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Article

A Spatial Decision Support System for Multi-Functional Landscape Assessment: A Transformative Resilience Perspective for Vulnerable Inland Areas

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Abstract: The concept of transformative resilience emerges from complex recent literature and represents a way to interpret the potential opportunities to change in vulnerable territories, where a socio-economic change is required. This article extends the perspective of transformative resilience to assessing of the landscape multi-functionality of inland areas, exploring the potentials to identify a network of synergies among the different municipalities able to trigger a process of territorial resilience. A Spatial Decision Support System (SDSS) for multi-functionality landscape assessment aims to support the local actors to understand local resources and multi-functional values of the Partenio Regional Park (PRP) and surrounding municipalities, in the South of Italy, stimulating their cooperation to the management of environmental and cultural sites and the co-design of new strategies of enhancement.

Keywords: Spatial Landscape Patterns, Spatial Composite Indicators, Landscape Functions, Landscape Resilience, ANP method, Geographic Information System (GIS).

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1. Introduction

Within the urban studies, the *resilient thinking (*Bahrami & Hemmati, 2020) [1] has addressed to different aspects of the urbanisation process, e.g. the adaptation of cities to climate changes (Yan et al., 2014) [2], the urban local-spatial resilience (Zhang et al., 2020) [3], urban ecosystem and metabolism (Elliot et al., 2019) [4], and the resilience in spatial planning (Lu & Stead, 2020) [5]. Indeed, many authors have listed meanings of resilience according to multiple research fields and scientific interests, likewise relating it to the landscape concept. To emphasise which landscapes' features, geographical data, indicators, and assessment methods have to be referred to how the stakeholders come into play to define a decision-making problem addressed to the formulation of sustainable development strategies [6,7] (Borriello et al., 2015; Cerreta & Panaro, 2017a), a definition of *landscape resilience* should be critically selected and shared within the scientific debate. Definitions of resilience have generally matched up to the concept of ability to preserve status or adapt to a new condition after a shock (Holling, 1973) [8]. In particular, Beller et al. (2015) have related the resilience to the landscape capacity to retain ecological functions and processes, biodiversity, resources despite many stressors and turbulences [9].

According to a socio-ecological perspective - by which the landscape is a result of human-natural interactions (ELC, 2000) [10] - the communities' self-organisation after shocking events (Hahn & Nykvist, 2017) [11] and the multi-functionality [12,13] (Keinast, 2009; Ioja et al., 2014) make a landscape resilient.

Some recent studies (Copeland et al., 2020) [14] have underlined the transformative aspects of resilience and the normative implications of measuring it, where adaptive and transformative capacities (Parsons et al., 2016) [15] are related to spatial context characteristics, top-down or bottom-up methods and inherent properties of a socio-economic system expressed by the ability of individuals, stakeholders, and communities to learn from and respond to changes, in a dynamic process [16,17] (Cutter, 2016; Saja et al. 2019).

Contemporary approaches to resilience [18-23] (Stones, 2005; Norris et al., 2008; Leach et al., 2012, Stokols et al., 2013; Arnall, 2015; Satyal et al., 2017) have recognised it as a process rather than an outcome, where four resource pools interact: social capital, community competence, information and communication, and economic development. Indeed, the landscape, considered as a complex socio-ecological system, embeds human activities [24] (Matthews & Selman, 2006) and biophysical land units which continuously change [25-27] (Cerreta & Panaro, 2017b; Cerreta et al., 2020; Cerreta et al., 2018), and provides those seeking to enhance the resilience of vulnerable components in identifying opportunities for complex transformation, when conditions of prolonged stress affect it.

In a spatial assessment procedure, the landscape units - or mapping units - have been used to determine the investigation field according to widespread types and characters (i) [28] (Bastian et al.,2006), to collect data and make them more consistent by mathematical and statistical aggregation procedures (ii) [29] (Barreto et al., 2010), and, finally, to shift these data into evaluation criteria (iii) [30,31] (Keenan & Jankowski, 2019; Bastian et al., 2014). Therefore, landscape transformative resilience can be conceived as an expression of its multi-functionality, i.e. the feature of providing multiple uses and functions at the same location [32,33] (Kato & Ahern, 2009; Ahern 2014). Based on this conceptualisation, an assessment of the interconnection among ecological flows and social dynamics - both expressed in terms of service-providing landscape elements [34] (Termorshuizen and Opdam, 2014) - has allowed exploring strategies of adaptation to changes within an interdisciplinary perspective [35] (Ahern, 2013). According to Hobbs (2014), multi-functional landscapes have encompassed the full range of landscape elements and those services they provide to human well-being [36] (Hobbs et al. 2014). At the same time, Potschin & Haines-Young (2006) have related sustainability to the landscapes' capacity to provide goods and services for future generations, evaluating the quality of those services in monetary and non-monetary terms [37] (Potschin & Haines-Young 2006).

Considering landscape and Ecosystem Services (ES) through their functions and goods has been a useful approach to identify benefits for human beings and to quantify the full cost of their loss, to engage stakeholders and local communities in a constructive dialogue [38] (De Groot, 2006). In this perspective, Valles-Planells et al. (2014) have recommended the Landscape Services (LS) concept as a ground for transdisciplinary research which has matched landscape ecology to sustainability [39] (Valles-Planells et al, 2014), and in which LS are: "the contributions of landscapes and landscape elements to human well-being" [30] (Bastian et al., 2014). Furthermore, the authors have interpreted the LS concept as a specification of ES by which the multi-functionality allows analysing the spatial configuration of benefits and services for humans at the landscape scale. Moreover, LS framework, as a multi-dimensional approach of the Ecological Economics which includes ES, has allowed evaluating *structure-function-value* chains of the landscape [34,40,41] (Termorshuizen & Opdam 2009; Wu 2013; Costanza, 2020).

Notwithstanding some ambiguities in definitions, which have led Potschin & Haines-Young (2016) to define LS and ES as *boundary objects* for sustainability [42], many authors [30,34,39,41,43-46] (Burkhard et al. 2009; Termorshuizen and Opdam 2009; Frank et al. 2012; Syrbe and Walz, 2012; Willemen et al. 2012; Wu 2013; Bastian et al.,2014; Valles Planell, 2014) have remarked several arguments in using LS approach. Among these remarks, the followings were included as the most relevant for our investigation: (i) the explicit spatial dimension of the assessment has to emerge; (ii) the focus points out highlighting interrelationships among human activities and habitat; (iii) the relevance of the analysis for collaborative planning is high; (iv) historical landscape elements and natural features coexist in the investigated context; (v) the landscape attributes and their importance has to be inferred within a tourism-oriented sustainable strategy.

Furthermore, the operational framework of Multi-Criteria Decision Analysis (MCDA) [47] (Greco et al., 2016) has aided Decision Makers (DM) to make decisions efficiently through the monitoring, the management, and the assessment of the landscape's resources in a multi-dimensional context.

For the last three decades, Spatial Decision Support Systems (SDSS) combining MCDA and Geographic Information Systems (GIS) have been improving the evaluation, the interaction among local stakeholders, and the design of new sustainable scenarios [31,48] (Malczewski, 2006; Keenan & Jankowski, 2019). Integrating GIS tools with MCDA has meant, besides, bringing together spatial information, categorised based on multiple criteria, into a single evaluation index [49] (Chen et al. 2010), which has been one of the outcomes that the authors have resolved to achieve. Nevertheless, mapping LS as indicators of landscape resilience and sustainability [50] has been remaining a challenge for specialists, academicians, and DM. The proposed approach has tried to overcome some limitations of assessment techniques [51] (Wozniak et al, 2018), which are related to the subjectivity of evaluations based on scores awarded by experts [43] (Burkhard et al, 2009), introducing indicators of tourism facilities [52] (Weyland & Laterra, 2014) and metrics of attractive landscape features [53,54] (Mele & Poli, 2017; Campagna, 2016).

According to these topics, two interrelated research questions about the contribution of landscape evaluations in defining and planning sustainable development strategies have focused on:

- How can landscape features and multiple values be elicited in spatial decision-making processes?
- Which methods and tools allow measuring the transformative landscape resilience in terms of multi-functionality?

The purpose of the research has aimed to develop a Spatial Decision Support System (SDSS) to evaluate integrated enhancement strategies for a vulnerable landscape. The SDSS, indeed, was tested on a relevant inner area in the South of Italy, the Partenio Regional Park (PRP) and 27 Italian municipalities to define strategies for the enhancement of local resources and to generate a cooperative and collaborative network among all the municipalities around the park. The primary outcome of the article has referred to how spatial representation and landscape modelling aid understanding tangible and intangible features, informing decisions better, improving the communication among stakeholders, and building the common ground to react to critical situations and identify adaptive redevelopment opportunities.

The paper proceeds as follows: Section 2 introduces materials and methods describing the case study; Section 3 outlines the results; Section 4 show limitations and potentials of the proposed methodology in the conclusions; and Section 5 highlight new research topics to foster the scientific debate.

2. Materials and Methods

The paper presents a methodological approach based on an explicitly spatial assessment to investigate the relationships among multi-dimensional phenomena which affect the landscape pattern and its spatial distribution. This approach can be framed within the SDSSs methodology [55-58] (Simon 1960; Malczewski 1999; Malczewski & Rinner 2015; Cerreta et al., 2015) because it has implied data selection and landscape modelling to generate a representation model through spatial indicators and indices. The SDSS was structured in four phases referred to as *Intelligence* (i), *Design* (ii), *Choice* (iii), and *Outcome* (iv) (Figure 1).

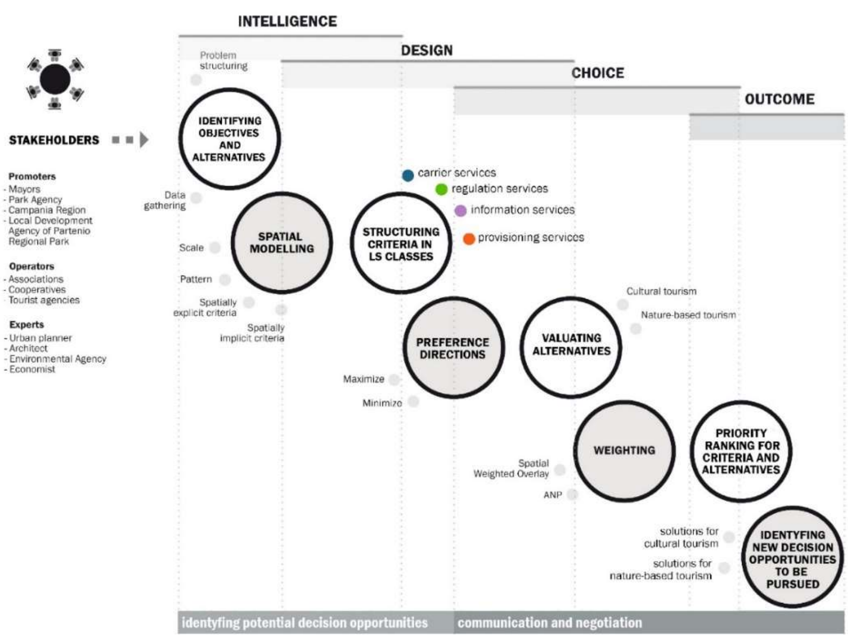

Figure 1. The methodological framework of a SDSS for the Partenio Regional Park (PRP)

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As mentioned above, the SDSS was tested on the case study of PRP. After a short description of the focus area, the in-depth methodology has been described in the next paragraphs.

2.1 Case Study

The study area is located in Campania Region, on Southern Italy, includes 27 municipalities, covers approximately 289.0 Km^2 with 67,594 inhabitants [59] (Istat, 2011), and 62.4 Km^2 of Natura 2000 sites are within the territory (Figure 2). Specifically, two protected zones, located in the study area, are referred to as the "Partenio" ridge, along the south-west side, with the highest peaks of "Montevergine" (1480 meters above sea level) and "Avella" mountains (1598 meters above sea level); while the second zone is located in the northern side and includes the wood of "Montefusco Irpino". PRP could be conceived, with its 148.7 Km^2 of forests, as a relevant green infrastructure for nearest inner areas.

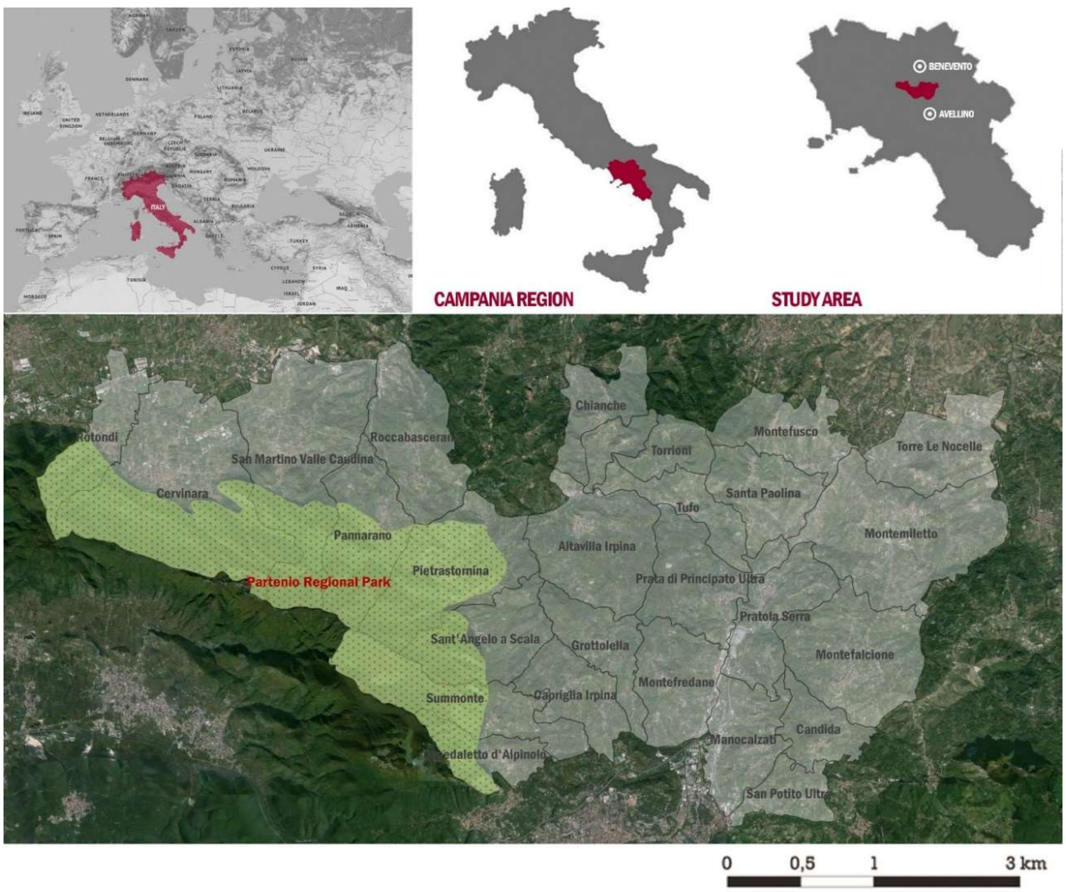

Figure 2. The study area

In 2008, a Local Action Group - referred to as *Gruppo di Azione Locale* (GAL) *Partenio* [60] - was established to support communities in promoting local resources for sustainable development. This organisation has been working to stimulate cooperation among different municipalities and defining a shared vision of local development for several years. Thanks to several projects, GAL Partenio has involved local communities in the identification of new development opportunities for the area. In particular, local promoters (Mayors, Park Agency, Campania Region, Local Development Agency of PRP), operators (associations that promote the local knowledge, resources, and attractions, cooperatives of local agricultural producers, professionals and inhabitants, and tourist agencies) and experts (urban planners, architects, environmental agency and economists) have been involved. During this process, a lot of issues have been investigated, and objectives have been identified. In order to support the design of a sustainable enhancement strategy for PRP and surrounding areas, the GAL Partenio has requested the Department of Architecture at the University of Naples "Federico II" a tool to manage all the information collected. A SDSS has been developed and its main four phases were described in the next Sections. Basically, it has permitted to examine relationships and trade-offs among economic, social, environmental, and cultural values.

2.2. Intelligence phase

In the Intelligence phase (i), the problem has been structured through three main steps:

1. Identifying the study area;
2. Describing the development directions and objectives identified by local communities;
3. Collecting and organising the first set of data.

More in detail, the study area has included the 27 Municipalities selected considering the proximity to and the relationship with the PRP. The principal directions of territorial development identified by locals have been outlined as:

- *Cultural Tourism* aimed at improving the local resources through a "wine/food path strategy" which allows reusing the old mining quarries by enjoying the naturalistic places, tasting local food, and strengthening the places of cultural interest;
- *Nature-based Tourism* addressed to foster naturalistic tourism, by implementing the quality of life through choices oriented to "slow mobility" and enhancing the amenities through the restoration of paths and guided tours in the PRP.

The different point of views and the objectives identified by local stakeholders have been summarised as listed below:

1) Preserve the natural heritage;
2) Enhance the tangible and intangible cultural heritage;
3) Promote sustainable tourism as an engine of economic development;
4) Improve accessibility and park services.

Indeed, the local communities aimed to implement the local economy (tourism development and local employability, to react to the widespread economic and social crisis significant in inland areas) without compromise the capacity to retain ecological functions and processes and local identity. Therefore, in the structuring of the problem, a multi-functional landscape perspective has been adopted, permitting to include the different issues of the case. The local resources have been classified into four main categories of Landscape Functions - referred to as *Regulation*, *Carrier*, *Information*, and *Provisioning* by de Groot (2006) [38] - and described as listed below:

- *Carrier Function*. It involves physical spaces, soils, and infrastructures through which the landscape-users can carry out daily activities (e.g. dwelling, hosting, moving). The carrier functions are essential to guarantee suitable fruition of the landscape, within a perspective of tourism development, but conversely, the use of these typologies of function can generate an irreversible loss of the original ecosystem.
- *Regulation Function*. It relates to the landscapes' natural capital's capacity to make the ecosystem processes work with their direct/indirect benefits to human-being. According to the Corine Land Cover (CLC) [61] classification, the local landscape is shaped by a sizeable part of the broad-leaved forest and transitional woodland shrub; while the presence of moors, natural grassland, mixed-forests, and sclerophyllous vegetation is more limited and spread. The natural classes of land cover indicate high values of ecological integrity and biodiversity in the focus area, seeing as how the regional park provides relevant ES for the surroundings (Figure 3). This means that each new action should be designed carefully for the ecological integrity of the area.
- *Information Function*. It involves human evolution and cultural fulfilment which can be reached through education, comprehension, observation, and fruition of the landscape with its tangible and intangible features. In the local context, the cultural heritage and history of the landscape are remarkable for monasteries, destinations for religious pilgrimage, ancient castles, but also quarries and fossils have that characterised the geomorphology of the mountain ridge and for naturalistic paths and open landscape spaces that make the landscape particularly attractive for education and science. These cultural and natural sites are also places in which the local community mainly recognised their own identity.

- *Provisioning Function*. It relates to the processes of conversion which the natural ecosystem carries out to shift the primary resources into living biomass. In the local landscape, the terrain's pyroclastic structure makes the soils fertile and productive so that some local products (i.e. nougat, truffle, and chestnuts) established a significant brand for the territory. It follows that, the finest farming product which soil allows having, the bigger the value of this landscape service.

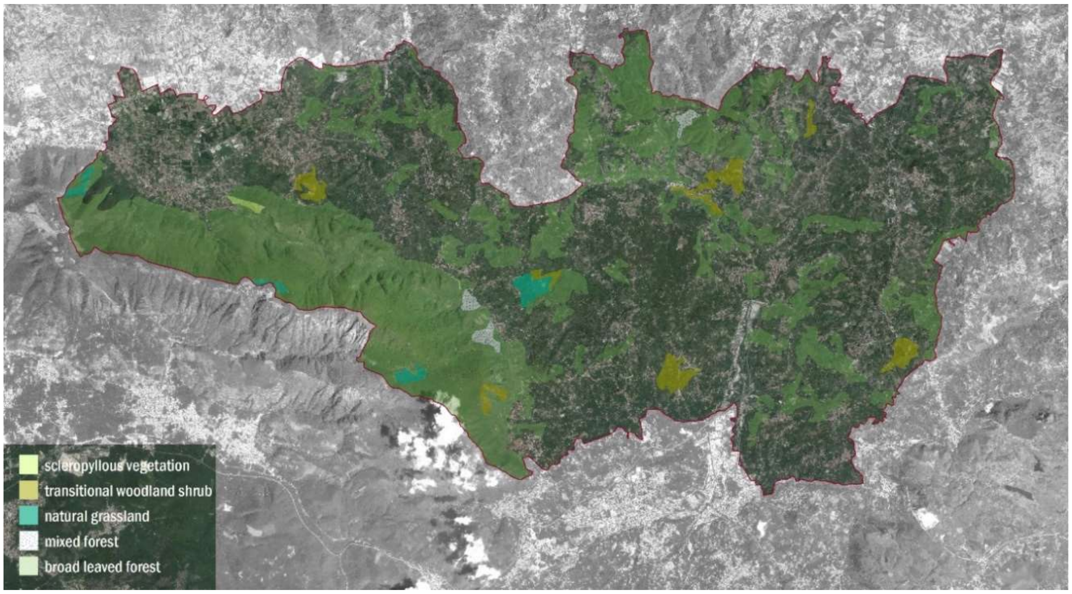

Figure 3. The Corine Land Cover classification

As described above, the problem of sustainable enhancement of the PRP has been modelled as a multi-criteria problem, in which the four Landscape Functions (Regulation, Carrier, Information, and Provisioning) represent the four main criteria to be taken into account and each function/criterion has been specified thanks to specific indicators.

Furthermore, to better identify a shared strategy in which all the municipalities could take part according to their territorial potentialities, significant attention has been done to the spatial representation of those indicators, to analyse and localise multi-functional values of territory.

Assuming that a criterion is a standard of judgment or a rule based on which alternative decisions can be evaluated and ranked [48] (Malczewski, 2006), the explicit or implicit spatial nature of criteria/indicators is essential. Both the explicit and implicit criteria/indicators are compounded by, inherently, spatial data (i.e. LULC classes, protected areas, etc.) [62,63] (Brookes 1997, Church et al. 2003). But, while the first has related to site characteristics - such as size, shape, contiguity - the latter use geographical features to transfer their spatial representation. In many cases, implicit spatial criteria (Herwijnen and Rietveld 1999) [64] consider spatial data to compute the level of achievement of the criterion and can involve spatial attributes such as distance, proximity, accessibility, elevation, slope [65,66] (MacDonald, 1996; Antoine et al. 1997). Both the typologies of criteria help Decision Makers achieve spatial representation to broaden and improve landscape knowledge.

In PRP case, the issue of the spatial representation of the indicators was addressed through spatial modelling of the multi-criteria problem, which contributed to improving the local landscape knowledge. In particular, authoritative data sources (Territorial Planning Offices, National Statistical Institute, etc.) have been matched with data open-source, and the Volunteered Geographic Information (VGI) [67] (Goodchild 2012) provided by Panoramio and OpenStreetMap applications. The spatial representation process of the indicators was shown in the next paragraph.

2.3 Design phase

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The Design phase (ii) relates to data processing and categorisation, according to the four categories of Landscape Functions (FS) relevant for the focus area. A spatial representation model was drawn processing raster data with a cell size (pixel) of 250 X 250 meters. Concurrently, the spatial indicators were normalised into a 0-1 range, and geo-located on a grid with the same MMU. In particular, data points, polygons, and lines were led to the same unit of analysis. Some operations in the GIS environment were performed in order to set up the indicators for the subsequent evaluation steps.

2.3.1 *Structuring indicators*

According to De Groot (2006) , the landscape services can be categorised in four macro-functions of the landscape. Moreover, each of these can be described to different indicators representing the local meaning of the function. Table 1 reports the classification in Function; Spatial indicators; Preference direction.

Table 1. The spatial indicators of Landscape Functions for the PRP

Criteria – Landscape Functions	Spatial indicators	Preference direction (pf)	ID
Carrier	Density of accommodation facilities	+	Car01
	Density of food services	+	Car02
	Uninhabited housing Index	-	Car03
	Housing density	-	Car04
	Index of accessibility	+	Car05
Regulation	Ecological integrity index	+	Reg01
	Environmental protection index	+	Reg02
Information	Density of cultural sites	+	Inf01
	Index of cultural events	+	Inf02
	Density of most photographed places	+	Inf03
Provisioning	Mean value of agricultural soils	+	Pro01

Each function can be explained through spatial indicators or indexes which have been derived from landscape features, as follows:

- *Carrier Function*. The specific functions that have been considered within this category include tourism facilities, habitation and transportation; while the following five indices express: *Density of accommodation facilities*; *Density of food services*; *Uninhabited housing Index*; *Housing density*; *Index of accessibility*.
- *Regulation Function*. The specific functions related to this category include environmental regulation provided by the natural areas; and they have been represented by the following two indices: *Ecological integrity index*; *Environmental protection index*.
- *Information Function*. Specific functions involve cultural ecosystem services which provide cultural, artistic, and aesthetic information, in this case, they have been represented by the following three indices: *Density of cultural sites*; *Index of cultural events*; *Density of most photographed places*.
- *Provisioning Function*. This category includes the cultivation function since it is crucial for the extraction of raw materials for human life; for this category, the only indicator provided relates to the *Mean value of agricultural soils*.

2.3.2 Spatial modelling

According to Barreto et al. (2010), when data differ in size, accuracy, and spatial definition, subdividing the surface of analysis into regular cell size turns out to be useful for mapping such heterogeneity [29] (Barreto et al., 2010). For this reason, a grid-based approach considering a Minimum Mapping Unit (MMU) of 6,25 hectares (250 meters per side) has been adopted. In this way, further data to progressively enhance the dataset can be vector or raster indifferently, since they have to be produced on a standard surface.

Since a relationship between infrastructures and landscape's points of interest was evident, a bandwidth of 5Km has been determined through a proximity analysis. The proximity has been calculated trough average of the nearest distance among point-based indicators *car01*, *car02*, *inf01*, and linear network of railways and roads, which have been modelled through the indicator *car05*. The analysis results pointed out that the range of maximum distances for each indicator scores between approximately 3.6 Km^2 (the minimum) and 6.5 Km^2 (the maximum). The mean has been subsequently used as a Kernel Density Estimation (KDE) parameter in the ArcGIS environment.

Since the choice of the bandwidth mostly affects the results of KDE, Spencer et al. (2017) suggest assigning the parameter taking account of limitations of instruments producing data [68] (Spencer et al., 2017). We adopted a twofold approach to choose the bandwidth: on the one hand, assessing the limitations of the available tools, on the other hand, assuming the aforementioned empirical approach related to the mean distance range.

In this way, all the indicators have been spatially represented. In the paragraph 3.1 has been reported their maps as an intermediate result of the landscape's multi-functionality assessment.

2.4. Choice phase

The "Choice" phase (iii) was addressed to the evaluation of the directions of the local development (*Cultural Tourism* and *Natural Tourism*) through the "Analytic Network Process" (ANP) method, which was performed with the software *Superdecisions* [69,70] (Saaty 2005; Saaty e Vargas 2005). The ANP multi-criteria method is an implementation of the Analytic Hierarchy Process (AHP), which includes the interrelationship between elements within a network of criteria [71] (Ishizaka, 2013).

The proposed approach has involved using the ANP compensatory multi-criteria method to investigate the relationships among the multiple Landscape Functions and to highlight the priorities of knowledge's domains involved to reach the goal.

The ANP has been implemented thanks to an exchange with experts taken place in two focus groups. During the first, the interactions among different Landscape Functions (*Criteria*) have been investigated, and inner and outer dependencies among indicators have been explored. This step has allowed building the network model in Figure 4 that reports the relationships and interactions among nodes (*Indicators*) and clusters (*Criteria - Landscape Functions*). This framework is similar to human thought processing since it allows examining the complexity of a problem through the pairwise comparison technique. Indeed, in the second focus group, the experts have carried out a pairwise comparison at the level of nodes and clusters.

More in detail, the ANP has been structured into four main phases. The first phase has allowed defining the main goal of the analysis; subsequently, the method has sorted the decisional problem into two fundamental elements: nodes, compounded by the main categories, and clusters that constitute sub-nodes' sub-categories.

The third and fourth phases have been carried out thanks to two focus groups with a team of experts. The relative results consist, respectively, of the super-matrix, that combines outer and inner interdependences between clusters and nodes, and finally the weights and the priority vectors related to each main category [72-74] (Lombardi et al., 2007; Attardi et al., 2014; Cerreta et al., 2015). In the proposed approach, normalised indices have been conceived as spatial indicators through which a team of experts, involved in the decision-making process, has expressed their preferences about the goal, analysing alternatives for sustainable tourism development with a transparent, inclusive, and plural approach. The authors have also introduced a control scenario, named Alternative 0, representing the landscape's current state without intervention, to facilitate comparing scenarios *Cultural Tourism* and *Nature-based tourism*. Finally, *Superdecisions* has provided a sensitivity analysis for checking the judgments' consistency.

The outputs of the ANP method have been reported in Table 4 that shows as *Cultural Tourism* (scenario 1) is the preferred scenario. In addition, in the same table, the "Normalised by indicators" column also highlights the contribution of each indicator in the implementation of that scenario. This information has permitted to identify the most suitable areas for *Cultural Tourism*, represented in the multi-functional landscape map (Figure 6).

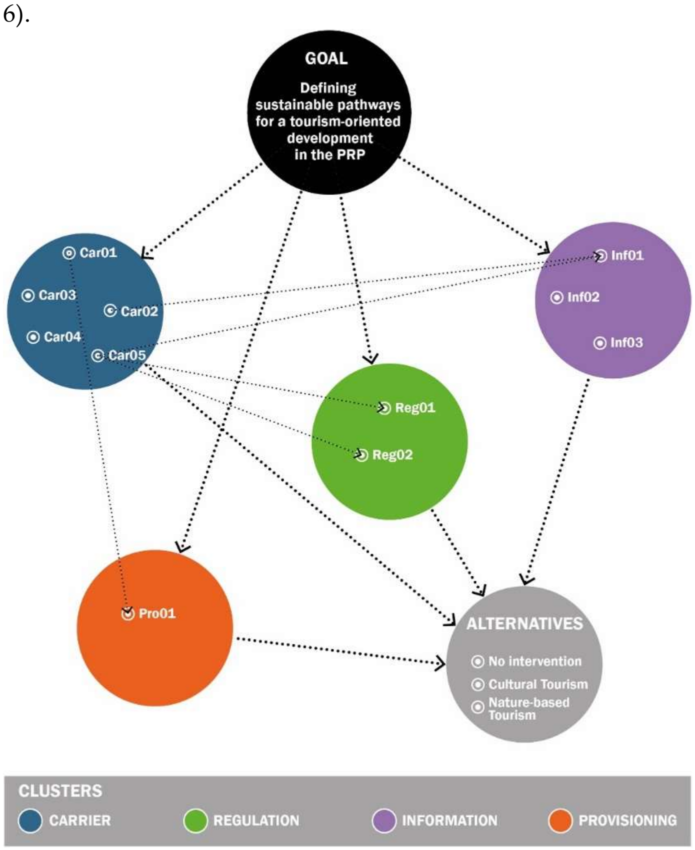

Figure 4. The graphical representation of the ANP network with inter-factorial dependencies among nodes and clusters.

Table 2. The weighted super-matrix

	No intervention	Cultural Tourism	Nature-based Tourism	Car 01	Car 02	Car 03	Car 04	Car 05	GOAL	Inf 01	Inf 02	Inf 03	Pro 01	Reg 01	Reg 02
No intervention	0.00000	0.00000	0.00000	0.04397	0.05237	0.08795	0.40539	0.01830	0.00000	0.08795	0.07692	0.06667	0.15618	0.07692	0.08795
Cultural Tourism	0.00000	0.00000	0.00000	0.33471	0.31849	0.24264	0.11397	0.21845	0.00000	0.66942	0.69231	0.46667	0.65864	0.23077	0.24264
Nature-based Tourism	0.00000	0.00000	0.00000	0.12132	0.12914	0.66942	0.48064	0.09658	0.00000	0.24264	0.23077	0.46667	0.18517	0.69231	0.66942
Car01	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.03254	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car02	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.04652	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

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Car03	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02975	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car04	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02855	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car05	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.11264	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
GOAL	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Inf01	0.00000	0.00000	0.00000	0.00000	0.50000	0.00000	0.00000	0.33333	0.11364	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Inf02	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.11364	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Inf03	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02273	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pro01	0.00000	0.00000	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Reg01	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.05556	0.12500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 3. The limiting super-matrix

	No intervention	Cultural Tourism	Nature-based Tourism	Car01	Car02	Car03	Car04	Car05	Tourism~	Inf01	Inf02	Inf03	Pro01	Reg01	Reg02
No intervention	0.00000	0.00000	0.00000	0.08138	0.06423	0.08795	0.40539	0.04579	0.05256	0.08795	0.07692	0.06667	0.15618	0.07692	0.08795
Cultural Tourism	0.00000	0.00000	0.00000	0.44269	0.43547	0.24264	0.11397	0.31309	0.24138	0.66942	0.69231	0.46667	0.65864	0.23077	0.24264
Nature-based Tourism	0.00000	0.00000	0.00000	0.14260	0.16697	0.66942	0.48064	0.24112	0.17896	0.24264	0.23077	0.46667	0.18517	0.69231	0.66942
Car01	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01539	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car02	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02200	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car03	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01407	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car04	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01350	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Car05	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.05327	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Tourism ~	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Inf01	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.20000	0.08249	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Inf02	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.05374	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Inf03	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01075	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pro01	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.12592	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Reg01	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.03333	0.06207	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 4. The priority ranking of ANP

Scenario/Indicators	Weight normalised by cluster	Limiting	Normalised by indicators
scenario 0	0,11114	0,05256	-
scenario 1	0,51043	0,24138	-
scenario 2	0,37843	0,17896	-
car01	0,13018	0,01539	0,029
car02	0,18606	0,022	0,042
car03	0,11899	0,01407	0,027
car04	0,11421	0,0135	0,026
car05	0,45056	0,05327	0,101
inf01	0,56126	0,08249	0,157
inf02	0,36562	0,05374	0,102
inf03	0,07313	0,01075	0,020
pro01	100.000	0,12592	0,239
reg01	0,45647	0,06207	0,118
reg02	0,54353	0,07391	0,140

2.5. Outcome phase

The “Outcome” phase (iv) has allowed defining the landscape multi-functionality map considering the network of weighted spatial indicators normalised into a 0-1 range.

Next to the evaluation process, which is the core of the choice phase, the spatial model has been implemented in the GIS environment by making the priority vectors, obtained from the ANP method, explicitly spatial. That has been performed through an additive aggregation rule that is expressed by the formula [1]:

$$M_i = \sum_{i=1}^{m} m_i w_i$$

Where:

- Mindex is the multi-functionality index;
- m_i is the normalised score of the ith spatial indicator;
- w_i is the global weight of the ith spatial indicator.

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The additive rule has been chosen as an aggregation procedure since it allows offsetting the indicators with lower values respect to those that reveal highest scores and incorporates trade-off among the indices [75,76] (Gan et al., 2017, OECD, 2008). In this way, the normalised sum of each contribution per cell related to services provisioning and the well-functioning clusters can be obtained. In literature, the additive rule has been applied, due to its simplicity, to calculate several indices, e.g. the Environmental Performance Index (EPI) [77] (Esty et al., 2018), the Information and Communication Technologies Index [78] (Fagerberg, 2001), the European Innovation Scoreboard (EIS) [79] (European Commission, 2018).

3. Results

In this paragraph, were shown the results of the spatial analyses carried out after the indicators identification and the multi-criteria analysis. In subsection 3.1 (*Intermediate Results*) the special indicators have been described. In subsection 3.2 (*Final Result*) has been described the multi-functional map of the PRP landscape that shows the most suitable zones to pursue the *Cultural Tourism*.

3.1 Intermediate Results

The description of the 11 spatial indicators is presented below, while Figure 5 shows their spatial representation.

3.1.1. Density of accommodation facilities (car01)

The indicator identifies the highest concentration of the tourism facilities points (e.g. hotel, B&B, guesthouse) through kernel density estimation in a bandwidth of 5Km. The indicator highlights the geographical clusters of significant provision for these services. These facilities are crucial for any strategy oriented toward boosting hospitality in the landscape and, therefore, the indicator value should be maximised. Indeed, the higher the values, the greater the likelihood to host people.

3.1.2. Density of food services (car02)

The indicator identifies the highest concentration of foodservice points (e.g. restaurants and holiday farms) through kernel density estimation in a bandwidth of 5Km. The indicator has been selected with the similar aim of *car01*. However, it has been the combined result of on-field research and OpenStreetMap data. This indicator, like the previous one, has been maximised since empowering territories to promote local foods and cookery skills could increase the landscapes' attraction and recreation for tourists.

3.1.3. Uninhabited housing Index (car03)

The indicators show the institutional dataset of census zones with specific information about the state of housing abandonment. Data have been aggregated on the MMU by computing the number of abandoned houses per square cell surface.

3.1.4. Housing density (car04)

The indicators have been drawn from the institutional dataset of census zones and provide information about the housing density. Data have been aggregated on the MMU by computing the number of houses per square cell surface. In this case, the index has been minimised since a low density represents this type of landscape's peculiar feature.

3.1.5. Index of accessibility (car05)

The indicator shows the network of railways and roads by computing the values through the track per cell's length. The current transportation system does not guarantee accessibility to some locations, as public transport is scarce or unsuitable to reach those places shaped by complex landscape morphology. The indicator has been maximised.

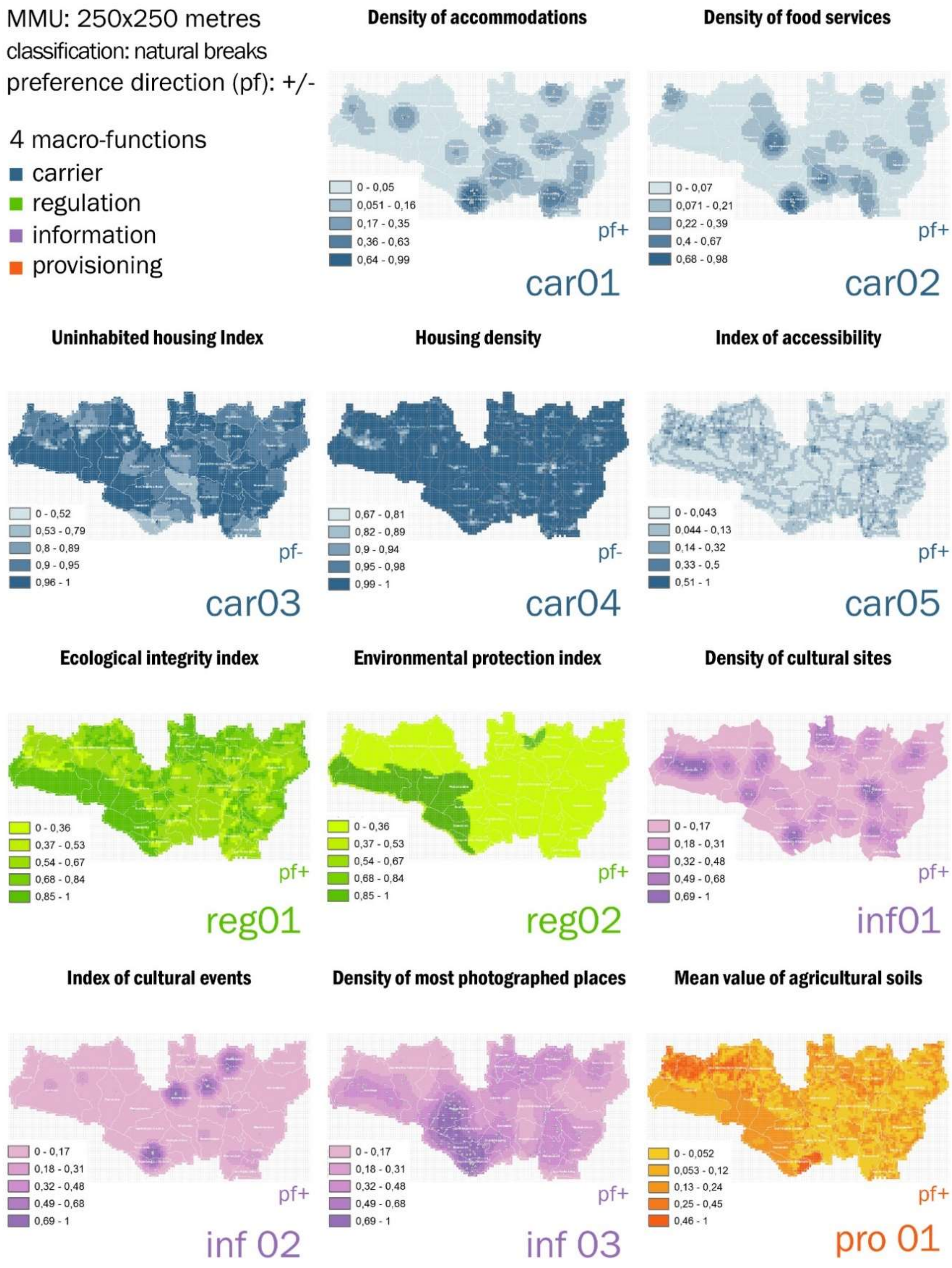

Figure 5. The 11 spatial indicators

3.1.6. Ecological integrity index (reg01)

The indicator shows the value per cell of the CLC classes according to their ecological integrity, representing the sum of the different contributions of ecosystems to provide regulation, provisioning, and cultural services. The scores have been derived from the assessment matrix of a land cover type provided from Burkhard et al. 2009 [43] (Burkhard et al., 2009) and have been placed on each surface of land use per cell, by performing the standardised weighted average to compute the final value. The indicator has been maximised, since a high value of ecological integrity means more services that the landscape provides to human well-being and cultural fruition of nature [39] (Valles-Planells, 2014).

3.1.7. Environmental protection index (reg02)

The indicator includes the percentage per cell of "Communitarian Interest Sites" (SIC) and "Special Protection Zones" (ZPS). These areas provide a relevant contribution to the regulation services maintenance/conservation. Despite setting boundaries of these zones does not imply the correct management of the natural areas, that could be conceived as the first step for protecting the natural capital of the landscape. In this perspective, also, this indicator has been maximised.

3.1.8. Density of cultural sites (inf01)

The indicator shows the kernel density estimation of cultural sites in a bandwidth of 5 Km. The richness of cultural sites with their historical, archaeological, spiritual values increases landscape capacity to provide learning from social-ecological structures that can be understood as the right way of interaction between anthropic and natural ecosystems. The indicator conveys the number of significant landscape elements per cell and has to be maximised as the previous ones.

3.1.9. Index of cultural events (inf02)

The indicator highlights the cultural vitality of the examined landscape by identifying the number of cultural events and their type/frequency. This index is an example of an implicitly spatial indicator since it needs processing information derived from surveys and event location to be represented. The map shows four main clusters in which the events are most consistent, and the kernel density conveys the polarisation of the municipalities which offer these services in a bandwidth of 5Km. The indicator has been maximised.

3.1.10. Density of most photographed places (inf03)

The indicator represents an excerpt of a point pattern, based on a code which identifies most photographed places by citizens and tourists in the study area. It simulates landscape attractiveness, as citizens or tourists perceive it. The indicator can be conceived as a proxy to represent an immaterial value of the landscape (e.g. a beautiful open space, panoramic point, identity-related feature, etc.). The highest value per cell, the most attractive the landscape.

3.1.11. Mean value of agricultural soils (pro01)

The indicator merges some specific classes of CLC and the mean value of the soils provided by the institutional dataset of the Italian "Agenzia delle Entrate" (Revenue Agency) [80]. This processing has been made explicitly spatial the approximated quality of agricultural production. The highest the value per cell, the bigger the quality of soil for provisioning services. The indicator has been maximised.

3.2 Final Result

The multi-functional landscape map is presented below; it represents the final result of the evaluation process on the territorial development directions of the PRP landscape.

In particular, the output of the ANP has identified that a suitable scenario to be implemented is that of *Cultural Tourism*. The ANP has also provided the contribution of each indicator for that scenario (Table 4 - Values normalised by indicators). Thanks to the additive aggregation rule shown in paragraph 2.5, the normalised values of indicators have been summed, building a spatial index of the multi-functionality of the PRP landscape.

The spatial representation of this index has been reported in Figure 6, a multi-functionality map that localises suitable areas to reach better Landscape Functions performances if the *Cultural Tourism* alternative were pursued. The map has highlighted how much the landscape multi-functionality would enhance, and which municipalities mostly benefit if scenario 1 (*Cultural Tourism*) was pursued.

Since the multi-functionality map has been drawn comparing three scenarios with experts, could be interesting to open the discussion to the local stakeholders and understand the sensitivity of their perceptions by comparing them with those of the experts.

Indeed, the usefulness of the result concerns the opportunity to open public debate about further scenarios to co-design, by visualising the spatial weights of the decisions in order to improve the comprehension and transparency of the decision-making process at different levels and scales.

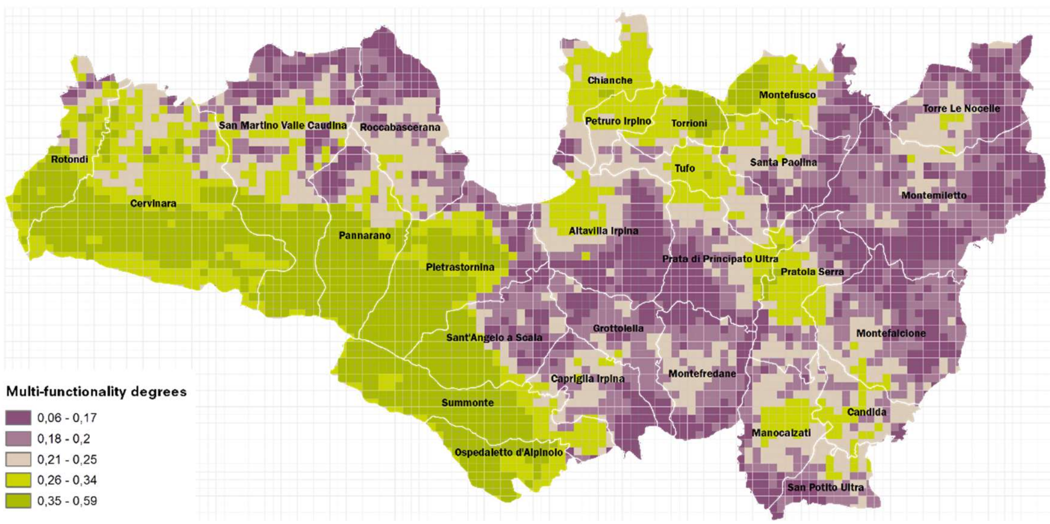

Figure 6. Composite map of the landscape multi-functionality

4. Discussion

The contribution of landscape evaluation and planning in defining and assessing sustainable development strategies in inland areas, where the conditions of socio-economic crisis make development processes difficult, has been explored structuring a Spatial Decision Support System (SDSS), articulated in four main phases, where multiple landscapes' features and related values have been elicited considering the approach of Landscape Ecosystem Services.

Simultaneously, the implementation of the ANP method in GIS environment has allowed measuring the transformative landscape resilience in terms of multi-functionality, by elaborating selected spatial indicators, describing and representing the multi-dimensional characteristics of the PRP's inland areas.

Modelling the landscape through a spatial grid with regular MMU is a way to simplify, make homogeneous and rationalise the multi-criteria aggregation process, and allows showing the impacts of the transformation from large scale to specific contexts.

Potentials of SDSS have related to the representation, the processing, and the analysis of complex data improving the quality of a decision-making process. Meanwhile, determining a Minimum Mapping Unit (MMU) allowed us to make data - extracted from various sources and affected by different resolutions and spatial entities - more homogeneous, by joining heterogeneous information on a standard surface and transforming it into normalised indices.

By contrast, numerous authors conclude that there is no optimal landscape composition and configuration that enhances or sustains all LS, but spatial patterns favour specific bundles of LS, e.g. Turner et

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al. (2013) [81] and Wu (2013) [41]. Thus, different types of landscapes (providing different sets of LS) may be considered sustainable.

According to this statement, apart from the multi-functional landscape which offers a moderate flow of different LS, the landscape providing a high flow of regulating services and a high flow of agricultural production were distinguished in the study area.

The use of the ANP method has allowed exploring the interaction among different Landscape Functions with a group of experts. In that sense, the opportunities for new tourism development of the area have been analysed from a multidisciplinary and interdisciplinary perspective. Moreover, the identification of the weight of the indicators with the experts has allowed the discussion on different points of view and the more accurate understanding of the impacts of the tourism development on the landscape functions. This experiment proved the potentiality of the ANP method in the decision processes on the landscape transformation especially if the method is implemented in a constructive way through an interactive approach with experts (as tested in the PRP case) or stakeholders.

Finally, the spatial representation of the outputs of the ANP has provided the GAL Partenio with a map-able to show also to local communities and stakeholders the multi-functional opportunities of their own landscape for Cultural Tourism supporting in that way negotiation and shared decisions phase on the future development of the area.

5. Conclusions

The Spatial Decision Support System (SDSS) for multi-functionality landscape assessment has aimed to support the local actors to understand local resources and multi-functional values of the PRP and surrounding municipalities, stimulating their cooperation to the management of environmental and cultural sites and the co-design of new tourism services.

The increasing interest and diffusion of geo-referenced data about landscape analysis and evaluation have led to new opportunities to represent, join, process, and assess spatial information to measure territorial resilience.

In this perspective, the methodological approach has been oriented to improve the acknowledgement and awareness of local resources, by defining a proposal of representing and processing the different data types. The elaboration of spatial indicators, able to describe the landscape's objective and subjective characteristics, selected and classified according to the LS approach, defines a complex framework where tangible and intangible components interplay.

The SDSS supports local resources' knowledge process, highlighting the potential and critical issues, and makes relationships among them explicit. The composite map of the landscape multi-functionality describes the areas of transformative resilience, where the degree of multi-functionality is highest. Through the map results, it is possible to represent a geography of the values, understand the role of each municipality and identify how a network of synergies can trigger a process of territorial resilience.

This map represents the conclusion of the evaluation process, and the starting point of the decision-making process, as it can be considered the basis for activating a dialogue between decision-makers, stakeholders, and local communities to enhance local resources and promote a territorial network strategy.

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