments (which characterized the first phase of the research) might be related to the manifest limitations in monetary quantifications of good and benefits, especially when relating to single objective analysis (Benra et al., 2022). Similarly, it is interesting how the focus on agricultural systems, considered significant for landscape multifunctionality (Bennett et al., 2021), also waned over time and probably flowed into broader areas such as landscape functioning and the study of interactions among multiple ES.

Regarding the diversity of methodologies adopted, spatial analysis and the mapping of ES appears to be a prevalent practice in the analyzed studies (Brunner et al., 2017; Salata et al., 2020), as well as the use of nonmonetary indicators to assess ES and their interactions and trade-offs. Data collection approaches range from conducting questionnaires (see Giedych and Maksymiuk, 2017; Mathey et al., 2015), semi-structured interviews (see Elbakidze et al., 2017) or focus groups (Kopperoinen et al., 2014), involving both experts and local actors and actresses. Also important is the application of MCDA methodologies in managing conflicting land use interests (Langemeyer et al., 2016), and to support planning of urban development zones (Grêt-Regamey et al., 2017).

In addition to focusing on specific case studies, some of the articles compared multiple case studies, both within the national borders (see Elbakidze et al., 2017; Giedych and Maksymiuk, 2017) and internationally (Friedrich et al., 2020; Momm-Schult et al., 2013; Turkelboom et al., 2018). The prevalence of studies carried out in countries of the Global North, however, including those analyzing case studies in developing countries (see Spangenberg et al., 2018; Teixeira et al., 2019), shows that awareness of the potential and importance of deepening research in the field are differently distributed across space.

2.4.2 Planning with nature

Among the applications of the ES frame in proactive planning, the green infrastructure concept offers interesting contributions in the conservation and design of green spaces with high ecological value (Baró et al., 2017a; Lanzas et al., 2019; Vasiljević et al., 2018) but also for the integration of the social value of open spaces in planning (Giedych and Maksymiuk, 2017; Meerow and Newell, 2017). Artmann et al. (2017) and Arcidiacono et al. (2016) attempt the integration of the green infrastructure concept in a city (Dresden, Germany) and regional (Lombardy, Italy) landscape plan, respectively. Applications of the framework are analyzed within Strategic Planning, to support strategies protecting or limiting urban growth (Salata et al., 2020). Among others, studies suggest interesting approaches to financial compensation to land owners (Carmona-Torres et al., 2011), or the programming of afforestation plans (Estrella et al., 2014).

Another important field of study is the integration of ES into environmental and land use management, with great emphasis on assessing the effects of land use changes. This is done through the consideration of trade-offs related to land use, the assessment of future scenarios, or the evaluation and perception of local actors involved in ES dynamics. Among others, de Groot (2006) considers conflicts of interest related to the planning of multifunctional landscapes, and Elbakidze et al. (2018) maps ES provision for the livability of territories through citizens' perspectives.

The research further shows how analyses related to ES can support the planning process through information and descriptive investigations. Interestingly, there are various applications in the field of landscape characterization, from the concept of liveability (Antognelli and Vizzari, 2017) to new approaches to zoning with respect to multifunctionality and benefits offered (Geneletti, 2013; Liu et al., 2019; Zhang et al., 2019). The integration of the ecological and social components of landscapes is further developed through the concept of Bundles, i.e., a set of positively correlated ES (demand or supply) across space and time (Raudsepp-Hearne et al., 2010). The concept shows a great potential in relating ES features to socio-economic factors and it can be used to identify and characterize landscapes as social ecological systems (Baró et al., 2017; Queiroz et al., 2015).

2.4.3 Limitations and future research

With respect to the limitations of the methodology, it's important to point out a set of shortcomings in order to support further research in the topic. First, it should be mentioned how CiteSpace's labelling method do not go in deep in the paper content but is limited to the consideration of the words in the titles and keywords of the clustered studies. Further research could go in the direction of analyzing paper contents to accurately define co-citation clusters. Furthermore, as co-citing studies do not necessarily deal with the same topic, the different relationships between studies are not represented with the same level of accuracy. For this reason, the resulting network should rather be understood as an indication on macro evolutions of the research trend in the field and not as static search fields.

As it emerges from this study, ES research and landscape planning represent a cutting-edge investigation topic, especially as it regards the multifunctionality of ecosystems (Artmann et al., 2019). Methods of integrating cultural values into the study of ES are beginning to emerge (Chen et al., 2019), suggesting a promising research direction. Avenues for future research are related to the analysis of how the social, cultural, and relational values of landscapes can be integrated into planning through the framework of ES. This quantitative literature review could be a basis for developing a qualitative analysis with respect to the topic of intersectionality between ecological values and social and cultural values.

2.5. The evolution of a framework

The concept of ES is increasingly attracting the attention of both academia and policymakers in the field of landscape planning. Through a general analysis of co-citations and research trends, as well as a careful selection and review of articles to identify the main applications, this study gives a solid scientific basis for addressing the issue and developing a new analysis.

The investigation offers a set of take-home messages. First, it can be noticed that a decreased interest toward economic assessments is opposed to a clear trend in the direction of the integration of cultural values in environmental studies. There is a growing attention in the exploration of the role of anthropogenic components in the perception of ecological benefits offered by landscapes. Several tools have been consolidated in the application of ES in planning, this is the case for Green Infrastructure, designed as a functional space for the provision of ES. Methodologically, a variety of nonmonetary indicators are being investigated to include ES in policies, mainly relating to mapping and spatial analysis.

This chapter supports the construction of a theoretical and methodological foundation for the following dissertation. On the one hand, it provides awareness of academic activity around the concept of ES in landscape planning, on the other hand, it offers insights for the design of the coming analysis. The choice of indicators for mapping social-ecological systems, the tools for the characterization of ES bundles, as well as the integration at policy level are derived from the review of published studies.

Chapter 3: Mapping bundles of Ecosystem Services supply and demand reveals interdependencies between inland areas and urban poles

Abstract

A key challenge of territorial cohesion is to cope with the increasing marginalization and inequalities brought by urbanization. The inland areas – defined as remote from the delivering of services such as health, education, and mobility – are undergoing a process of economic decline and depopulation, while not being recognized for their crucial role in terms of the ES they provide to human society. This role is often neglected by territorial policies, which ground their action in the socio-economic assets, failing to integrate the ecological sphere. Furthermore, the urban-rural dichotomy which characterize environmental analysis often disregard the socio-cultural heritage of the inland areas and ignore the polycentric condition of rural territories. To overcome this gap, this study advances a framework to analyze territorial ecological dependencies between inland areas and urban poles through the lens of landscapes as social-ecological systems, combining spatial features with patterns of ES supply and demand. The framework is applied in the regional case study of Le Marche, Italy, covering 12 ES through 24 spatial indicators (demand and supply) as well as assessing 9 socio-economic indicators for territorial characterization. The study develops in two parallel paths, on the one side testing ES bundles for the visualization of social-ecological systems, on the other applying ES budgeting to highlight interdependencies along the inland-urban gradient. In this way, the analysis provides suggestions for sustainable landscape development and regional cohesion with a social-ecological perspective.

3.1. Introduction

The process of urbanization together with the ongoing exponential growth of human activities is leading to increasing marginalization and inequalities between regions (Rockström et al., 2009). While cities are mostly associated with economic success and power (Sassen, 2018), the inland areas – defined as remote from the delivering of services such as health, education and mobility – are undergoing a process of economic decline and depopulation which increasingly subordinate them to urban centers (ESPON, 2021). In 2009 the urban population surpassed the number of people living in rural areas and the United Nations (2016) forecasts a global increase to 60% by 2030.

Inland areas are crucial in terms of goods and services they provide to human society, such as food and clean water, or climate and hydraulic regulation (Gebre and Gebremedhin, 2019). The great role they serve for the well-being of society was especially evident during the COVID-19 sanitary crisis, when the urban population recognized the value of inland areas for the availability of open spaces and recreational opportunities (Beckmann-Wübbelt et al., 2021; Derks et al., 2020). These benefits are increasingly assessed under the definition of Ecosystem Services (ES), useful to analyze urban-rural interdependencies (Gebre and Gebremedhin, 2019) and to integrate the link between natural and social systems in landscape planning (R.S. de Groot et al., 2010). Within this framework, ES supply represents the capacity of ecosystems to provide specific goods and services, while the demand refers to the amount of service desired by a society (Villamagna et al., 2013b). The calculation of budgets between ES supply and demand allows the exploration of mismatches and gaps between different areas (Burkhard et al., 2012). As demand is often not dependent from actual supply within a local system but rather from a larger spatial extent, spatial analyses can help visualizing mismatches among local systems.

Several studies assessed regional spatial interdependencies from an urban perspective, evaluating the effects of city growth on the rest of the region (Peng et al., 2020) or analyzing the ES supply-demand along the urban-rural gradient (Baró et al., 2017a). However, the dichotomy between urban and rural fails to integrate the role of inland areas, which host a great share of socio-cultural heritage (Antrop, 2005). Inland areas in fact consist of a multiplicity of small urban settlements that have shaped societies over centuries of human-nature interplay (Blondel, 2006). This is particularly evident in Mediterranean region, one of the world's biodiversity hotspots (Myers et al., 2000), where social-ecological balances are today threatened by increasing urban pressures and depopulation of local systems leading to two opposite scenarios: agricultural intensification in peri urban and accessible areas as well as abandonment of peripheric and mountainous areas (García-Llorente et al., 2012). While intensification of agricultural production may impact on the provision of regulating and cultural services (Felipe-Lucia et al., 2014), natural revegetation following the abandonment can help improve some ecological functions and services, such as erosion control and water quality (Bruno et al., 2021). However, abandonment of traditional agricultural and forest management practices (often associated with low-intensity and semi-subsistence) also bring important consequences in the loss of local traditional knowledge and sense of place (Iniesta-Arandia et al., 2015).

Such interaction and trade-offs are often tackled in the literature through the frame of social-ecological systems, which can help analyzing how social systems adapt to changes in their environment and, in turn, how the environment adapts to social changes (Binder et al., 2013). In the context of landscape planning, it is crucial to understand what kinds of social-ecological systems are present in a landscape, as different configurations of societal interactions with nature are characterized by different resource use patterns, human well-being outcomes, development trajectories, and potentials for environmental traps or collapse (Cumming et al., 2014). To approach this complexity, the concept of ES bundles can be effective in identifying areas of a landscape where ecosystem management has produced exceptional sets of ES and can be linked to distinct regional social-ecological characteristics (Raudsepp-Hearne et al., 2010). Many studies have applied this concept in order to characterize landscapes according to ES features (Baró et al., 2017a; Peng et al., 2020; Queiroz et al., 2015; Quintas-Soriano et al., 2019). However, the field still lacks evidence on how additional socio-economic factors affect the resilience and sustainability of ES bundles and which social-ecological characteristics are related to the supply and demand of ES (Bennett et al., 2015; Rieb et al., 2017).

This paper explores landscapes as social-ecological systems combining spatial features with patterns of ES supply and demand. Building upon the methodology of Raudsepp-Hearne et al. (2010) in the construction of bundles, it further analyses the role of socio-economic indicators on ES patterns. Parallelly, through budgeting, spatial interdependencies are investigated in support of policy-making for inland areas (Barca et al., 2012; Gebre and Gebremedhin, 2019). Figure 10 provides a visual illustration of the two aims of the paper: a) to develop and test an approach to map social-ecological systems in a Mediterranean case study and b) to highlight spatial interdependencies in order to support balanced and just development between urban poles and inland areas. In this sense the study intends to provide a tool for the sustainable landscape development on the one hand and for regional cohesion strategies on the other.

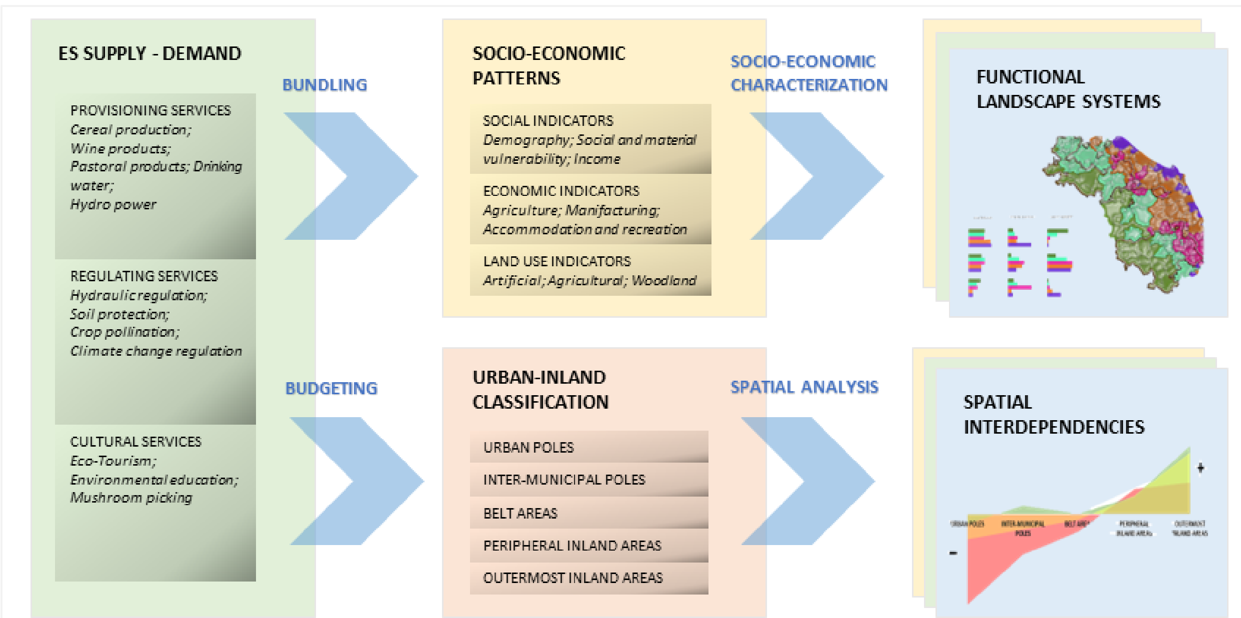

Figure 10: Structure of the chapter flow. Areas represent layers of information while arrows the flow of analysis.

3.2. Materials and methods

3.2.1 Study area: Le Marche Region

The study is conducted in Le Marche, a region (9.344 km²) in central-Italy bounded on the east by the Adriatic Sea and on the west by the Apennine chain. Characterized by a high landscape diversity, it represents the typical Mediterranean region, making of it an optimal case study that allows the extension of the results to other Mediterranean areas (Bevilacqua, 2013). In terms of morphology, Le Marche comprises a western mountain area, a central hilly belt characterized by rural landscapes surrounding small settlements, and a coastal area consisting of an urban continuum along the Adriatic seaside. From the coastal strip, urbanizations expand along the valley, where faster road connections penetrate the inner part of the region toward major towns and allows links with the western side of the Apennines.

Le Marche inland areas, as other Mediterranean areas of Europe, have been for years at the center of the international academic and political debate, in terms of development policies and the fight against the phenomena of depopulation and economic decline. The phenomena are combined in this region with the effects of the severe Earthquake that hit the inland areas of Central-Italy in 2016-2017. Causing 41,000 displaced persons, 388 injured and 303 dead, the event had catastrophic effects on the built heritage but also in exacerbating the dynamics of abandonment. While the physical reconstruction is today barely started, regional governance debates best approaches to support life in the area.

The issues of inland areas development are tackled at the Italian national level by the *SNAI – National Strategy for Inland Areas,* which classifies municipalities according to their distance from public services considered essential, namely: health, education and mobility (Figure 11). The SNAI supported pilot actions for enhancing life quality in inland areas. In Le Marche, the Regional Environmental Landscape Plan (*Piano Paesistico Ambientale Regionale - PPAR*) is configured as a territorial plan, and refers to the entire regional territory, including natural areas with cultural value, but also urban or degraded areas. Information on ES providing areas (Mountain forests, agro-ecosystems, etc.) and potential beneficiaries (in the urban poles and coastal areas) can provide relevant insights for the integration of a Green Infrastructure perspective into future landscape planning tools.

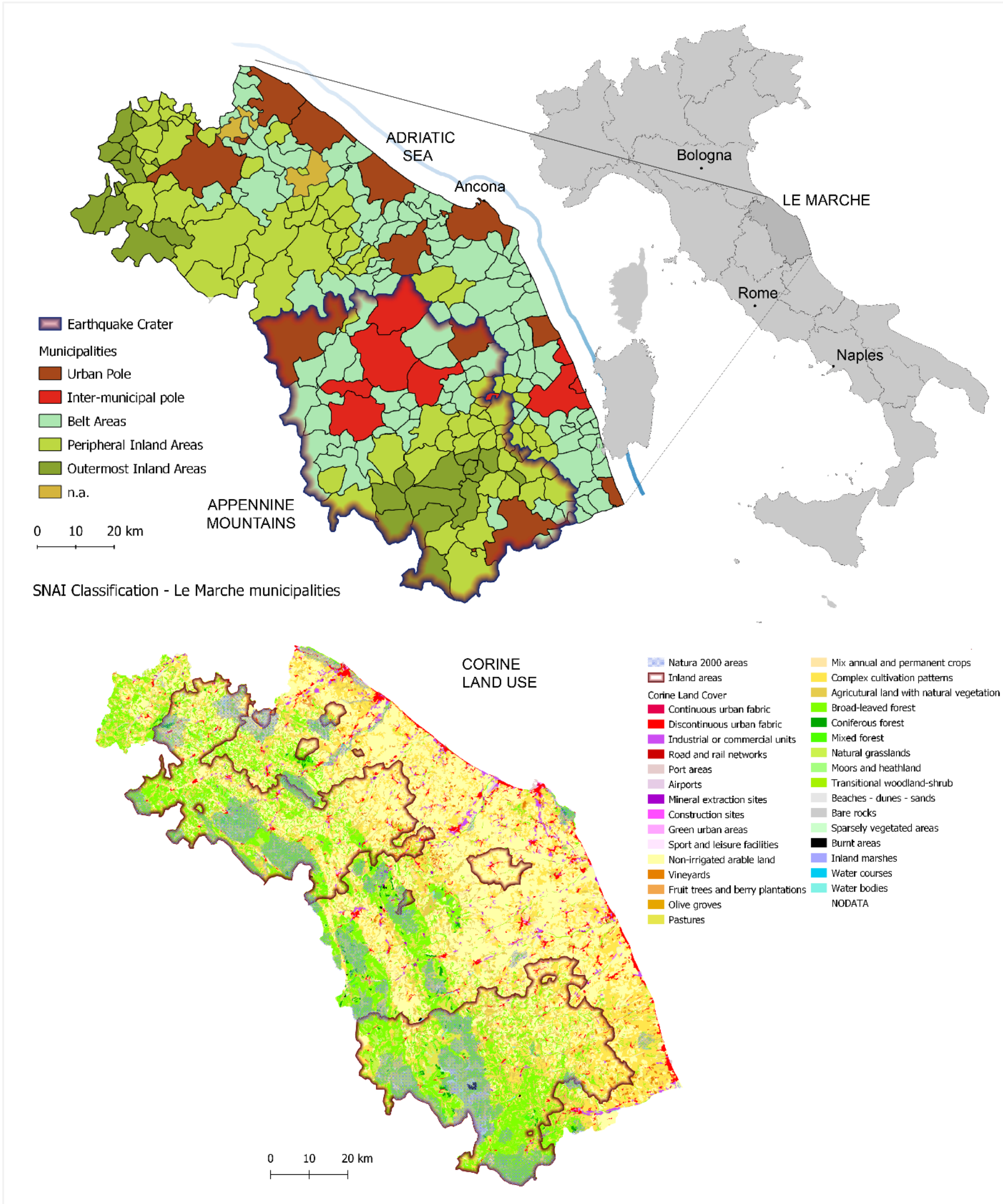

Figure 11: Le Marche land use regional map (bottom) and the SNAI inland area municipalities classification (up). Through the identification of municipal poles delivering services, the SNAI categorize municipalities, in relation to travel distance, into 5 classes: Urban poles, providing services; Inter-municipal pole (peri-urban), travel time less than 20 minutes; Belt areas, between 20 and 40 minutes; Peripheral inland areas, between 40 and 75 minutes; Outermost inland areas, with travel time of over 75 minutes.

3.2.2 Ecosystem Services mapping

The identification of context-relevant ES indicators is the first step for the analysis of social-ecological systems (Burkhard et al., 2012). In this regional analysis we selected 12 ES and 9 socio-economic features in 227 municipalities of Le Marche Region. The services were classified according to the CICES classification as 5 Provisioning Services, 4 Regulating Services and 3 Cultural Services (Haines-Young and Potschin-Young, 2018). Table 3 shows the list of ES and relative indicators of supply (i.e. ecosystems' capacity to deliver ES) and demand (i.e. the amount of ES required or desired by society) (Villamagna et al., 2013b).

Individual indicators were chosen to visualize and compare municipal values across the region. Despite the high variability of sizes in municipal areas (range from 272,08 to 3,85 km^2) the municipal units allowed a high availability of data and an emphasis on the local administrative actions. In fact, municipalities - and systems of municipalities - are considered main actors in spatial transformation processes for the local scale (Barca, 2009; Calafati, 2015; Felipe-Lucia et al., 2014). Maps of supply and demand of individual ES were developed using QGIS 3.10.11 A Coruña. Within the Provisioning categories, supply refers to the tangible goods produced, and demand refers to the actual consumption by the population. For the regulating services, supply refers to potential supply and demand is related to the risk arising from the shortage of the service according to current environmental rules and policies. Regarding cultural services both supply and demand refer to potential values, e.g. through existence of infrastructure or presence of service seekers in the region.

Provisioning services

P1 Cereal production indicators are related to actual production (supply) and consumption (demand). The supply value at municipal scale is derived by the spatialization of total regional production on the hectares of municipal surfaces dedicated to agriculture (agriculture census). The demand is mapped by spatializing the total consumption by population density. The assumption here is that the consumption is equally shared among the regional population. The *P2 Wine production* was mapped similarly to P1, with the difference that the demand (consumption) is spatialized according to population over 16 years old, the age below which wine consumption is prohibited in Italy. The *P3 Pastoral products* refers to the production of cheese from goat and sheep farming while the demand considers the available data of total cheese consumption. *P4 Drinking water* relates to the total water delivered by the Marche regional aqueducts. Data on supply consists of the total regional water extracted, spatialized by the punctual catchments weighted by the maximum uptake allowed by the Regional Aqueduct Master Plan (Regione Marche, 2014). Data on demand relies on the actual water delivered by the regional network, thus excluding losses (ISTAT, 2019). *P5 Hydro power* indicators are related to the electricity produced by regional water plants (supply) and the actual consumptions for residential and industrial purposes (demand). The supply accounts for the nominal power of plants, which are added up within the municipalities they belong to (SIGERI, 2020), while demand spatializes average regional consumptions by the number of inhabitants (domestic consumption) and companies active of each municipality (industrial consumption).

Regulating services

R1 Hydraulic regulation refers to the role played by the natural ecosystem in retaining water during rain events and therefore decreasing the regional flood risk. The supply is mapped according to the Curve Number (CN) parameter, which predicts direct runoff or infiltration from excess rainfall (USDA, 1969). Input information for the CN method are the Hydrologic soil group database (Regione Marche) and Corine Land Cover (2018). Indicator for demand are the areas of municipalities in flood risk mapped by the Regional Hydrogeological Plan (PAI) as P3 and P4. The ES *R2 Soil protection* relates to the capacity of ecosystems to prevent soil loss and therefore nutrient loss. The supply follows the indicator of Potential sediment retained, mapped through the model InVEST Nutrient Delivery Ratio (Sharp et al., 2014). As for the demand, the ES was mapped according to the data available at EU scale through the RUSLE 2015 model, resolution 100m (Panagos et al., 2015).

R3 Crop pollination refers to the capacity of ecosystems to provide habitats for pollinator species, essential for ecosystem functioning as well as for several agricultural activities. The supply map uses available data at EU scale available for the year 2010, assuming minor changes in the potential of land cover cells to provide crop pollination. The indicator follows a relative scale between 0 and 1 and is based on input information including relative suitability of land cover cells to host pollinator populations, the availability to provide floral resources and the average activity of bees as a result of climatic variation (Zulian et al., 2013). The demand is instead related to the dependency of cultures by pollination, for which the cultures of each municipality were linked to dependency values (Joint Research Centre et al., 2014). The mapping of the ES *R4 Climate change regulation* assumes the net zero CO_2 emission as the ideal condition, in line with the EU's commitment to global climate action under the Paris Agreement (EU, 2021). In this sense, the supply indicator assesses the total CO_2 absorption by ecosystems and the demand accounts the emissions of the production sector. The data follow a report of Assessment and quantification of atmospheric emissions in Le Marche Region (UNIVPM, 2019).

Cultural services

Cultural services embrace non-material benefits people obtain from nature and include Environmental education, as well as Eco-Tourism and Mushroom picking, together considered within the definition of Recreational services.

C1 Eco-Tourism refers to the capacity of ecosystems to provide opportunities for tourism directed towards natural cultural environments, intended to do sport activities, and observe wildlife. Supply maps follow the indicator of existing trekking tracks, mapped in the Open Street Maps platform (2021). The kilometers of tracks are summed for each municipality and spatialized within the municipal areas. On the other hand, the demand is related to the presence of tourist structures, considering camping sites and Agri-tourisms for coastal municipalities (in order to exclude seaside tourism) and all tourist structures for the rest of the municipalities. *C3 Mushroom picking* demand indicators follows the distribution of licenses per municipality, provided by Le Marche regional authorities. On the other hand, the supply values were calculated following the methodology by Marino et al., 2014, assuming an average annual production of 1,5-3 kg mushrooms per hectare of forested surface, though Corine Land Cover Classes 231, 243, 244, (weight 1) 311, 312, 313, 321, 322, 324, (weight 2) under 2000 m altitude and with slopes lower than 80%. We considered the DEM Marche (100 m) and extract elevation, then intersect with CLC forested areas.

Finally, *C2 Environmental education* was considered as the process of learning from nature both in formal academic programs, to complement traditional forms of learning, and in less-than-formal settings, such as through the interpretive services offered at natural parks or farms. The indicator of demand is related to population at the age of schooling (6–16-year-old) living in each municipality. The supply map is related to the location of Environmental Education Centers (CEA) and Didactic Farms (DF), recognized by Le Marche Region. Data per municipality was provided by Le Marche regional authorities and weights were assigned as follows: 3 points per each CEA and 1 per each DF.

Table 3: List of selected Ecosystem Services and indicators for supply and demand. When not specified, the unit is the same for Supply (S) and demand (D). Abbreviations: "ppl"=people; "Inhab"=inhabitants; "Lic"= licenses

Ecosystem Service	Unit	Supply indicator	Data source	Demand indicator	Data source
P1 Cereal production	Tons/year/ km^2	Cereal production per municipality	ISTAT 2019	Cereal consumption per municipality	ISMEA 2020
P2 Wine products	Tons/year/ km^2	Wine production per municipality	ISTAT 2019	Wine consumption per municipality	OIV 2014
P3 Pastoral products	L/year/ km^2	Cheese production per municipality	ISTAT 2019	Cheese consumption per municipality	CLAL 2020
P4 Drinking water	1000 m^3/ year/km^2	Water catchments by aqueducts per municipality	"Piano Regolatore Acquedotti" Marche	Water delivered by municipal networks	ISTAT 2019
P5 Hydro power	Gwh/year/ km^2	Hydroelectric nominal production of local power plants	SIGERI 2020	Housing and industrial electricity consumption	TERNA 2019
Ecosystem Service	**Unit**	**Supply indicator**	**Data source**	**Demand indicator**	**Data source**
R1 Hydraulic regulation	K (0-100) (S) Km^2 /Km^2 (D)	Water retained on total rainfall (1-CN)	SCS Curve Number method (CLC 2018)	Area at hydraulic risk on total municipal area (%)	ISTAT 2017
R2 Soil protection	Tons/Km2/ year	Potential sediment retained by soil	InVEST Sediment Delivery Ratio model (CLC 2018)	Annual soil loss by water erosion	EU dataset (JRC 2016)
R3 Crop pollination	K (0-1) (S) K (D)	Relative Pollination Potential of municipal surface	EU dataset (MAES, 2010)	Crop dependency by pollinator	Capri model (ESTIMAP 2013)
R4 Climate change regulation	Mg CO^2/km^2/ year	CO2 absorption per municipality	Emissions Data (Marche 2019)	CO2 emissions per municipality	Emissions Data (Marche 2019)
Ecosystem Service	**Unit**	**Supply indicator**	**Data source**	**Demand indicator**	**Data source**
C1 Eco-Tourism	Km/km^2 (S) ppl/km" (D)	OSM footpaths mapped per municipality	OSM (2021)	Nr. hosts at eco-tourist facilities	Marche dataset (2019)
C2 Environmental education	K/km^2 (S) Inhab /Km^2 (D)	Nr. education centers per municipality	Marche dataset (2019)	Population in schooling age per municipality	ISTAT 2019
C3 Mushroom picking	Tons/km^2/ year (S) Lic/km^2 (D)	Suitable surfaces per municipalities	Corine Land Cover (2018)	Nr. licenses per municipality	Marche dataset

3.2.3 Socio-economic characterization

For the socio-economic characterization of social-ecological systems three groups of indexes were chosen: Social, Economic and Land Use indicators. Table 4 shows the socio-economic indicators selected and their definition.

The *Social indicators* aim at highlighting the main social components of territorial systems. The S1 Demographic index measures the percentage ratio between the population of elderly age (65 years and older) and the population of young age (less than 15 years). The S2 Social and material vulnerability index estimates the vulnerability for each territory, based on 7 different dimensions of “material” and “social” vulnerability. The higher it is, the greater is the risk of discomfort in that area. The S3 Income accounts the municipal means of per capita income (euro/person).

The *Economic indicators* follow the three-sector model in economics, focusing on specific activities relevant for the study. E1 Primary sector index looks at the people employed in companies extracting raw materials, including the ATECO classes A - Agriculture, forestry and fishing and B - Extraction of minerals from quarries and mines. E2 Secondary sector index focuses on people employed in manufacturing companies, specifically the ATECO classes C - Manufacturing activities. Finally, E3 Tertiary sector considers employees from companies from the ATECO classes I - Accommodation and food service activities and R - Artistic, sporting, entertainment, and recreational activities.

The *Land Use indicators* aim to read the territory through the Corine land cover (CLC) data, calculated in municipal units through spatial analysis (QGIS). L1 Artificial surfaces reads the incidence of artificial surfaces (CLC layer 1) on the total area. L2 Agricultural surfaces looks at the incidence of agricultural surfaces (CLC layer 2) on the total area, L3 Forests and seminatural areas the incidence of Forests and seminatural areas (CLC layer 3) on the total area.

Table 4: Socio-economic indexes, relative unit, and definition. Abbreviations: "emp" stands for employed in the economy sector, "inh" stands for inhabitants of the municipality.

Social Indicator	**Unit**	**Description**
S1 Demography (population aging)	K (age/age)	The indicator represents an index of population aging, consisting in the percentage ratio between the population of elderly age (65 years and older) and the population of young age (less than 15 years).
S2 Social and material vulnerability	K	The indicator is structured through the combination of seven elementary indexes that describe the main "material" and "social" dimensions of vulnerability: 1) percentage incidence of the 25- to 64-year-old population without a degree; 2) percentage incidence of households with potential economic distress; 3) percentage incidence of households with potential welfare distress; 4) percentage incidence of population in severe housing distress; 5) percentage incidence of households with 6 or more members; 6) percentage incidence of single-parent young adult families; 7) percentage incidence of 15–29-year-olds who are inactive and not studying. The higher the value of the index, the higher the vulnerability level of the municipality.
S3 Income	Euro/inh/km^2	The indicator accounts the municipal average of total taxable per capita income. Unit: euro/person.
Economic Indicator	**Unit**	**Description**
E1 Agriculture, forestry and fishing	Emp /1000 inh / km2	The indicator considers the municipal population employed in companies of primary sector. It accounts companies of ATECO classes A - Agriculture, forestry and fishing and B - Extraction of minerals from quarries and mines.
E2 Manufacturing activities	Emp /1000 inh / km2	The indicator considers the municipal population employed in companies of secondary sector. It accounts companies of ATECO class C - Manufacturing activities.
E3 Accommodation and recreational activities	Emp /1000 inh / km2	The indicator considers the municipal population employed in companies of secondary sector. It accounts companies of ATECO classes I - Accommodation and food service activities and R - Artistic, sporting, entertainment and recreational activities. Unit:
Land use Indicator	**Unit**	**Description**
L1 Artificial surfaces	Km^2 art / km^2 tot (%)	The indicator assesses the incidence of Artificial surfaces (CLC layer 1) on the total area
L2 Agricultural surfaces	Km^2 agr / km^2 tot (%)	The indicator assesses the incidence of Agricultural surfaces (CLC layer 2) on the total area
L3 Forests and seminatural areas	Km^2 nat / km^2 tot (%)	The indicator assesses the incidence of Forests and seminatural areas (CLC layer 3) on the total area

3.2.4 Data analysis

To allow comparisons across municipalities, both ES and social-ecological indicators were spatially standardized, dividing each value by municipal area. Before analyzing the data, measurements obtained for each indicator were further normalized by maximum and minimum value, excluding the values out of range through the substitution of values differing from mean for 2x Standard deviation. The following paragraphs describes the methodology for the analysis within specific stages. The R code can be found in Appendix 3.C.

Mapping: We used QGIS 3.10.11 A Coruña to produce maps of the indicator's distribution. Each municipality was assessed using the same set of ES and socio-economic indicators, considering average values per each spatial unit. Individual maps of supply and demand were produced to visualize patterns of the single indicators. Afterwards, an analysis of hotspots and coldspots highlighted the municipalities with highest and lowest values of ES supply and demand. The value was calculated summing the normalized value of the 12 ES. The hotspots-coldspots analysis was integrated with an assessment of the multifunctionality, in order to evaluate the diversity in ES provision, which was calculated though Simpson's diversity index in R software Package: vegan (Oksanen et al., 2017).

Bundling: We defined different ES supply-demand bundle types using cluster analysis in R software package Factoextra (Kassambara and Mundt, 2020). We classified municipalities into clusters based on similar combinations of both ES supply and demand values, using K-means clustering algorithm which minimizes the variability withing the groups. A principal component analysis (PCA) was carried out to identify the main explanatory factors and distribution of the 12 ES across the municipalities. We used Rose wind chart to facilitate the visualization of ES demand and supply characteristics.

Correlation: The spatial correlation analysis was carried out using R software Corrplot package (Taiyun and Viliam, 2021). To identify weak and strong relationships (existence of synergies and tradeoffs), associations between pairs of ES were detected using Pearson parametric correlation test.

Socio-economic characterization: The socio-economic characterization was developed through the calculation of the mean value of each normalized indicator within the municipalities included in the Bundles. The results are then displayed in a bar graph according to the social, economic and land use characteristics.

Budgeting: Finally, to hypothesize flows of goods and services, the information on supply and demand of services was calculated in ES budgets as the difference between demand and supply (Burkhard et al., 2012). To visualize possible interdependencies among urban poles and inland areas, the budgets are summed within each category. To compare supply and demand indicators we reclassified in a 1-100 scales the ES R1 Hydraulic regulation, R3 Crop pollination, C1 Eco-Tourism, C2 Environmental education and C3 Mushroom picking.

3.3. Results

3.3.1 Patterns of ES Supply and Demand

This section presents an overall summary of the ES patterns of supply and demand (Figure 12), while the detailed results per each single ES can be found in the supplement material Appendix 3.A – Individual Ecosystem Services.

Within the provisioning services, the supply of P1 Cereal production highlights a main agricultural strip in the mid-low hilly area from south to north. No values are recorded in the south-western mountain areas while lower values concern the rest of the inland areas. Differently, P2 Wine products, shows a spotted concentration of production in areas recognized as DOC and DOP, such as: Rosso Conero (in the area of Ancona), Rosso Piceno (in the low Ascoli Piceno Province) and Verdicchio (area of Jesi and Matelica). Looking at the ES related to pastoral activities, P3 records productions mostly in the mountain part in the southwest and in the north of the region, while low or no values are mapped along the coast. Moving on to water resources, P4 Drinking water highlights different profiles for the northern and southern part of the region: the north offers a rather uniformed distribution with hotspots corresponding to the main water withdrawal points, while the south shows a strong supply from the mountain areas. Similarly, P5 Hydro power highlights hotspots of production in the mountain area in the southwest of the region and other municipalities along the rivers but no major differences are recorded within the regional area. In terms of ES demand, all the provisioning services show the highest values in the coast and in the main urban poles, where both population density and consumption are higher.

Regulatory service maps are linked by a consistent and marked supply in the upland and forested belt. As for the R1 Hydraulic regulation and R2 Soil protection, the maps show high values for the mountain areas while low values are mapped in low hilly fields. The R3 map refers to the relative pollination potential and follows the presence of forests and trees in the inner belt of the region. The same applies for the absorption of CO2. As for the demand, R1 and R2 highlight spots of higher pressure, in hilly areas characterized by land instability. R3 reveals the dependency of cultures from pollination especially in the hilly area devoted to fruit trees and partially oilseeds.

R4 relates to the emission of CO_2, with the map showing higher values for the municipalities of the coast, as well as the first hill belt, hosting most of the regional manufacturing activities. Interesting to note is the concentration of R4 demand in the footwear production sector located in the central south part of the Region.

Regarding the cultural services, C1 Eco-tourism relates to the indicator of available hiking paths and shows higher values in mountain municipalities and protected areas. C2 Environmental education reveals an equal spatial distribution of supply connected to the Regional Education Centers and didactic farms. Finally, the supply of C3 Mushroom picking is related to geographical condition allowing habitats for mushrooms and have higher values in forested mountain areas coinciding with the inner belt. As for the demand, C1 and C2 refer mainly to the coastal areas, while C3 gives higher values in various territorial hotspots in the region.

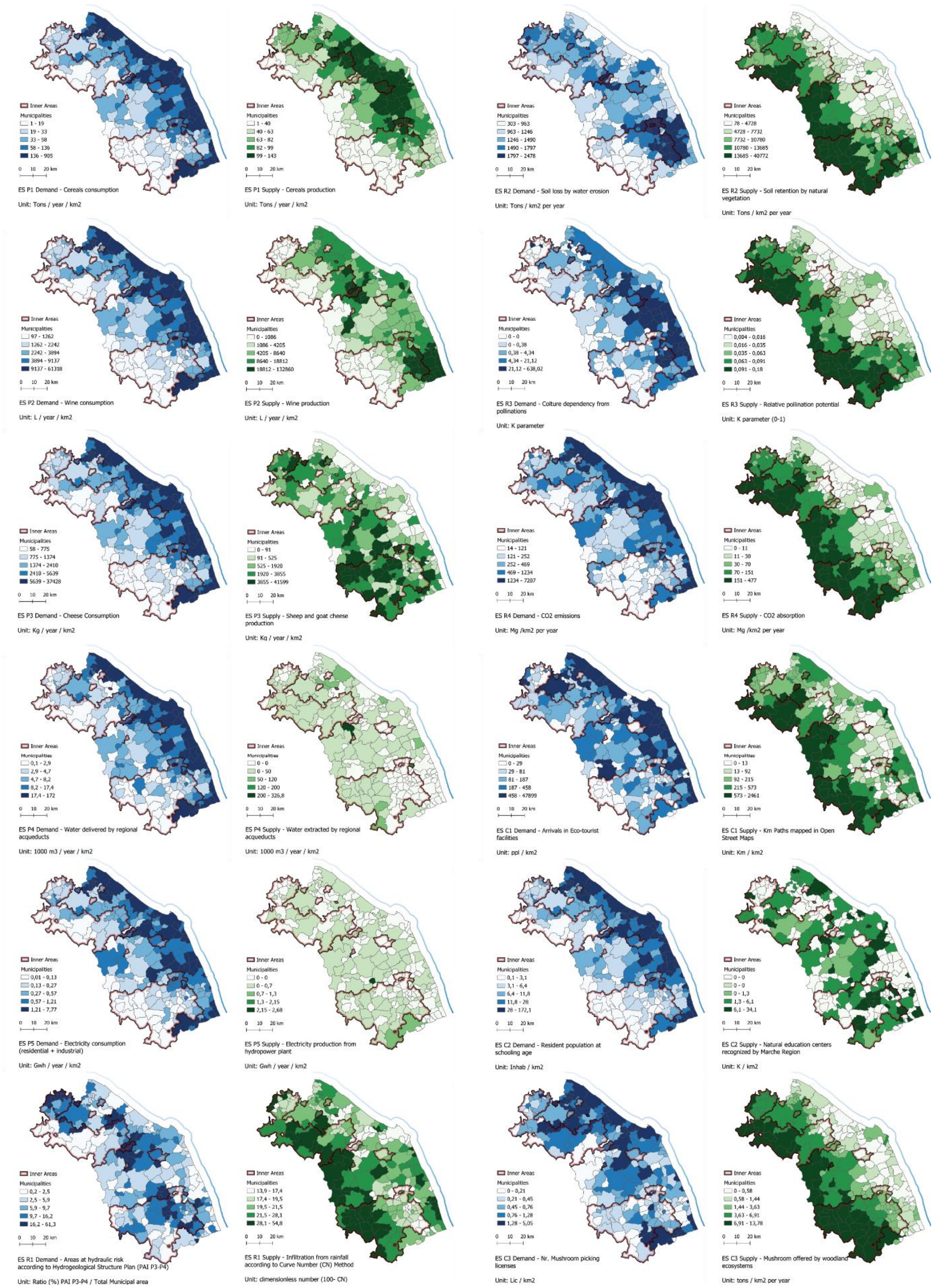

Figure 12: Maps of Ecosystem Services supply (green) and demand (blue). Single higher-definition maps can be found in the Appendix 3.B

The hotspots-coldspots analysis explores the aggregated values of ES supply and demand, highlighting the areas which mostly provide services and the ones who mostly demand them. Figure 13 suggests a strong inequality in terms of demand-supply following the inland-coastal gradient. Hotspots of supply can be found in the south-western municipalities, partly coinciding with the Sibillini National Park, and the northern part following the Apennine chain. The municipalities with low supply values are found in the coastal areas and in the first hill range, with the latter presenting the lowest values. Simultaneously, the coastal municipalities present a very high demand, with a declining gradient towards the mountains.

Together with the hotspots-coldspots analysis, we mapped the multifunctionality of each municipal area by calculating the Simpson's diversity in the ES supplied. As shown in Figure 13, the main multifunctional landscapes do not always coincide with the hotspots of ES provision, but primarily cover the upper hills and piedmont areas. Other municipalities characterized by high multifunctionality are those hosting protected areas along the coast, where provisioning services are combined with cultural and regulating services. On the other hand, low multifunctionality is associated with the first hill range, coinciding with the area of strong cereal production.

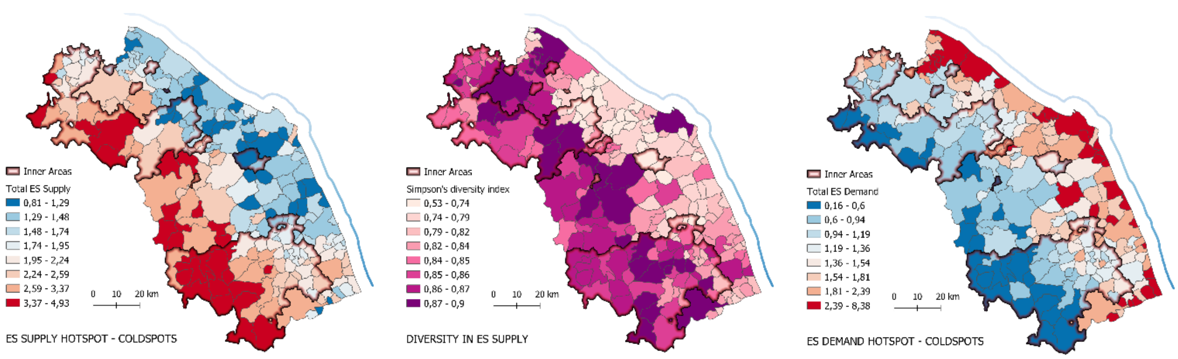

Figure 13: Hotspots-coldspots of ES supply (left), diversity in ES supply (center), hotspots-coldspots of ES Demand (right). Single higher-definition maps can be found in the appendix 3.B

3.3.2 ES Bundles: clustering ES supply and demand

The ES bundles analysis allowed to group the 228 municipalities of Le Marche Region in 5 clusters of ES supply-demand characterized by their supply-demand patterns (see Table 5), which matched the coastal-inland gradient.

Bundle 1 ("Urban coast") includes 22 municipalities corresponding to the main urban settlements of the coast, together with the small municipalities in the highly urbanized "Tronto Valley", in the southern part of the Region. The Bundle is characterized by high ES demand, which reaches the greatest mean value for all the ES except R1 Hydraulic regulation and R3 Climate change regulation (the only ones lower than 0,30). The Supply values are generally low, with the exception of P1 Cereal production reaching a mean value of 0,48. Interestingly, the provision of C2 Environmental education, mapped through the indicator of education structures officially recognized by the Region, presents the highest value among the five clusters (0,32).

Bundle 2 includes 58 municipalities and is named "Cropland" due to the highest values in P1 Agricultural products (0,69). It consists of hilly rural units together with sub-urban municipalities also located along the coast, but with lower population density than the ones of Bundle 1. In terms of ES Demand, it displays moderately high values for all the ES except for P4 Drinking water, R1 Hydraulic regulation, R3 Climate change regulation and C1 Eco-tourism (lower than 30). In terms of ES Supply, it presents a similar condition as for the urban coastal, with a higher value in P1 (0,69) and slightly lower values for the other ES.

Table 5: Bundles mean values for indicators of ES supply and demand

BUNDLE	DEMAND											
	P1	P2	P3	P4	P5	R1	R2	R3	R4	C1	C2	C3
B1 Urban coastal	0,92	0,92	0,92	0,85	0,83	0,14	0,34	0,13	0,86	0,33	0,95	0,75
B2 Cropland	0,33	0,33	0,33	0,27	0,38	0,25	0,45	0,14	0,31	0,11	0,36	0,38
B3 Cropland at hydraulic risk	0,13	0,13	0,13	0,12	0,14	0,47	0,78	0,22	0,13	0,02	0,13	0,16
B4 Mosaic cropland forest	0,09	0,09	0,09	0,08	0,10	0,43	0,53	0,02	0,09	0,02	0,09	0,27
B5 Mountain forests	0,03	0,03	0,03	0,05	0,03	0,16	0,21	0,00	0,05	0,01	0,03	0,14

BUNDLE	SUPPLY											
	P1	P2	P3	P4	P5	R1	R2	R3	R4	C1	C2	C3
B1 Urban coastal	0,48	0,32	0,11	0,22	0,12	0,37	0,17	0,20	0,11	0,21	0,32	0,07
B2 Cropland	0,69	0,17	0,07	0,10	0,06	0,26	0,19	0,12	0,06	0,10	0,17	0,07
B3 Cropland at hydraulic risk	0,61	0,47	0,25	0,03	0,09	0,21	0,40	0,32	0,13	0,08	0,26	0,16
B4 Mosaic cropland forest	0,46	0,07	0,27	0,06	0,05	0,31	0,45	0,53	0,45	0,25	0,14	0,49
B5 Mountain forests	0,14	0,02	0,23	0,23	0,10	0,73	0,78	0,80	0,77	0,72	0,16	0,89

Bundle 3 (‘‘Cropland at hydraulic risk”) includes a similar number of municipality than Bundle 2 (57) and differs from it mainly for the presence of a strong demand for R2 Soil protection and, to a lesser extent, for R1 Hydraulic regulation. Except for the three regulation services, all the other ES Demand present lower values than the first two clusters (all below 0.20), mostly related to the lower population density. In terms of ES supply, the slight decrease in P1 Agricultural products is accompanied by a sharp increase in P2 Wine products. This suggests a possible connection between the cultivation of Wine trees and hydraulic instability and, interestingly, the greater demand for hydraulic protection is also associated with greater supply of the service.

Bundle 4, named ‘‘Mosaic cropland forest”, groups those municipalities (n=51) located in the high hills and in the piedmont areas of the regions. In terms of ES demand, values drop for almost all ES except C3 Mushroom picking (0,27) and the regulatory services. Those services decrease compared to Bundle 2, but remain high with a value of 0,45 for R1 Hydraulic regulation and 0,53 for R2 Soil protection. With respect to the supply, the decrease in P1 agricultural products (which anyway presents a moderate level (0,46)) is combined with an increase in all regulatory services (all higher than 0,30), together with C1 Eco-tourism (0,25) and C3 Mushroom picking (0,49).

Finally, ***Bundle 5*** is called ‘‘Mountain forests” (n = 40) as it clusters municipalities characterized by high altitude and a great amount of woodland and natural areas. This area hosts only a few large urban settlements and agriculture is absent or minor. This bundle shows by far the highest supply values for all regulating services (all above 0,70) and recreational services as C3 Mushroom picking (0,89) and C1 Eco-tourism (0,72). Services related to water reveal the highest supply of P4 Drinking water (0,23) and the second highest for P5 Hydropower (0,10). In terms of ES demand, the values are the lowest for all the services.

The PCA analysis illustrates the bundles composition in a two-dimensional graph, with Dim1 and Dim2 explaining 39% and 19,1 % of the total variance respectively. Explaining most of the differences, Dim1 relates to the altitude gradient, from high mountain areas to low coastal areas through the hilly municipalities in the central part of the region. The gradient is also linked with the decreasing population density from mountain to coast and the consequent demand for ES. Associated to Land Use features, Dim2 has minor significance and cannot be related to specific municipal characteristics. The graph shows how municipalities included in C1 Urban Coastal and C5 Mountain Forest are noticeably separate from the rest, while C2, C3 and C4 have multiple intersections. Together with the spatial map and the visualization of ES values through wind rose charts, Figure 14 presents the ES Bundles characterization in Le Marche regional case study.

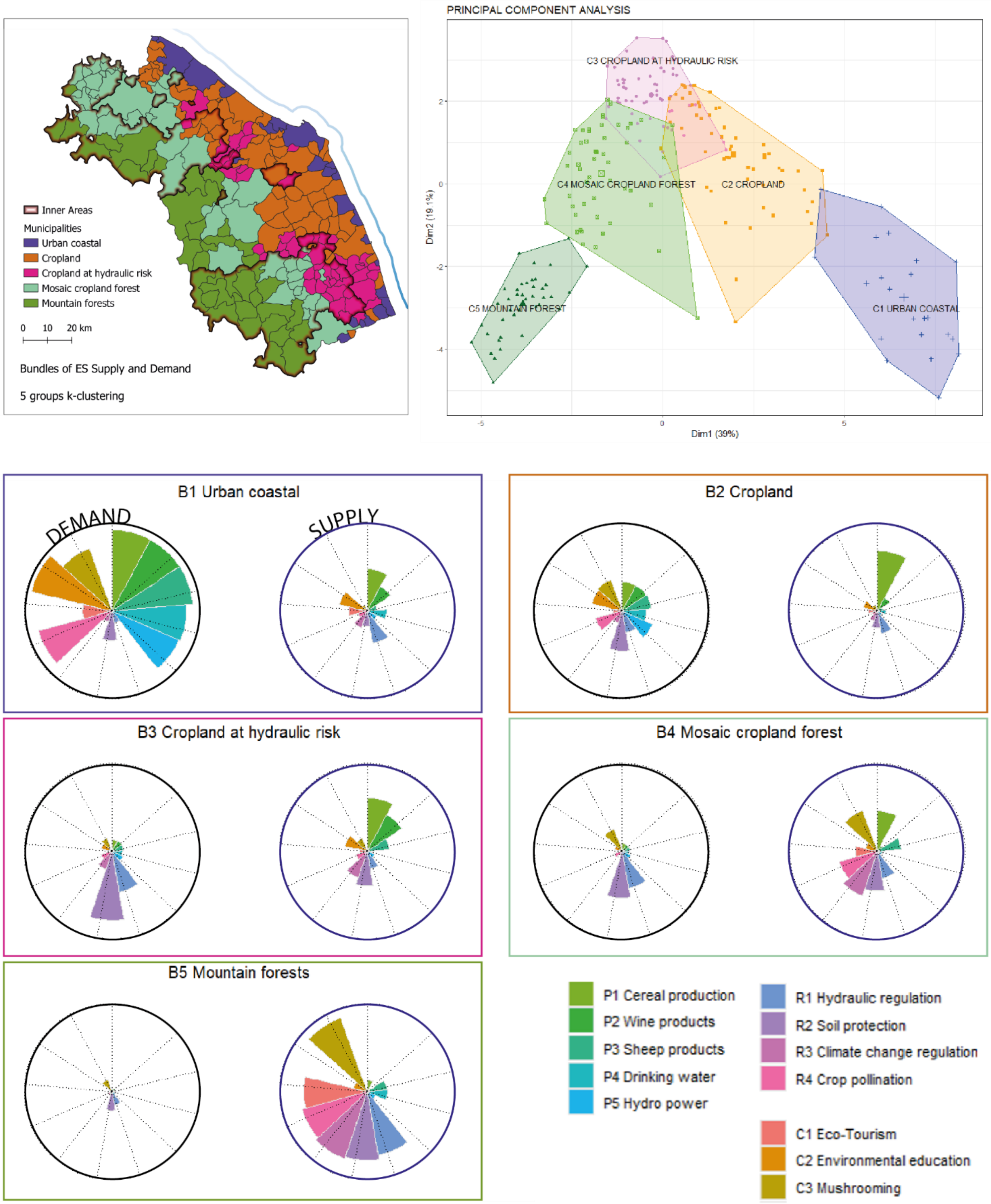

Figure 14: Regional map of ES Bundles (up-left), Principal component analysis (up-right) and Rose wind charts of ES indicators (Bottom). The charts indicate normalized values of supply (right circle) and demand (left circle).

3.3.3 Social-ecological systems: Socio-economic patterns and ES associations

Figure 15 shows a summary of the spatial patterns of socio-economic indicators (the single maps can be found in the supplementary materials – Appendix 3.C). Looking at social indicators, S1 Demographic index shows clear imbalances between inland areas and urban poles with younger residents mapped in the coastal municipalities and the inland systems at serious risk of depopulation. The map of S2 Social and material vulnerability displays a variety of results across the region, with high values of the indicator mostly in the central southern part of the region. S3 highlights a clear link between income of population and the inland areas limits, with the inland municipalities presenting lowest regional per capita income values.

As for the economic indicators, the E1 reveals a significant prominence of Agriculture, forestry and fishing sector for the south of the region. The indicator E2 related to manufacturing activities presents the highest values for the sub-urban municipalities close to the Urban coastal continuum. Finally, the accommodation and recreational activities (E3) highlights peak values in the coastal southern municipalities (probably connected to seaside tourism) and individual hotspots in the inner side of the region. It should be noted that the mapping presents in the case of economic indicators higher values for smaller municipalities.

As for the Land Use, L1 shows the incidence of Artificial surfaces on the total municipal value and emphasizes a clear contrast between the coastal municipalities and the inner territories. The map shows artificial land use strips infiltrating from the coast toward the mountains especially in one central and one southern valley of the region. L2 highlights a central low-hill area, close to the seaside, dedicated to agriculture, in opposition to low – close to zero – values in the mountain municipalities. L3 shows a mountain belt of woodland and seminatural areas, with lower-altitude spots connected to protected areas closer to the coast.

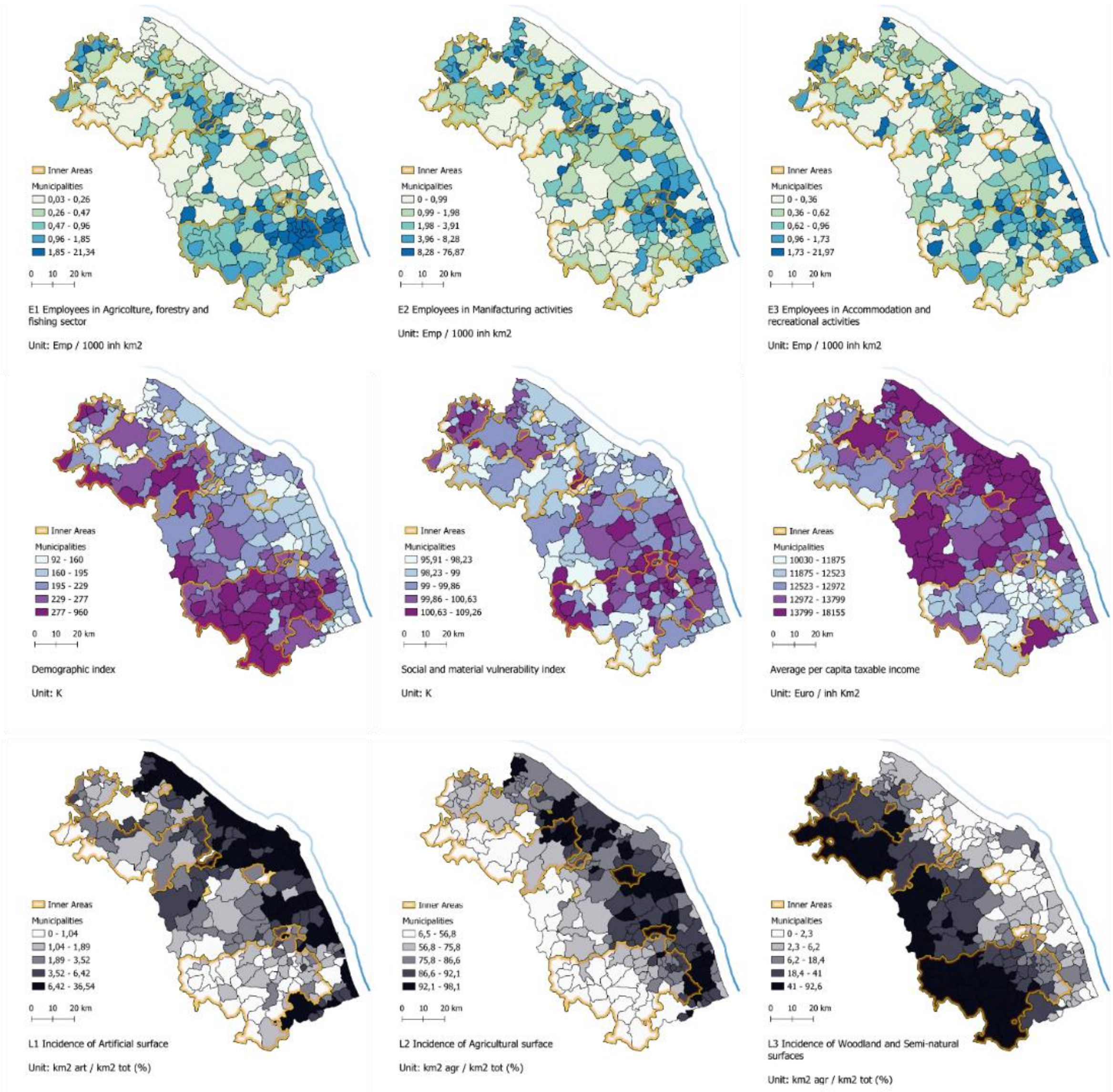

Figure 15: Spatial patterns of socio-economic indicators. Single higher-definition maps can be found in the Appendix 3.C

Socio-economic characterization of Bundles

The correlation analysis shows that socio-economic indicators are mostly significant in characterizing the five detected bundles. Especially, among the social indicators, the most significant correlation is found in S1 Demography (cor = 0.45) and S3 Income (-0.31). The positive correlation between Bundles number (as defined from B1-B5) and aging index proves a tendency of aging of population along the coastal-mountain gradient, while the negative correlation of the income shows how wealth decreases towards mountain areas. On the other hand, S2 Vulnerability does not show significant correlation with the bundles structure (p-value > 0,05). As for the Economic indicators, E1 Agriculture does not present a significant correlation, while E2 Manufacturing and E3 Accommodation and recreation have a less significant correlation (respectively cor = -0.14 and cor = -0.22). Finally, the Land Use indicators show correlation values over 0,6 and prove to be useful to characterize the ES bundles. The values of L1 Artificial areas characterize mostly the B1 Urban bundle (46% or land use), with lower values for all the other bundles. L2 Agricultural areas describes the best bundles B2 and B3 (respectively 91% and 90%), but also highlighting moderate values in B1 Urban areas (79%) and B4 Mosaic cropland forest (66%). Last, L3 Woodland and seminatural areas gives the highest values in B5 Mountain forest (70%), followed by B4 Mosaic cropland forest (34%). Figure 16 shows the socio-economic data according to the significance of the indicator to characterize the bundles.

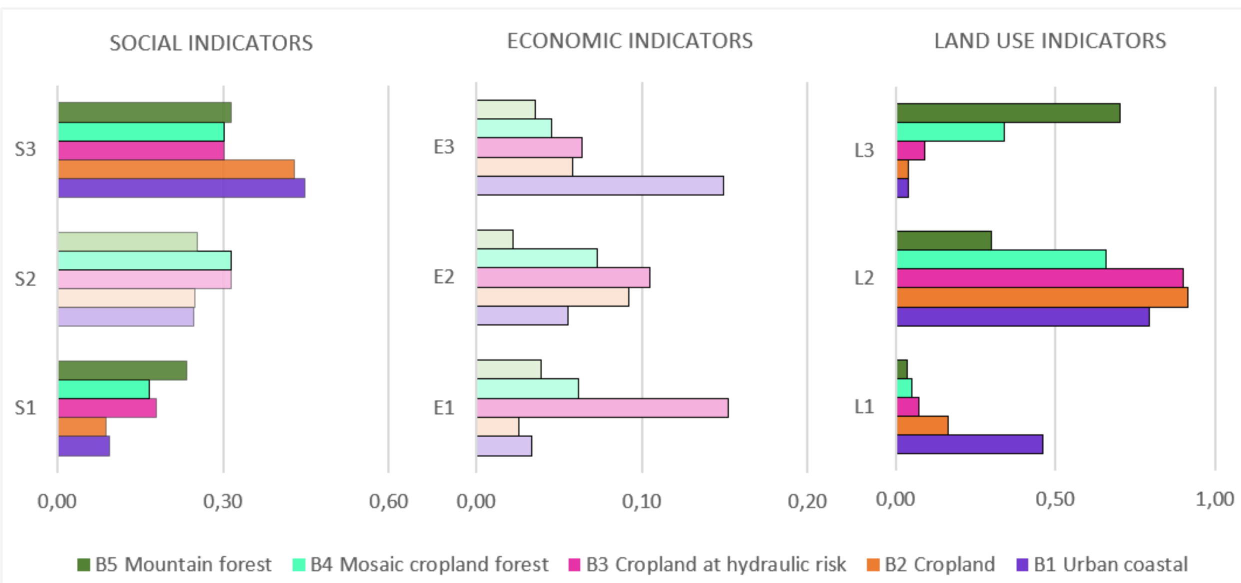

Figure 16: Socio-economic characterization of the ES Bundles. The bars indicate average normalized values of the socio-economic indicators within the municipalities included in the Bundles. Transparency indicates low correlation between the indicator and the bundles categories

ES Trade-offs and synergies

The Pearson parametric test between pairs of ES indicators showed significant correlations among many ES in the case study of Le Marche region (*Figure 17*). Especially, we observed a pattern of trade-offs, first between the supply of P1 Agricultural products and all the regulation services, together with C1 Eco-tourism and C3 Mushroom picking. Smaller negative correlation was also detected between those services and P2 Wine products. In terms of demand, light trade-offs can be noticed between the demand of R1 Hydraulic regulation and the provisioning services, and also between the demand of R1 Hydraulic regulation and R2 Soil protection and the cultural services and R4 Crop Pollination. Looking at synergies, strong positive correlation was found among the supply of all the Regulating services, together with C1 Eco-tourism and C3 Mushroom picking. In terms of demand, very strong synergy was found between the demand of all the provisioning services, R4 Climate change regulation and C2 Environmental education, probably related to population density. Also, C1 Eco-tourism and C3 Mushroom picking showed a significant correlation with the urban demand areas. When comparing areas of supply with areas of demand, *Figure 17* shows that the correlation is often absent or very low, proving how the areas of demand differ from areas of supply. Regarding the Diversity index, a strongest negative correlation is shown in relation to P1, reinforcing the results denoting agricultural production as a limit factor for the supply of other services. On the other hand, a positive correlation is shown within the regulation services, C1 Eco-tourism and C3 Mushroom picking.

Linking socio-economic variables with Ecosystem Services

To explore links between ES behavior and local characteristics, the correlation analysis dedicates a deeper look with respect to socioeconomic characteristics. In terms of the S1 Demography index, referring to aging of the population, it is possible to observe: i) a weak negative correlation with the supply of P1 cereal production, ii) weak positive correlations with the supply of all the regulating services and Eco-tourism and Mushroom picking, iii) a negative correlation with the demand of the majority of ES and iv) a positive correlation with the Diversity in ES Supply. While with S2 there are no relevant correlations observed, the situation with S3 is mirrored to S1.

Economic indexes do not show noticeable associations, with the only exception of a minor positive correlation between E1 and the P2 supply and R3 Demand. On the other hand, land use indexes represent the main factors characterizing the bundles. L1 Artificial surfaces shows light negative correlation with P3 Pastoral products and very negative with all the regulation services, Eco-tourism and Mushroom picking. On the other hand, very positive correlation is found with the demand of all provisioning services, crop pollination and the cultural services. In terms of L2 Agricultural surfaces a strong positive correlation can be noticed with P1 Cereal production and, lighter, with P2 Wine products. Negative correlations are displayed with all the regulation services, eco-tourism and Mushroom picking. Concerning the demand, Figure 17 shows light positive correlation with almost all the ES indicators (except for eco-tourism). Finally, L3 Forests and seminatural areas display negative correlation with P1 Cereal production, and lightly also with P2 wine products. Positive correlations are found with all the regulating services, C1 eco-tourism and C3 Mushroom picking. In terms of demand, a light negative correlation can be found with almost all the demand.

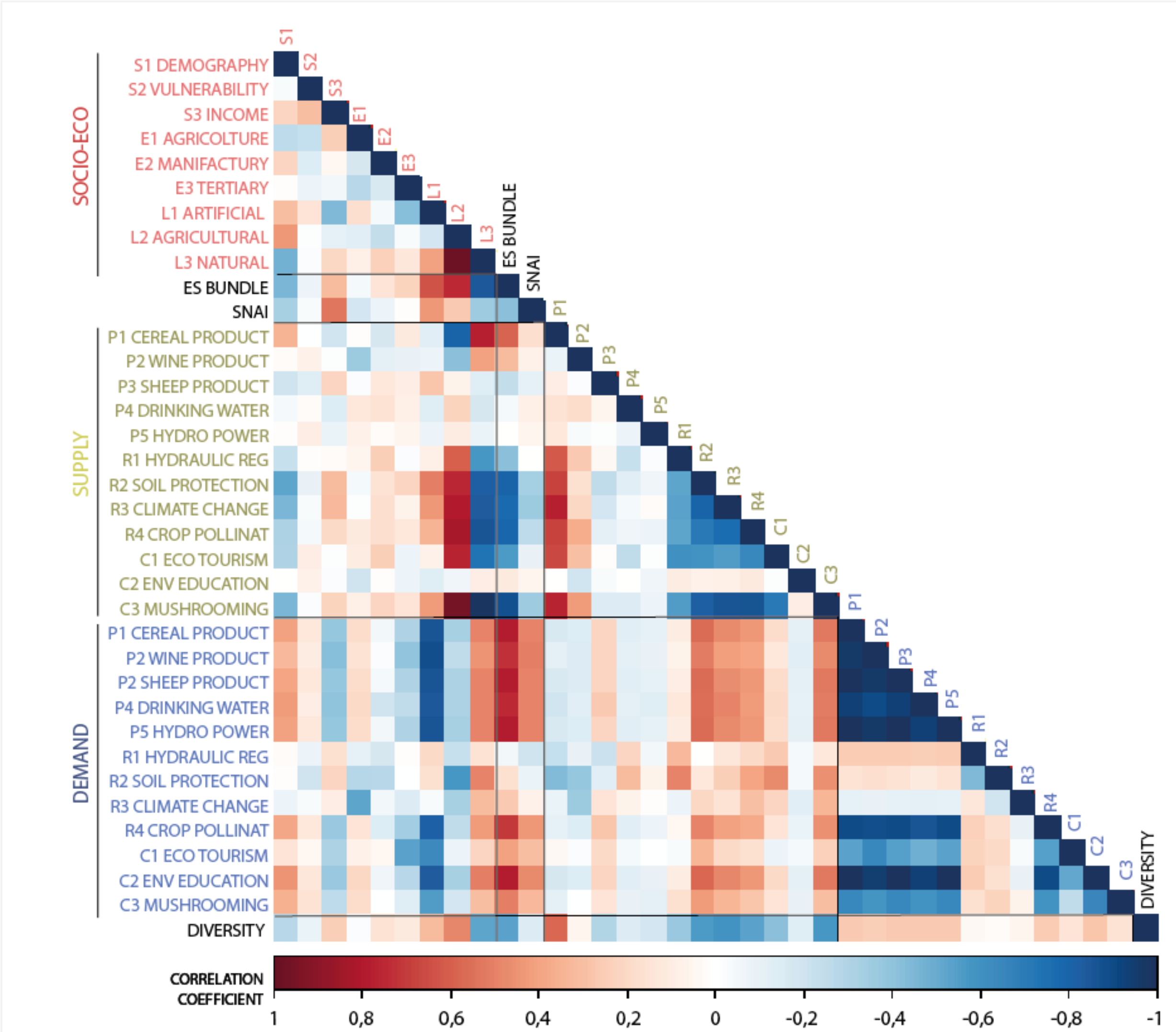

Figure 17: Spatial correlation between ES demand indicators (left) and ES Supply indicators (right)

3.3.4 Interdependencies among urban and inland systems

A strong correspondence was found between the composition of Bundles with respect to the SNAI classification (Figure 18). This is particularly clear for the Bundle B1 which includes the main urban and intermunicipal poles, together with belt areas. Similarly, B5 and B4 are mostly dominated by outermost and peripheral inland areas. Focusing on the Bundles gradient from the coast to the mountains, the graph shows a general trend of growing number of inland municipalities and declining of belt areas. Nevertheless, it is interesting to notice how the urban poles are still present in the Bundle B5. This result draws the picture of a polycentric territory, with major settlements also part of the mountain bundles. Lastly, noteworthy is the absence of urban poles from B3, characterizing the Bundle as lower population density.

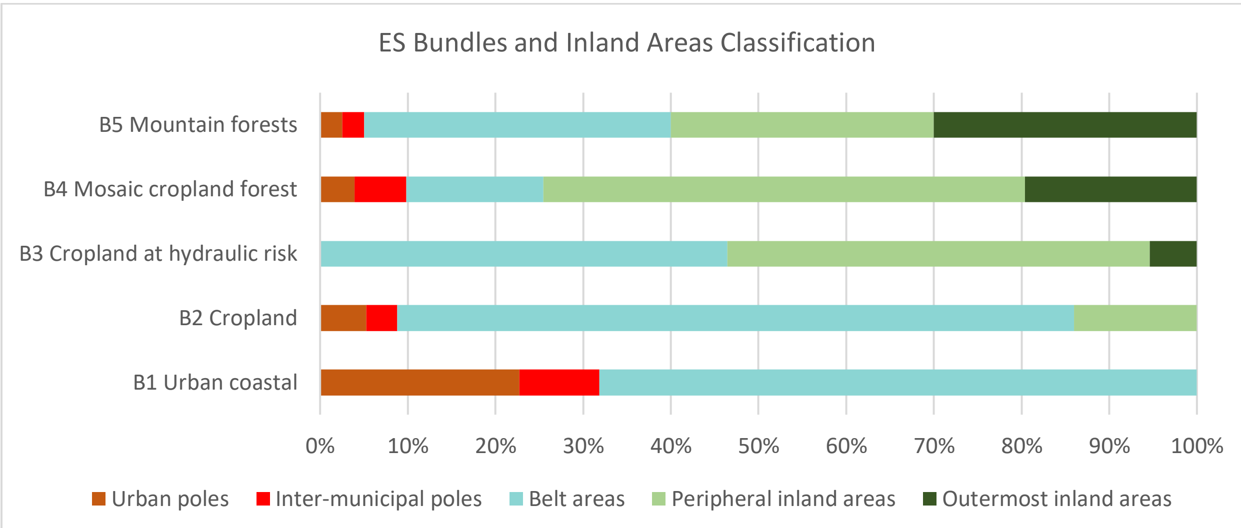

Figure 18: Characterization of ES Bundles in respect of the SNAI Inland Areas classification.

Figure 19 shows the supply-demand budget within the SNAI municipal categories. It demonstrates the extent to which each category has a deficit or a surplus within Provisioning, regulating and cultural services.

Starting from the Provisioning services, it is possible to observe how the budget of ES P1, P2 and P3 for Urban Poles gives a deficit, with a peak on P2 (-0,45) and P3 (-0,56). Similarly Inter-municipal poles present minus values except for a net value for P1. On the other hand, Inland areas offers a surplus for all the values, reaching the maximum in the ES P1 (+0,41). Looking at the water resources, the picture of dependency of Poles toward inland areas becomes lighter: the strong deficit presented by the Urban poles (-0,34 for P4 and -0,52 for P5) is not matched by a strong supply by the Peripheral inland areas, which have a surplus of only 0,14 for P4 and 0,06 for P5. As for the rest of the municipalities, Peripheral inland areas present an approx. net value and the Belt areas a lighter but still relevant deficit: -0,16 for P4 and -0,26 for P5.

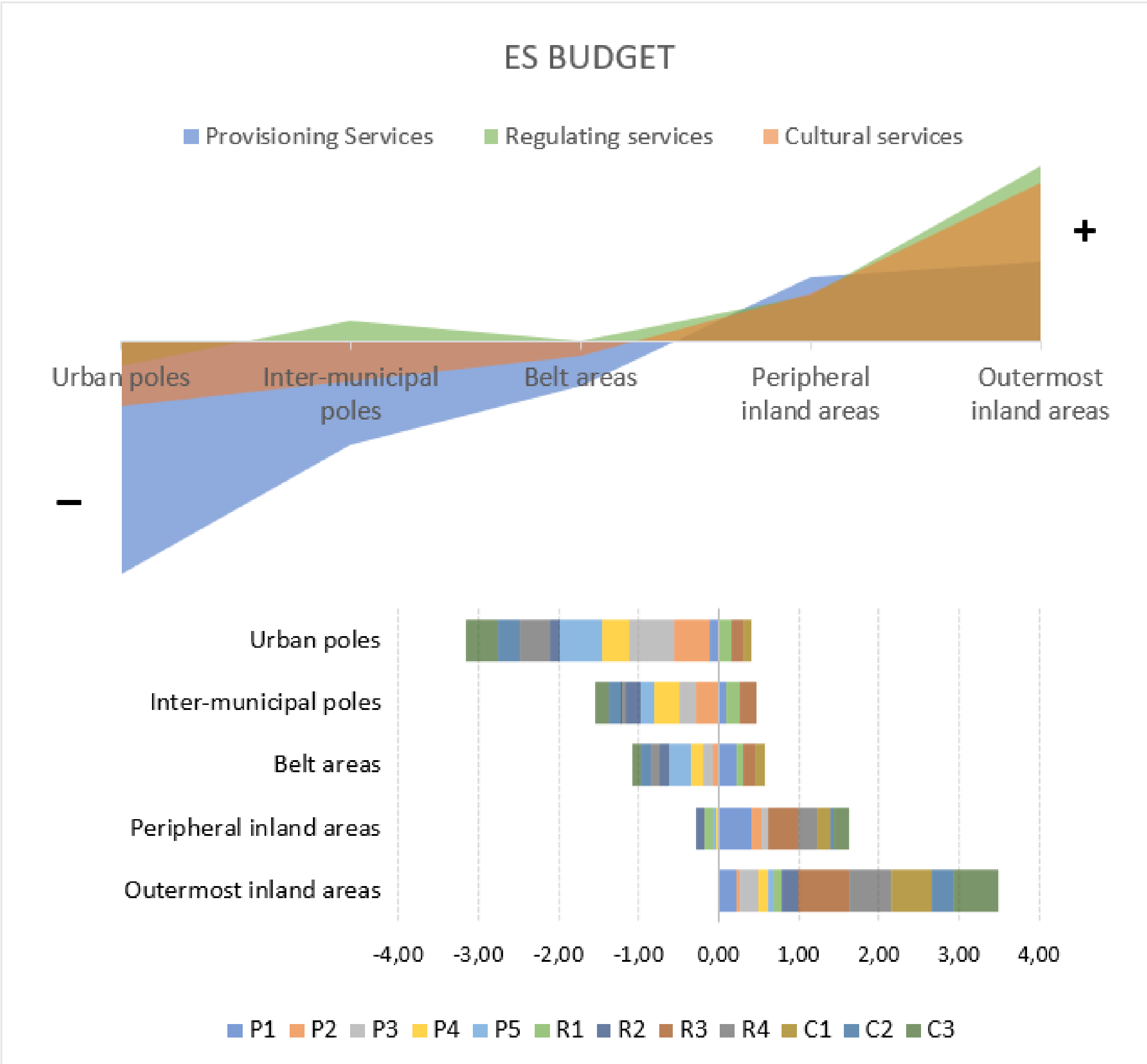

Figure 19: Area chart (up) of the ES categories Budget for each SNAI municipal category, and bar chart (bottom) summing up deficit and surplus per each ES

Concerning regulating services, R1 Hydraulic regulation and R2 Soil protection have differing patterns. In the case of Hydraulic regulation, Urban and intermunicipal poles give positive values, respectively 0,15 and 0,19, while soil protection yields negative values of -0,12 and -0,19. Interestingly, the peripheral inland areas present deficits both for R1 (-0,09) and R2 (-0,12). Regarding services related to biological cycles, the R3 Pollination shows a positive balance for all the municipal categories, whereas the Climate Change regulation (R4) reveals another imbalance, with large deficits connected to urban poles and surpluses in budget within inland municipalities.

Finally, cultural services are considered. Surprisingly, C1 Eco-tourism presents a positive budget for all the municipal categories (except a net value for Inter-municipal poles), with the peak reached by Outermost inland areas reaching a value of +0,50. On the other hand, C2 Education and C3 Mushroom picking show strong deficit for urban poles (respectively -0,27 and -0,40) and surplus values in Outermost inland areas (+0,27 and +0,56). However, as supply and demand values for cultural services were reclassified from different units it is important to note that the comparison has no values in absolute numbers but only in spatial terms.

3.4. Discussion

3.4.1 Patterns of social-ecological interaction using ES Bundles

The study proved useful in characterizing landscapes as social-ecological systems relating ES patterns to local socio-economic characteristics. In respect to other researches applying the concept of Bundles in the relation between demand and supply of ES (Baró et al., 2017a; Peng et al., 2020; Queiroz et al., 2015; Quintas-Soriano et al., 2019), the present work integrated the ES analysis with a socio-economic characterization, allowing the interpretation of patterns of human-nature interactions. These patterns are the result of complex interactions associated with local, historical and cultural processes (Antrop, 2005), which in Le Marche as in other Mediterranean regions, are shaped by the combination of the ecological and biophysical assets, together with local management practices (Balzan et al., 2018; Blondel, 2006). The Bundles analysis identified 5 landscape systems based on 12 ES supply and demand which were then characterized through 9 socio-economic indicators.

The regional landscape systems can be interpreted along a coastal-mountain gradient drawn by the raising of altitude and decreasing of population density. Further characterized in other studies through land cover characteristics (e.g. agricultural land cover in Queiroz et al., 2015 and Quintas-Soriano et al., 2019), here the urban-inland classification highlights a polycentric regional feature that locates major urban poles also in mountain Bundles. This validates the limitation of the urban-rural dichotomy beyond metropolitan areas, where local characteristics are not captured through regional-scale analysis (Grêt-Regamey et al., 2014). In our study, the urban Bundle includes coastal areas and small urbanized municipalities along the valleys, excluding major inland urban centers characterized by lower population density. Hilly and valley municipalities which don't fall in the urban system are part of Bundles 2 and 3, named "Cropland" and "Cropland at hydraulic risk". In this context, several studies show how maximizing agricultural production is likely to have effects in the decrease of regulatory services (Balzan et al., 2020; Felipe-Lucia et al., 2020). As regulating services are rarely the main emphasis of trade-offs, but often are the most impacted (Turkelboom et al., 2018), it is important to connect the socio-economic patterns with the provision of ES. The regional case study presents a picture of small-scale and diverse farming systems in synergy with local ecosystems (Bevilacqua, 2013), nevertheless, the analysis indicates a relevant trade-off between agricultural production and the set of regulating ES.

Following along the coastal-mountain gradient, the bundles 4 and 5 ("Mosaic cropland forest" and "Mountain Forest") correspond to those landscapes hosting a share of woodland and seminatural areas. While bundle 4 is still characterized by minor agricultural activities (and consequent ES supply of cereal production), bundle 5 shows high levels of all services related to forested land use (Balzan et al., 2020). Confirming findings advanced by other studies (e.g. Baró et al., 2017; Felipe-Lucia et al., 2018; Raudsepp-Hearne et al., 2010), a strong synergy is displayed in forested mountain areas between regulating and recreational services. In these systems, the ecological benefits associated with afforestation are linked to recreational opportunities and aesthetics appreciation, which are also associated with the presence of built infrastructure and human activities (Langemeyer et al., 2018).

3.4.2 Implications for sustainable landscape development

This study offers key elements for the sustainable development of landscapes as the information on ES patterns is proved to be useful for landscape planning by many practitioners (Albert et al., 2014; Mascarenhas et al., 2014). The added value lies in improved opportunities for integrating local assets in management measures, accounting trade-offs and synergies within local stakeholders and developing targeted response measures (Albert et al., 2016). We highlight in this section three key elements for regional landscape planning related respectively to i) the preservation of the identity of inland systems by supporting local ecosystem management and responsible ecotourism strategies, ii) the enhancement of sustainable agriculture through small-scale farming and sustainable practices (also in relation to CAP), iii) a special attention on multifunctional landscape management practices, such as pastoralism.

The first regards the management of inland systems under economic and demographic instability. From a socio-economic perspective, the inland systems are characterized in our study by a high aging rate and low incomes. Those trends are confirmed in other Mediterranean regions (Balzan et al., 2020) and poses major challenges to regional planning for their impact in land management (Bruno et al., 2021). While abandonment in remote ecosystems carries along reforestation and a consequent increase in regulatory services, such as water regulation and soil retention, it is also important to ensure forest management to increase structural heterogeneity and therefore the supply of multiple ES (Felipe-Lucia et al., 2018). Traditional management practices can be promoted through the enhancement of eco-tourism strategies, based on a fruitful interaction with local systems (Aretano et al., 2013). In our mapping for Le Marche Region, high supply values in recreational services may indicate a potential development also confirmed by national strategies (MIBACT, 2017). However, tourism development must take into account possible treats for the cultural identity of an area, together with possible degradation of natural systems due to mass tourism and the impact of the relative infrastructure (Gössling, 2002).

The second element regards the sustainable management of agricultural land. As we known, the maximization of provisioning services also leads to changes in ecosystem functioning and biodiversity loss (Felipe-Lucia et al., 2020). These trends are partly mitigated in Le Marche regional case study by the growing rates of organic production (SINAB, 2020) and the small-scale system which characterizes local agriculture (Bevilacqua, 2013). This latter factor is increasingly addressed by the literature as a crucial factor for supporting biodiversity. Tscharntke et al., (2021) argues that increases in cropland heterogeneity with at least 20% seminatural habitat per landscape should be a key recommendation in current biodiversity frameworks. This topic is today at the center of a major political debate as the common agricultural policy (CAP) 2021-27 is being discussed. Despite the poor expected positive benefits in terms of environmental protection and climate change mitigation (Pe'er et al., 2019), the new CAP embraces eco-schemes based on the needs and priorities identified at national/regional level. In this sense, regional governance can move in the direction of integrating local assets into new programming.

Finally, we underline a third element connected to landscape multifunctionality, considered crucial for biodiversity conservation and human well-being (Balzan et al., 2020). Although mountain landscapes have the greatest ES supply, the regional case study associates foothill landscapes with the greatest diversity rate. In addition to conservation approaches, which are already implemented in the region, practices that balance agricultural productivity with social-ecological benefits should be promoted as agri-environmental measures (Iniesta-Arandia et al., 2015). This is the case of pastoralism, which in our study relates to the inland systems. This practice is considered a main factor for shaping cultural landscapes, as well as a practice of biodiversity protection (Oteros-Rozas et al., 2014). Globally declining (Dong et al., 2011), pastoral systems are considered to be vulnerable and should be supported for the variety of services they provide, including food security in a climate change (Krätli et al., 2013).

3.4.3 Implications for regional cohesion

Cohesion strategies aiming at equitable and just regional development must build on existing territorial links and interdependencies. The study showed how urban development is strictly based on its linkage with inland areas on which it depends for the availability of natural resources (Gebre and Gebremedhin, 2019). This dependency concerns all the 12 ES taken into account and leads to relevant consequences in terms of environmental equity (Bennett et al., 2015; Pascual et al., 2014).

Among the main results, the study associates the lowest income to the main hotspots of ES supply. Those partially coincide with inland areas which are characterized by an income gap with urban poles (Romagnoli and Mastronardi, 2020). To address this gap from a ES perspective, a growing number of policies apply the concept of PES (Payment for Ecosystem Services) to promote environmental conservation and social development goals (Wunder et al., 2020). However, the PES strategies are often designed on a single environmental objective (e.g., compensation for the delivery of fresh water form coastal to mountain municipalities), and single-objective approaches are proved to show limitation in fostering fair and balanced development (Benra et al., 2022). Pascual et al., 2014 stress how the support should go beyond the distribution of income or benefits, but rather take into consideration the different dimensions of equity. Those also involve procedural dimensions including the role of local actors in decision-making and their cultural identities, values and knowledge systems (Pascual et al., 2014).

In the context of regional development, place-based strategies aim at integrating the local assets and knowledge in the design and delivery of public policies (Barca et al., 2012). It is opposed to spatially blind provision of public subsidies that have characterized the past welfare policies for inland areas in Italy (Viesti, 2016). Though place-neutral policies, public subsidies have led to the sole outcome of reducing social tensions, weakening the political weight of inland areas (Barca, 2018). The ES perspective, on the other hand, can support the characterization of local assets emphasizing the role and perspective of local actors in landscape management (Felipe-Lucia et al., 2015). Especially in Mediterranean areas, integrated methodologies and stakeholders' involvement have been scarcely applied (Nieto-Romero et al., 2014) and it is crucial that cohesion policies support participatory processes when defining interventions. It is especially relevant as responses to trade-offs depend on the level of awareness of stakeholders (Turkelboom et al., 2018) and the civic engagement itself constitutes social-ecological process that directly generates ES and benefits for human well-being (Krasny et al., 2014).

The regional cohesion can be further analyzed through the actual flow between areas of supply and demand classifying ES according to their proximity and suitability of use (Burkhard et al., 2014). While the food services are considered "*decoupled*" as they can be transported and imported from elsewhere, others, such as fresh water, hydraulic risk and soil protection can be seen as *proximal*, as the user systems need to be geographically related to providing areas (Baró et al., 2017a). This poses a certain urgency in the management of proximity services. The regional case study shows how urban areas are dependent on inland systems for the provision of regulating services, where changes in supply systems might have direct effects on the land stability of the regional systems.

3.4.4 Avenues for future research

A growing field of research investigates the effects that ES demand in one place can have in the socio-ecological dynamics of a distant place (Sonderegger et al., 2020). This field is addressed within the definition of "telecoupling", which takes into account cross-scale social relations, as decisions made at local scales are often shaped by actors at larger scales (Martín-López et al., 2019). Its integration into the regional study could lead to interesting insights about environmental equity beyond the local dimension.

Within regional boundaries, the service flow analysis could be further investigated to highlight stakeholders' power relations. Aspects such as land stewardship, access rights, and governance systems are stressed to be important in the definition of relationships between supply and demand for ES (Felipe-Lucia et al., 2015). Furthermore, Mapping Cultural ES through social analysis (questionnaires, participatory mapping, focus groups), can partly compensate the simplification given by indicators in assessing social-ecological phenomena (Baró et al., 2017a).

This study represents a first stone for the construction of Le Marche regional Green Infrastructure. Data on ES supply can support the establishment of robust decision support tools to facilitate decision making in land use management, to balance food production from agriculture sector as well as environmental protection (Morri and Santolini, 2022). A comparison of the ES Bundles with the existing regional ecological networks (REM) could further investigate the topic of biodiversity and ecological connectivity.

3.5 Towards a recognition of territorial interdependencies

The ES assessment proved to be a powerful tool to analyze landscapes as social-ecological systems. The study highlighted bundles of ES supply and demand further explaining them as landscape units associated to local socio-economic assets. This allowed to propose management practices for sustainable landscape development. Furthermore, ES supply and demand were explored in terms of budgets within urban poles and inland areas as classified by the SNAI. The exercise underlined existing dependencies of urban towards inland systems in terms of environmental resources.

ES patterns are mostly shaped by spatial socio-cultural conditions, especially land use, demography, and income. Integrating these features in cohesion strategies can support regional governance in the path toward more equitable and sustainable development. Analyzing interdependencies beyond the urban-rural dichotomy enabled the study to recognize the polycentric characteristic of the regional case study which also presents urban conditions in mountain forest bundles. As for tradeoffs between services, they were found especially in agricultural areas, between the supply of provisioning and regulating services, while synergies characterize the mountain systems where a set of regulating and cultural services are supplied. In relation to this and the global pressures facing inland ecosystems, we offered suggestions for sustainable landscape planning.

We demonstrated how areas of demand differ from areas of supply and concentrate in the most densely populated areas. We suggest that cohesion policies should embed a place-based approach integrating local characteristics in the strategies for regional development. This needs to be pursued by involving stakeholders, whose perspective is needed to ensure a balanced and sustainable development within regions.

This chapter contributed to the thesis objective of developing a mapping approach for landscapes as social-ecological systems, which is capable of highlighting spatial interdependencies between local systems. In particular, recommendations to planning can be offered in terms of 1) the integration of multi-sectoral governance; 2) the development of a territorial approach through systems of municipalities; 3) the contribution of an ecological perspective to territorial cohesion.

Above all, this third aspect makes it possible to create a new narrative on spatial interdependencies, in which inland areas can be central to the provision of ES.

Chapter 4: Including the perspective of social actors in landscape planning through the ecosystem service co-production framework: an empirical exploration.

Abstract

Research on ES has become a dominant field in landscape management, for framing the relationship between people and nature. Although ES are defined as “the benefits society derives from ecosystems”, a growing body of literature is stressing how benefits from nature to people does not occur independently but in most of the cases require a significant human contribution, addressed through the concept of ES co-production. In this frame, the contribution of social systems to ES co-production remains unclear, it’s not clear how different stakeholders depend on and benefits by which ES, and at which degree they interact with each other. Here, we introduce a framework for integrating the perspective of local actors in landscape planning, through their role in ES co-production. By means of questionnaires and focus groups, local stakeholders in the Fiastra Valley rural case study are asked on preferences for local ES and their anthropic contribution in ES co-production. Through the analysis of these data, the chapter investigates on stakeholders’ dependency, benefits and access to decision making, and their collaboration across scales. Implications for sustainable management practices are developed especially regarding the role of local actors in landscape transformation, collaborative planning, and access to decision-making. The integration of the ES co-production framework in planning proved useful in visualizing the collaboration networks among social actors, with municipalities being the main actor on the local scale.

4.1. Introduction

A key challenge in regional planning lies on the integration of social components in environmental evaluation, in order to take into account the complexity of local social-ecological systems. Those systems are the result of the action and interaction between nature and human activity, which shaped the territory to produce food, fiber, timber, mostly consisting of private goods, while natural systems provided other services, predominantly public, crucial for society (Früh-Müller et al., 2016). The last decade has seen increasing attempts to assess this interaction through the concept of landscape, considered the most suitable spatial unit for managing ecosystems (Forman and Godron, 1986; Tallis et al., 2015) and whose definition allows the valuation of the physical entities and their perception (European Landscape Convention, 2000). In this context, landscape planning faces the challenge of reconciling competing sectorial interests working on the same areas for different purposes, in order to guarantee the multifunctionality of landscapes as a condition for a sustainable development (R.S. de Groot et al., 2010; Sargolini and Gambino, 2016).

The Ecosystem Services (ES) framework is increasingly applied by planners and decision makers for its capability to integrate in one assessment a great variety of benefits humans derive from ecosystems (IPBES, 2019; TEEB,2010). Several studies developed tools for the valuation of provisioning, regulating and cultural services in order to support planning recognizing spatial environmental relations (Albert et al., 2016; Grêt-Regamey et al., 2017; Langemeyer et al., 2016). These frameworks mostly refer to the assessment of physical components, to support land-use decision making toward the goals of sustainable development (Grêt-Regamey et al., 2017). Yet, development strategies need to integrate the social dimension of sustainability to support resilience of communities through their role in the management of ecosystems (Bennett et al., 2015).

Today, a growing body of literature is focusing on the concept of ES co-production (Fischer and Eastwood, 2016; Jericó-Daminello et al., 2021; Lavorel et al., 2020; Palomo et al., 2016), stressing how benefits from nature to people does not occur independently but in most of the cases require a significant human contribution (Díaz et al., 2015). Co-production of ES includes several anthropogenic components relating with natural systems, such as motivation or education (human capitals), values and norms (social capitals), machinery and infrastructure (physical capital) and credits or direct payments (financial capitals) (Palomo et al., 2016). ES can be coproduced by anthropic activities through the direct management of service flow (e.g. agricultural activity, forest management) or as users, benefiting and valuing a service (e.g. the preference for a product or a tourist destination, or the ecosystem function toward an environmental risk). Together with stakeholders interested in or investigators on the services, those roles shape the interaction between society and natural systems and are crucial in the investigation on landscape as social-ecological systems.

Figure 20 illustrates the theoretical framework proposed in this study, distinguishing physical from cognitive co-production (Fischer and Eastwood, 2016; Palomo et al., 2016). The former refers to the physical action on ecosystems involving measurable external changes and relates to the anthropogenic and natural contribution on the landscape. The latter belongs to the cognitive processes related to the individual perception of the benefits and addresses the importance of perceived quality of life for landscape planning and management. The application of the ES co-production framework on landscapes as social-ecological systems has the potential to assess dependencies and benefits of stakeholders for ES and to highlight collaborations among them (Opdam et al., 2015a; Turkelboom et al., 2018). The acknowledgement of the role of actors and its implication on stakeholders relations can provide planning with an integrated valuation tool, including stakeholders perspectives in the management of ecosystems (Rieb et al., 2017).

However, the contribution of social systems to ES co-production remains unclear. There is a lack of evidence on how people value ES and perceive benefits to their quality of life, according to their role in society (Bennett et al., 2015). It’s not clear how different stakeholders depend on and benefits by which ES, and at which scale they interact with each other (Martín-López et al., 2019). In this frame, the analysis of spatial relations is crucial for understanding power asymmetries and the distribution of ES among the beneficiaries (Bennett et al., 2015). Furthermore, recent findings (Jericó-Daminello et al., 2021) highlight discrepancies between how stakeholders perceive themselves as co-producers and how others perceive them.

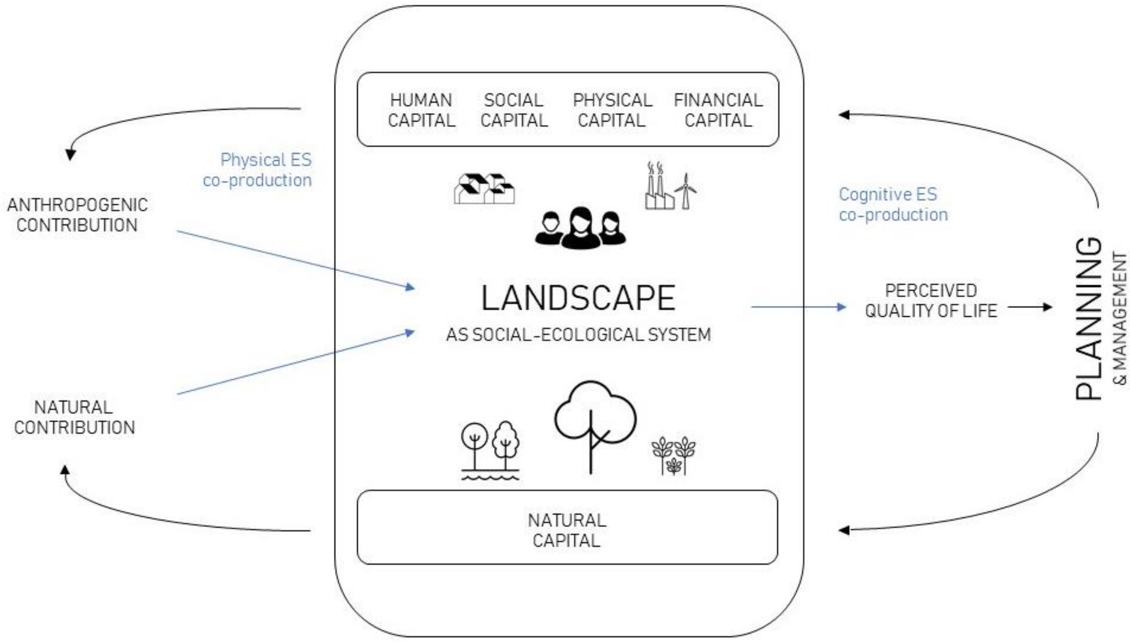

Figure 20: Ecosystem Services co-production in the landscape as social-ecological system.

Against this background, the present study aims to test the integration of perception of social actors in landscape planning through their role in ES co-production. Co-production is used as a framework to explore local perception of different stakeholder groups and understand anthropic contributions to ES offered by landscapes. Following an approach that explicitly refers to the planning dimension, we look at (a) the main ES perceived by local stakeholders, (b) the anthropogenic contributions involved in ES co-production, (c) the implications of ES co-production on the relationship among stakeholders.

Furthermore, the work focusses on a case study recently affected by earthquake (Central-Italy earthquake 2016-2017), where a debate is open on ideas of development for the area, and new opportunities are open to rethink planning based sustainability and resilience toward extreme events.

4.2. Methodology

4.2.1 Study site: the Fiastra Valley landscape

The Fiastra Valley (43° 9’ N, 13° 50’ E) is a sparsely populated rural district, covering a hilly area characterized by ancient settlements and agricultural land crossed by the Fiastra river (Figure 21). The land cover is mainly arable land, with few forests characterizing mostly riparian and high-inclination areas. Its territory is constituted by six municipalities and counts about 11.764 inhabitants for 181,2 km^2 of land. It is located in the inner part of Le Marche region, in central Italy, at the foothills of the Apennine mountains.

The main economic occupation is related to Manufacturing activities (34% of the employed versus a national average of 21%) while agriculture, forestry and fishing represent a relevant sector with 11% of the employees (double of the national value). The average per-capita income is 12.238 euros, toward a national average of 21.800 euros. Activities of accommodation and restaurant services interest today 9% of employment in the Valley, but development strategies for the area are stressing the potential of eco-tourism for future development (SNAI Alto Maceratese, 2019), as the case study touches two protected areas: The *Monti Sibillini National Park*, and the *Abbadia di Fiastra Natural Reserve*. The main threats of the area are related to the socio-economic consequences of depopulation, which in the Fiastra Valley reach - 5% (calculated between 2011-2018) comparing to the regional average -1%.

Through the analysis of the regional context a base-list of 9 relevant ES for Marche region is defined: Agricultural products, Drinking water, Hydroelectric energy, Hydraulic regulation, Climate regulation, Air purification, Eco-Tourism, Environmental education, Intrinsic value. This is taken as a star point to be integrated through free listing activity with local stakeholders.

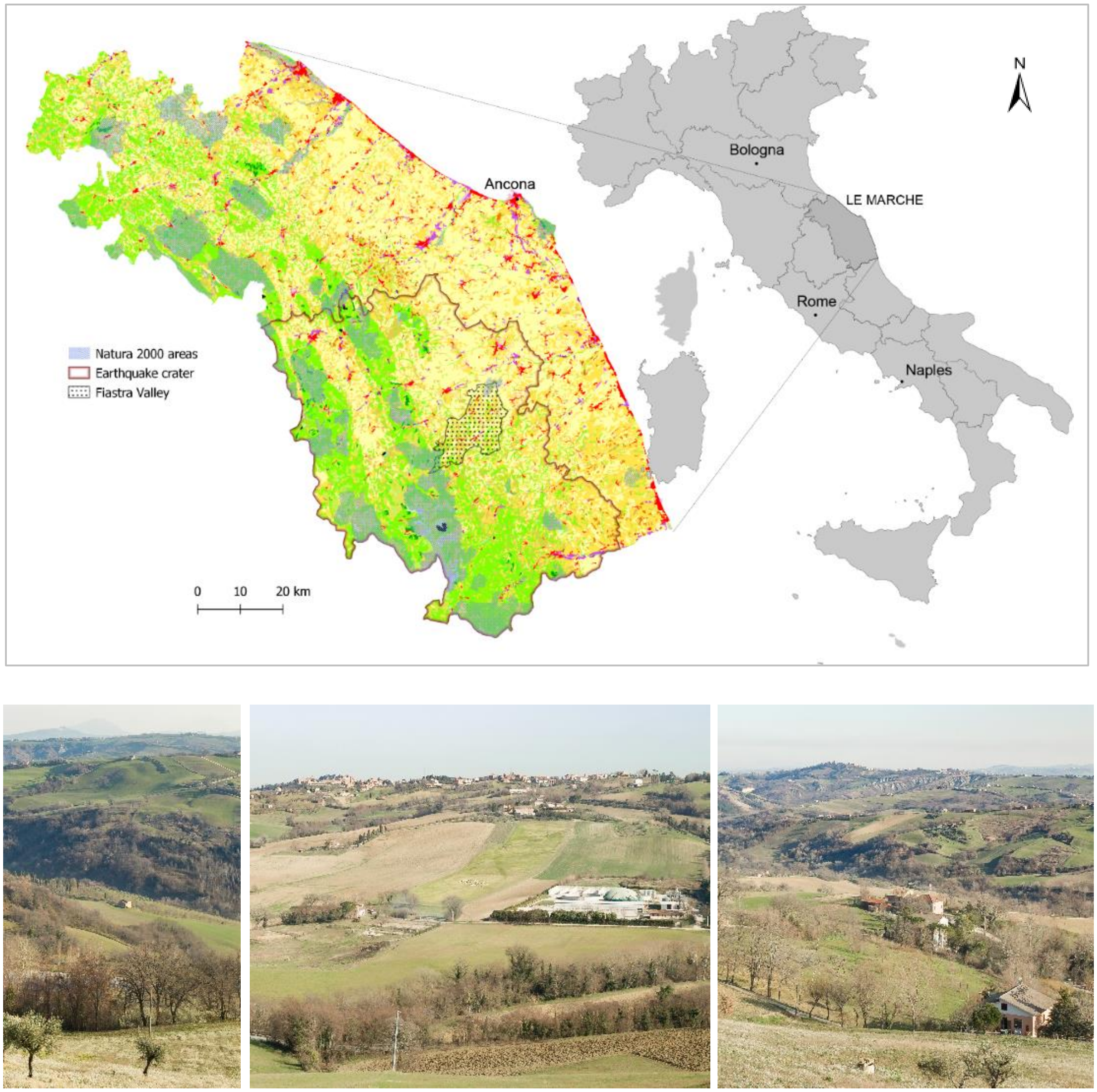

Figure 21: Location of the Fiastra Valley landscape study site in Le Marche Region (base CLC 2018)

Social actors of Fiastra Valley were involved in the data collection according to five stakeholder groups: *Production* includes workers from the agriculture sector, agronomy and local producers; *School and research* includes school teachers, university students, ecology experts and a representative from environmental centers; *Culture and commerce* includes tourist managers, hotel, agritourism and restaurant owners, café and local shop owners; *Planning and administration* includes members of the municipality, Engineers, architects and planners, as well as the local water distribution company; *Society* includes members of local associations, artists, family doctors, local recreationists and citizens. Table 6 presents the stakeholder groups addressed in the study.

Table 6: Stakeholders of Fiastra Valley Ecosystem Services, grouped in stakeholder groups and participants to the local questionnaire

STAKEHOLDERS GROUPS	STAKEHOLDERS	SCALE	DESCRIPTION	QUESTIONNAIRE PARTICIPANTS
Production	Agriculture	Local	Actors involved in the agriculture sector, both farmers and agronomists	5
	Local producer	Local	Actors involved in artisanal activities made in a traditional or non-mechanized way using local natural resources	2
School and research	School	Local	Teachers from schools of the Fiastra Valley, including primary and first-grade secondary schools.	3
	Environmental center	Local	Representatives from local centers for environmental education	1
	Ecology expert	Regional	Academics and researchers from universities or regional ecologists and sociologists	1
	University students	Local	Students enrolled in university living or having roots in the Fiastra Valley	2
Tourism and commerce	Tourist manager	Local	Managers of local tourism, including travel agencies, tour guides, mountain guides.	2
	Regional tourists	Regional	Tourists from Le Marche region	-
	Foreigner tourists	Interregional	Tourists from out of Le Marche region	-
	Nearby distribution	Local	Grocery stores with local products	1
	Large distribution	Interregional	Supermarkets and inter-regional distribution chains	-
	Bars, restaurants and agritourisms	Local	Businesses where meals and drinks are served and places of aggregation for local population and tourists.	3
Planning and administration	Municipalities	Local	Fiastra Valley municipal authorities.	4
	Engineers, architects, and planners	Regional	Single people or studios involved in the technical environmental planning and management	3
	Regional authorities	Regional	Le Marche regional authorities	-
	Water distribution company	Regional	Representative from the local water distribution company	1
Society	Fiastra Valley citizens	Local	People living in the territory of the Fiastra Valley	3
	Urban citizens	Regional	People living in the main cities of Le Marche region	-
	Artist	Local	Local people who habitually practice creative productions in relation with nature	1
	Family doctor	Local	Local community doctor who treats patients with minor or chronic illnesses	1

Associations for local promotion	Local	Cultural and environmental associations active in the local context	2
Local recreationists	Local	Local citizens practicing sport or other open-air activities in the valley	1

4.2.2 Identifying and assessing preferences for Ecosystem Services. Focus group

To identify and assess the preferences stakeholders relate to local ES in July 2021 we organized focus groups involving a total of 27 people. To facilitate the activities, participants were divided in two groups, according to their roles:

- Focus group A – Civil Society, composed by *School and research* (school teachers), *Society* (members of associations), *Production* (farmers and local producers) (15 participants)
- Focus group B – Management, composed by *Planning and administration* (municipal representatives, planners and architects) and *Tourism and commerce* (tourist managers) (12 participants)

After introducing the concept of ES, the participants were asked to take part in a free listing exercise, answering questions about the benefits that society in the Fiastra Valley receives from ecosystems. Participants had 15 minutes to answer in private, with a maximum of three post-its per question: (i) What does nature in the Fiastra Valley mean to you? what is the importance of nature for this area? (ii) What are the benefits that Fiastra Valley provides for your well-being/to fulfill your organizational goals? (iii) What goods and products does nature in the Fiastra Valley provide to society? How does nature support the local economy?

The post-its were collected and analyzed by facilitators which extrapolated individual concepts addressing natural contribution to people. Those concepts were finally grouped in ES. The list of ES was integrated with the regional base-list (see chapter 2.1) sharing the process with all the participants. The final list of ES was displayed on a board and participants were asked to vote the three ES they considered most relevant for the Fiastra Valley.

4.2.3 Assessing Ecosystem Services co-production. Face-to-face questionnaire

To assess the role of local stakeholders regarding the co-production of ES, the participants of the focus groups were invited to respond to a questionnaire. The number of participants was integrated through snow-balling technique aimed at identifying additional respondents within the stakeholders identified in

Table 6.

Overall, a total of 35 people took part in the questionnaire. The stakeholder group *Production* (7 participants) included workers from the agriculture sector (5), and local producers (2). *School and research* (8 participants) involved schoolteachers (3), university students (2), an ecology expert (1) and a representative from an environmental center (1). *Culture and commerce* (6 participants) included tourist managers (2), Bar-, restaurant- and agritourism- owners (3) and a local shop owner (1). *Planning and administration* (8 participants) included members of the municipalities (4), Engineers, architects, and planners (3), and a member of the water distribution company (1). *Society* (8 participants) included members of associations for local promotion (2), an artist (1), a family doctor (1), a local recreationist (1) and citizens (3).

To facilitate the compilation of the questionnaire, the respondents were assisted though face-to-face interviews. Due to safety precautions during the COVID-19 pandemic, interviews were mainly conducted by video-call, except in circumstances where respondents did not have access to online platforms. In case of qualitative information useful to justify eventual choices and support discussion, the results of the questionnaire were combined with notes taken by the interviewers. The interview lasted between 30 to 70 minutes per participant, depending on the number of services they expressed to play a role in, as structured in the questionnaire (see the full script in the Appendix 4.B), following the 5 sections:

1. *Role in ES co-production.* The participants were asked to select one ES in which they play a role from the list of ES arranged by the focus group (Table 7.a), and specify which role they play in it (among the list Table 7.b)

2. *Capitals involved*. Participants were asked to assess non-natural capital inputs through which they are contributing to the ES co-production, namely: Human capital, Social capital, Physical capital and financial capital (see description in Table 7.c)
3. *Dependency, benefits, and influence on decision making processes.* From a list of stakeholders, the participants are asked to assess dependency on and benefits from the ES per each stakeholder. The same question is repeated for themselves. The participants are also asked to rate the access in decision-making both for themselves and the others (see definitions in Table 7.d).
4. *Collaboration among stakeholders*. In case the participants have a role as *manager* of the service, they are additionally asked to indicate which of the listed stakeholders they work with in the provision of the service.
5. The last part is dedicated to the *social-ecological characterization of the participants.* Here the participants are asked about their environmental behavior (frequency of visits to protected areas, consumption of organic and local products, waste recycling habits) as well as age, gender, occupation/activity.

Table 7 Characterization of ES co-production. (a) list of Ecosystem Services considered, (b) definition of roles for local actors, (c) capitals involved, (d) stakeholder involvement (e) stakeholder collaboration.

a) Ecosystem Services List		
Provisioning ES	Regulating ES	Cultural ES
P1 Agricultural products P2 Drinking water P3 Hydroelectric energy	R1 Hydraulic regulation R2 Climate regulation R3 Air purification	C1 Eco-Tourism C2 Environmental education C3 Sport activity C4 Intrinsic value C5 Sense of place C6 Aesthetic beauty C7 Mental wellbeing C8 Artisan products

b) Stakeholder roles regarding ES and definitions				
User *Receive the benefits of the services*	Managers *His/her/their activity supports the offer of this service*	Negatively influenced *Bothered by the presence of the service*	Interested *Not a direct user but believe in its importance*	Investigator *You care about this service from a research point of view*

c) Anthropogenic capitals involved in ES co-production and definitions			
Human capital *knowledge, education, motivation, skills, or health*	Social capital *values and norms, formal and informal networks, or trust*	Physical capital *machinery, tools, infrastructure, or built capital*	Financial capital *savings, credits, grants or direct payments*

d) Stakeholder involvement		
Dependency for the ES *Which stakeholder rely on/depend on the service*	Benefit from the ES *Which stakeholder receives benefits from the ES*	Access to decision making *Who contribute to decisions related to the management or status of the ES*

e) Stakeholder collaboration (*Only for Managers),*
Stakeholders with whom would collaborate with, to provide the service

4.2.4 Data analysis

To answer the research questions, the data collected in the focus groups and the interviews were organized, statistically analyzed and visualized through R software (RStudio Team, 2021), using packages fmsb (Nakazawa, 2021), dplyr (Wickham et al., 2021) and ggplot2 (Wickham, 2016). The full code is available at the supplementary materials (Appendix 4.E).

Within data organization, respondents' answers in questionnaire sections D and E (see Table 7) were normalized per each stakeholder and per stakeholder groups, by dividing the number of selected stakeholders by the total number of stakeholders within the stakeholders group. The results were then aggregated per ES and stakeholder classification of the respondent.

Regarding the statistical analysis, the Shapiro-Wilk test was used to check whether the respondents' answers followed a normal distribution. As for the preferences expressed by focus groups, it showed that the distribution of the answers by participants departed significantly from normality. The test was run also to analyze the distribution of the answers of questionnaire respondents regarding the capitals involved in ES co-production and again the result differed from normality.

Based on this outcome, non-parametric tests were used to verify the significance of the differences among the responses. As for the preferences expressed in numerical data within the focus group, Wilcoxon's rank sum test was used to assess the significance of the differences between the *Focus group A: Civil Society* and the *Focus group B: Administration*. As for the differences on capitals involved in ES co-production, giving that the Likert scale employed (1 to 5) consists in categorical data, the *Chi-square test* was performed.

4.3. Results

4.3.1 Preferences for Ecosystem Services

Participants of the Focus Groups indicated, through free listing, a great variety of benefits society receives from Ecosystems in the Fiastra Valley, resulting in 147 statements related to Ecosystem Services. As it can be noticed from Table 8, most of participants included statements which were grouped as *C7 Mental wellbeing*, and many also addressed *C5 Sense of Place* (24 participants) and *C1 Eco-Tourism* (16 participants). Only participants of the Focus group 1 (Civil Society) addressed *C2 Environmental education* and only participants from Focus group 2 (Management and administration) addressed *P2 Drinking water*. *R2 Climate regulation* was addressed only by one statement from Focus group 1.

Table 8: Nr. of statements related to Ecosystem Services expressed by participants at the Focus Groups during free listing activity

FG1	FG2	Tot	ES Group	FG1	FG2	Tot	ES Group
15	13	28	C7 Mental wellbeing	2	2	4	C3 Sport activity
15	9	24	C5 Sense of place	2	1	3	R3 Air purification
10	6	16	C1 Eco-Tourism	0	2	2	P2 Drinking water
7	4	11	P1 Agricultural products	1	0	1	R2 Climate regulation
5	6	11	C8 Artisan products	0	0	0	P3 Hydroelectric energy
7	3	10	C6 Aesthetic beauty	0	0	0	R1 Hydraulic regulation
5	4	9	C4 Intrinsic value				
5	0	5	C2 Environmental education				

Furthermore, the participants of the focus groups voted their preferences for the defined ES, and showed a high preference for cultural ES (Figure 22). The most voted ES were: *C6 Aesthetic beauty* (19% of votes), *C5 Sense of place* (16% of votes), *C8 Artisan products* (15% of votes), *C7 Mental Well-being* (10%). Four other ES were voted by 6% of the participants (*P1 Agricultural products*, *P2 Drinking water*, *C1 Eco-Tourism*, *C4 Intrinsic value*) and the rest received less than 5% of the votes. Nobody expressed a preference for *P3 Hydroelectric energy*. Looking at ES categories, besides cultural services being the most voted with 7,8 votes per service, provisioning services received an average of 3,3 votes per ES and regulating services got 2.

Looking at differences between the two focus groups, the statistical analysis stated that FG1 responses are not significantly different from FG2 responses. In addition, it is interesting to notice that *C2 Environmental Education* (4%) and *R3 Air purification* (1%) were considered only by participants from FG1, while *R2 Climate regulation* (4%) and *R1 hydraulic regulation* (3%) were chosen only by participants of FG2.

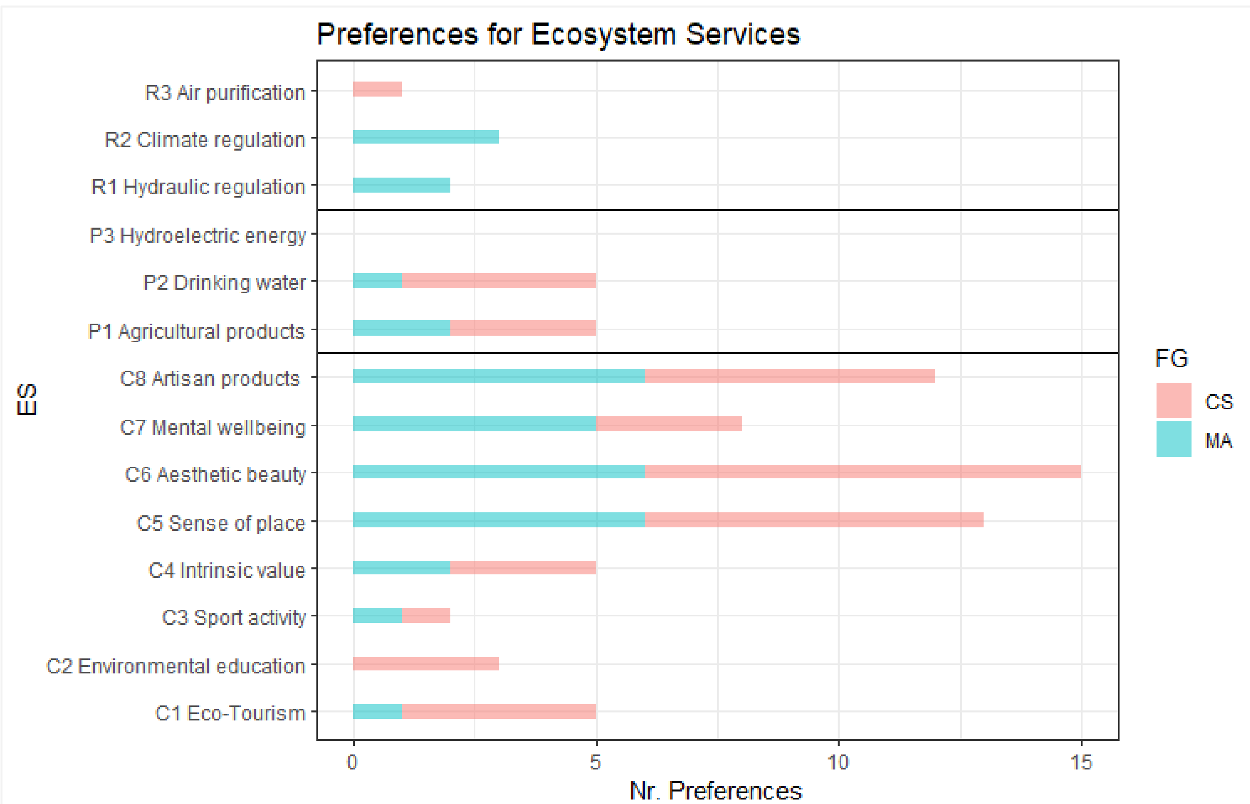

Figure 22: Preferences for Ecosystem Services in the local case study. Data in red are from Focus group 1 – Civil Society (CS), composed by: School and research (school teachers), Society (members of associations), Production (farmers and local producers). Data in blue are from Focus group 2 – Management (MA), composed by Municipal and administration (municipal representatives, planners and architects) and Tourism and commerce (tourist managers).

4.3.2 Anthropogenic contribution in ES co-production

Stakeholders' role

Information on the role of stakeholder in ES co-production was extracted from the questionnaire sections A and B, that resulted in a total of 76 ES co-production records, representing in average 2,2 responses per person (Figure 23). Respondents within the Stakeholder group *Production* (7 participants) expressed 9 ES records; *School and research* (8 participants) 18 ES records; *Tourism and commerce* (6 participants) 10 ES records; *Planning and Administration* (8 participants) 15 records; and *Society* (8 participants) 24 records. Respondents were aged between 22 and 71, with a balanced proportion of men and women. In terms of spatial distribution, they well represented the six municipalities of the case study (see Appendix 4.C for details).

As a first result, it can be noticed how the local stakeholders stated co-production in all the ES of the list, with the exception of *P3 Hydroelectric energy* and *R3 Air purification*. The main ES to be selected were *C5 Sense of place* (13%), *C1 Eco-tourism* (12%), *C8 Artisan products* (12%) and *P1 Agricultural products* (11%). All the others interested a share of 6-9% of ES records, with exception of *R1 Hydraulic regulation* and *R2 Climate regulation* which regarded only 3% (2 ES records).

Respondents described their role in ES co-production mostly as *Users* (50,0% of ES records) and *Managers* (40,8%). Only 6,6% of records regarded the role *Interested* and 1,3% *Investigator*. The figure shows the results per Stakeholder groups, and differences can be noticed between the ES: looking at *C5 Sense of place*, 60% of ES roles account *Users* and 40% *Managers*; as regards *C1 Eco-tourism* 22,2% are *Users*, 66,6% *Managers* and 11,1% *Investigators*; *C8 Artisan products* includes 66,6% *Users* and 33,3% *Managers*; while *P1 Agricultural products* comprises 62,5% *Managers* and 37,5% *Users*.

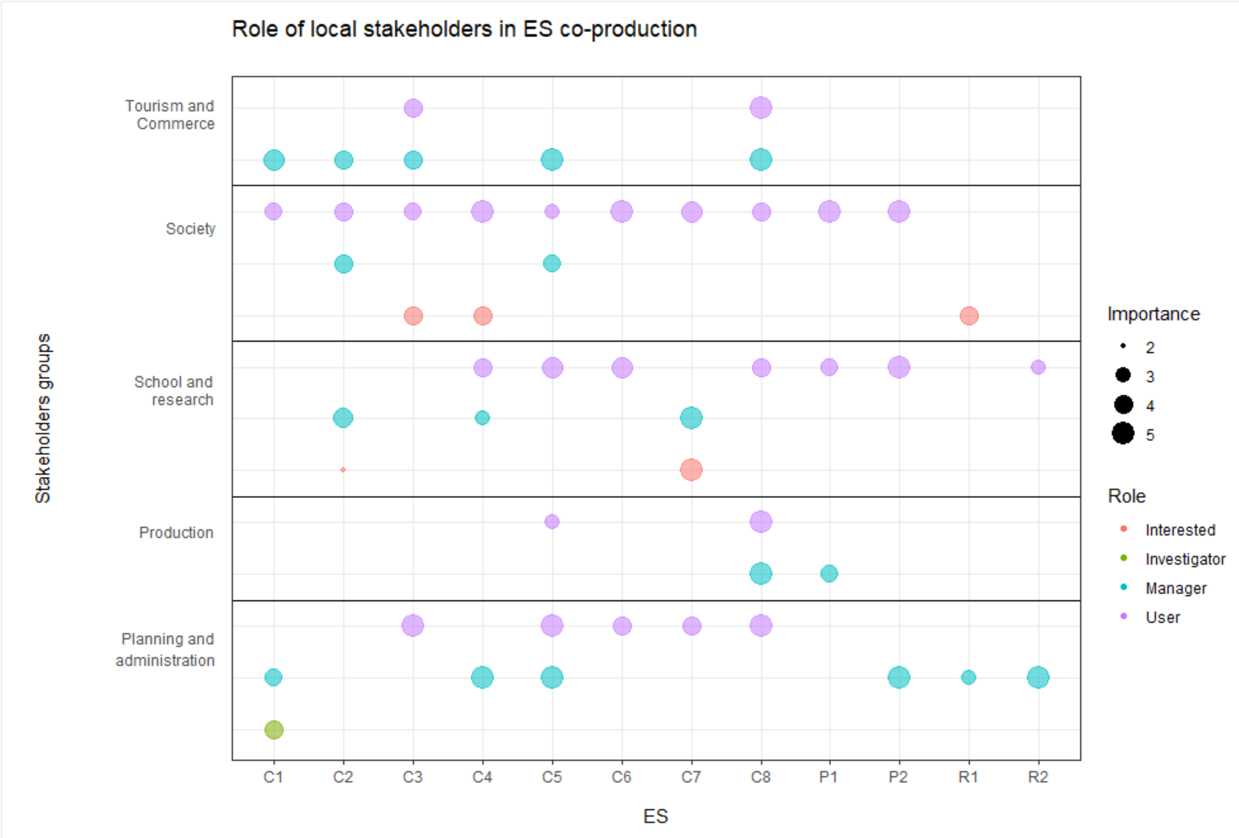

Figure 23: Role of Stakeholders in ES co-production of the local case study. Importance was rated through a 1-5 Likert scale, the value 1 does not appear as no respondent selected it. Note that P3 and R3 are not represented in the graph as none of the respondents selected as having a role in them.

Looking at the distribution of roles per Stakeholder groups, we see how the *Tourism and commerce* and *Production* groups refer to high rates of *Managers*, concerning respectively 80% and 78% of the ES records. The group *School and research* accounts 28% of *Managers*, 71% of *Users* and 11% of *Interested*, while *Planning and administration* share an equal composition of *Managers* and *Users* (47%) with a 7% of *Investigators*. *Society* includes 75% of *Users*, 13% of *Managers* and 13% of *Interested*.

Capitals involved

Overall, most of respondents referred to ES co-production through high human and social capitals (in average 3,62 and 3,69 out of the 1-5 scale), while physical and financial capitals had less relevance (in average 2,22 and 2,23). The significancy of differences among answers was tested per stakeholders groups (SH.GROUPS) and per Ecosystem Services (ES) and Table 9 shows how *Social Capitals* involved in ES co-production depend on the ES considered.

Table 9: Results of the Chi-square test on the distribution of answers on the capitals involved in ES co-production, per Stakeholders groups (SH.GROUPS) and per Ecosystem Service (ES)

Variables		**df**	**p-value**	**Variables**		**df**	**p-value**
SH.GROUPS	HUMAN CAPITAL	16	0.6908	ES	HUMAN CAPITAL	44	0.1627
SH.GROUPS	SOCIAL CAPITAL	16	0.2228	ES	SOCIAL CAPITAL	44	0.0327
SH.GROUPS	PHISICAL CAPITAL	16	0.0650	ES	PHISICAL CAPITAL	44	0.2164
SH.GROUPS	FINANCIAL CAPITAL	16	0.0798	ES	FINANCIAL CAPITAL	44	0.3291

Looking at the anthropogenic capitals involved in specific ES, some interesting differences can be observed in the graphs of Figure 24. Considering the human capital, the highest values are expressed for *C2 Environmental education* (4,33) and *C6 Aesthetic beauty* (4,17), while the lowest are related to *P2 drinking water* (2,5) and *C8 artisan products* (2,5). Social capitals are highest for C2 *Environmental education* (4,67) and *C1 Eco-tourism* (4,56) and lowest for *P2 Drinking water* (2,33) and *C8 Artisan products* (2,75). Physical capital: highest in *P2 Drinking water* (3,67) and *C1 Eco-tourism* (3,11); lowest are *R2 Climate regulation* (1,50) and *C4 Intrinsic value (1,60).* Financial capital: highest is *P2 Drinking water* (3,67) and *C1 eco-tourism* (3,00); lowest for *C4 Intrinsic value* (1,60) and *C5 Sense of place* (1,90).

Regarding ES Categories, Cultural services are mostly co-produced by Social (4,2) and Human capitals (3,9), while values of Physical and Financial capitals are lower (respectively 2 and 2,2). Regulating services account first Human (3,2) and then Social (3) capitals, while Physical and financial capitals both correspond to the value of 2. Provisioning services see a growing relevance of Physical and Financial capitals, with the first being the most relevant (together with financial capitals – 3,2) and the second having a value of 3, together with human capitals (the lowest value among the categories).

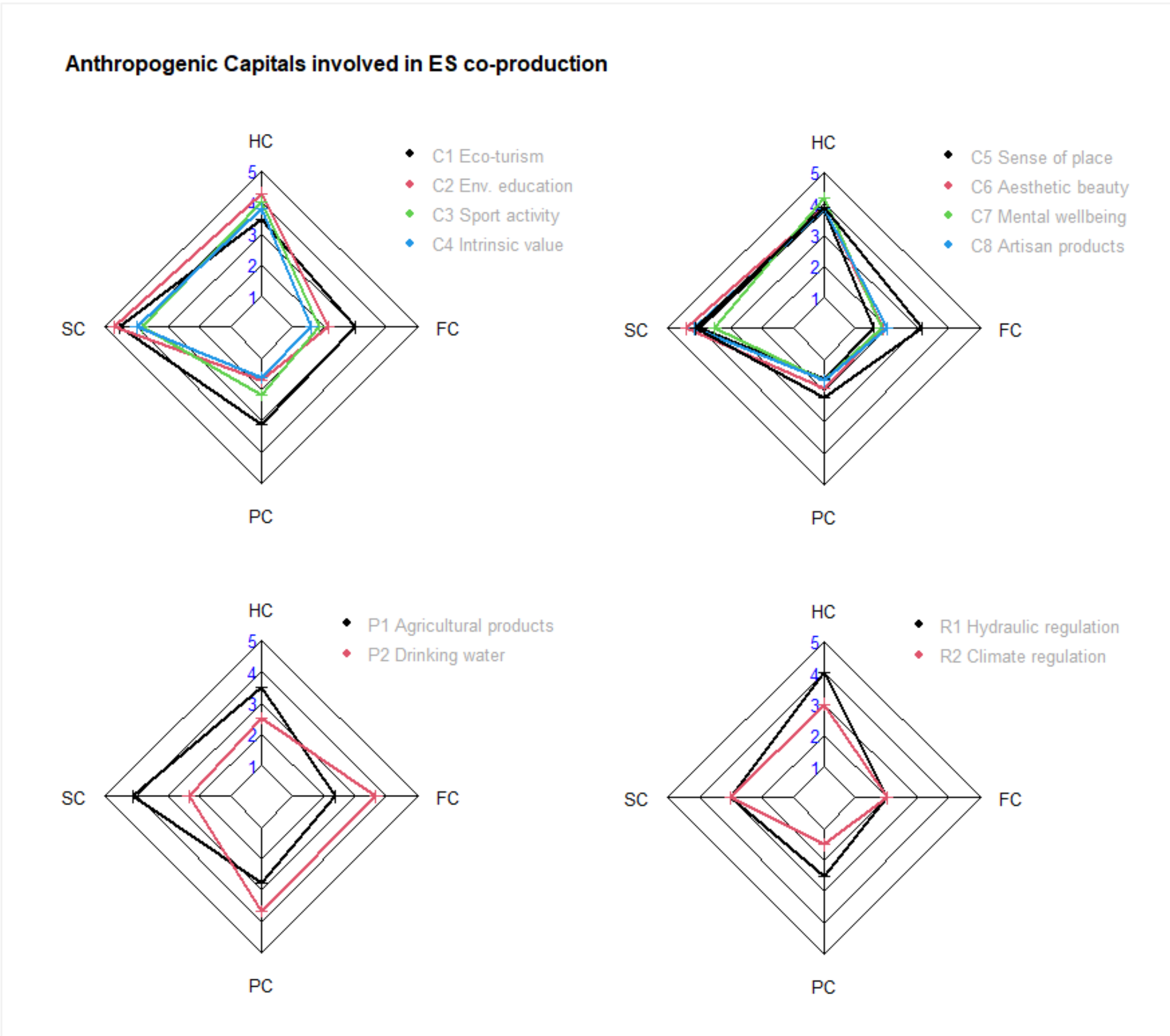

Figure 24: Anthropogenic capitals involved in the co-production of Ecosystem Services as stated by local actors: Human capitals (HC), Social capitals (SC), Physical capitals (PC), Financial capitals (FC)

4.3.3 Implications on stakeholders relations

Stakeholders' dependency, benefits and access to decision making

The questionnaire (section D) addressed the topic of stakeholders' dependency for ES, the benefits they derive from the ES, and the access to decision-making regarding those ES. Figure 25 shows the normalized answers from the whole sample of respondents, looking at the five defined stakeholder groups. The graphs show respondents' perception on the different stakeholder groups, data on self-perception can be found in Annex 3.

The importance for the ES was discussed as the dependency of stakeholders on the existence of the specific ES they play a role in. Results in this section showed great relevance for *Production* for the *P1 Agricultural products* (90%), *C8 Artisan products* (86%) and *P2 Drinking water* (75%). The Stakeholder group School and Research was considered dependent on *C2 Environmental education* (61%) and partly on *C4 Intrinsic value* (44%). Tourism and commerce had general low values in terms of dependencies, with 45% related to *C1 Eco-tourism*. Planning and administration have also generally low values with mid rates regarding *R2 Climate regulation* (67%) and *R1 Hydraulic regulation* (50%). Finally, society have mid values for *C5 Sense of place* (55%), *C4 Intrinsic value* (50%), *R2 Climate regulation* (50%), *C3 Sport activity* (48%), *C2 Environmental education* (42%), and *C6 Aesthetic beauty* (40%).

In terms of benefits stakeholder groups receive from ES, we observed relevant changes in respect to dependency. Stakeholders belonging to the Producer group generally have lower benefits (36% of stakeholders are considered as dependent but only the 22% receive benefits from ES). The group School and research also showed a decrease of 14% to 25%. On the other hand, stakeholders within the Tourism and commerce group were selected as beneficiaries of benefits with a value almost twice as high as that of dependency (35% versus 19%). As for the two other groups, Planning and administration decreased from 23% to 7%, while society increased from 33% to 48%.

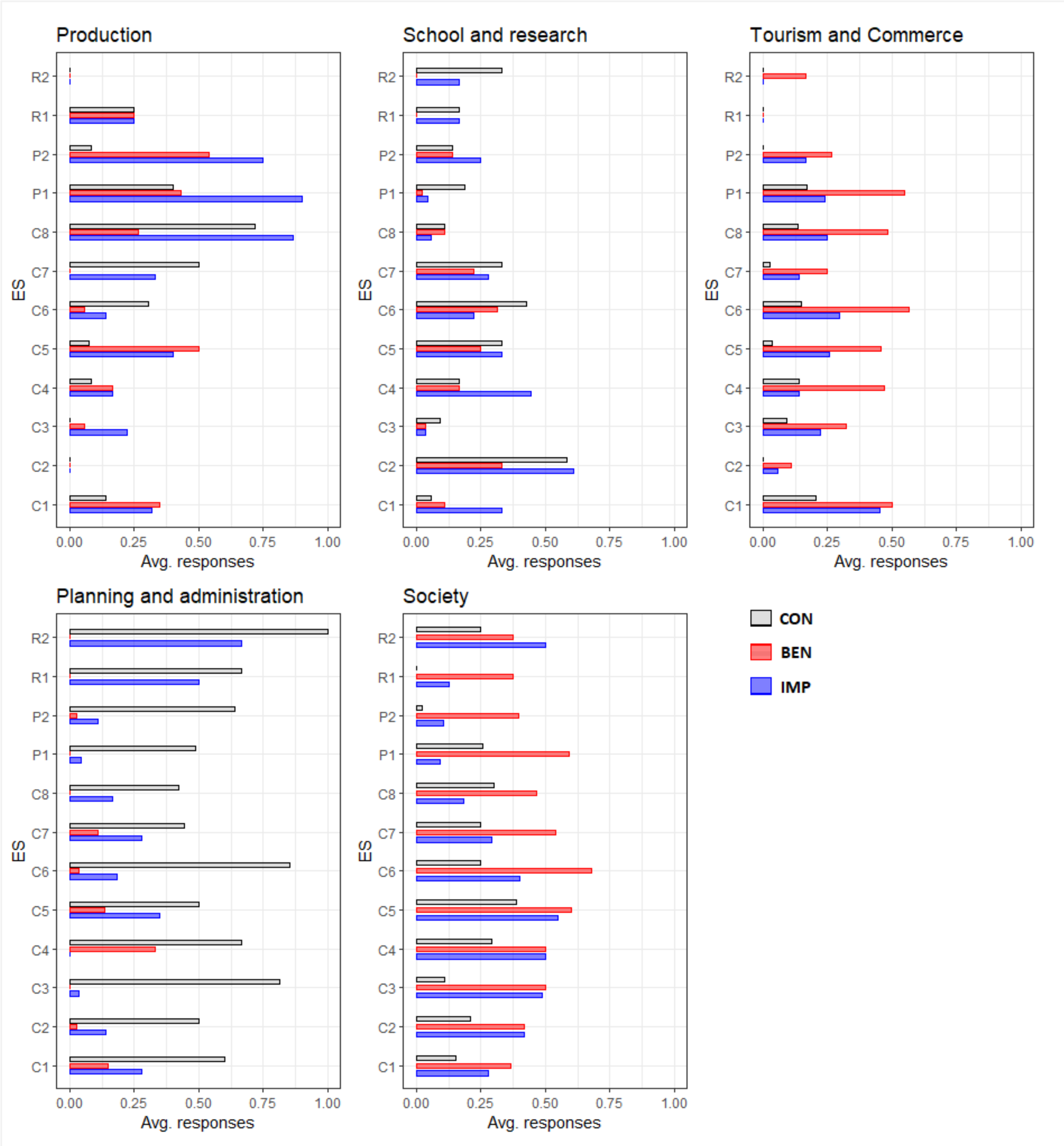

Figure 25: Perception of questionnaire respondents on stakeholder groups regarding how much they consider the ES is important for them (IMP), the benefits they get (BEN) and their contribution to decision making (CON).

Looking at the contribution to decision-making, results show also here a discrepancy in respect to dependency values. Table 10 presents the analysis looking at the difference between contribution to decision making (CON) and dependency on ES (IMP). In these terms, we can notice how the production sector does not have access to decision-making as it should, regarding dependence on ES, with an overall value of -15%, which increases to over 50% when considering specific provisioning services. The School and research sector presents a balanced situation (-0,11%), while Tourism and Commerce and Society show a total negative value of, 11 and 12% respectively. On the other hand, the stakeholder group Planning and administration is seen as having most of the relevance in decision-making, while being poorly dependent on most of the ES.

Table 10: Differences in respondents' perception between Dependency on the Ecosystem Service and access to decision-making.

ES	PRO	SCH	TOU	PLA	SOC	TOT
C1	-18,06%	-27,78%	-25,00%	32,41%	-12,50%	-12,35%
C2	0,00%	-2,78%	-5,56%	36,11%	-20,83%	-0,93%
C3	-22,22%	5,56%	-12,96%	77,78%	-37,50%	-1,23%
C4	-8,33%	-27,78%	0,00%	66,67%	-20,83%	0,93%
C5	-32,50%	0,00%	-22,50%	15,00%	-16,25%	-12,22%
C6	16,67%	20,37%	-14,81%	66,67%	-15,28%	8,02%
C7	16,67%	5,56%	-11,11%	16,67%	-4,17%	0,93%
C8	-15,00%	5,56%	-11,67%	25,56%	11,67%	2,22%
P1	-50,00%	14,44%	-6,67%	44,44%	16,67%	5,74%
P2	-66,67%	-11,11%	-16,67%	52,78%	-8,33%	-7,87%
R1	0,00%	0,00%	0,00%	16,67%	-12,50%	0,00%
R2	0,00%	16,67%	0,00%	33,33%	-25,00%	5,56%
	-14,95%	-0,11%	-10,58%	40,34%	-12,07%	-0,93%

Self-perception in decision-making

After rating the contribution of other stakeholders to decision-making, the respondents to the questionnaire were asked to value their own influence as well. The data shown in Figure 26 represent how respondents stated the contribution of other stakeholders in decision-making (A), how they rated their own contribution (B) and finally the rate of under-/over- estimation (C) obtained dividing the value of A by B and displayed by a cartesian heat map.

A Perception on the others, though the percentage of SH involved within the SH groups

C1	C2	C3	C4	C5	C6	C7	C8	P1	P2	R1	R2	
0,1	0	0	0,1	0,1	0,3	0,5	0,7	0,4	0,1	0,3	0	Production
0,1	0,6	0,1	0,2	0,3	0,4	0,3	0,1	0,2	0,1	0,2	0,3	School and research
0,2	0	0,1	0,1	0	0,1	0	0,1	0,2	0	0	0	Tourism and Commerce
0,6	0,5	0,8	0,7	0,5	0,9	0,4	0,4	0,5	0,6	0,7	1	Planning and administration
0,2	0,2	0,1	0,3	0,4	0,3	0,3	0,3	0,3	0	0	0,3	Society

B Self-perceived involvement in decision-making, on a normalized Likert scale 1-5

C1	C2	C3	C4	C5	C6	C7	C8	P1	P2	R1	R2	
-	-	-	-	0,4	-	-	0,5	0,6	-	-	-	Production
-	0,6	-	0,7	0,8	0,5	0,6	0,4	0,8	0,2	-	0,6	School and research
0,9	0,8	0,3	-	0,6	-	-	1	-	-	-	-	Tourism and Commerce
0,8	-	0,4	0,4	0,7	0,4	0,4	0,8	-	0,8	0,4	0,4	Planning and administration
0,4	0,5	0,5	0,4	0,6	0,6	0,2	0,4	0,8	0,3	0,2	-	Society

C Rate of under-/over- estimation, obtained by dividing A/B

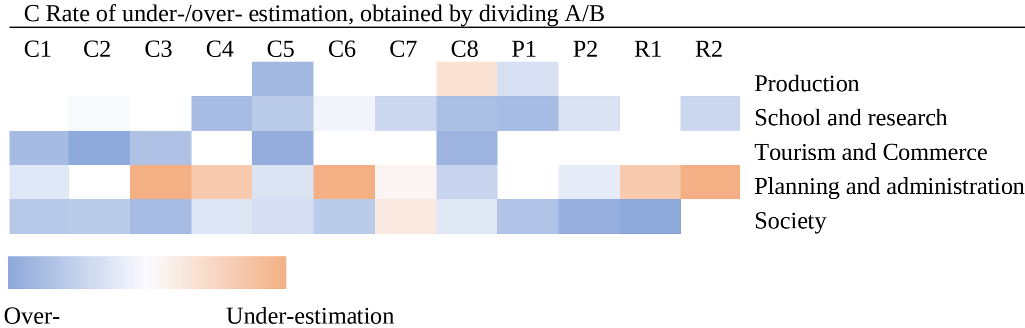

Figure 26: Cartesian heatmap representing the rate between the weight respondents gave to the category and the self-perception on contribution to decision-making. Data are presented only for ES which Stakeholders stated to have a role in. Over-estimation means that the Stakeholder group perceive higher role in decision-making than what stated by the rest of local actors.

It is noticeable that most stakeholder groups over-estimate their own role when answering about themselves compared to what others think about them. The Production sector in particular showed an over-estimation with a rate of +0,2 in relation to C5 Sense of Place. School and research over-estimate their role for C4 Intrinsic value (+0,2), for C8 Artisan products (+0,3) and P1 Agricultural products (+0,2). Tourism and commerce showed +0,2 for C1 Eco-Tourism; 0 for C2 Environmental education; +0,1 for C5 Sense of place; +0,1 for C8 Artisan products and Society 0,2 for C3 Sport activity; 0,3 for P1 Agricultural products; 0,1 for P2 Drinking water; and 0 for R1 Hydraulic regulation.

On the other hand, the main under-estimation is related to Planning and administration, which under-estimate their role for R2 Climate regulation (-2,9), C6 Aesthetic beauty (-2,1), C3 Sport activity (-2) and C4 Intrinsic value (-1,7). The sector of Production also under-estimates its role in regards of C8 Artisan products (-1,3).

Collaboration across scales

The questionnaire section E tackled the topic of collaboration among stakeholders and "Managers" in ES co-production, which defined networks of collaboration regarding the provision of specific ES. Table 11 shows relations among stakeholders organized by stakeholder groups.

Specifically, the *Production* stated to collaborate mostly with the *Production* sector (0,43) and partly with *Tourism and commerce* (0,29), the other values are lower than 0,2. Respondents from *School and research* collaborate mostly with *Planning and administration* (0,53) and partly with the other stakeholder groups, while very low value is related to *Tourism and Commerce* (0,03). *Tourism and commerce* stated collaboration mostly with *Production* (0,63), and partly with the others categories, and the lowest value for *School and research* (0,17). *Planning and administration* collaborate mostly with stakeholders from the same category - *Planning and administration* (0,54) - and low values of collaboration (<0,2) are stated for the rest. Finally, *Society* collaborates partly (0,33) with *Planning and administration* and barely (<0,2) with the rest.

Table 11: Collaboration among SH groups. The number express the average amount of SH (normalized value related to SH group) selected by respondents in the questionnaire

Collaboration among SH groups					
Respondents:	Answ: Production	Answ: School and	Answ: Tourism an	Answ: Planning an	Answ: Society
Production	0,43	0,09	0,29	0,05	0,11
School and researc	0,40	0,47	0,03	0,53	0,30
Tourism and Comn	0,63	0,17	0,25	0,29	0,34
Planning and admi	0,19	0,17	0,11	0,54	0,13
Society	0,17	0,11	0,06	0,33	0,17

Looking at the single stakeholders, Figure 27 shows the relations between stakeholders, distributed according to the scales of action. In particular, the municipalities are the major actor in play, with 13,8% of collaboration (42% as source and 58% as target). Also, *Bars*, *restaurants and agritourism* are major players, involved in 12,7% of the collaborations (mainly as source – 73%). The main collaborations are related to the ES *C1 – Eco-tourism* (31%), followed by *C2 – Environmental education* (13%) and *C8 Artisanal products* (11%).

Regarding the spatial dimension, it can be seen that most of the collaborations are at interest to stakeholders at the local scale (83,8%), while regional and inter-regional stakeholders are involved in only 14,6% and 1,5% of the collaborations respectively. *Planning and administration* and *School and research* are the sectors that mostly connect the local with the regional scale, including the 80% of stakeholders that are interested by beyond-local-scale connections. The inter-regional scale network regards only stakeholders from the *Tourism and commerce* group.

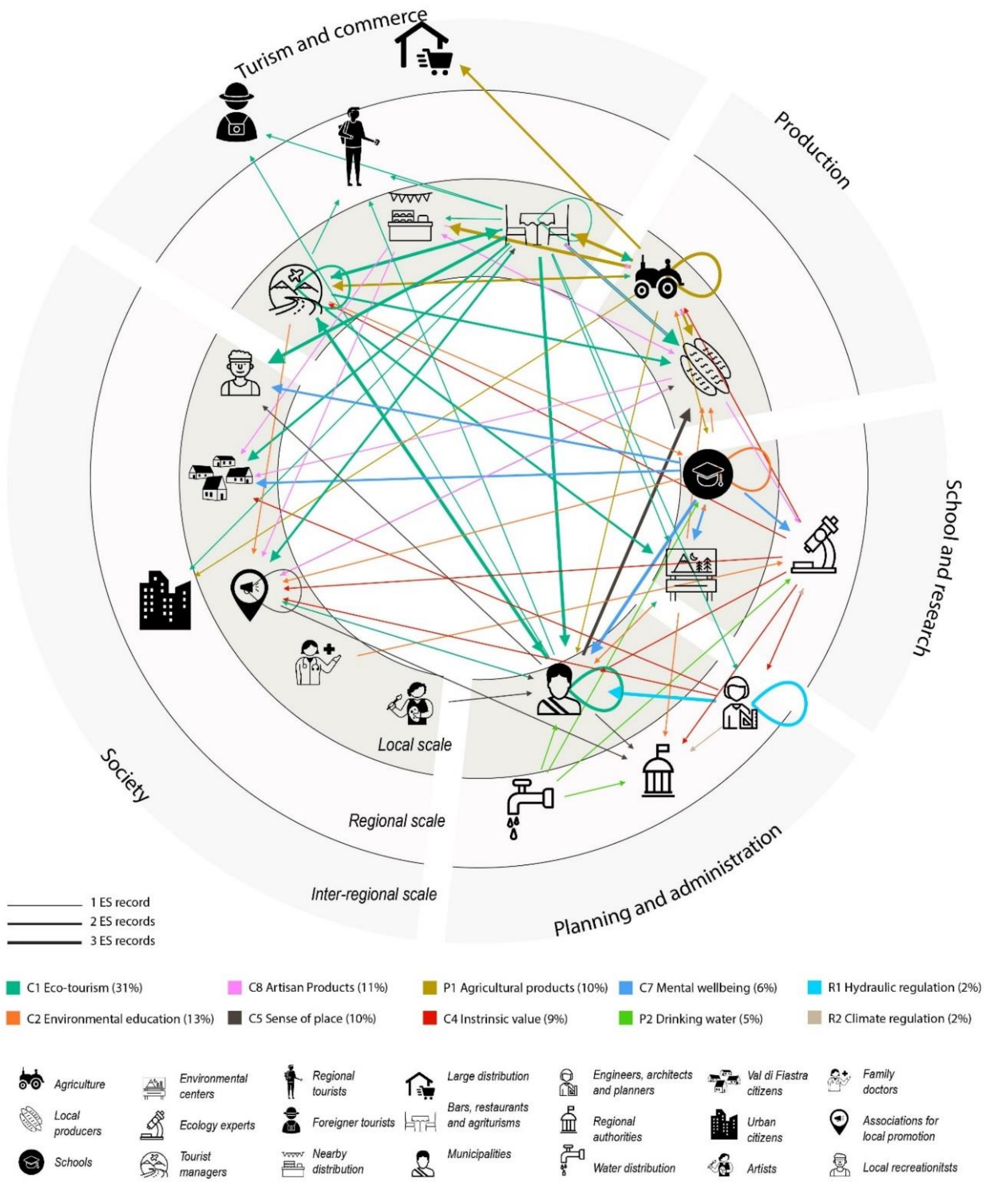

Figure 27: Ecosystem Services stakeholders in the local case study. The stakeholders are organized in stakeholder groups and scale of action

4.4. Discussion

4.4.1 Lessons learned from the integration of ES co-production in landscape planning

Role of local actors in landscape transformations

This study sought to include the perspective of social actors in landscape planning through the application of the ES co-production framework to a local case study. Our findings confirm that stakeholders associate great values to local ecosystems and identified several ES people derive from nature in the local case study. From the list of services defined by the local focus group, almost all of them were related to a co-production rate from respondents, through different roles: Society and the Education system were mostly stated as users, while production, tourism and commerce sector should be addressed as managers of the ES. As a general result of the analysis, the theoretical framework proved useful in highlighting social roles in landscape transformation, that, when properly integrated into planning, can support a sustainable and resilient development (Gret-Regamey, 2008).

As we know, local actors take roles in the co-production of services through different kind of resources, knowledges, and expectations they invest in natural capitals (Palomo et al., 2016). Our empirical exercise demonstrated that human and social capitals have the greatest role in the co-production of services in rural environment. Among the others, social actors referred to education or knowledge (human capitals) as drivers for interaction with natural capitals, and to values and norms (social capitals) as incentives for their businesses. The exercise proved useful not only in showing how stakeholders act physically on the environment (physical co-production), but also how anthropic capitals shapes the perception of a service (cognitive co-production) supporting the valuation and protection of the environment (Fischer and Eastwood, 2016). In this sense, in accordance with other studies on relational values (Arias-Arévalo et al., 2017) we argue that pluralistic valuation approaches should be included into planning to take into account the complexity of landscapes and consider the diverse motivation and interests that brings social actors to interact with the environment.

Looking at the close link between biophysical conditions and population perception, the questionnaire results showed a low interest of local actors in regulation services in a rural case study that is not particularly exposed to risks (both in terms of air quality and hydraulic aspects). In this way, the study confirms the connection between risk exposure and perception of regulatory service and suggests the relevance of people's perception for the adoption of conservation measures in planning (Lewis and Harvey, 2001). Among the regulatory services, special mention should be made of climate regulation, a service not linked to local assets but to a global dimension. In this case, the role of local ecosystems for the global warming cause is recognized by the planning and administration stakeholder group (voted as ES preferences), which, however, under-estimate its contribution to decision making in this service.

Embracing the multiple aspects of human-nature interaction, the ES framework offers the opportunity to acknowledge different drivers of changes in landscapes and supports a multifunctional vision of landscape (Díaz et al., 2015; Felipe-Lucia et al., 2018; Fischer et al., 2015; Mascarenhas et al., 2014). The greater role of physical and financial capitals in provisioning services should teach the need to balance the enhancement and protection of ES with the demands of related anthropic activities. As the infrastructure of potable water mainly relies on physical and financial capitals, also regional agricultural systems require physical support for their resilience toward global challenges. The same argument applies to Eco-tourism, which, given the role played by physical and financial co-production, might be classified as provisioning service, in accordance with other studies (e.g. Pueyo-Ros, 2018). In this sense, we argue that the framework can support integrated assessment in planning by defining specific support in the different planning sectors.

Cultural values of landscapes

The empirical exercise on the local case study underscored the usefulness of the ES co-production approach to display cultural values of rural landscapes. Those values are becoming more important as European policies (among others, *European Landscape convention, 2000)* call on governments to recognize landscapes as an essential component of people`s lives and expression of their cultural and natural heritage. The inclination of local stakeholders for ES such as Aesthetic beauty or Mental wellbeing shows the relevance of intangible benefits in the relation human-nature. Those benefits are often not caught by planning (R.S. de Groot et al., 2010; Ruckelshaus et al., 2015) but we argue that they should be pushed ahead as indispensable elements of landscape planning and could provide a rich basis for development strategies for inland areas.

This could lead to a realignment of the of cultural heritage preservation agendas, especially in areas recently affected by catastrophic events where cultural elements are seen as the main connections for displaced populations to their original areas (EdT, 2018). The prominent rate of co-production regarding sense of place as an ES found in our study shows awareness among local actors of the interdependence of nature and communities in sense of belonging to a place. Reconstruction strategies must therefore consider this interaction when planning emergency housing or the future development of rural settlements (EdT, 2018; Sargolini et al., 2022).

With regards to tangible cultural services, strategies on inland areas often consider tourism as a mantra for the development of rural areas, as it can support economic diversification and has the potential to generate income and employment (Aretano et al., 2013; Petrosillo et al., 2007; Pueyo-Ros, 2018). Nevertheless, the focus group did not express great preferences for Eco-Tourism, with an even lower value when considering the Civil Society focus group. On the other hand, in terms of co-production it is a quite engaging ES, being the most selected, with a high rate of managers (66%), not only from the tourism and commerce sector but also from planning and administration. For these reasons development strategies should support eco-tourism as a potential growing sector, while taking into account the roles of stakeholder's categories and the values they connect to it (Aretano et al., 2013).

Insights on collaborative planning and access to decision-making

The study highlights several implications of ES co-production on relations among stakeholders. The three main findings regard: the discrepancy between dependency and decision making on the ES; the divergency between self and other's perception on the service; the network of collaboration connecting social actors. Those relations are proved to affect the equity of the distribution of ES (Palomo et al., 2016) and need to be considered much stronger in planning as they influence how ecosystem structures eventually turn into benefits (Fischer and Eastwood 2016). The discrepancies between dependency and benefits for ES as well as between dependency and access to decision making need to be accounted as possible indicators of environmental injustices and lack of equity in distribution of benefits (Calderón-Argelich et al., 2021; Fischer et al., 2015).

Considering the stakeholders' dependency, benefits and access to decision making, the investigation in the rural case study reveals how social actors related to Production sectors are the most dependent on ES. This is the case especially when focusing on tangible benefits, as the provision of water and agricultural products, or the cultural value of artisan products. They are the most dependent, while sharing the benefits with the Tourism and commerce sector, and the rest of society. This discrepancy on perspectives gets even more significant when analyzing the access to decision making, where the role of stakeholders is not recognized in the management of the ecosystems, as their dependency for the service would suggest. We stress here that better access of the production sector to the management of the ecosystems might support a higher distribution of ecosystem benefits and give insight to planning in the direction of environmental justice (Calderón-Argelich et al., 2021).

The second main result considers the difference between self and other's perception of their own role in decision-making. This aspect is crucial in research on ES co-production, as the way people perceive themselves shapes the co-production process (Fischer and Eastwood, 2016). In accordance with Jericó-Daminello et al. (2021) our findings confirm that the self-perceived role is frequently higher than the attributed role. As perception mismatches might lead to conflicts in stakeholders management (Zoderer et al., 2019), planning should support the raising of the awareness of territorial actors on the actual roles they have in the co-production of ES.

As for the last aspect considered, the study demonstrated the effectiveness of co-production in displaying the dense network of collaborations around the provision of ES. Two main outcomes can be synthetized from the results: the prominence of the local dimension as a scale of interaction, and the relevance of municipalities as actors connecting the diverse stakeholders. The former includes interactions within the production sector, collaborating mostly within itself and partly with tourist and commerce, and through the institutional actors, where school and research collaborate mostly with planning and administration (and planning and administration with itself). The latter has a downside related to the poor horizontal collaborations among actors, except a few with associations and local producers. In accordance to Opdam et al. (2015), this demonstrates how using ES in planning has a strong multisectoral potential and stimulates the engagement of actors with diverging backgrounds. Nevertheless, collaboration and social learning can be fostered only through the support of novel assessment and design tools (Opdam et al., 2015a) and collaborative planning must be open to the integration of innovative tools for ensuring participation.

4.4.2 Strengths and shortcomings in using the concept of ES co-production in analyzing landscapes as social-ecological systems

The integration of the ES co-production framework in landscape planning proved useful in highlighting the role of social actors in the management of ES at landscape scale. The concept is useful in connecting the ecological and social sphere by focusing on links between ES interdependencies and the perception of stakeholder involvement. In this way, integrating it into planning has the advantage of emphasizing relations among actors and accounting possible environmental inequities deriving from the provision of the services. Social evaluation methods are more and more implemented in planning, and participatory processes are explicitly addressed by policies as in the case of *The new Leipzig Charter, 2020*[4]. However, the implementation of social analysis requires large economic and human resources, which are not often available in contexts such as non-urban settings. Moreover, the distance of rural areas from places of decision making makes them often refractory and less willing to participate.

The study also showed a great ability to capture cultural ES and assess the cultural values of landscapes. The inclusive methodology allowed the analysis to be directed towards the benefits that participants associate with ES, and this directly directed the work toward cultural ES. Nevertheless, cultural services are more related to people's perceptions, and it is not possible to exclude a bias of respondents in representing an entire category of stakeholders. This aspect requires further research. A combination of social network analysis (SNA) and descriptive

[4] The New Leipzig Charter provides a key policy framework document for sustainable urban development in Europe. The Charter promotes the concept of 'integrated development' policy and set out the key principles behind it. The document is available at:
https://ec.europa.eu/regional_policy/sources/docgener/brochure/new_leipzig_charter/new_leipzig_charter_en.pdf

statistics might support the selection of stakeholders (Jericó-Daminello et al., 2021) toward the definition of a more representative sample. However, participants' answers might not always represent the category but personal experience (e.g. out of the professional environment) and this weakness could be overcome expanding the number of participants.

Further research might enlarge the territorial scope of the analysis to urban case studies, as well as more peripheric areas e.g. mountain areas or national parks. This would allow the analysis of the differences in social roles in areas more related to the demand of ES (e.g., urban areas) or to the offer of ES (e.g. rural/peripheric areas) (Baró et al., 2017a). In this way the study can offer a picture of territorial interdependencies, looking at power relations and spatial differences in access to decision-making (Gebre and Gebremedhin, 2019). Furthermore, a focus group with regional authorities might account the discussion about trade-offs related to ES co-production and therefore support a more equal distribution of benefits.

4.5. Accounting people's perception in landscape planning

To our knowledge, this study represents the first explicit application of ES co-production framework to landscape planning though an empirical work on a real case study. Results show that rural actors associate great cultural values to local landscapes, defining a series of ES they receive from ecosystems. Those services are actively co-produced by a different range of stakeholders both as managers, acting on the state of ecosystems, and users, benefiting from the services and valuing them. Moreover, using the ES co-production framework in landscape planning can highlight implications on stakeholder relations, stressing the extent actors depend on and benefit from the service. The comparison of those relations to the access to decision making can give an inside to the equity of the distribution of services among stakeholders and support environmental justice in regional planning.

The comparison between self- perception and perception by others regarding access to decision making showed how there is a general over-estimation of own roles, with the exception of the planning and administration sectors, which should take better account of the relevance of their position in the management of ES. The integration of the ES co-production framework in planning proved useful in visualizing the collaboration networks among social actors, with municipalities being the main actor on the local scale.

Through the methods of social analysis, this chapter addressed the thesis objective of developing a framework for analyzing the role of local stakeholders through the concept of ES co-production. The integration of stakeholders in landscape planning allowed to highlight dependency and benefits relationships between society and nature, deriving implications for landscape planning on stakeholders' relationships and access to decision making. In addition to the relevant consequences in terms of environmental justice, the chapter proves the importance of a participatory approach to regional development, where local stakeholders are to be involved in the definition of strategies. This aspect will be developed specifically in the closing chapter of the dissertation.

To conclude, this analysis, together with the biophysical analysis in chapter 3, allow us to grasp the dual component of the landscape, on the one hand capturing the biophysical and economic territorial assets, and on the other investigating the perception of local actors in the co-production of these assets. the ES framework has proven to be a useful tool for capturing these aspects, exploiting the inherent and fundamental relationship between humans and ecosystems.

Chapter 5: Conclusions and further research

5.1 Introduction

While writing these conclusions, on July 3, 2022, a serac collapsed on the mountain of Marmolada, in the Dolomites, killing seven people, injuring other eight while 15 others are still missing. As Italy is facing an extraordinary early heatwave and a lack of rainfall – particularly in the Po valley, undergoing its worst drought in 70 years – water is rationed to the population for drinking purposes, power plants are to be shut down, and agriculture has already announced more than 30% loss of total national production (France-Presse, 2022). We are already experiencing the catastrophic consequences of the growth of human activities at the expenses of ecosystems functions and their ability to provide contributions to society in the future. Today more than ever, transformative changes are needed to integrate the value of nature into human development patterns through mutually supportive local and global actions (IPBES, 2019).

Figure 28: Ice serac breaks off on the Marmolada. Credits: LaPresse/Luca Bruno

In this sense, the dissertation offers a new perspective on cohesion policies focusing on the ecological values of local systems (Magnaghi, 2010). Through the lens of ES new spatial interdependencies foster an ecologically oriented place-based approach where socio-economic patterns are coupled with environmental characteristics. The results thus argue for a transformative change, not only placing at the center the areas of ES provision, but also highlighting the role of anthropogenic systems co-producing those ES. Within this cause, the dissertation advances ES research in bridging the science-policy gap, also referred to as "implementation" gap (Levrel et al., 2017), addressing the unavailability of knowledge for practical implementation, as well as proposing an interdisciplinary framework for integrating different science perspectives and planning sectors. The dissertation supports governance with inclusive and adaptive approaches to achieve sustainable cohesion policy at regional and local scale. On the one hand, the centrality of local systems, and on the other hand, the role of actors in the ES co-production allows for moving toward a participatory planning model based on the relationship between the social and the ecological spheres.

As for the conceptual and methodological contribution, the dissertation validates the potential of ES in integrating different planning domains, facilitating discussions and bridging between ecological and socioeconomic aspects (Albert et al., 2014; Grêt-Regamey et al., 2017; Ruckelshaus et al., 2015). The research applies the ES concept on the analysis of landscapes as social ecological systems, in which the anthropogenic and natural components are interconnected to the point that they must be investigated within the same evaluation. The research was successful in advancing the understanding of social ecological systems though the concept of ES, while developing implications for landscape planning providing practical recommendation to achieve sustainability at a regional and global scale.

This chapter synthesizes the outcomes of my dissertation, organizing them around the three main components outlined in the introduction. The first paragraph concerns the scientific advances in methodology, mainly relating to the thriving research domain of ES in landscape planning. The second paragraph provides suggestions for planning to capture the complexity of landscapes as social-ecological systems. This served as a lens for addressing the core objective of the thesis, territorial cohesion, which is the topic of the third paragraph. Here, insights are offered toward an ecological perspective on cohesion policies. To facilitate reading, the paragraphs are structured following the three objects of the thesis: i) analyzing the fields of application of the ES concept in landscape planning, identifying of the main implementation practices; ii) developing an approach to map landscape as social-ecological systems while delivering insights for landscape planning and regional cohesion; and iii) developing a framework for the analysis of the role of social actors within social-ecological systems through ES co-production.

5.2 Conceptual and methodological contributions

The main innovation of the research lies in the dual analysis addressing the complexity of the landscape: on the one hand, the environmental assessment investigates the tangible components of socio-ecological systems, and on the other hand, the social analysis seeks to capture the perceptions of communities (Sargolini, 2013). In this sense, the double dimension of the landscape is portrayed, Chapter 3 investigates the objectivity of the biophysical dimension through spatial indicators, while Chapter 4 explores the subjectivity experienced by those who live the territory. The integration of two different working frameworks allows the construction of a complex methodology, which provides an important contribution to multidisciplinarity in landscape planning and governance.

The study framework builds on the integration of the multiple benefits ecosystems contribute to human well-being, including the social and cultural perspective on the ES cascade model (Haines-Young and Potschin-Young, 2010; Martín-López et al., 2014). Yet, as benefits from nature do not occur independently but often require significant human contributions, the role of social systems is further analyzed though the ES co-production framework (Palomo et al., 2016). The landscape application is furthermore relevant because its scale is considered the most appropriate to the integration of social need and preferences to environmental assessments (Nogué and Sala, 2018; Tallis et al., 2015). The contribution of this work to ES science regards the use of novel methods for literature review, as well as the integration of spatial and social evaluation methodologies.

Chapter 2 presents the application of the methods of systematic literature review on the topic of ES in planning. The study identifies relevant research in the integration of ES in planning and systematically reports quantitative findings on methodology and sectors of application. The novelty of this study lies in the application and testing of the co-citation analysis methodology, which allowed the identification of research clusters, especially in relation to the temporal development of ES research and pivotal studies (Chen, 2006). The study also presents the innovative aspect of considering the totality of ES applications in planning, going beyond sectoral perspectives and approaches.

In Chapter 3, the spatial dimension is assessed building on the concept of ES bundles (Raudsepp-Hearne et al., 2010), and developing it in the direction of the supply-demand perspective (Baró et al., 2017). The supply and demand definition (Villamagna et al., 2013a) allows the operationalization of the framework on territorial interdependencies, through budgeting operation (Burkhard et al., 2012). The novelty of this paper lies in the application of the analysis on the inland areas framework, which allowed the assessment of interdependencies between urban poles and inland areas beyond the urban-rural dichotomy (Lucatelli et al., 2019). Furthermore, the landscape characterization of the identified social-ecological systems represents a useful application of the ES bundles research on a Mediterranean region. The spatial assessment of supply and demand of a set of 12 locally relevant ES are a base for the development of a green infrastructure within the regional landscape planning context.

Conceptual and methodological contributions on the analysis of social systems within the landscape context are developed in Chapter 4. Here, the ES co-production concept is operationalized through focus groups and interviews on the value of nature for society in the local case study of Fiastra Valley. Building on the framework developed by Fischer and Eastwood (2016), as well as its implication on human's role in ecosystems and sustainability drawn by Palomo et al. (2016), the study uses the concept of co-production to read the connections between social and ecological components in the landscape as social ecological system. In this frame, social relations are explored in order to understand power asymmetries and the distribution of ES benefits across the beneficiaries (Bennett et al., 2015). A recent application of the framework (Jericó-Daminello et al., 2021) highlighted discrepancies between how stakeholders perceive themselves as co-producers and how others perceive them. Focusing on stakeholders' dependency and benefits, the study offers a new tool for understanding stakeholders' relationships and access to decision making, which can provide insights for more equitable and sustainable planning. Furthermore, the study demonstrated the effectiveness of co-production framework in displaying the dense network of collaborations related to ES dynamics.

5.3 Implications for landscape planning

Given the outlined methodological base, the research aimed at developing insights for regional governance and landscape planning to cope with drivers of transformation integrating social and ecological goals (R.S. de Groot et al., 2010). The multidisciplinary approach described in the previous paragraph aimed at addressing the complexity of landscape as social-ecological systems. While landscape planning and management has historically often been based on a reductionistic understanding and linear models of the world (Holling and Meffe, 1996), this thesis attempts to approach the complex interaction of different, and sometimes competing, land use characteristics in face of continuous biophysical as well as social changes, considering the local and the regional scale. Following the objectives stated in the previous chapter, the dissertation first accounted the knowledge domain, through the analysis of the state of the art on the integration of ES in planning (Chapter 2), and then developed a new functional landscape characterization through the concept of ES (Chapter 3), including the role of social actors in the perception of landscapes through their role in ES co-production (Chapter 4). The following paragraphs present the main implication of the studies for landscape planning.

The literature review showed a thriving and growing research area, characterized especially by countries from the Global North, also addressing case studies in developing countries (Spangenberg et al., 2018; Teixeira et al., 2019). In the integration of ES in planning, a wide range of methodologies are adopted, ranging from spatial analysis to social data collection through questionnaires and interviews, or focus groups (Elbakidze et al., 2017; Giedych and Maksymiuk, 2017). This variety of methods brings several application fields and tools. Among proactive planning the most relevant concept results to be the one of green infrastructure, applied both at city scale and regional scale (Arcidiacono et al., 2016; Artmann et al., 2017; Baró et al., 2017). Integration of ES in Strategic Planning includes strategies to protect or limit urban growth (Salata et al., 2020), while Environmental and land use management show great emphasis on assessing the effects of land use changes. Research shows how analyses related to ES can support the planning process through new approaches to zoning with respect to multifunctionality and benefits offered by ecosystems (Geneletti, 2013; Liu et al., 2019).

In Chapter 3, the application of ES Bundles to map landscapes as social-ecological systems highlighted avenues of sustainable development for local landscapes in a Mediterranean regional case study. The study highlighted bundles of ES supply and demand further explaining them as landscape units associated to local socio-economic assets. The regional landscapes system was interpreted along a coastal-mountain gradient drawn by the rising altitude and decreasing population density (Queiroz et al., 2015; Quintas-Soriano et al., 2019). Those functional landscape units are mostly shaped by spatial socio-cultural conditions, especially land use, demography, and income. Analyzing interdependencies beyond the urban-rural dichotomy enabled the study to recognize the polycentric characteristic of the regional case study which also presents urban conditions in mountain forest bundles. Particularly interesting for regional decision-making, ES tradeoffs were found in agricultural areas, between the supply of provisioning and regulating services, while synergies characterize the mountain systems where a set of regulating and cultural services are supplied (Balzan et al., 2020; Felipe-Lucia et al., 2020). In relation to the global pressures faced by inland ecosystems, recommendations were offered for sustainable landscape planning: i) preservation of the identity of inland systems through the support of local ecosystem management and responsible ecotourism strategies, ii) the enhancement of sustainable agriculture through small-scale farming and sustainable practices (also in relation to CAP), iii) pay special attention on multifunctional landscape management practices, in the local case study represented among the others by pastoralism.

The use of the ES co-production framework to visualize the role of local stakeholders within social-ecological systems (Chapter 4) allowed the integration of the social perspective in landscape planning, in respect to their dependency and benefits from ES, as well as their access to decision making. To our knowledge, this real case application represented the first explicit integration of ES co-production framework to landscape planning. Results show that rural actors associate great cultural values to local landscapes, visualized though a set of ES they receive from ecosystems (Díaz et al., 2018). Those services are both physically co-produced by actions on the state of ecosystems, as well as valued through the perception as users, benefiting from the services and valuing them (Palomo et al., 2016). The study thus proved the efficacy of ES framework in visualizing how landscapes are co-produced by social and natural components, assessing both the physical social-ecological patterns and the perception of local communities (Sargolini and Gambino, 2016). Incorporating the central role of people in landscape assessment, the study suggests that collaboration and social learning should be fostered through collaborative planning, integrating innovative tools for ensuring participation (Opdam et al., 2015b).

5.4 Towards an ecological perspective on cohesion policies

While advancing environmental sciences on the application of the ES concept in landscape planning, this dissertation aimed at providing regional governances with a scientific "environmental argument" in support of territorial cohesion. As described in the introduction, the process of urban growth led to increasing inequalities between regions (Rockström et al., 2009) and inland areas are undergoing a process of economic decline and depopulation (ESPON, 2021). The Territorial Agenda 2030[5] encourages spatial planning and policymaking to promote a balanced and harmonious territorial development between and within regions. To approach this challenge, this thesis read territorial interdependencies through the lens of ES, emphasizing the role of inland systems in providing benefits to society.

The argument of territorial interdependencies arises from the awareness that the growth of urban settlements is based on the exploitation of natural capitals mostly coming from inland areas (Folke et al., 1997; Gebre and Gebremedhin, 2019). Chapter 3 investigates the topic through the spatial

[5] The Territorial Agenda 2030 underlines the importance of and provides orientation for strategic spatial planning and calls for strengthening the territorial dimension of sector policies at all governance levels. The document is based on the meeting of Ministers for Spatial Planning and Territorial Development and/or Territorial Cohesion 1 December 2020, Germany.
https://ec.europa.eu/regional_policy/sources/docgener/brochure/territorial_agenda_2030_en.pdf

analysis of ES demand and supply in Le Marche regional case study, characterized by growing polarization both in demographic and economic terms. As other Mediterranean areas, the region can be read through local systems of municipalities which are deeply different in terms of socio-economic profiles and spatial characteristics, ranging from remote mountain areas to urbanized valleys and coastlines (Calafati and Mazzoni, 2009). The results highlighted a strong dependency of urban areas on inland systems concerning nearly the total set of 12 ES taken into consideration. The analysis further demonstrates how areas of demand differ from areas of supply and concentrate in the most densely populated areas. On the other side, systems providing services are located in areas remote from cities, where the great availability of natural resources support the delivery of ES. In this sense, the thesis produced a new environmental-based argument toward territorial cohesion where inland areas should no longer be defined by their condition of marginality and backwardness, but acquire a central position in the provision of benefits for the whole society. While cohesion policies often addressed disadvantaged areas though welfarist approaches based on "compassionate compensations" (Barca, 2018), this dissertation shows how inland systems should be supported for their role in the ES provision and the protection of biodiversity.

Nevertheless, the high aging indexes as well as the income gap toward the urban areas, draw urgent challenges for the resilience of inland systems. Actions in the direction of environmental justice should go beyond the redistribution of income or benefits but also include the role of local actors in decision making as well as their cultural identities, values and knowledge systems (Pascual et al., 2014). The importance of local involvement is further underlined in the investigation of social systems though ES co-production (Chapter 4). Here the results show discrepancies between dependency and decision making, stressing the need for processes of social inclusion in landscape management. The exercise offers insights in terms of the equity of the distribution of ES (Palomo et al., 2016) and how ecosystem structures eventually turn into benefits (Fischer and Eastwood, 2016). Stakeholders' perspectives are crucial to ensure a balanced and sustainable development within regions and its integration in planning constitute civic practices that can directly generate societal benefits (Krasny et al., 2014).

When including the perspective of local actors, the notion of participation can be helpful. Difficult to define (Pellizzoni and Osti, 2003), two factors primarily structure participatory processes: the will to act and the extent of the possibilities of intervention. Referring to the sphere of policy generation processes, the extent of citizens' possibilities of intervention in decision-making processes can be structured according to the "scale of participation" proposed by Arnstein, (1969). Figure 29 shows different rungs of intervention ranging from *Nonparticipation* to different degrees of *citizen power*. Empowerment is indeed crucial in cohesion policies, in the sense of increasing citizens capacities of elaboration and intervention as well as defining their own development horizons (Bobbio and Pomatto, 2007). The ability to increase citizens' active participation also means inclusion of those actors generally excluded from decision-making processes. By assigning roles to stakeholders of ES co-production, this research goes in the direction of enabling local actors to assume responsibility and expand the possibility of influencing decision-making.

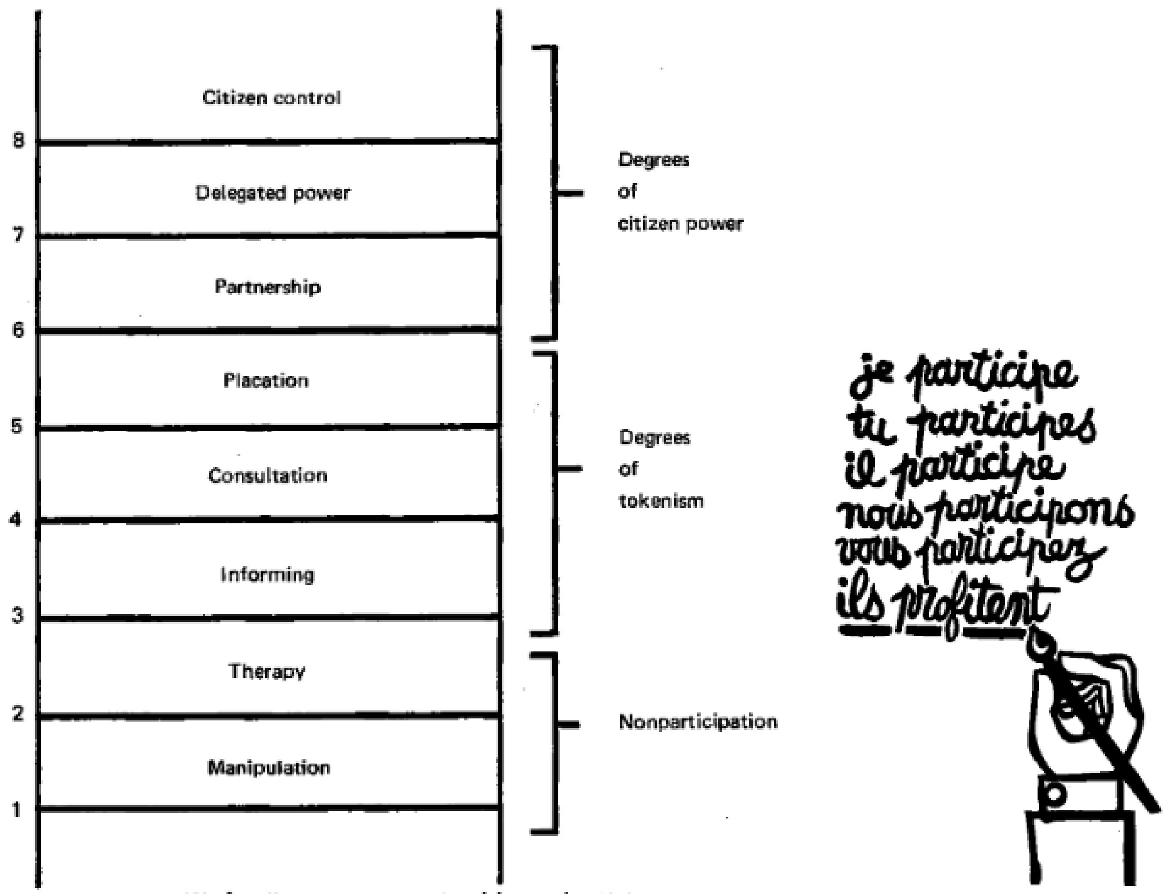

Figure 29: Eight Rungs on a Ladder of Citizen Participation, from Arnstein (1969)

Through the integration of people's perspective, the dissertation proposes new tools for the design of place-based policies, also referring to the process of 'policy territorialization'. According to Galli et al. (2013), the territorialization of policies has a double characteristic: first, it means moving from a sectoral to a territorial and integrated logic, linking not only the different sectors but also individuals and operators, secondly, it means strengthening bottom-up activities and collaboration. With this aim, this research follows the objective of overcoming the cognitive crisis of the central state caused by the regionalization of the contemporary countryside, fostering the active and conscious participation of the different actors in the rural areas (Pellizzoni and Osti, 2003). Participation and integration are, therefore, key words for a new model of rural development policies as well as for the application of a multifunctional planning perspective.

In many ways, these concepts are well known and debated within the cohesion policy discourse, although they are far from being applied in the concrete application of policies (Barca et al., 2012). Overcoming this gap, this research builds on participation and integration to create an ecologically oriented place-based approach, combining local social-ecological assets through the lens of landscape. This approach can overcome the idea of fit-for-all solutions designed by central governments, which characterized past welfare policies for the inland areas in Italy (Viesti, 2016), and instead support the development of approaches based on local landscape characteristics. In accordance with The territorial Agenda 2030, this place-based approach builds on local capabilities and aim to promote innovative ideas through the interaction of local knowledge with external actors, in line with the existing territorial interdependencies.

To conclude, suggestions toward new ecological cohesion policies can be drawn from the conducted analysis as well as the theoretical conceptualization behind this thesis. Beyond the crucial base of information given by spatial analysis, involvement and participation become necessary in the case of local development and integrated projects. The limits of a top-down, technocratic approach have been made visible by twenty years of European cohesion policy applications and a new orientation towards the construction of active communities is necessary. It becomes evident therefore how policies should support processes rather than project, supporting the empowerment of local actors for the self-development of their own paths.

5.5 Limitations and further research

This dissertation is built on strong methodologies, based on peer reviewed studies (e.g. Burkhard et al., 2012; Palomo et al., 2016; Raudsepp-Hearne et al., 2010; Villamagna et al., 2013), as well as international scientific reports (e.g. Manual for ES evaluation from "LIFE+MGN Making good natura"). Outputs and methodological choices have been assessed and discussed together with regional authorities, which supported the research in the frame of the VAUTERECO project. Nevertheless, limitations are to be accounted, both on the methodologies used and on their application. Starting from the literature review (Chapter 2), it should be mentioned how CiteSpace's labelling method takes into consideration only the words contained in the titles and keywords of the clustered co-citing studies. As co-citing studies do not necessarily deal with the same topic, the respective labels do not represent them with the same degree of accuracy, and the result should be understood just as an indication on macro evolutions of the research trend in the field (Chen, 2006). As the spatial analysis is concerned (Chapter 3), we must account the limitation of biophysical indicators in displaying processes and functions associated with ES. In fact, while the mapping methods have been generally chosen as fitting as possible with regional characteristics, the lack of data availability did not allow the selection of good spatial predictors especially concerning cultural ES. In this case, additional field work addressing local actors through survey could improve the quality of the assessment (Baró et al., 2017). Similarly, concerning the social analysis (Chapter 4), it is not possible to exclude the bias of respondents in representing an entire category of stakeholders. A combination of social network analysis (SNA) and descriptive statistics might support the selection of stakeholders (Jericó-Daminello et al., 2021) toward the definition of a more representative sample. However, both for Chapter 3 and 4 the translation of the methodology in planning practice should account that the implementation of social analysis requires large economic and human resources, which are not often available in the rural context.

Those limitations together with the outlined complexity of the topic approached, suggest the need of more empirical explorations to increase our understanding of landscapes as social-ecological systems through the concept of ES. In the direction of future research, I suggest a set of avenues of research:

First, the literature review on the topic of the applications of ES in planning could be combined with a qualitative analysis, focusing on papers explicitly addressing the concept of social-ecological systems. In this way, interesting insights could be offered on how the social-ecological systems perspective is used in the integration of ES in Landscape planning.

Regarding the spatial analysis, advancements can be designed through a redefinition of the analytical boundaries of the study. As for now, both the spatial extension mapping and the rationality of methods are limited within regional boundaries – e.g. the demand for eco-tourism accounts for the arrivals in regional tourist structures, rather than their actual places of origin – lacking the consideration of important knowledge with respect to the location of drivers. A broadening of the boundaries of evaluation could extend the analysis to the "telecoupling" effects accounting cross-scale social relations, as decisions taken at local scales are often shaped by actors at larger scales (Martín-López et al., 2019). Its integration into the regional study could lead to further insights on environmental equity beyond the local dimension. Furthermore, within regional boundaries, the service flow analysis could be further investigated to highlight stakeholders' power relationships. Aspects such as land stewardship, access rights, and governance systems are stressed to be important in the definition of relationships between supply and demand for ES (Felipe-Lucia et al., 2015).

Regarding the ES co-production framework proposed, enlarging the application to diverse case studies could prove the effectiveness of ES co-production in analyzing the role of social systems, along with allowing the comparison between actors from different local contexts. Indeed, the framework could be applied to urban landscapes as well as more remote areas, comparing the results and deriving more general conclusions. The analysis of differences in social roles in areas highly characterized by ES demand (e.g., urban areas) or ES supply (e.g. mountain/peripheric areas) can offer a picture of territorial interdependencies, looking at power relations and spatial differences in access to decision-making (Gebre and Gebremedhin, 2019). Moreover, a focus group with regional authorities might account the discussion about trade-offs related to ES co-production and connect them to land use decision making toward a more equal distribution of benefits.

In terms of concrete development of this dissertation in regional planning tools, this study represents a first stone for the construction of Le Marche regional Green Infrastructure. The data on ES supply can boost the establishment of robust decision support tools to facilitate decision making in agriculture to balance food production and environmental protection (Morri and Santolini, 2022). A comparison of the ES Bundles with the existing regional ecological networks (REM) could further investigate the topic of biodiversity and ecological connectivity.

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Supplementary material

Appendix 3.A – Individual Ecosystem Services

Provisioning services

The ES P1 Cereal production was mapped according to actual production (supply) and actual consumption (demand). *The supply map* highlights a main production strip in the mid-low hilly area from south to north. No supply is recorded in the south-western mountain areas while lower values concern the rest of the inland areas. The service supply also decreases on the coast due to a major level of urbanization. *The demand map* highlights a high consumption associated with the coastal municipalities and to the urbanized valleys penetrating the inner region.

As for the Cereal production, the ES P2 Wine production was mapped following indicators of actual production (supply) and actual consumption (demand). *The supply map* reports concentration of productions in areas recognized as DOC and DOP, such as: Rosso Conero (in the area of Ancona), Rosso Piceno (in the low Ascoli Piceno Province) and Verdicchio (area of Jesi and Matelica). The rest of municipalities presents a diffuse a moderate supply level, apart from mountainous areas, which are not prone to the cultivation of wine. The *demand map* is related to population density and accounts higher values in the coast and in the main urban poles.

The ES P3 Pastoral production was mapped through the indicator of cheese production (supply) and consumption (demand). *The supply map* shows that productions are mostly located in the mountain part in the southwest and in the north of the region, while low productions are mapped along the coast. Pastoral productions are thus distinctive among local productions, characterizing themselves as high hill and mountain activities. Similarly to ES P1 and P2, the *demand map* is related to population density and reports higher values in the coast and in the main urban poles.

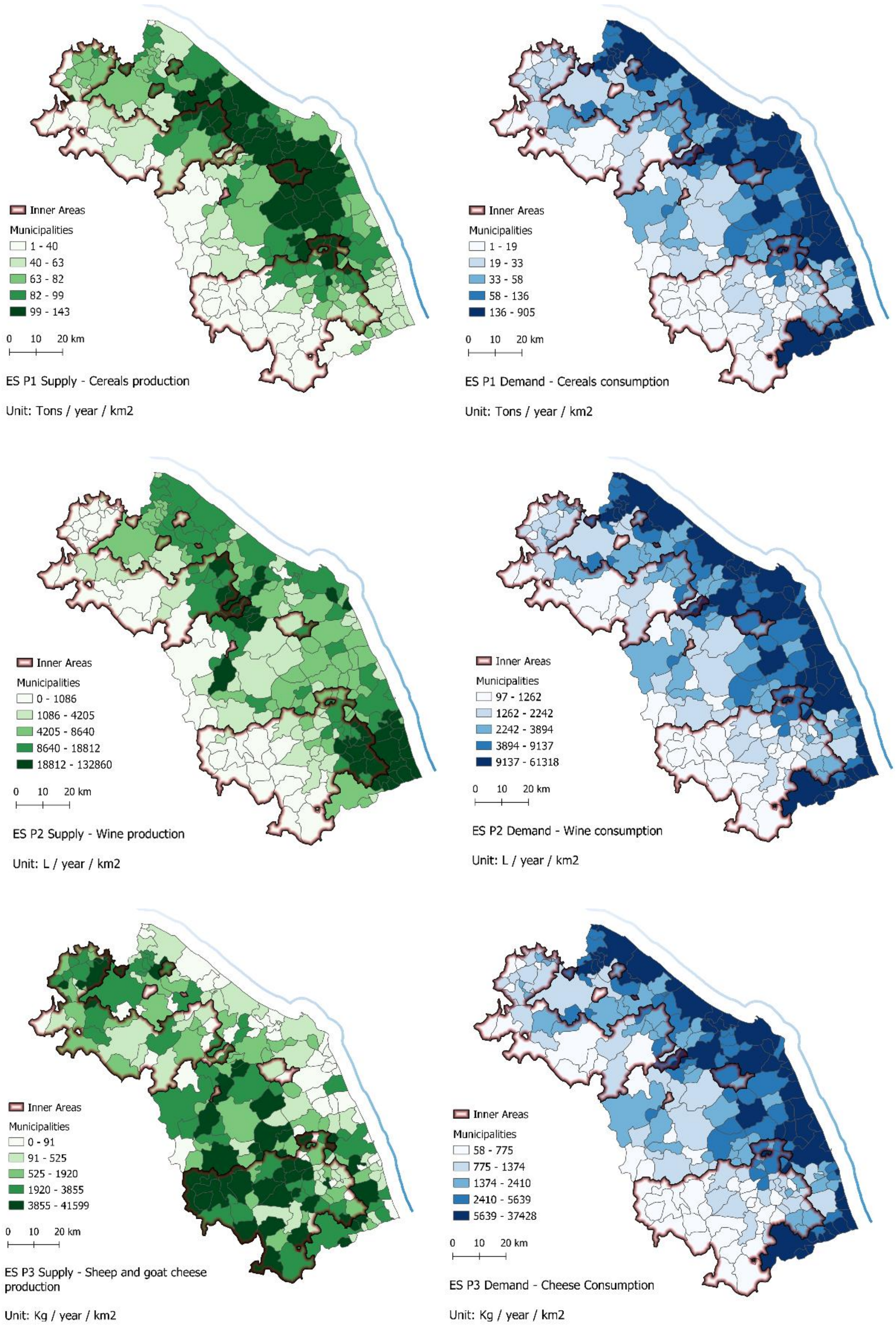

Figure SM1: Spatial patterns of ES P1 Cereal production (up), P2 Wine products (center) and ES P3 Pastoral products (down), indicators. The map on the left indicates ES supply, on the right ES Demand.

The ES P4 Drinking water relates to the water distributed by the local aqueducts. The supply indicator is defined as the concessions allowed by Le Marche Region for the capture of water for drinking purposes while the demand refers to the actual water delivered by the network to the population. The *supply map* highlights different profiles for the north and south of the region: the north offers a rather uniformed distribution with hotspots municipalities corresponded to the main water withdrawal points, while the south shows a strong supply from the inland areas. The *demand map* relates to population density with higher values on the coast and main urban centers.

The ES P5 Hydro power was mapped through the nominal power of regional hydroelectric plants (supply) and the energy consumption by population and companies (demand). The supply map highlights hotspots of production in the mountain area in the southwest of the region and other municipalities along the valley. As in the case of P5 drinking water, the supply is distributed throughout the municipalities without major unbalances. The *demand maps* draw the actual consumption along the areas of higher population densities, on the coast and in the main urban poles.

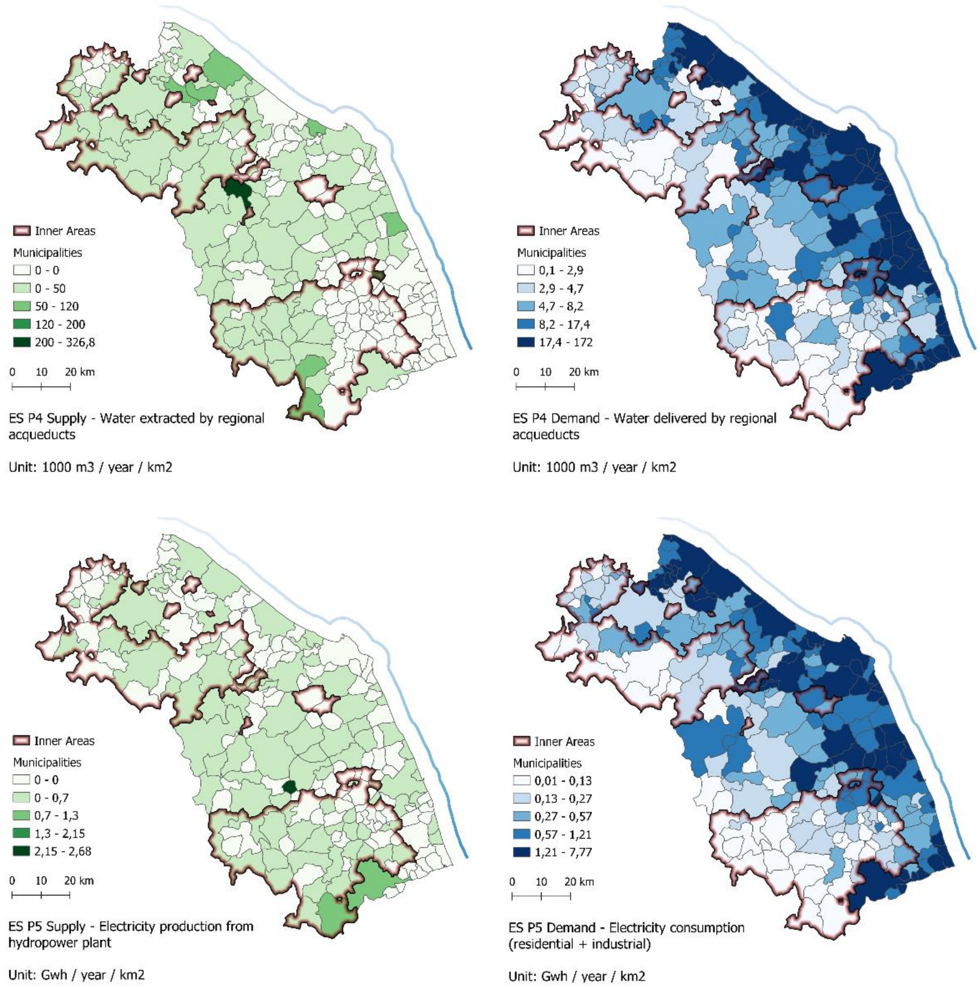

Figure SM2: Spatial patterns of ES P4 Drinking water (up) and ES P5 Hydro power (down) indicators. Left: ES supply, right: ES Demand.

Regulating services

ES R1 Hydraulic regulation relates to the flood risk from extreme events (demand) and the role of vegetation in rainfall infiltration (supply). The *supply map* shows high values for the mountain forested areas while low values are mapped in low hilly fields. The *demand map* highlights three spots of higher pressure, respectively in a southern, central and northern hilly areas.

The ES R2 Soil protection refers to the loss of soil due to water erosion and the role of ecosystems in retaining nutrients. The *supply map* shows how highest soil retention values correspond to areas covered by woodland and pastures. The demand map indicate an hotspot in the southwest, with general higher values on the hilly belt.

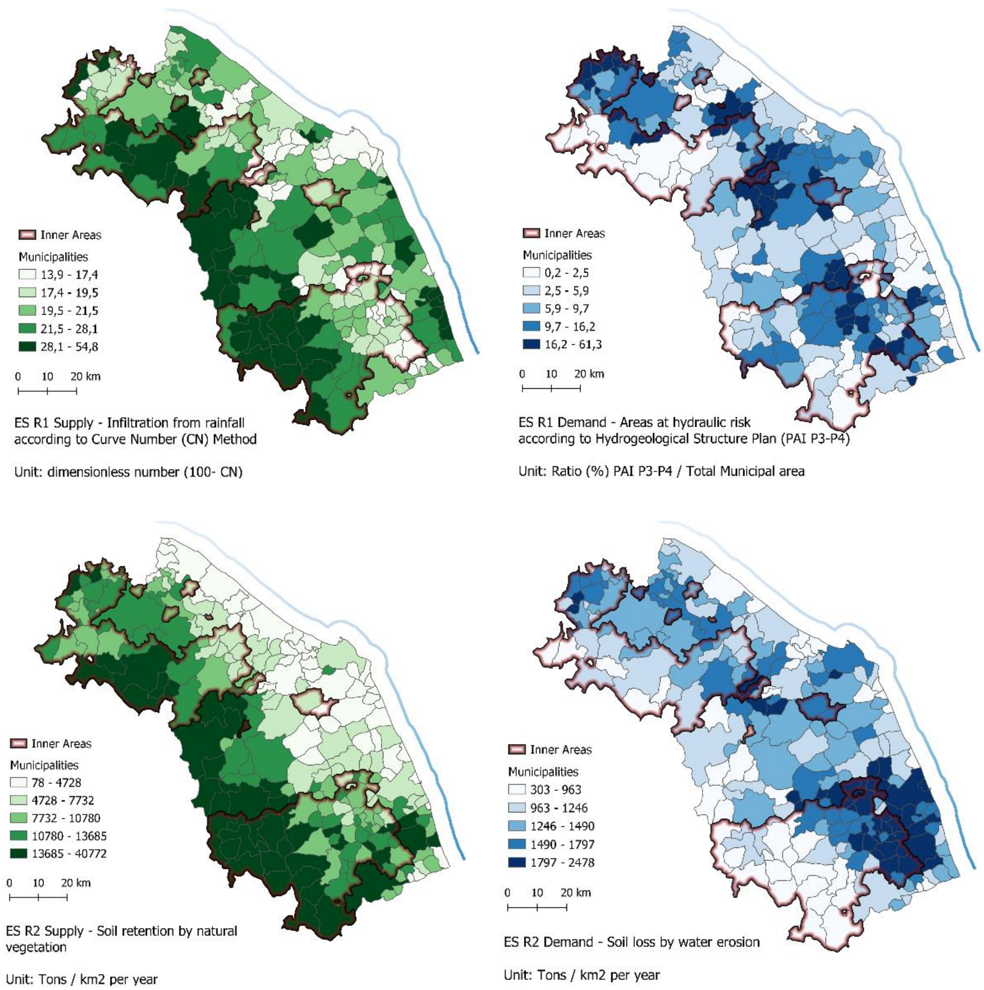

Figure SM3: Spatial patterns of ES R1 Hydraulic regulation (up) and ES R2 Soil Protection (down) indicators. Left: ES supply, right: ES Demand.

The map of R3 Crop Pollination refers to the service provided by a wide range of insect species that with the help of wind allow plants and trees to develop fruits, vegetables and seeds. The *supply map* refers to the relative pollination potential and is related to the presence of forests and trees in the inner belt of the region. The *demand map* reveals the dependency of cultures from pollination especially in the hilly area devoted to fruit trees and partially oilseeds.

R4 Climate change regulation concerns processes related to atmospheric chemical composition, particularly to the greenhouse effect. The *supply map* related to the absorption of CO2 by ecosystems and, as for the ES crop Pollination, it shows higher values in the forested inner belt of the region. The *demand* is related to the emission of CO2 and the map gives higher values for the municipalities of the coast, together with the first hilly belt, hosting most of the regional industrial activities. Interesting to note a particular concentration in the footwear production sector located in the central south part of the Region.

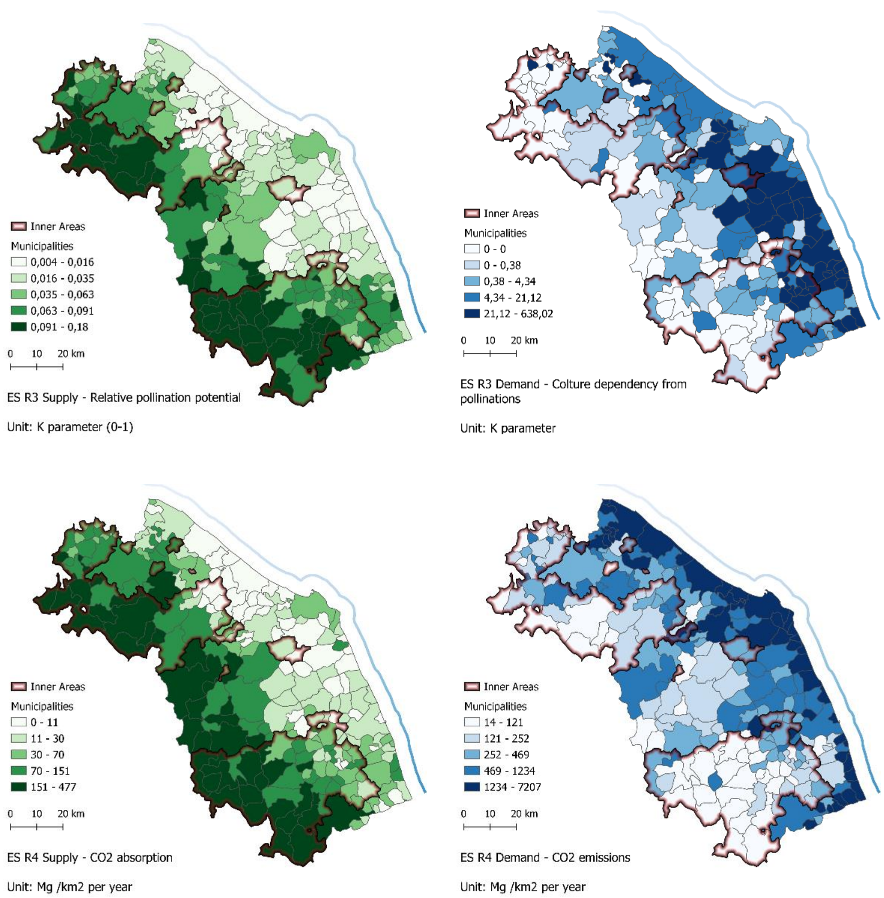

Figure SM3: Spatial patterns of ES R3 Crop Pollination (up) and ES P4 Soil Erosion regulation (down) indicators. Left: ES supply, right: ES Demand.

Cultural services

The ES C1 Eco-tourism relates to the recreational pleasure people derive from natural or cultivated ecosystems. The *supply map* relates to the indicator of available hiking paths and shows higher values in mountain municipalities and protected areas. *The demand* is related to visitors in eco-touristic structures and interests mainly the coastal area with some inland hotspots.

As well as C1, the activity related to C3 Mushroom picking reflects a leisure interest related to ecosystems. In this case the demand refers not to incoming tourists but to local residents. The *supply map* is related to geographical condition allowing habitats for mushrooms and have higher values in forested mountain areas coinciding with the inner belt. The *demand* is connected to the distribution of mushroom license in the regional territory and gives higher values in territorial hotspots spread throughout the region.

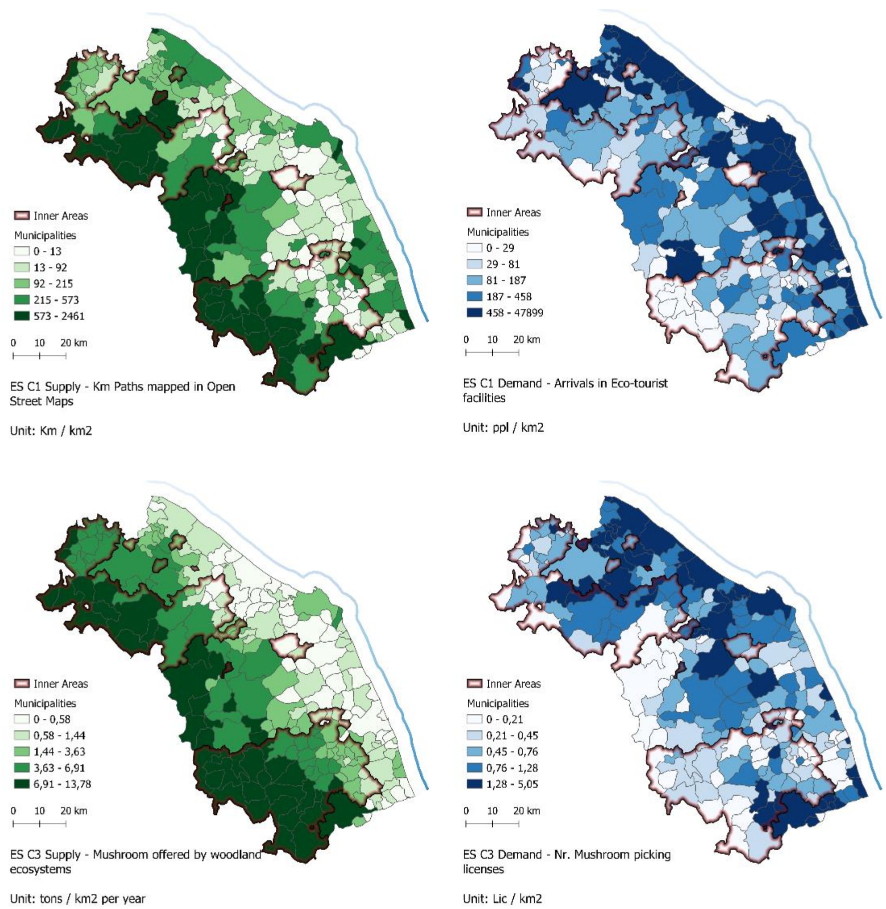

Figure SM4: Spatial patterns of ES C1 Eco-Tourism (up) and C3 Mushroom picking(down) indicators. Left: ES supply, right: ES Demand.

C2 Environmental education relate to the process of learning from nature both in academic programs and in informal settings. For this reason, the *supply map* shows an equal distribution of spots connected to the Regional Education Centers and didactic farms, without any clear difference among inland areas and more urban contexts. The *demand* is centered in more populated areas, especially the coastal poles hosting younger population.

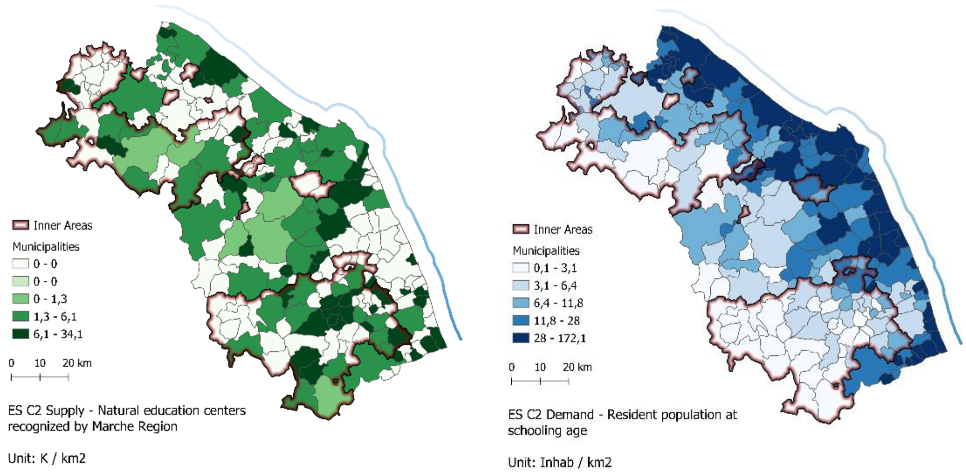

Figure SM5: Spatial patterns of C2 Environmental Education (down) indicators. Left: ES supply, right: ES Demand.

Appendix 3.B – Individual socio-economic indicators

The results of the socio-economic characterization are shown in respect to the three categories of indicators. The *social indicators* include S1 Demographic index, S2 Social and material vulnerability index and S3 Income, the *economic indicators*, refers to the three economic sectors E1 Primary sector, E2 Secondary sector, and E3 Tertiary sector, and the *land use indicators* include L1 Artificial surfaces; L2 Agricultural surfaces; L3 Forests and seminatural areas.

Patterns of social indicators

S1 Demographic index relates to the ageing of the population and shows clear un-balances between inland areas and urban poles. S2 Social and material vulnerability, accounting seven different dimensions of social and material vulnerability, gives a patchy picture of the region, with high values of the indicator mostly in the belt areas. The last social indicator, S3 Per capita taxable income, highlight again a homogeneous correspondence between the income of population and the inland areas classification, with coastal and urban municipalities having the highest income and the inland areas, the lowest values.

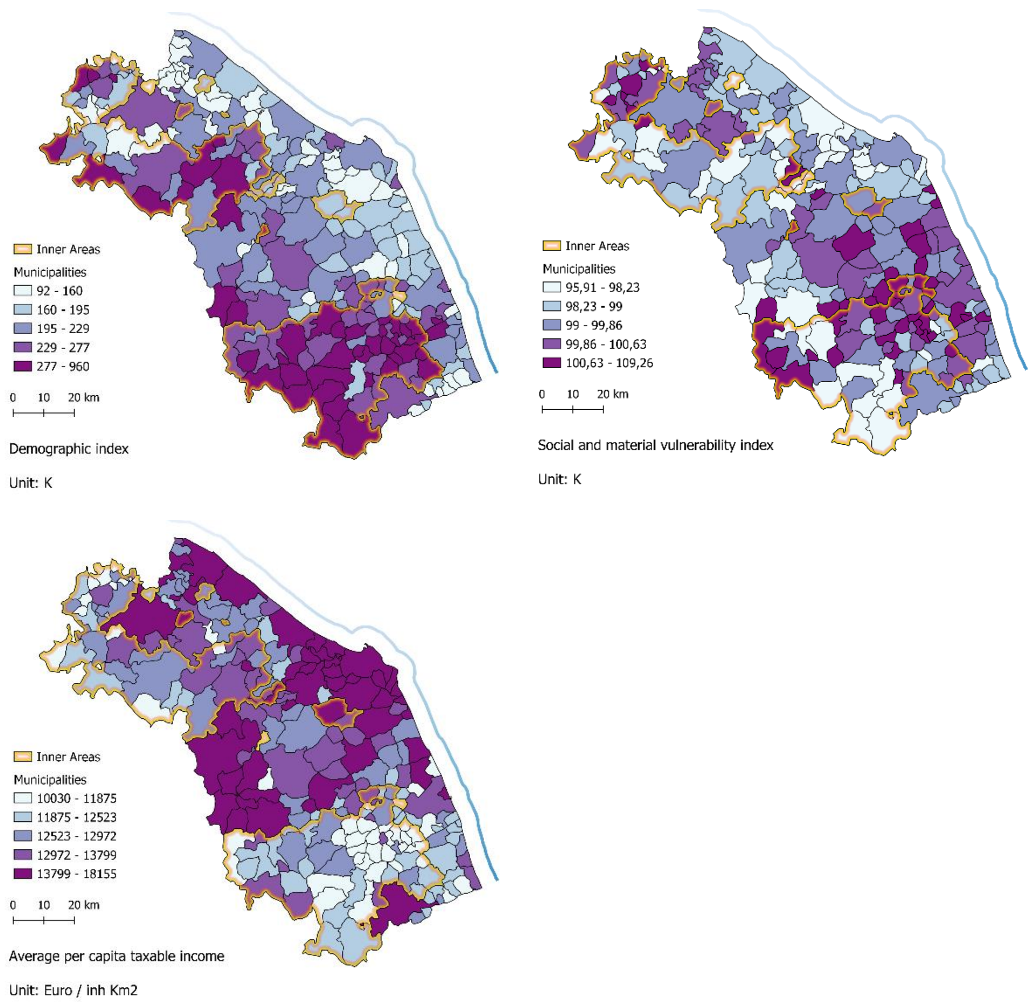

Figure SM6: Spatial pattern of the socio-economic indicators

Patterns of economic indicators

The maps show the distribution of the economic indicators, respectively illustrating employment in the Primary sector (E1), Secondary sector (E2) and the Tertiary (E3). The first indicator shows a significance prominence of Agriculture, forestry and fishing sector for the south of the region. The indicator related to manufacturing activities indicates high value for the municipalities close to the coast. Finally, the accommodation and recreational activities highlight peak values in the coastal southern municipalities (probably connected to seaside tourism) and individual hotspots in the inner side of the region.

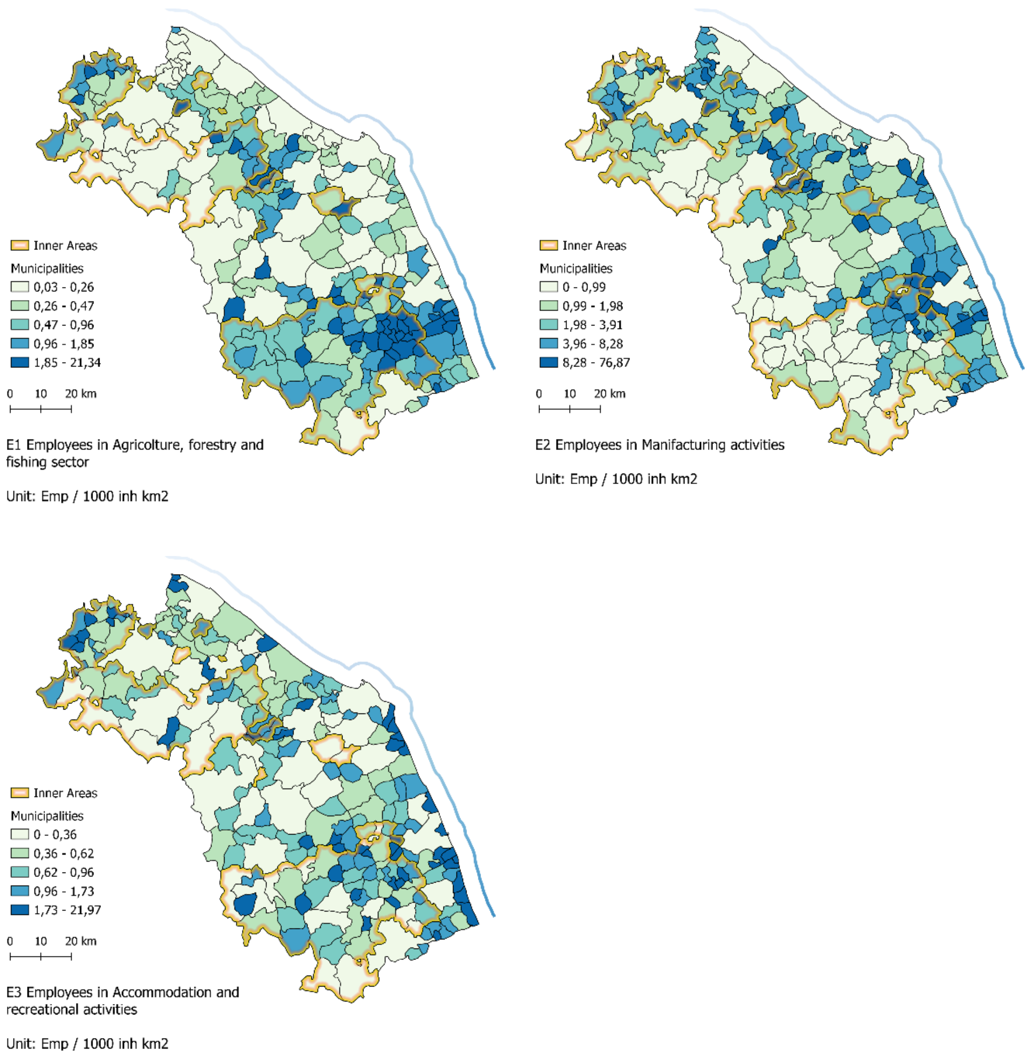

Figure SM7: spatial patterns of economic sectors (E1 primary, E2 secondary, E3 tertiary)

Patterns of land use indicators.

The selected indicators focus on three specific land uses: L1 Artificial surfaces; L2 Agricultural surfaces; L3 Forests and seminatural areas. The L1 shows the incidence of Artificial surfaces on the total municipal value and highlight a clear difference between the coastal municipalities and the in-land territories, with valley strips from the coast toward the mountain in the center of the region. L2 highlight a central hilly area dedicated to agriculture, with very low value in the mountain municipalities. L3 shows a mountain belt of woodland and seminatural areas, with lower values in the area of Monte Conero and the southern province.

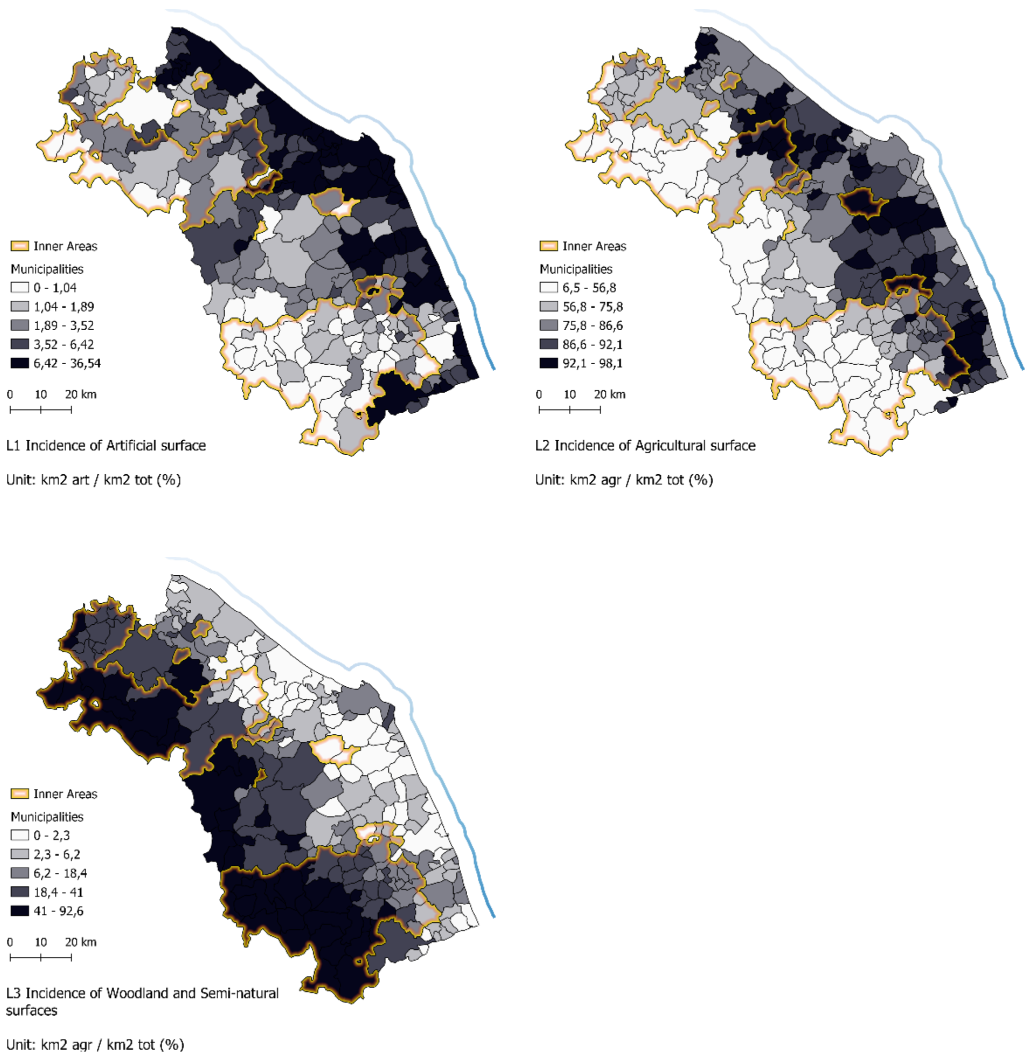

Figure SM8: Spatial patterns of the Land Use indicators

Appendix 3.C – R code

#1) Data upload

R.input <- read.csv2 ("C:/Users/…”)

 # I devide the ES dataframe from the Socio-economic dataframe
R.input <- data.frame(R.input)
ES_Data <- select (R.input, P1_S, P1_D, P2_S, P2_D, P3_S, P3_D, P4_S, P4_D, P5_S, P5_D, R1_S, R1_D, R2_S, R2_D, R3_S, R3_D, R4_S, R4_D, C1_S, C1_D, C2_S, C2_D, C3_S, C3_D)
SOCIO_Data <- select (R.input, SNAI, S1, S2, S3, E1, E2, E3, L1, L2, L3)
ES_Data_S <- select (R.input, P1_S, P2_S, P3_S, P4_S, P5_S, R1_S, R2_S, R3_S, R4_S, C1_S, C2_S, C3_S)
ES_Data_D <- select (R.input, P1_D, P2_D, P3_D, P4_D, P5_D, R1_D, R2_D, R3_D, R4_D, C1_D, C2_D, C3_D)

2) Install packages

library(tidyverse) library(dplyr) library(tidyr) library(ggplot2) library(reshape2) library(ggthemes) library(fmsb) library(gridExtra) library(grid) library(lattice) library(scales) library(stats) library(corrplot) library("xlsx") library("factoextra") library(vegan)

3) Analysis

 # 3.1) K-Means clusters
 # I keep the input data in a separate dataset
ES_Data1 <- ES_Data
#Determine number of clusters
wss <- (nrow(ES_Data)-1)*sum(apply(ES_Data,2,var))
for (i in 2:15) wss[i] <- sum(kmeans(ES_Data, centers=i)$withinss)
plot(1:15, wss, type="b", xlab="Number of Clusters",
  ylab="Within groups sum of squares")
 # K-Means Clusterization
set.seed(123)
fit <- kmeans(ES_Data, 5) # 5 cluster solution
# get cluster means
aggregate(ES_Data,by=list(fit$cluster),FUN=mean)
# append cluster assignment
ES_Data1 <- data.frame(ES_Data, fit$cluster)
ES_Data1 <- rename (ES_Data1, CLUSTER = fit.cluster)

 # 3.1.2) Analyse clusters
#cluster number for each municipality
fit$cluster
head(fit$cluster, 4) #i look at the first 4
 # Cluster size
fit$size
 # Cluster means
fit$centers
fviz_cluster(fit, ES_Data, geom="point")+
 scale_colour_manual(values = c("violet", "darkgreen", "orange", "blue", "green")) +
 scale_fill_manual(values = c("violet", "darkgreen", "orange", "blue", "green")) +
 ggtitle("PRINCIPAL COMPONENT ANALYSIS")+

```
  annotate("text", x=7, y=-3, label= "C1 URBAN COASTAL")+
  annotate("text", x=2.5, y=0, label= "C2 CROPLAND")+
  annotate("text", x=0, y=3, label= "C3 CROPLAND AT HYDRAULIC RISK")+
  annotate("text", x=-1, y=0, label= "C4 MOSAIC CROPLAND FOREST")+
  annotate("text", x=-4, y=-3, label= "C5 MOUNTAIN FOREST")+
  theme_bw()

# 3.1.3) Reorder clusters
# Operation should be run only once
# N. 4 URBAN COASTAL (1)
# N. 3 CROPLAND (2)
# N. 1 CROPLAND AT HYDRAULIC RISK (3)
# N. 5 MOSAIC CROPLAND FOREST (4)
# N. 2 MOUNTAIN FOREST (5)
ES_Data1$CLUSTER <- ifelse(ES_Data1$CLUSTER==1, 3,
             ifelse(ES_Data1$CLUSTER==2, 5,
                  ifelse(ES_Data1$CLUSTER==3, 2,
                       ifelse(ES_Data1$CLUSTER==4, 1,
                            ifelse(ES_Data1$CLUSTER==5, 4,
                                 NA  ))))) # all other values map to NA
SOCIO_Data$CLUSTER <- (ES_Data1$CLUSTER)

# 3.2) Creation of a new Dataframe related to clusters (5 cluster solution) and related to supply-demand
# related to clusters
CLU1 <- dplyr::filter(R.input,BUNDLE=="1")
CLU2 <- dplyr::filter(R.input,BUNDLE=="2")
CLU3 <- dplyr::filter(R.input,BUNDLE=="3")
CLU4 <- dplyr::filter(R.input,BUNDLE=="4")
CLU5 <- dplyr::filter(R.input,BUNDLE=="5")
clusters <- data.frame(colMeans(CLU1), colMeans(CLU2),
                   colMeans(CLU3), colMeans(CLU4),
                   colMeans(CLU5))

# related to supply-demand (related to analysis with 11 ES)
CLU1_S <- select(CLU1, "P1_S","P2_S","P3_S","P4_S","P5_S","R1_S","R2_S","R3_S","R4_S","C1_S","C2_S",
            "C3_S")
CLU1_D <- select(CLU1,"P1_D","P2_D","P3_D","P4_D","P5_D","R1_D","R2_D","R3_D","R4_D","C1_D",
"C2_D","C3_D")
CLU1_SOCIO <- select (CLU1, "S1", "S2", "S3", "E1", "E2", "E3", "L1", "L2", "L3")

# Same operation for CLU2, CLU3, CLU4, CLU5

CLU5_SOCIO <- select (CLU5, "S1", "S2", "S3", "E1", "E2", "E3", "L1", "L2", "L3")
clusters_s <- data.frame(colMeans(CLU1_S), colMeans(CLU2_S),
                   colMeans(CLU3_S), colMeans(CLU4_S),
                   colMeans(CLU5_S))
clusters_d <- data.frame(colMeans(CLU1_D), colMeans(CLU2_D),
                    colMeans(CLU3_D), colMeans(CLU4_D),
                    colMeans(CLU5_D))
clusters_socio <- data.frame(colMeans(CLU1_SOCIO), colMeans(CLU2_SOCIO),
                        colMeans(CLU3_SOCIO), colMeans(CLU4_SOCIO),
                        colMeans(CLU5_SOCIO))

#3.3) Spatial correlation

# 3.3.1) Pearson parametric correlation between ES (synergies and trade-offs)
```

```
# If the p-value is < 0,05, then the correlation between x and y is significant.
corr_S <-cor(ES_Data_S)
CS <- corrplot(corr_S, method = 'square', type = 'lower', diag = FALSE)
corr_D <-cor(ES_Data_D)
CD <- corrplot(corr_D, method = 'square', type = 'lower', diag = FALSE)
grid.arrange(CS, CS, nrow=1, top = textGrob("Correlation in ES Demand and
Supply",gp=gpar(fontsize=20,font=3)))

# 3.3.2) Correlation between bundles and Socio-economic data
# If the p-value is < 0,05, then the correlation between x and y is significant.
# I consider socio economic data
corr_SOCIO <- cor(SOCIO_Data)
corrplot(corr_SOCIO, method = 'shade', order="AOE")

# 3.3.3) Correlation between all the variables
corr_TOT <- cor(R.input_to.plot)
corrplot(corr_TOT, method = 'color', type="lower")
#SOCIAL INDICATORS
# Correlation between budnles and S1 Demography (Result: 6.673e-13 -> very significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$S1, method = "pearson")
# Correlation between budnles and S2 Vulnerability (Result: 0.2789 -> not significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$S2, method = "pearson")
# Correlation between budnles and S3 Income (Result: 1.014e-06 -> very significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$S3, method = "pearson")
#ECONOMIC INDICATORS
# Correlation between budnles and E1 Agricolture (Result: 0.5408 -> not significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$E1, method = "pearson")
# Correlation between budnles and E2 Manifacturing (Result: 0.02881 -> significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$E2, method = "pearson")
# Correlation between budnles and E3 Accommodation and recreation (Result: 0.0004779 -> significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$E3, method = "pearson")
#LAND-USE INDICATORS
# Correlation between budnles and L1 Artificial areas (Result: 2.2e-16 -> very significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$L1, method = "pearson")
# Correlation between budnles and L2 Agricolture areas (Result: 2.2e-16 -> very significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$L2, method = "pearson")
# Correlation between budnles and L3 Woodland areas (Result: 2.2e-16 -> very significant)
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$L3, method = "pearson")

# 3.3.3) Correlation between bundles and SNAI classification
# Correlation between bundles and SNAI classes (Result: 6.108e-11 -> very significant)
# If the p-value is < 0,05, then the correlation between x and y is significant.
cor.test(SOCIO_Data$CLUSTER, SOCIO_Data$SNAI, method = "pearson")

# 3.4) DIVERSITY INDEX
#I calculate diversity index (TOT)
DIV <- diversity(ES_Data, index = "simpson", MARGIN = 1, base = exp(1))
#I calculate diversity index for SUPPLY
DIV <- diversity(ES_Data_S, index = "simpson", MARGIN = 1, base = exp(1))
ES_Data1$Diversity <- DIV
```

4) Data visualization

 # 4.1) ES bundles visualization

```
# 4.1.1) I build the graphs for clasters socio-economic characteristics
clusters_socio$Socio <- c("S1 Demography", "S2 Vulnerability", "S3 Income",
                  "E1 Agricolture", "E2 Manifacturing", "E3 Accommodation and recreation",
                  "L1 Artificial areas", "L2 Agricultural areas", "L3 Woodland and semi-natural areas")
  clusters_socio %>%
   ggplot()+
   geom_col(aes(x=colMeans.CLU1_SOCIO.,y=Socio),
            width = 0.12,
            alpha=0.5,
            position = position_nudge(y = 0.30),
            fill = "blue",
            colour ="black")+
   geom_col(aes(x=colMeans.CLU2_SOCIO.,y=Socio),
            width = 0.12,
            alpha=0.5,
            position = position_nudge(y = 0.15),
            fill="orange",
            col="black")+
   geom_col(aes(x=colMeans.CLU3_SOCIO.,y=Socio),
            width = 0.12,
            alpha=0.5,
            position = position_nudge(y = 0),
            fill="purple",
            col="black")+
   geom_col(aes(x=colMeans.CLU4_SOCIO.,y=Socio),
            width = 0.12,
            alpha=0.5,
            position = position_nudge(y = -0.15),
            fill="yellow",
            col="black")+
   geom_col(aes(x=colMeans.CLU5_SOCIO.,y=Socio),
            width = 0.12,
            alpha=0.5,
            position = position_nudge(y = -0.30),
            fill="darkgreen",
            col="black")+
   labs(title = "BUNDLES SOCIO-ECONOMIC CHARACTERISTICS")+
   theme_bw()

# 4.1.1) I build the graphs for clasters supply
clusters_s$Supply <- c("P1 Cereal production", "P2 Wine products", "P3 Sheep products",
                   "P4 Drinking water", "P5 Hydro power", "R1 Hydraulic regulation",
                   "R2 Soil protection", "R3 Climate change regulation",
                   "R4 Crop pollination", "C1 Eco-Tourism", "C2 Environmental education",
                   "C3 Mushrooming")
s1 <-
  ggplot(clusters_s, aes(x=seq(1,360,by=360/nrow(clusters_s)),y=colMeans.CLU1_S.)) +
  geom_bar(width=360/nrow(clusters_s),stat='identity',position = "stack",colour=("grey90"),aes(fill=Supply)) +
  geom_hline(yintercept = 1 ,linetype="dotted")+
  geom_vline(xintercept = seq(37,396,by=360/nrow(clusters_s)),linetype="dotted")+
  coord_polar()+
  guides(fill="none")+
```

```
  theme_void()

# Same code for plotting s2, s3, s4, s5

# 4.1.2) I build the graphs for clasters demand
clusters_d$Demand <- c("P1 Cereal production", "P2 Wine products", "P3 Sheep products",
                      "P4 Drinking water", "P5 Hydro power", "R1 Hydraulic regulation",
                      "R2 Soil protection", "R3 Climate change regulation",
                      "R4 Crop pollination", "C1 Eco-Tourism", "C2 Environmental education",
                      "C3 Mushrooming")
d1 <-
  ggplot(clusters_d, aes(x=seq(1,360,by=360/nrow(clusters_d)),y=colMeans.CLU1_D.)) +
  geom_bar(width=360/nrow(clusters_d),stat='identity',position = "stack",colour=("grey90"),aes(fill=Demand)) +
  geom_hline(yintercept = 1 ,linetype="dotted")+
  geom_vline(xintercept = seq(37,396,by=360/nrow(clusters_d)),linetype="dotted")+
  coord_polar()+
  guides(fill="none")+
  theme_void()

# Same code for plotting d2, d3, d4, d5

# 4.1.3) I print supply-demand graphs for each cluster
c1 <-   grid.arrange(d1, s1, nrow=1, top = textGrob("B1 Urban coastal",gp=gpar(fontsize=15,font=1)))
c2 <-  grid.arrange(d2, s2, nrow=1, top = textGrob("B2 Cropland",gp=gpar(fontsize=15,font=1)))
c3 <-  grid.arrange(d3, s3, nrow=1, top = textGrob("B3 Cropland at hydraulic risk",gp=gpar(fontsize=15,font=1)))
c4 <-   grid.arrange(d4, s4, nrow=1, top = textGrob("B4 Mosaic cropland forest",gp=gpar(fontsize=15,font=1)))
c5 <-  grid.arrange(d5, s5, nrow=1, top = textGrob("B5 Mountain forests",gp=gpar(fontsize=15,font=1)))
#c6 <-  grid.arrange(d6, s6, nrow=1, top = textGrob("ES Bundle 6",gp=gpar(fontsize=15,font=1)))

# Print all together
c_tot <- grid.arrange(c1, c2, c3, c4, c5)
#ggsave(c_tot, "C:/Users/toma/documents/plot.png")
#LOCATION.PNG <- "C:/Users/toma/documents/ES-Bundles.png"
#png(c_tot, filename = LOCATION.PNG, width = 480, height = 480, units = "px", pointsize = 12)

# 5) export dataframes
LOCATION <- "C:/Users/toma/documents/R-output.xlsx"
LOCATION.CSV <- "C:/Users/toma/documents/R-output-to_gis.csv"
write.xlsx(as.data.frame(ES_Data1), LOCATION, sheetName = "ES-Mapping")
write.xlsx(as.data.frame(clusters), LOCATION, sheetName = "clusters")
write.xlsx(as.data.frame(DIV), LOCATION, sheetName = "diversity")
write.csv(ES_Data1, LOCATION.CSV)

write.xlsx(as.data.frame(CLU1), LOCATION, sheetName ="Bundle 1")
write.xlsx(as.data.frame(CLU2), LOCATION, sheetName ="Bundle 2", append=TRUE)
write.xlsx(as.data.frame(CLU3), LOCATION, sheetName ="Bundle 3", append=TRUE)
write.xlsx(as.data.frame(CLU4), LOCATION, sheetName ="Bundle 4", append=TRUE)
write.xlsx(as.data.frame(CLU5), LOCATION, sheetName ="Bundle 5", append=TRUE)
```

Appendix 4.A – Focus group materials

During the focus group participants were asked to freely list benefits society derive from ecosystems, answering thought post-its to the following questions: (i) what does nature in the Fiastra Valley mean to you? what is the importance of nature for this area? (ii) what are the benefits that Fiastra Valley provides for your well-being/to fulfill your organizational goals? (iii) what goods and products are given to society by nature in Fiastra Valley? (iv) how does nature sustain the local economy? The following tables present the content of the post-its, which were then translated into ES categories by moderators.

Group 1 - Sunday 11 July 2021

ES CATEGORY	POST-IT CONTENT
Environmental education	1. I benefici offerti dalla natura della Val di Fiastra sono molteplici: ispirazione per la pratica didattica, motivazione, armonia ed educazione alla bellezza 2. Una vallata "sociale" ha benefici psicologici e indubbiamente educativi 3. La Val di Fiastra è ambiente privilegiato di apprendimento 4. È bellezza che educa
Scientific (*together with Environmental education)	1. Attraverso spazi di crescita, studio, osservazione
Eco-tourism	1. Creare un turismo alternativo 2. La natura offre opportunità di lavoro in ambito turistico alla riscoperta di radici profonde 3. Impatto sul turismo 4. Turismo esperienziale 5. B n b 6. La natura della Val di Fiastra sostiene l'economia attraverso il turismo (da potenziare) 7. Turismo 8. Ospitalità interattiva 9. Turismo 10. Ambiente naturale gradevole e non disagevole [accessibilità]
Sport activity	1. Piste ciclabili e pedonali nella vallata 2. Bike/e-bike
Mental well-being	1. La natura offre un benessere generale che rigenera "il corpo e lo spirito" 2. La natura nella Val di Fiastra sostiene l'economia attraverso il benessere di chi vi abita 3. Mi permette di avere ritmi più a misura d'uomo 4. Ippocrate diceva "Fa che il cibo sia la tua medicina e la medicina il tuo cibo". Partendo dalla prima osservazione, possiamo concepire quanto la natura e i suoi frutti siano indispensabili per la salute di chi vive in un determinato ecosistema

	5. Possibilità di pensare e di perdersi 6. Scoperta, cultura e benessere 7. Salute, ispirazione, equilibrio 8. Mi ritempra, riempie il mio animo di bellezza e di vita 9. Gli attimi di riflessione guardando la natura ricaricando le energie 10. Benessere, poesia, tranquillità 11. Favorisce il benessere 12. La valle del fiastra offre un benessere generale 13. Ritmi umani 14. Natura= rinascita 15. Serenità, tranquillità
Intrinsic value	1. La natura è assolutamente intrinseca alla vita nella Val di Fiastra, parlare della sua importanza sembra quasi inadeguato perché non è qualcosa di altro rispetto al vivere in questi territori ma da forma e condiziona e permette o meno esperienze quotidiane 2. All'interno di una visione dicotomica uomo-natura, quest'ultima indubbiamente significa molto. Io credo però che dovremmo superare questa distinzione e considerarci come parte stessa della natura, che è un elemento imprescindibile per la nostra sopravvivenza. In quest'ultima prospettiva la natura non ha molto significato, è semplicemente tutto 3. Possiamo capire come la natura sostenga l'economia, soprattutto nella nostra vallata, attraverso un esercizio molto utile ma altrettanto inquietante. Immaginiamo una realtà distopica in qui tutti quegli elementi della natura che diamo per scontati (e infiniti) scompaiono. Forse così riusciremmo a percepire il suo valore, è essenziale. Inutile elencare i servizi che la natura offre al turismo, all'agricoltura, all'arte nella vallata, sarebbe una lista infinita
Biodiversity (*together with intrinsic value)	1. L'importanza della natura nella val di fiastra sta nel polmone verde e nella biodiversità che questo ecosistema offre 2. Spazio, diversità, ricchezza
Sense of place	1. L'impatto dell'ambiente sull'uomo, animali, piante e viceversa 2. La natura è l'aspetto principale che rende la vallata unica (colline, montagne, boschi, borghi, fiumi che combinano colori sapori odori ad ogni stagione) 3. Natura significa ambiente agricolo + tradizioni agricole, radici della nostra storia. Caratteristiche queste peculiari e fondamentali per il futuro 4. La natura nella val di fiastra è bacino di accoglienza e di cura della comunità che la compongono e la popolano. La natura è intreccio e trama delle nostre espressioni 5. Senso di appartenenza 6. Identità-relazione 7. Natura è territorio e tutto cioè che circonda i borghi abitati che li avvolge creando un'atmosfera unica di cui apprezziamo il valore solo quanto per diversi motivi legati al comportamento umano e la intacchiamo 8. Il bene più importante è la molteplicità e la ricchezza in anni di cura da parte dei contadini sentinelle del territorio. Un patrimonio che va scomparendo 9. Identità in cui tutti ci riconosciamo 10. La natura è l'essenza del territorio della val di fiastra, il patrimonio comune
Sense of community (*together with Sense of place)	1. Società= coesione 2. Aggregazione 3. Cittadinanza attiva 4. La natura, oltre che per la mera sopravvivenza e benessere di chi vive in un'area, è importante anche per definire un'identità, una cultura e un'immaginazione di una comunità abitativa 5. Nella val di fiastra la natura è prospettiva per il futuro
Aesthetic beauty	1. La bellezza innanzitutto 2. La bellezza 3. Nella val di fiastra la natura è educazione alla bellezza, all'armonia

	4. Cosa significa la natura= bellezza, libertà, autonomia, armonia.. da gustare assaporare fodere e da educare
Source of inspiration (*together with Aesthetic beauty)	1. È fonte di ispirazione 2. Panorami che arrivano all'anima 3. Contemplazione e silenzio che favoriscono l'autenticità e la ricerca del senso della vita
Artisan products	1. Possibilità di prodotti artigianali locali 2. Forni a legna con uso di pasta madre 3. Botteghe con produzioni artigianali locali 4. Punti vendita di prodotti artigianali locali 5. Tipicità enogastronomiche locali
Agricultural products	1. Impatto sull'agricoltura e allevamento con le sue risorse 2. La natura della val di fiastra sostiene l'economia attraverso l'agricoltura (da rendere sempre più ecosostenibile) 3. Agricoltura 4. Attraverso una produzione agricola più attenta all'ambiente 5. Ambiente ricco di opportunità nell'attività agricola 6. Essendo un territorio di cultura agricola, credo che sostenga molto l'economia locale. Occorre una nuova visione per lasciare che ci sostenga sempre di più 7. Attraverso risorse alimentari
Air purification	1. Scarso inquinamento 2. Acqua aria suolo poco inquinati
R2 Climate Regulation	1. Attraverso risorse climatiche
Disservices (not included in the study)	1. Dopo il sisma la natura è più maligna e non sempre sostiene l'economia locale
Others not included within ES categories	1. Beni e servizi alla società forniti dalla natura 2. La natura fornisce i beni di sostentamento (acqua, aria pulita, cibo sano…) alla società 3. La natura è un capitale, e i "frutti" sono gli interessi. Se consumiamo il capitale lo depauperiamo, non avremo il sostegno del capitale iniziale 4. Offre beni primari di qualità ed opportunità in tutti i settori, basta crederci 5. Territorio della valle, ricco di natura e di storia, rimasto sufficientemente intatto nei secoli sicuramente di più rispetto ad altre aree del maceratese 6. Volano economico e di sviluppo ecosostenibile 7. Offre opportunità di lavoro (anche non troppe) ma in un ambiente lavorativo speciale 8. La possibilità di stare nella natura "facilmente" con tutte le conseguenze positive che la natura ha sull'individuo 9. Con l'aiuto di una adeguata pista ciclabile, si potrebbe: godere meglio la natura, utilizzare il percorso per spostamenti dal capoluogo ai luoghi di lavoro

Group 2 – Saturday 17 July 2021

ES CATEGORY	POST-IT CONTENT
Eco-tourism	1. Credo che la natura in questo territorio per la sua società ed economia locale rivesta un ruolo fondamentale, basti pensare ad esso come una delle risorse principali per l'economia locale attrazione per il turismo locale e non 2. Natura come meta di turismo per la sua bellezza 3. Turismo e attività 4. Esperienza di contatto con il paesaggio / paesaggio culturale (parco archeologico / parco Abbadia di Fiastra) (**) 5. servizi di ristorazione con viste mozzafiato, 6. viabilità, ristoro, infrastruttura
Sport activity	1. Servizi culturali legati agli spazi aperti naturali (es. Parco archeologico) 2. Grandi aree di svago, e di incontaminazione
Mental wellbeing	1. Possibilità di pensare un vivere e un lavorare/progettare più a misura d'uomo 2. Il relativo equilibro tra natura e costruito (ma anche il costruito laddove lo permetta) ** 3. Possibilità di pianificare il proprio lavoro in maniera più efficace su quelle che sono le necessità della comunità locale (val di fiastra e comunità dei piccoli borghi) 4. Ambiente capace di infondere serenità 5. La ridotta pressione antropica agisce favorevolmente su elementi quali congestione, i tempi di vita, l'intensità delle relazioni 6. Qualità della vita, tempi di vita lenti, silenzio 7. Potenziali effetti sulla disponibilità di equilibrio psichico 8. Qualità della vita 9. I benefici sono vivere nel silenzio ed arrivare velocemente in una città caotica. Poter spostarsi tra un cantiere e l'altro e non smettere mai di guardarsi intorno meravigliati 10. Respiro più ampio (***). Serenità 11. Se il rapporto è virtuoso, permette di agire i propri bisogni. Restituisce il ritmo sensato e imprescindibile 12. La natura aiuta a scandire i tempi e gli spazi dell'abitare, del fare 13. Muoversi liberamente, fermarsi a riflettere. Aver tempo per noi
Intrinsic value	1. La natura è l'elemento primo e fondamentale della valle, cioè da cui esso trae la sua essenza. 2. La val di fiastra è un prodotto di un lungo processo di antropizzazione. Il concetto di natura va dunque contestualizzato. È una "costruzione sociale".
Biodiversity (*together with intrinsic value)	1. Una natura peri-urbana in grado di contenere grande biodiversità 2. Importanza della natura come biodiversità
Sense of place	1. Siamo una vallata, siamo nati in un luogo che per conformazione ci protegge e ci dirige velocemente dal mare alla montagna. 2. Scala dei borghi, rapporti di intimità – che si instaurano con i luoghi 3. La val di fiastra offre una mediazione tra le aree costiere e le più interne. Mediatore culturale e di paesaggio 4. Natura patrimonio dei luoghi in termini di identità culturale
Sense of community (*together with Sense of place)	1. Pratiche dal basso e autodeterminazione, da indagare, beneficio che si potrebbe trarre dalla "replicabilità" 2. La natura è elemento identitario (valle del fiastra , natura nel nome che la comunità si è dato) 3. Natura come servizio principale/primario per la comunità e il territorio 4. Difendere il nostro ambiente naturale e crearne un opportunità di luogo dove vivere e lavorare sarà la sfida più importante che abbiamo davanti a noi

	5.
Aesthetic beauty	1. Viste mozzafiato 2. La bellezza quasi incontaminata ed un paesaggio unico
Source of inspiration (*together with aesthetic beauty)	1. È cornice di attivazione progettuale, sguardo a processi partecipativi
Artisan products	1. Il legame d'oro marchigianità – enogastronomia (** sense of place) 2. artigianato locale e gastronomia di ottima qualità 3. saperi per la trasformazione dei prodotti dell'agricoltura 4. indagando tra gli autoctoni, filiera corta 5. produttori legati al territorio 6. prodotti enogastronomici locali
Agricultural products	1. I prodotti dell'agricoltura locale per la loro genuinità sostengono l'economia ed è apprezzabile il contributo legato alla ristorazione. Molta può esser fatto ancora per creare nuove filiere 2. Natura è agricoltura e allevamento 3. Cibo 4. Sostentamento
Drinking water	1. L'economia è sostentata facilmente dalla natura che offre acqua per i campi 2. Acqua per i campi
Air purification	1. aria
Disservices (not included in the study)	1. laddove distrugge
Others not included within ES categories	2. Risultato di lungo periodo del rapporto comunità antropica/natura. È questa interazione che beneficia le economie locali 3. La natura è in ogni impresa 4. È la natura selvaggia, ma anche quella coltivata, quasi rigogliosa. Questo contrasto tra le colture locali e il fiume lasciato quasi al suo corso, genera al voglia di rendere più accessibile questi luoghi, ma non solo per i turisti, quanto per coloro che vi abitano. Deve diventare uno scambio equo tra società ed habitat 5. La natura che diventa infrastruttura 6. La natura come estensione del centro urbano e non come qualcosa di altro 7. Tornare ad essere al centro del nostro sviluppo economico 8. In una realtà come la val di fiastra la natura è alla base dell'economia, in tutti i settori 9. Simbolo dell'operosità tipica delle marche 10. Difficile immaginare una natura isolata: il servizio benessere è dato dalla comprensione ed il relativo equilibrio tra dato naturale e vite degli abitanti

Appendix 4.B – Full script of the questionnaire

Ciao,

il questionario che segue riguarda il tuo ruolo come attore locale nella co-produzione dei servizi ecosistemici della Val di Fiastra.

Iniziamo selezionando un servizio ecosistemico in cui hai un ruolo. Il tuo ruolo potrebbe essere centrale nell'offerta del servizio, ma anche di semplice beneficiario o interessato.

Sezione A - Ruolo nella coproduzione di servizio

Hai un ruolo in queste categorie di servizi? (Seleziona tutte le voci applicabili)

- P1 Produzioni Agricole
- P2 Offerta Acqua Potabile
- P3 Offerta Energia Idroelettrica
- R1 Regolazione Idraulica
- R2 Regolazione Climatica
- R3 Purificazione dell'Aria
- C1 Eco-Turismo
- C2 Educazione Ambientale
- C3 Attività Sportiva
- C4 Valore Intrinseco
- C5 Senso di appartenenza alla comunità
- C6 Bellezza
- C7 Benessere Psico-fisico
- C8 Prodotti artigianali ed Enogastronomici

2. Stai considerando un servizio specifico all'interno della categoria?

____

3. Qual è il tuo ruolo?

- Utente (fai esperienza di questo servizio e ne ricevi i benefici)
- Manager (la tua attività permette l'offerta di questo servizio)
- Influenzato negativamente (sei infastidito dalla presenza di questo servizio)

- Interessato (non sei utente diretto ma credi nella sua importanza)
- Investigatore (ti occupi di questo servizio da un punto di vista di ricerca)
- Altro: ____

Sezione B. Capitali antropici

4. [capitale umano] Quanto di questo ruolo è collegato alla tua conoscenza, educazione, motivazioni, abilità o salute? Ad esempio: il tuo ruolo in questo servizio è collegato al tuo diploma o a un certificato che hai ottenuto ad un corso di formazione.

   1 2 3 4 5

5. [capitale sociale] Quanto di questo ruolo è collegato a valori e norme, reti formali e informali o fiducia? Ad esempio: il tuo ruolo in questo servizio è collegato alle persone che conosci nell'ambiente professionale/associativo, la fiducia che i clienti hanno su di te

   1 2 3 4 5

6. [capitale fisico] Quanto di questo ruolo è collegato ai tuoi macchinari, strumenti, infrastrutture o capitale costruito? Ad esempio: il tuo ruolo in questo servizio è collegato a uno specifico macchinario che possiedi

   1 2 3 4 5

7. [capitale finanziario] Quanto di questo ruolo è collegato ai tuoi risparmi, crediti, sovvenzioni o pagamenti diretti? Ad esempio: il tuo ruolo in questo servizio è collegato al denaro che hai investito in esso / che utilizzi per usufruire del servizio

   1 2 3 4 5

Sezione C. Dipendenza e relazioni su larga scala

8. Quanto diresti che questo servizio è importante per te? Quanto fai affidamento /dipendi da questo servizio (per il tuo quotidiano / per la tua vita / per la tua attività)? es: economicamente o idealmente

   1 2 3 4 5

9. Credi che questo servizio sia importante per altri attori? (fanno affidamento/ dipendono da questo servizio)

- A Agricoltori
- A Produttori locali
- A Grande distribuzione
- A Distribuzione di prossimità A Bar, ristoranti e agriturismi B Istituti scolastici
- B Centri di Educazione ambientale o altre attività (Es. Mamma asina a Colmurano)
- B Esperti e Studiosi nei settori ambientali
- C Gestori Turistici
- C Associazioni per la promozione locale
- C Attori legati alla ricreazione locale (Jogging etc) C Turisti regionali
- C Turisti stranieri
- D Amministrazioni Comunali
- D Architetti e pianificatori
- D Autorità regionali
- E Cittadini della Val di Fiastra
- E Cittadini delle città (es: Macerata, Civitanova, Ancona)
- Altro: ____

10. Chi beneficia di questo servizio?

- A Agricoltori
- A Produttori locali
- A Grande distribuzione
- A Distribuzione di prossimità A Bar, ristoranti e agriturismi B Istituti scolastici
- B Centri di Educazione ambientale o altre attività (Es. Mamma asina a Colmurano)
- B Esperti e Studiosi nei settori ambientali
- C Gestori Turistici

- C Associazioni per la promozione locale
- C Attori legati alla ricreazione locale (Jogging etc) C Turisti regionali
- C Turisti stranieri
- D Amministrazioni Comunali
- D Architetti e pianificatori
- D Autorità regionali
- E Cittadini della Val di Fiastra
- E Cittadini delle città (es: Macerata, Civitanova, Ancona)
- Altro: ____

11. Nel caso hai un ruolo nella fornitura del servizio, con chi collabori per la fornitura di questo servizio?

- A Agricoltori
- A Produttori locali
- A Grande distribuzione
- A Distribuzione di prossimità A Bar, ristoranti e agriturismi B Istituti scolastici
- B Centri di Educazione ambientale o altre attività (Es. Mamma asina a Colmurano)
- B Esperti e Studiosi nei settori ambientali
- C Gestori Turistici
- C Associazioni per la promozione locale
- C Attori legati alla ricreazione locale (Jogging etc) C Turisti regionali
- C Turisti stranieri
- D Amministrazioni Comunali
- D Architetti e pianificatori
- D Autorità regionali
- E Cittadini della Val di Fiastra
- E Cittadini delle città (es: Macerata, Civitanova, Ancona)
- Altro: ____

Sezione D Influenza sulle decisioni relative al servizio

12. Contribuisci alle decisioni relative alla gestione o allo stato di questo servizio?

1 2 3 4 5

13. Quali altri attori contribuiscono alle decisioni relative alla gestione o allo stato di questo servizio?

- A Agricoltori
- A Produttori locali
- A Grande distribuzione
- A Distribuzione di prossimità A Bar, ristoranti e agriturismi B Istituti scolastici
- B Centri di Educazione ambientale o altre attività (Es. Mamma asina a Colmurano)
- B Esperti e Studiosi nei settori ambientali
- C Gestori Turistici
- C Associazioni per la promozione locale
- C Attori legati alla ricreazione locale (Jogging etc) C Turisti regionali
- C Turisti stranieri
- D Amministrazioni Comunali
- D Architetti e pianificatori
- D Autorità regionali
- E Cittadini della Val di Fiastra
- E Cittadini delle città (es: Macerata, Civitanova, Ancona)
- Altro: ____

14. Chi altro potresti suggerirci potrebbe avere conoscenze pertinenti su questo servizio?

____

Sezione E – Informazioni generali sull'intervistato

15. Hai visitato qualche area protetta naturale durante l'ultimo anno?

- Sì
- No

Se sì, dove? ____

16. Di solito acquisti o consumi prodotti biologici e/o a km0?

1 2 3 4 5

17. Di solito separi i rifiuti?

1 2 3 4 5

18. In che comune abiti?

____

19. Qual è il tuo genere?

- Donna
- Uomo
- Altro ___________

20. Quanti anni hai?

____

21. Qual è la tua attività? che lavoro fai?

____

Appendix 4.C – Characterization of questionnaire respondents

This chapter presents a profile of the demographic and socioeconomic characteristics of the participants of the questionnaire. Respondents were aged between 22 and 71, with a similar proportion men and women. They had a good representation of the six municipal territory.

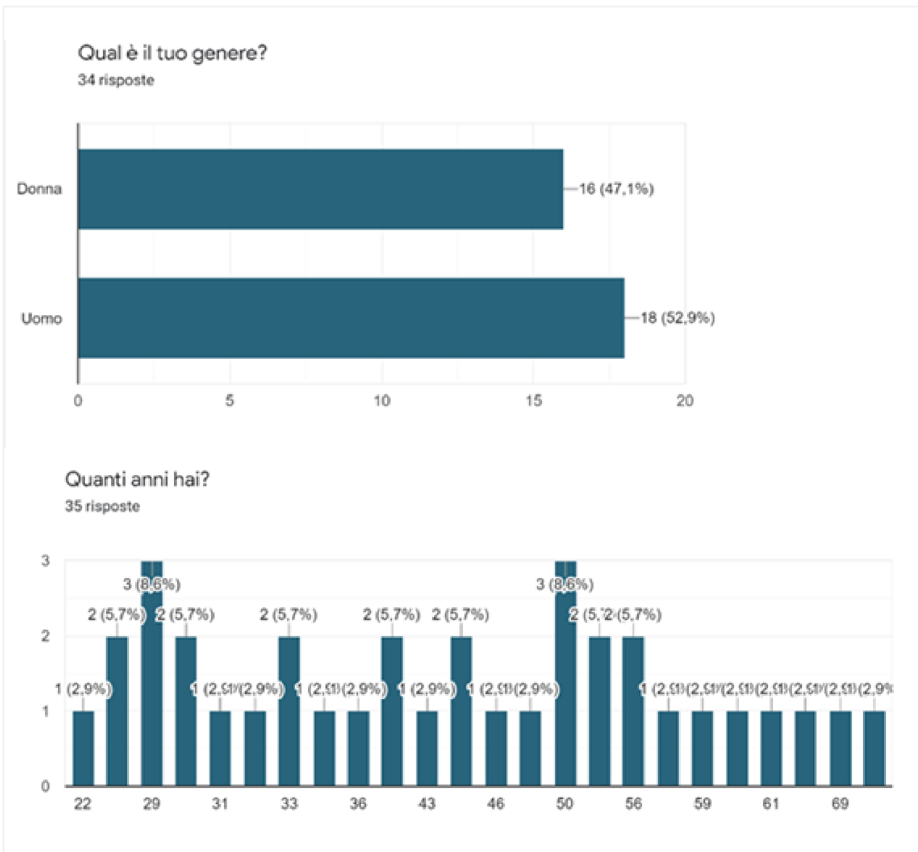

Figure SM9: age of the respondents (below) and number and percentage of respondents' gender (above)

As the environmental awareness could influence questionnaire answers, participants were asked about their environmental behavior. The results show high preference for biological or local products, while almost the whole sample makes recycling collection.

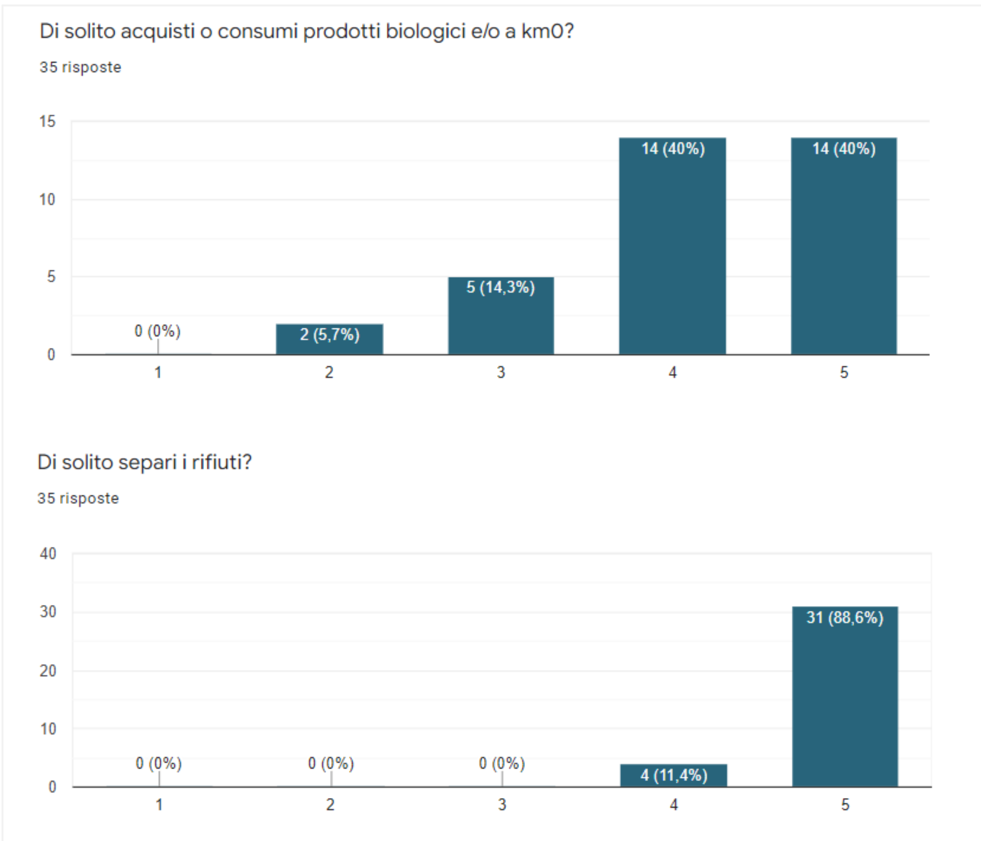

Figure SM10: environmental behavior of questionnaire respondents

Appendix 4.D – Statistical Analysis

Regarding the statistical analysis, the Shapiro-Wilk test was used to check whether the respondent answers followed a normal distribution. The null hypothesis (H0) states that the variable is normally distributed, and the alternative hypothesis (H1) states that the variable is not normally distributed. After running this test:

- if $p \leq 0.05$ the null hypothesis can be rejected (i.e. the variable is not normally distributed)
- if $p > 0.05$ the null hypothesis cannot be rejected (i.e. the variable may be normally distributed)

the value of the test statistic *W* results from the following formula:

$$W = \frac{\left(\sum_{i=1}^{n} a_1 x x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where:

- $X_{(i)}$ being the *i*th order statistic, i.e., the *i*th-smallest number of the sample;
- $\bar{x} = (x_1 + \cdots + x_n)/\, n$ is the sample mean
- $a_i = (a_1, \ldots, a_n) = \frac{m^T V^{-1}}{C}$

  where $C = \|V^{-1}m\| = (m^T V^{-1} V^{-1} m)^{1/2}$

  and $m = (m_1, \ldots, m_n)^T$

As for the preferences expressed by focus groups, the Shapiro-Wilk test showed that the distribution answers by participants departed significantly from normality *(results W = 0.9058, p-value = 0.01569).* The test was run also to analyze the distribution of the answers of questionnaire respondents regarding the capitals involved in ES co-production and the result also here differed from normality:

Based on this outcome, non-parametric tests were used to verify the significance of the differences among the responses. As for the preferences expressed in numerical data within the focus group, Wilcoxon's rank sum test was used to assess the significance of the differences between the *Focus* *group A: Civil Society* and the *Focus group B: Administration*. As for the differences on capitals involved in ES co-production, giving that the Likert scale employed (1 to 5) consists in categorical data, the *Chi-square test* was performed.

Preferences for Ecosystem Services

As stated in the methodology, the voting exercise concerned two focus groups, being the first named *Civil Society*, the second *Management.* The significance of the differences among the answers of the two focus groups were tested through Wilcoxon test method. As the result gave W = 112, and p-value = 0.53, which is more than the set significance level alpha = 0.05, we can conclude that FG1 responses are not significantly different from FG2 responses. Beside this, from *Figure 22* can be observed that C2 Environmental Education (4%) and R3 Air purification (1% of votes) regarded participants only the Focus group 1, while *R2 Climate regulation* (4%) and *R1 hydraulic regulation* (3%) were voted by participants in Focus group 2.

Appendix 4.E – R code

#1) Data upload

```
mydata <- read.csv (file.choose("C:\\"))

#function Sapply and Summary give general information on data frame
sapply(input_R,class)
summary(input_R)

#transform input data in data.frame and integer numbers in numeric
input_R_FG <- data.frame(input_R_FG)
input_R_FG$CS <- as.numeric(input_R_FG$CS)
input_R_FG$MA <- as.numeric(input_R_FG$MA)

#install the packages from the library
library(tidyverse) library(dplyr) library(tidyr) library(ggplot2) library(ggthemes) library(fmsb) library(gridExtra)
library(grid) library(lattice) library("xlsx")
```

 # 2) Data organization

```
SH_DIN %>% add_row(ES = "C1")

# 2.1) create new Dataframe related to ES and SH GROUP

# related to ES
P1 <- dplyr::filter(input_R,ES=="P1")
P2 <- dplyr::filter(input_R,ES=="P2")
R1 <- dplyr::filter(input_R,ES=="R1")
R2 <- dplyr::filter(input_R,ES=="R2")
C1 <- dplyr::filter(input_R,ES=="C1")
C2 <- dplyr::filter(input_R,ES=="C2")
C3 <- dplyr::filter(input_R,ES=="C3")
C4 <- dplyr::filter(input_R,ES=="C4")
C5 <- dplyr::filter(input_R,ES=="C5")
C6 <- dplyr::filter(input_R,ES=="C6")
C7 <- dplyr::filter(input_R,ES=="C7")
C8 <- dplyr::filter(input_R,ES=="C8")

#related to SH GROUP
PRO <- dplyr::filter(input_R,SH.GROUP=="PRO")
TOU <- dplyr::filter(input_R,SH.GROUP=="TOU")
PLA <- dplyr::filter(input_R,SH.GROUP=="PLA")
SOC <- dplyr::filter(input_R,SH.GROUP=="SOC")
SCH <- dplyr::filter(input_R,SH.GROUP=="SCH")

#2.2) Aggregate data through variables

#2.2.1) new Dataframe of input data aggregated by ES and Role (for graph 2)
temp <- input_R %>%
  group_by(ES, Role, SH.GROUP) %>%
  summarise_each(funs(mean))
Role_ES <- subset(temp, select = -c(SH, ï..ID, IMP, BEN, CON,
                                Contribution,
```

```
                    HC, SC, PC, FC,
                    IMP_PRO,    IMP_SCH,        IMP_TOU,        IMP_PLA,        IMP_SOC,  IMP_TOT,
                    BEN_PRO,    BEN_SCH,        BEN_TOU,        BEN_PLA,        BEN_SOC,  BEN_TOT,
                    CON_PRO,    CON_SCH,        CON_TOU,        CON_PLA,        CON_SOC,
        CON_TOT))
Role_ES$SH.GROUP_Role <- paste(Role_ES$SH.GROUP,Role_ES$Role,sep=" - ")

#2.2.2) create new Dataframes with average values of capitals per ES
temp <- input_R %>%
  group_by(ES) %>%
  summarise_each(funs(mean()))
temp2 <- subset(temp, select = -c(SH,Role, ï..ID,
                  SH.GROUP, IMP, BEN, CON,
                  Importance, Contribution))
CAP_ES <- subset(temp2, select = -c(IMP_PRO,      IMP_SCH,        IMP_TOU,        IMP_PLA,
        IMP_SOC,  IMP_TOT,
                    BEN_PRO,    BEN_SCH,        BEN_TOU,        BEN_PLA,        BEN_SOC,  BEN_TOT,
                    CON_PRO,    CON_SCH,        CON_TOU,        CON_PLA,        CON_SOC,
        CON_TOT))

#2.2.3) create new Dataframe with average values of stakeholders dynamics per ES and SH.GROUP
temp <- input_R %>%
  group_by(ES, SH.GROUP) %>%
  summarise_each(funs(mean))
SH_DIN <- subset(temp, select = -c(SH,Role, ï..ID, IMP, BEN, CON,
                   HC, SC, PC, FC))

#2.2.4) create new Dataframe with average values of stakeholders dynamics per ES
temp <- input_R %>%
  group_by(ES) %>%
  summarise_each(funs(mean))
SH_DIN_TOT <- subset(temp, select = -c(SH, SH.GROUP, Role, ï..ID, IMP, BEN, CON,
                    HC, SC, PC, FC))

#2.2.5) create new Dataframe with average values of Collaboration grades per ES and SH.GROUP
temp <- input_R_COL %>%
  group_by(SH.GROUP) %>%
  summarise_each(funs(mean))
SH.GROUP_COL <- subset(temp, select = -c(ES, SH, Role, COL, ï..ID))

temp <- input_R_COL %>%
  group_by(SH) %>%
  summarise_each(funs(mean))
SH_COL <- subset(temp, select = -c(ES, SH.GROUP, Role, COL, ï..ID))

#2.3) related to the results of the two focus group
FG1 <- dplyr::filter(input_R_FG,FG=="CS")
FG2 <- dplyr::filter(input_R_FG,FG=="MA")

#2.4) SH_DIN

SH_DIN_ES <-
  SH_DIN %>%
  group_by(ES) %>%
  summarise_each(funs(mean))
```

```
SH_DIN_SH.GROUP <-
  SH_DIN %>%
  group_by(SH.GROUP) %>%
  summarise_each(funs(mean))
```

3) Statistical analysis

```
# 3.1) Verify normal distribution // shapiro-wilk
# the p-value > 0.05 implying that the distribution of
# the data are not significantly different from normal distribution
shapiro.test(input_R$HC)
shapiro.test(input_R$SC)
shapiro.test(input_R$PC)
shapiro.test(input_R$FC)

shapiro.test(input_R_FG$VOTE)
# results W = 0.9058, p-value = 0.01569

# 3.2) Verify significant difference among variables

# in case the data are categorical // chi-square test
# in case the data are numerical // Kruskal test

# 3.2.1) Chi-square test
# For a Chi-square test, a p-value that is less than or equal to your
# significance level indicates there is sufficient evidence to conclude
# that the observed distribution is not the same as the expected distribution.
# You can conclude that a relationship exists between the categorical variables.

# is there significant difference among SH.GROUP for the value they associate to capitals?
chisq.test(table(input_R$SH.GROUP,input_R$HC))
chisq.test(table(input_R$SH.GROUP,input_R$SC))
chisq.test(table(input_R$SH.GROUP,input_R$PC))
chisq.test(table(input_R$SH.GROUP,input_R$FC))
#no significant difference for any Capital

#is there significant difference among ES for the value the respondents associate to capitals?
chisq.test(table(input_R$ES,input_R$HC))
chisq.test(table(input_R$ES,input_R$SC))
chisq.test(table(input_R$ES,input_R$PC))
chisq.test(table(input_R$ES,input_R$FC))
#significant difference only for social capital (SC) - p-value = 0.03268

#3.2.2) Kruskal test
# P-value ≤ α: The differences between some of the medians are statistically significant
# P-value > α: The differences between the medians are not statistically significant

#is there significant difference among SH.GROUP for the value they associate to capitals?
kruskal.test(HC ~ SH.GROUP, data = input_R)
kruskal.test(SC ~ SH.GROUP, data = input_R)
kruskal.test(PC ~ SH.GROUP, data = input_R)
kruskal.test(FC ~ SH.GROUP, data = input_R)
#result: there is no relevant relationship

#is there significant difference among ES for the value the respondents associate to capitals?
kruskal.test(HC ~ ES, data = input_R)
```

```
kruskal.test(SC ~ ES, data = input_R)
kruskal.test(PC ~ ES, data = input_R)
kruskal.test(FC ~ ES, data = input_R)
#result: there is no relevant relationship

#3.3) I check significant differences by focus groups through Wilcoxon test
wilcox.test(FG1$VOTE, FG2$VOTE)
```

4) Data analysis

```
# 4.1) I calculate the percentage of roles among users, managers, interested and investigator
# for the four main ES

# C5 Sense of place
proportions <- table(C5$Role)/length(C5$Role)
percentages <- proportions*100
view(percentages)

# C1 Eco-Tourism
proportions <- table(C1$Role)/length(C1$Role)
percentages <- proportions*100
view(percentages)

# C8 Artisan products
proportions <- table(C8$Role)/length(C8$Role)
percentages <- proportions*100
view(percentages)

# P1 Agricultural products
proportions <- table(P1$Role)/length(P1$Role)
percentages <- proportions*100
view(percentages)
```

#5) Data visualization

```
# 5.1) Display the preferences from local stakeholders for Ecosystem Services (Focus group)
#plot ES-SH, with horizontal bars
input_R_FG %>%
  ggplot(aes(x=ï.., y=VOTE))+
  geom_col(aes(fill=FG),
           width = 0.3,
           alpha=0.5)+
  labs(y="Nr. Preferences", x="ES", title = "Preferences for Ecosystem Services")+
  coord_flip()+
  geom_vline(xintercept=11.5, colour="black")+
  geom_vline(xintercept=8.5, colour="black")+
  theme_bw()


#5.2) Display the role of local stakeholders in Ecosystem Services

#5.2.1) plot ES-SH, respect to roles, respect to importance
#input_R %>%
#  ggplot(aes(ES, SH))+
#  geom_point(aes(size=Importance,
#              colour=Role,
```

```
#               alpha = 0.5))+
#  labs(title = "Role of local stakeholders in ES co-production")+
#  theme_bw()+
#  geom_hline(yintercept=4.5, colour="black")+
#  geom_hline(yintercept=7.5, colour="black")+
#  geom_hline(yintercept=11.5, colour="black")+
#  geom_hline(yintercept=16.5, colour="black")

#5.2.2) plot ES-SH.GROUP, respect to roles, respect to importance
Role_ES %>%
  ggplot(aes(ES, SH.GROUP_Role))+
  geom_point(aes(size=Importance,
              colour=Role,
              alpha = 0.5))+
  labs(title = "Role of local stakeholders in ES co-production",
       y="Stakeholders groups")+
  theme_bw()+
  geom_hline(yintercept=3.5, colour="black")+
  geom_hline(yintercept=5.5, colour="black")+
  geom_hline(yintercept=8.5, colour="black")+
  geom_hline(yintercept=11.5, colour="black")

#5.3) I display capitals involved in ES co-production as Radar Plot

# name rows as the first column (as asked by radarchart funct)
CAP_ES <- CAP_ES %>% remove_rownames %>% column_to_rownames(var="ES")

# I divide the data in four (Select rows by position) and add max and min values (as asked by radarchart funct)
temp <- dplyr::slice(CAP_ES, 1:4)
CAP_ES1 <- data.frame(rbind(rep(5,1), rep(1,1), temp))
temp <- dplyr::slice(CAP_ES, 4:8)
CAP_ES2 <- data.frame(rbind(rep(5,1), rep(1,1), temp))
temp <- dplyr::slice(CAP_ES, 9:10)
CAP_ES3 <- data.frame(rbind(rep(5,1), rep(1,1), temp))
temp <- dplyr::slice(CAP_ES, 11:12)
CAP_ES4 <- data.frame(rbind(rep(5,1), rep(1,1), temp))

#I use the function par to aggregate the 4 graphs
op <- par(mar=c(1, 2, 2, 1),mfrow=c(2, 2))

# I build radar 1
CAP_ES1 %>%
  radarchart(cglty = 1,       # Grid line type
           cglcol = "black",  # Grid line color
           pcol = 1:4,        # Color for each line
           plwd = 2,          # Width for each line
           plty = 1,          # Line type for each line
           pty = 3,
           axistype = 1,
           caxislabels = c("1","2", "3", "4", "5"),
           title = "Anthropogenic Capitals involved in ES co-production")+
  legend("topright",
         legend=(c("C1 Eco-turism","C2 Env. education","C3 Sport activity","C4 Intrinsic value")),
         bty= "n", pch=16,
         col=1:11,
         text.col="darkgrey", cex=1, pt.cex=1)
```

 # I repeat the same code for building radar 2, radar 3, radar 4

#5.4) display stakeholder dynamics

#5.4.1) What respondents think about others

```
#Group "Production"
g1 <-
SH_DIN %>%
  group_by(ES) %>%
  summarise_each(funs(mean)) %>%
  ggplot()+
  geom_col(aes(x=IMP_PRO,y=ES),
           width = 0.12,
           alpha=0.5,
           position = position_nudge(y = -0.15),
           fill = "blue",
           colour ="blue")+
  geom_col(aes(x=BEN_PRO,y=ES),
           width = 0.12,
           alpha=0.5,
           position = position_nudge(y = 0),
           fill="red",
           col="red")+
  geom_col(aes(x=CON_PRO,y=ES),
           width = 0.12,
           alpha=0.5,
           position = position_nudge(y = 0.15),
           fill="grey",
           col="black")+
  labs(title = "Production", x="Avg. responses")+
  lims(x=c(0,1))+
  theme_bw()
```

I repeat the same code for Group "school and research", Group "Tourism and commerce", #Group "Planning and administration", #Group "Society"

```
# Total (the five groups together)
grid.arrange(g1, g2, g3, g4, g5, nrow=2)
```

 # 5.4.1) What respondents think about themselves

```
#Group "Production"
#g1b <-
#temp <- data=filter(SH_DIN, SH.GROUP=="PRO")
input_R %>%
#  filter(SH.GROUP=="PRO")%>%
  ggplot()+
  geom_boxplot((aes(y=Contribution,x=ES)),
               size = 1,
               alpha=0.5)+
  labs(title = "Production", x="Self responses", y="Decision-making")+
lims(y=c(0,5))+
  theme_bw()
  labs(title = "Production (self)", x="Avg. responses")
```

I repeat the same code for Group "school and research", Group "Tourism and commerce", #Group "Planning and administration", #Group "Society"

#Total (the five groups together)
grid.arrange(g1b, g2b, g3b, g4b, g5b, nrow=2)

 # 6) Export dataframes

LOCATION <- "C:/Users/toma/documents/R-output.xlsx"

write.xlsx(as.data.frame(PRO), LOCATION, sheetName = "PRO")
write.xlsx(as.data.frame(SCH), LOCATION, sheetName = "SCH", append=TRUE)
write.xlsx(as.data.frame(TOU), LOCATION, sheetName = "TOU", append=TRUE)
write.xlsx(as.data.frame(PLA), LOCATION, sheetName = "PLA", append=TRUE)
write.xlsx(as.data.frame(SOC), LOCATION, sheetName = "SOC", append=TRUE)
write.xlsx(as.data.frame(SH_DIN), LOCATION, sheetName = "SH_DIN", append=TRUE)
write.xlsx(as.data.frame(SH_DIN_ES), LOCATION, sheetName = "SH_DIN_ES", append=TRUE)
write.xlsx(as.data.frame(SH_DIN_SH.GROUP), LOCATION, sheetName = "SH_DIN_SH.GROUP", append=TRUE)
write.xlsx(as.data.frame(CAP_ES), LOCATION, sheetName = "CAP_ES", append=TRUE)

Additional achievements during the Ph.D. Period

Articles published in journals, edited books, and book chapters

- Giacomelli, M., Calcagni, F., (2022). *Borgofuturo+. Un progetto locale per le aree interne*. Quodlibet, Macerata ISBN 9788822912862
- Giacomelli, M. (2022). *Le interazioni tra natura e cultura nell'innalzamento della qualità della vita*, in: PROGETTO RINASCITA CENTRO ITALIA – Nuovi sentieri di sviluppo per L'Appennino Centrale interessato dal sisma del 2016. CARSA Edizioni, Pescara ISBN 978-88-501-0411-6
- Giacomelli, M. (2022). *Reti ecologiche nelle regioni del sisma*, in: Sargolini, M., Pierantoni, I., Polci, V., Stimilli F., (edited by) PROGETTO RINASCITA CENTRO ITALIA – Nuovi sentieri di sviluppo per L'Appennino Centrale interessato dal sisma del 2016. CARSA Edizioni, Pescara ISBN 978-88-501-0411-6
- Giacomelli, M (2022). *Ecologia*. in: L. Lazzarini, S. Marchionni, & C. Rossignolo (edited by), WALKING THE SHRINKAGE – 21 parole chiave e 5 temi per descrivere la contrazione in cammino, Politecnico di Torino, Torino. ISBN 978-88-85745-85-8
- Giacomelli, M., Calcagni, F., De Luca, C., Giacomelli, D (2022). *Un processo partecipato per le aree interne. Borgofuturo+* in: Collettivo PRiNT (edited by), AREE INTERNE E COMUNITÀ – Cronache dal cuore dell'Italia, Pacini editore, New Fabric, Pisa. ISBN 979-12-5486-028-1
- Giacomelli, M. (2022) *I paesaggi come sistemi socio-ecologici: comprendere le relazioni aree urbane-interne attraverso la lente dei servizi ecosistemici*. In: Rete di Giovani Ricercatori per le Aree Interne (edited by) LE AREE INTERNE ITALIANE – Un banco di prova per interpretare e progettare i territori marginali, List, Babel urbanization. ISBN: 8832080680
- De Luca, C., Tondelli, S., Giacomelli, M., Calcagni, F. (2020). *Communities-based rural regeneration: The experience of "Borgofuturo +" project in Marche Region*. Urbanistica Informazioni – special issue. ISSN 0392-5005
- Sargolini, M., Giacomelli, M., Perna, P. (2019). *La rete ecologica nazionale*, in: *Rapporto dal Territorio 2019* (Properzi, P. and Ombuen, S.), INU edizioni, Roma 2019, Italy. ISBN 978-88-7603-210-3. Pag. 75-81

Presentations at conferences

- Giacomelli, M. (2022). *Mapping bundles of Ecosystem Services supply and demand reveals interdependencies between inland areas and urban poles.* Ecosystem Services Partnership Europe conference in Heraklion, Greece, 10-14 October 2022
- Giacomelli, M. (2022). *La mappatura di servizi ecosistemici rivela interdipendenze tra aree interne e poli Urbani: considerazioni per le strategie di coesione regionale*. XXIV Conferenza Nazionale SIU Società Italiana degli Urbanisti - Dare valore ai valori in urbanistica. 23-24 Giugno 2022, Brescia
- Giacomelli, M. (2021). *The integration of ecosystem services in landscape planning: a systematic literature review*. Ecosystem Services Partnership Europe conference in Tartu, Estonia 7-10 June
- Giacomelli, M., Benetti, S. (2020). *Le aree protette come sistemi socio-ecologici: l'approccio dei servizi ecosistemici nell'analisi dei rapporti natura-società*. Giornata di studi INU XII - Benessere e/o salute? 90 anni di studi, politiche, piani – Online, 18 December
- Giacomelli, M. (2020). *I paesaggi come sistemi socio-ecologici: rafforzare la resilienza delle aree interne attraverso la valorizzazione dei servizi ecosistemici*. Rete Nazionale per le Aree Interne: Workshop di Giovani Ricercatori. 16-17 April, Politecnico di Milano, Milano
- Giacomelli, M. (2019). *Mapping individual perceptions in rural environments: a participatory approach for the integration of Cultural Ecosystem Services in territorial planning*, Ecosystem Services Partnership world conference 10. Hannover, Germany 21-25 October

Lectures at university courses and seminars

2023

- Lecturer, *Brown Bag Lecture*. At the Habitat Unit – Berlin Institute of Technology. Lecture on Bottom-up initiatives in Italy's rural inland areas. Berlin, Germany, 31 January 2023

2022

- Discussant, *Urban Promo. Progetti per il paese*. At the session "Agende urbane del cibo. Lo strumento del living lab come promotore di nuovi modelli alimentari". Torino, Italy, 14 October 2022. https://urbanpromo.it/content/uploads/sites/20/2022/09/Programma-UP2022_web.pdf
- Lecturer, *at the Master: AREE INTERNE Strategie per la prevenzione, riduzione del rischio e rigenerazione post disastro naturale*, *University of Camerino*. Title of the lecture: Il progetto VAUTERECO e le analisi dei servizi ecosistemici. Ascoli Piceno, Italy, 9 September 2022
- Tutor, *SoAVe Summer School, Camminare nei paesaggi della produzione energetica. Laboratorio del Cammino*. The summer school explores the methodological contribution of walking in urban planning and design discipline. Basilicata, Italy, 29 August - 8 September 2022. https://www.laboratoriodelcammino.com/summer-school-2022
- Lecturer, *Along a line, NO-CITY Summer School*. Title of the lecture: Borgofuturo+. A local project in the upper Macerata area" Poggio Nativo (RI), Italy, 31 August 2022.
- Tutor, *Along a line, NO-CITY Summer School*. Alongaline is a 8-day intensive course to work out concurrent views of today's urban entanglement. Rome and Monti Reatini, Italy, 27 August - 4 September 2022, https://www.summerschoolsineurope.eu/course/17057/alongaline
- Lecturer, *Ruritage Savonia Summer School*. Title of the lecture: Landscapes of regeneration – the experience of Borgofuturo+. Kuopio, Finland, 12 May 2022.
- Lecturer, *PhD programme, School of advanced studies – Unicam*. Within the Phd lectures program, I gave the lecture on THE SYSTEMATIC LITERATURE REVIEW - Identify and critically evaluate studies approaching a research topic. Camerino, Italy, 28 March 2022.

2021

- Lecturer, *PhD Research Talks – School of Architecture and design, University of Camerino*. Discussion with Prof. Santolini on the topic "I paesaggi come sistemi socio ecologici: nuove relazioni tra sistemi urbani e interni attraverso l'analisi dei servizi ecosistemici". Ascoli Piceno, Italy, 28 January 2021.

- Tutor, *Recycland Summer School, camminare nei territori in contrazione. Laboratorio del Cammino*. The summer school explores the methodological contribution of walking in urban planning and design discipline. Basilicata, Italy, 29 August - 6 September 2021.
- Lecturer, *at the Master: Planning in a changing climate – Faculty of Architecture*, University of Bologna. Title of the lecture: Participation and regeneration in rural areas: the case of RURITAGE and BORGOFUTURO. Bologna, Italy, 21 December 2021.
- Lecturer, *at the Master: Innerland. Development strategies and regeneration post natural disaster, University of Camerino*. Title of the lecture: Il progetto VAUTERECO - valutazione degli assetti urbani e territoriali per la resilienza delle comunità. Ascoli Piceno, Italy, 17 September 2021.
- Discussant, *Le giornate del BeneStare*. Title of the session: Rigenerare/Ricostruire/Ripensare. Servigliano, Italy, 12 september 2021. https://agenziares.it/le-giornate-del-benestare/

2020

- Tutor, *Laboratorio di Pianificazione Città e Paesaggio*, School of Architecture and Design, University of Camerino, Teaching support and coordination of inter-university project with IUAV and Roma3
- Co-organizer, *Conferenza RISE (Verso un) Piano Nazionale Coordinato di Riqualificazione Integrata Sismico-Energetica del Patrimonio Edilizio e dei Sistemi Territoriali*, 27 ottobre 2020, supporto all'organizzazione
- Tutor, *Laboratorio del Cammino*, summer school of the inter-university network developing innovative teaching projects aimed at exploring the methodological potential of walking in urban planning
- Lecturer, *Corso di Teoria dell'urbanistica, University of Camerino*. Title of the lecture: I Servizi Ecosistemici nella pianificazione Urbana e Territoriale. Ascoli Piceno, Italy, 10 November 2020
- Attendee, *Research Methodology in social sciences – urban studies and spatial planning*. Winter school on research methods organized by DIDA Architecture department, University of Florence. Firenze, Italy, 29-31 January 2020

2019

- Co-organizer, *Conference Natural risks and communities, REDI – Reducing risks of natural Disasters.* School of Architecture and Design - University of Camerino, Ascoli Piceno, Italy, 19 December 2019

- Attendee, *Urbanpromo Green*, conference organized by the Italian National Institute of Urban planning (INU) at the IUAV University of Venice. Venice, Italy, 19 - 20 September 2019.

Scientific projects

- *Vautereco - Valutazione degli Assetti Urbani e TErritoriali per la REsilienza delle COmunità* (September 2020 – September 2022), funded by the Italian Ministry of Environment, the project supports the definition of Le Marche Regional Sustainable Development Strategy. The project declines the resilience of territories through assessments (both of construction methods and territorial planning) aimed at allowing rapid response to both extreme events and those climatic and socio-economic changes that heavily impact lives of communities in the inland areas.

- *Made In-Land - MAnagement and DEvelopment of INLANDs* (January 2019 – June 2021) funded by Interreg Italy – Croatia 2014 – 2020 Programme. The project is focused on the protection and the valorization of cultural/natural assets of the hinterlands areas by developing a new cross-border strategy that unleashes their potential through their inclusion in wider networks and markets. Nine public institutions are involved representing 5 different regional territories in Italy and Croatia

- *Ruritage - Heritage for Rural Regeneration* (June 2018 - May 2022) is a 4-year EU-funded project under the Horizon 2020 programme. Ruritage establishes a new heritage-led rural regeneration approach, transforming rural areas into laboratories for sustainable development, building on the enhancement of their unique Cultural and Natural Heritage potential.

Formal research networks

- *Laboratorio del Cammino* (Laboratory of Walking) is an inter-university network of researchers aimed at exploring the methodological potential of walking in urban planning and design disciplines. Part of the network are DARCH/Università degli Studi di Palermo; DAStU/Politecnico di Milano; DiST/Politecnico di Torino; DA/Università degli Studi di Bologna; DICAAR/Università degli Studi di Cagliari; DiCEM/Università degli Studi della Basilicata; SAAD/Università degli Studi di Camerino; D'da/Università degli Studi di Pescara; DIDA/Università degli Studi di Firenze; DIA/Università degli Studi di Parma; LAUD/Bilkent University.

- *NOCITY* is an open inter-university educational program, studying the urban condition by difference. It organizes a shared program within university planning laboratories and the annual summer school *Alongaline*. Part of the network are TU Delft; IUAV University of Venice; ENSAP Lille; AA School of Architecture; DPA Roma Tre; ETH Zurich; University of Trieste; University of Camerino; ENSA Versailles

- *Rete Nazionale dei Giovani Ricercatori per le Aree Interne* (National Network of Young Researchers for Inland Areas) included 150 young researchers from around 50 Italian and foreign universities to discuss their research and build thematic and territorial synergies. It was established within the Dastu department of the Politecnico di Milano.