Bridging Biodiversity Conservation Objectives with Landscape Planning Through Green Infrastructures: A Case Study from Sardinia, Italy

Sabrina Lai(✉) and Federica Leone

Dipartimento di Ingegneria Civile, Ambientale e Architettura (DICAAR), University of Cagliari, Cagliari, Italy
{sabrinalai, federicaleone}@unica.it

Abstract. The definition of Green Infrastructure (GI) provided by the European Commission in its 2013 Communication "Green Infrastructure: Enhancing Europe's Natural Capital" regards GI as a network having the Natura 2000 sites at its core, able of delivering numerous ecosystem services, and "strategically planned", stressing the importance of GI in integrating ecological connectivity, biodiversity conservation, and multi-functionality of ecosystems. Consequently, the spatial identification and management of GI is an important issue in planning, and especially in landscape planning as understood in the European Landscape Convention.

Building on a previous work by Arcidiacono et al. (2016), this paper tests a methodology whereby the spatial configuration of a GI is identified in relation to four aspects (conservation value, natural value, recreation value, anthropic heritage) which summarize the multifaceted character of landscape. The methodology is tested in the Italian region of Sardinia, by applying it in the coastal landscape units defined in the Regional Landscape Plan currently in force which overlap the metropolitan area of Cagliari.

We argue that this methodology can effectively help integrate biodiversity conservation objectives into spatial planning by implementing article 10 of the Habitats Directive, stating that relevant features of the landscape should be managed so as to improve the ecological coherence of the Natura 2000 network.

Keywords: Green infrastructure · Landscape planning · Ecosystem services

1 Introduction

A fundamental definition of Green Infrastructure (GI) was provided by the European Commission in its Communication "Green Infrastructure: Enhancing Europe's Natural Capital" [1], where GI is regarded as a network having Natura 2000 sites at its core, able of delivering numerous ecosystem services, and "strategically planned", hence stressing the importance of GI's in integrating ecological connectivity, biodiversity conservation, and multi-functionality of ecosystems. This definition particularly highlights three important aspects: first, the idea of a network; second, planning and

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management issues; third, the ecosystem services concept [2]. Moreover, in the European context the importance of GI is remarked by the European Union (EU) in its Biodiversity Strategy, whose target no. 2 regards GI as a key element to maintain and enhance ecosystems and their services. In addition, action no. 6 promotes the use of GI through the development of a European "Green Infrastructure Strategy" and of a strategic framework in order to identify priorities for ecosystem restoration in each Member State [3].

From this conceptual perspective, the concept of GI is closely connected with the broader issue of biodiversity conservation for three main reasons. First, the identification of a GI focuses on the designation and maintenance of natural and semi-natural areas in developed, and sometimes even built-up, landscapes. Second, it entails the development of ecological connections among different habitats so as to allow species movements. Third, it uses a language that can be understood by people that play a key role on urbanization processes, such as planners and private businesses [4]. Consequently, the spatial identification and management of GI is an important issue in planning, and especially in landscape planning as understood in the European Landscape Convention. As Snäll et al. [5] put it, a spatially explicit approach is needed in designing a GI, because only such an approach "can support land managers' decisions in real-world situations at the operational level". Hence, the spatial identification and management of GI represent a significant issue for planning at various scale levels. As a matter of fact, the integration of GI within planning policies can support decisions having implications for conservation and protection of landscapes and environment, in terms of knowledge about territory [6] and in relation to their capacity of combining ecological, social and cultural functions [7].

Within this framework, in this study we analyze multifunctional GI and discuss the issue of its spatial configuration in the case study of the metropolitan city of Cagliari, Italy. In addition, we argue that the identification of GI can ease the integration of biodiversity conservation within planning policies in order to promote the implementation of Council Directive 92/43/EEC "on the conservation of natural habitats and of wild fauna and flora" (the so-called "Habitats" Directive), whose article no. 10 states that Member States must promote the management of key elements of landscape which are significant for natural biodiversity.

This article is structured into five sections. The first reviews the relevant literature to identify the open issues to which the research is contributing. The second provides information on the case study and defines the methodological approach. The results are presented in the fourth section, while the last section discusses the results, identifies strengths and caveats of the methodological approach and provides directions for future research.

2 Literature Review: Key Constituents of Multifunctional Green Infrastructures

According to the European Commission [8, p. 1], "GI […] promotes integrated spatial planning by identifying multifunctional zones and by incorporating habitat restoration measures into various land-use plans and policies." From this perspective, multi-functionality represents a key element in the spatial definition of a GI due to the multi-functional use of natural capital that allows to address multiple purposes, among which prominent are biodiversity conservation and ecosystem services production [7].

Various research has advocated GI as a means to ensure ecological connectivity, in connection to ecological corridors [9, 10] either to ensure connections among protected areas [11], or, and in opposition to grey infrastructures such as transportation networks, to ensure ecological functions between and within cities and towns, hence with a view to benefitting human populations and economies first [12]. Such views risk emphasizing the ecological function of GI while leaving other functions in the background. Incorporating GI within spatial planning therefore serves the purpose of “accounting for trade-offs and synergies among multiple ecosystem services in a spatially explicit context” [5].

Building on a previous work by Arcidiacono et al. [13], we assume that the spatial configuration of a multifunctional GI, able to maintain and enhance both natural resources and elements upon which the relations between people and places are grounded, can be identified in relation to four aspects which summarize the multi-faceted character of landscape.

The first, conservation value, accounts for the presence of natural habitat types of Community interest, listed in Annex I of the Habitats Directive. According to art. 1 of the Habitats Directive, a natural habitat is deemed of Community interest when it is endangered or threatened with extinction in its natural range, or has a small natural range, or exhibits typical characteristics of one or more of the nine biogeographical regions to which Member States of the EU belong. Moreover, since 1999 the European Commission has produced an interpretation manual of such habitats [14] and some Member States have tailored the EU manual to their national and local specificities and produced national or regional maps of natural habitats of Community interest.

The second, natural value, accounts for biodiversity in a broader sense, beyond the intrinsic conservation value implicit in the definition of the Habitats Directive. The concept of ecosystem services has recently taken hold worldwide to refer to those goods and services provided by nature that sustain life and human well-being, and hence has met with some criticisms from ecologists and environmental scientists because it focuses on the capability of biodiversity to satisfy human needs, therefore neglecting its intrinsic value and leading to commodification of nature [15, 16]. Various categorizations of ecosystem services have been proposed so far; among the most widely used, the “Common International Classification of Ecosystem Services” (CICES) only considers final goods and services, that is those for which a human demand exists (in accordance with Boyd and Banzhaf [17]), and groups them into three main categories: provisioning, regulating, and cultural services. In accordance with Müller [18], and with Fisher and Turner [19], other categorizations, such as the “Millennium Ecosystem Assessment” (MA) [20] and “The Economics of Ecosystems and Biodiversity” (TEEB) [21], also include a fourth group (labeled supporting services, or habitat services) that accounts for ecological functions and integrity, not directly “consumed” by people but necessary for ecosystems to produce final goods and services. Within this framework, natural value in this study accounts for biodiversity’s quality, which implies its ecological integrity, current levels of ecosystem functions, its capability to supply human-demanded ecosystem services notwithstanding pressures and threats to habitats.

The third, recreation value, is a final ecosystem service part of the cultural services group. In the MA taxonomy [20, p. 58], this group includes different kinds of non-material benefits derived from ecosystems such as “spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences”. Recreation, in particular, accounts for the fact that landscapes and natural habitats are among the factors that people take into account when deciding where they want to spend their holidays or just some leisure time, which not only positively affects on residents’ and tourists’ quality of life and wellbeing, but also impacts directly and indirectly on local economies. In contrast to the other cultural ecosystem services, recreational services can be measured through economic indicators [22]. The TEEB [21], for instance, suggests that the recreational value related to biodiversity could be evaluated in monetary terms through travel cost methods, which have indeed been used by several scholars (among many, [23–25]), sometimes in combination with willingness to pay exercises [26] or with contingent valuation methods [27]. A different approach is that of non-monetary evaluation, regarded as able to capture in a broader and multidimensional way people’s understanding and valuing of non-tangible ecosystem services [28]. Various methods can be applied in non-monetary evaluations, and two frameworks, one [29] that categorizes them into three broad groups: quantitative, qualitative and deliberative, and one that looks at deliberative methods only [28], have been proposed. Among such methods, quantitative methods (either non-consultative or consultative), in principle, could easily be used to assess recreation values, as they merely imply collecting data on tourists and visitors from official statistics (as in [30]) or carrying out ad-hoc surveys. However, because of the costs and time needed to gather them, such data are often unavailable; as a consequence, social-media based approaches have recently been proposed that estimate visitor preferences and numbers using the number of pictures uploaded to social media such as Flickr [31, 32], also coupled with Instagram [33], as a proxy.

The fourth, anthropic heritage, accounts for the interactions between natural and human factors as understood in the European Landscape Convention, whereby landscape is a complex system that includes not only individual historic monuments and landmarks, but also minor spots of land [34] that have contributed to shaping the identity of European cultures. Anthropic heritage, in this sense, is not restricted to archaeological remains, historic monuments, listed buildings, or areas of outstanding beauty, but is grounded on people’s perception of their territories, and on the recognition that different places show different characters. In compliance with the Convention, whose implementation varies across countries [35], landscapes are to be protected, managed and planned. Consequently, landscape plans are the tools whereby landscapes are interpreted, anthropic heritage is identified and protection devices taking various forms that span from strict regulations to soft guidelines to orient future scenarios are devised.

3 Materials and Methods

3.1 Case Study

The scale of a whole city has been advocated [36] as the minimum ideal scale for spatial planning to set up GI aiming at preserving biodiversity, maintaining ecosystem services. We chose as a case study the metropolitan city of Cagliari, in the Italian region of Sardinia, where a Regional Landscape Plan (RLP), set up in compliance with the Italian Landscape Code (Decree Enacted by Law no. 42 of 2004, which implements the European Landscape Convention in Italy), has been in force since 2006 and where an extensive Natura 2000 network, covering almost 19% of the regional land area, has been designated.

The metropolitan city of Cagliari is partially included within three out of the 27 Coastal Landscape Units identified in, and ruled by, the RLP. Such plan does not give explicit provisions for setting up a regional GI; however, it does provide building and planning restrictions in sensitive contexts so as to preserve ecological functions (art. 23 and 26 of the plan implementation code), and it gives directions on the necessity to integrate Natura 2000 sites within a single coherent network (art. 34 of the plan implementation code). The study area overlaps 20 Natura 2000 sites, out of which 13 sites of community importance (SCIs) and 7 special areas of conservation (SACs).

Our study area, mapped in Fig. 1, therefore encloses (i) the metropolitan city area of Cagliari, as well as (ii) the entirety of the three coastal landscape units that overlap the metropolitan city area, and (iii) all of the 20 Natura 2000 sites that either are completely included therein, or partially overlap it.

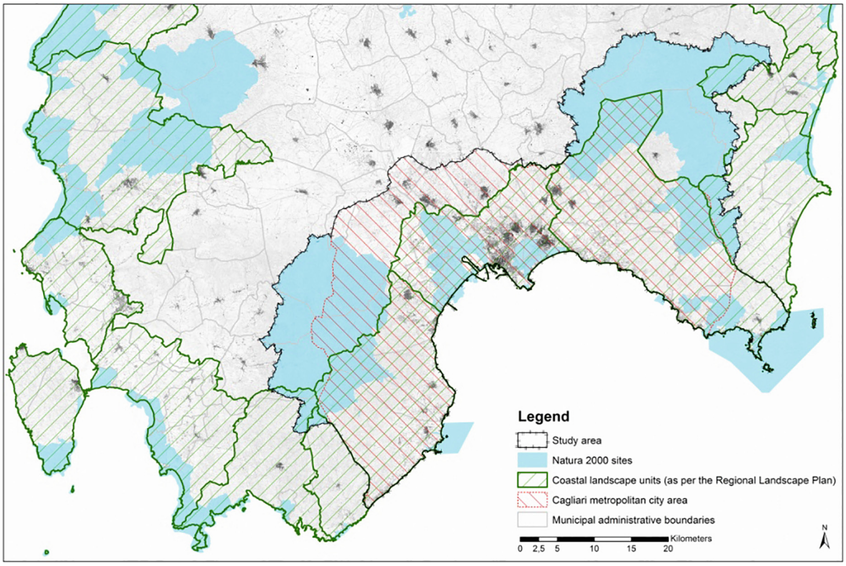

Fig. 1. Study area

3.2 Methodology

The four constituent values that, in our framework, can be used to identify the spatial configuration of a GI were calculated and mapped in a GIS-based environment.

Conservation Value. Conservation value (CONS_VAL) accounts for the presence of natural habitat types of Community interest. As mentioned, such habitats have been enlisted in Annex I of the Habitats Directive on the basis of their being rare, or threatened, or typical within a given biogeographical region; moreover, the Directive gives prominent importance to a small number of habitats classed as "priority" habitats. Hence, and building on a recent report [37, pp. 27–28] that ranks the importance of habitats of Community interest in Sardinia with a view to defining a regional monitoring plan, we calculate this value as follows:

- for areas where no habitats of Community interest have been identified:

$$CONS\_VAL = 0 \tag{1}$$

- for areas hosting habitats of Community interest:

$$CONS\_VAL = P * (R + T + K) \tag{2}$$

where:

- P indicates whether a given habitat is enlisted as priority habitat (P = 1.5 in case of priority habitat, P = 1 in case of non priority habitat);
- R denotes rarity, which, for each habitat of Community interest, can be evaluated on the basis of the number of Natura 2000 sites in which the presence of the habitat has been recorded in the standard data forms [38]. The figures can be retrieved from the official website of the European Environment Agency[1] and normalized in the interval (1 ÷ 5); the lower the number of occurrences, the higher the value of R;
- T stands for threats, which are recorded in each Natura 2000 standard data form. For each Natura 2000 site, the number of threats recorded in the standard data forms is counted and normalized it in the interval (1 ÷ 5); the higher the number of threats, the higher the value of T;
- K stands for knowledge: since reliable and up-to-date information gathered through on-site surveys is not available for every habitat of Community interest and for every Natura 2000 site, we deem the level of knowledge important from a conservationist's standpoint. The level of knowledge was assessed by experts within a recent regional monitoring project titled "Monitoring the conservation status of habitats and species of Community interest within Natura 2000 sites in Sardinia" [39, pp. 42–44]. For each habitat, the level of knowledge was therefore classed as "good", "acceptable", "insufficient", "poor". We converted these judgments into values in the interval (1 ÷ 4), where the worse the level of knowledge, the higher the value of K. We chose to assign a

[1] http://natura2000.eea.europa.eu.

maximum score (4) lower than those of both R and T (5) due to the fact that K (contrary to R and T) depends on subjective assessments.

As a results, where habitats of Community interest are present the value can range from 1 (minimum conservation value) to 21 (max conservation value). Such values were subsequently normalized, hence CONS_VAL takes values in the (0 ÷ 1) interval.

The following two spatial datasets were used: the first, the so-called "carta della natura" ("Nature map", [40]), has a scale of 1:50,000, and makes use of the CORINE biotopes nomenclature, while the second, the so-called "carta degli habitat" ("Habitat map", [41]), has a scale of 1:10,000 and maps habitats of Community interest by using the Habitats Directive taxonomy within Natura 2000 sites only. The interoperability between the two taxonomies was handled through a conversion tool made available by the Italian Superior Institute for Environmental Protection and Research [42], which allowed us to map habitats of Community interests also outside Natura 2000 sites using the "Nature map".

Natural Value. Natural value (NAT_VAL) accounts for the potential capability of biodiversity to supply final ecosystem services in face of threats and pressures. For this purpose, we used the software "InVEST"[2], tool "Habitat quality", which produces habitat quality maps by combining information on land covers and threats to biodiversity, on the basis of the assumption that areas having high values of habitat quality can better support biodiversity. The input data required by the tool and used to feed the model are as follows:

1. A raster land cover map. We used the 2008 Land Cover Map produced by the Regional administration of Sardinia that we first reclassified at the third level of the CORINE[3] taxonomy and next converted into a raster map having cellsize 25 * 25 m.
2. A list of current threats to biodiversity, and for each threat a weight (which denotes the threat's relative importance), a decay distance and function. After examining the standard data forms of the 20 Natura 2000 sites included in our study area, we selected those threats that generate negative impacts on the land zone of these sites (marine areas are out of the scope of this study) and that can be mapped. As a result, we obtained a list of ten pressures and threats; for weights and decay distances, we delivered a questionnaire to local experts in the field of biodiversity and environmental impact assessment. In the questionnaire, the weight was to be expressed using a "Likert" scale 1–5, hence grading the relative importance of a given threat, while the decay distance was to be provided in kilometers. For each threat, we next averaged both the weights and the decay distances provided by the surveyed experts; moreover, the weights were normalized in the (0 ÷ 1) interval as required by InVEST. Table 1 provides a list of the ten selected threats, as well as their

[2] InVEST is a free software program developed within the Natural Capital Project and available at http://www.naturalcapitalproject.org/invest/.

[3] CORINE is acronym of "COoRdination de l'INformation sur l'Environnement", French for "Coordination of information concerning the environment".

Table 1. Threats to biodiversity in the study area, parameters for the InVEST model (weight, decay distance and function), and spatial data sources

Code	Threat name	Weight	Decay distance (km)	Decay function	Data source[a]
T01	Cultivation	0.58	1.63	linear	2008 Land Cover Map
T02	Grazing	0.68	0.58	linear	2008 Land Cover Map
T03	Removal of forest undergrowth	0.79	0.65	linear	2008 Land Cover Map
T04	Salt works	0.63	0.83	linear	2008 Land Cover Map
T05	Paths, tracks	0.53	0.55	linear	Regional multi-precision database
T06	Roads, motorways	0.95	3.00	linear	Regional multi-precision database
T07	Airports	0.95	4.75	linear	2008 Land Cover Map
T08	Urbanized areas	0.95	3.25	linear	2008 Land Cover Map
T09	Discharges	1.00	3.50	linear	2008 Land Cover Map
T10	Fire	0.95	2.05	linear	2011–2015 Fire maps

[a]All of the spatial datasets can be freely downloaded from the regional geoportal http://www.sardegnageoportale.it.

averaged weights and decay distances, and, as for weights only, also normalized. The decay function was always set as “linear”.

3. A raster map for each current threat source. Table 1 lists, in detail, the data sources used.
4. A vector map representing accessibility to sources of degradation, in terms of relative protection to habitats provided by legal institutions. We considered regional and national parks, as well as areas protected and managed by the public regional forestry agency, as having the highest protection and hence lowest accessibility level (score 0.2); a second level we used was that of Natura 2000 sites (score 0.5); all the rest of the study area was considered as completely accessible (score 1). All the maps were available from the regional geoportal.
5. A matrix listing habitat types (where habitats represent resources and conditions present in an area that can support the life of given organisms, and therefore are not restricted to those of Community interest accounted for by CONS_VAL) and their sensitivity to each threat. The sensitivity of each habitat to each threat was developed using a two step expert-based approach: first, each land cover code (at the third level of the CORINE taxonomy) was given a trichotomous value (1 if the land cover could be intrinsically regarded as habitat; 0.5 if it could be considered habitat contingent on external factors; else 0); second, for each land cover code that could be considered as habitat, a score representing that land cover’s sensitivity to each threat was assigned. An excerpt of this matrix is provided in Table 2.
6. A so-called “half-saturation constant”, having default value 0.5 in the InVEST tool.

Table 2. An excerpt of the sensitivity matrix concerning agricultural land covers

Land cover code	Habitat score	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10
211	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
212	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
221	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
222	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
223	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
231	1	1	0.5	0	0	0.5	1	0.2	0.5	1	1
241	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
242	0.5	0	0.5	0	0	0	0.5	0	0.5	0.5	0.5
243	1	0.5	1	0.5	0	1	1	0.2	1	1	1
244	1	0.5	0.5	1	0	1	1	0.2	1	1	0.5

Recreation Value. Recreation value (REC_VAL) is connected to people's (both locals' and tourists') appreciation of nature and biodiversity. In the absence of official data on visitors' numbers, we used the software "InVEST", tool "Recreation model". This tool gathers data from the social media Flickr, whose users upload geotagged pictures on the platform, and counts the total photo-user-days in specific locations (either cells or polygons) by using location, username and date in which the images were shot so as to avoid double counting. The unit of measure is therefore "photo-user-day" (PUD); one PUD means that, in a given spatial unit and on a specific day, one unique photographer took at least one photo. The study area was gridded using a square 100-meter grid; for each cell, the average PUD per year between 2010 and 2014 was calculated by the model, and subsequently normalized in the interval ($0 \div 1$).

Anthropic Heritage. Anthropic heritage (ANTH_HER) takes account of the landscape assets protected under the RLP, in force in Sardinia since 2006. For each protection level defined in the plan, a score was assigned in the ($0 \div 1$) interval depending on the level of restriction stemming from the plan implementation code, having also regarded to other restrictions originating from national and regional legislation. The full list of protection levels is provided in Table 3, together with reference to the articles of the implementation code that provide rules and directions for each protection level, and finally the score we assigned, expressing the anthropic heritage value. As for the spatial layout, the full spatial dataset of the protection levels established by the RLP is retrievable from the regional geoportal. It is worth noting that parcels subject to multiple protection levels were assigned the score corresponding to the strictest protection level in force in that parcel.

Total Value. In each specific location, the total value corresponds to the sum of the four above-listed values (CONS_VAL, NAT_VAL, REC_VAL, ANTH_HER), each ranging in the ($0 \div 1$) interval; as a result, total value can range in the interval ($0 \div 4$). The total value was calculated through a GIS geoprocessing tool after converting the

Table 3. Anthropic heritage; types of landscape protection levels established in Sardinia by the RLP, and value assigned on the basis of the restrictions in force

	Type	Plan implementation code: ruling articles	Value
Environmental assets	Coastal strip	8, 17, 18, 19, 20	1
	Coves, cliffs and small islands	8, 17, 18	0.8
	Sand dunes and beaches	8, 17, 18	0.8
	Coastal wetlands	8, 17, 18	0.8
	Areas above 900 m	8, 17, 18	0.8
	Lakes, reservoirs, wetlands and their 300-m buffers	8, 17, 18	1
	Rivers, creeks and their 150-m buffers	8, 17, 18	1
	Areas of significant importance for wild animals	17, 18, 38, 39, 40	0.2
	Areas of significant importance for plant species	17, 18, 38, 39, 40	0.2
	Grottos and caves	8, 17, 18	0.8
	Monumental trees	8, 17, 18	0.2
	Natural monuments (as per regional law 1989/31)	8, 17, 18	0.5
	National parks and marine protected areas	8, 17, 18	0.5
	Volcanoes	8, 17, 18	0.5
Historic and cultural assets	Listed buildings and areas (art.146 Decree 42/2004)	8	0.8
	Listed archaeological heritage	8, 47	1
	Archaeological areas subject to building restrictions	8, 47	0.5
	Areas with prehistoric, historic, cultural remnants	8, 47, 48, 49, 50	1
	Historic districts	8, 47, 51, 52, 53	0.8
	Traditional Sardinian farmer's building complexes	8, 47, 51, 52, 54	0.8

two raster maps (NAT_VAL and REC_VAL) into vector maps (CONS_VAL and ANTH_HER were already vector).

4 Results

The results of our model are represented in Figs. 2 and 3, where the former displays the spatial distribution of each of the four single values, while the latter maps the spatial distribution of the total value, and therefore can be used to delineate the spatial configuration of the GI within our study area.

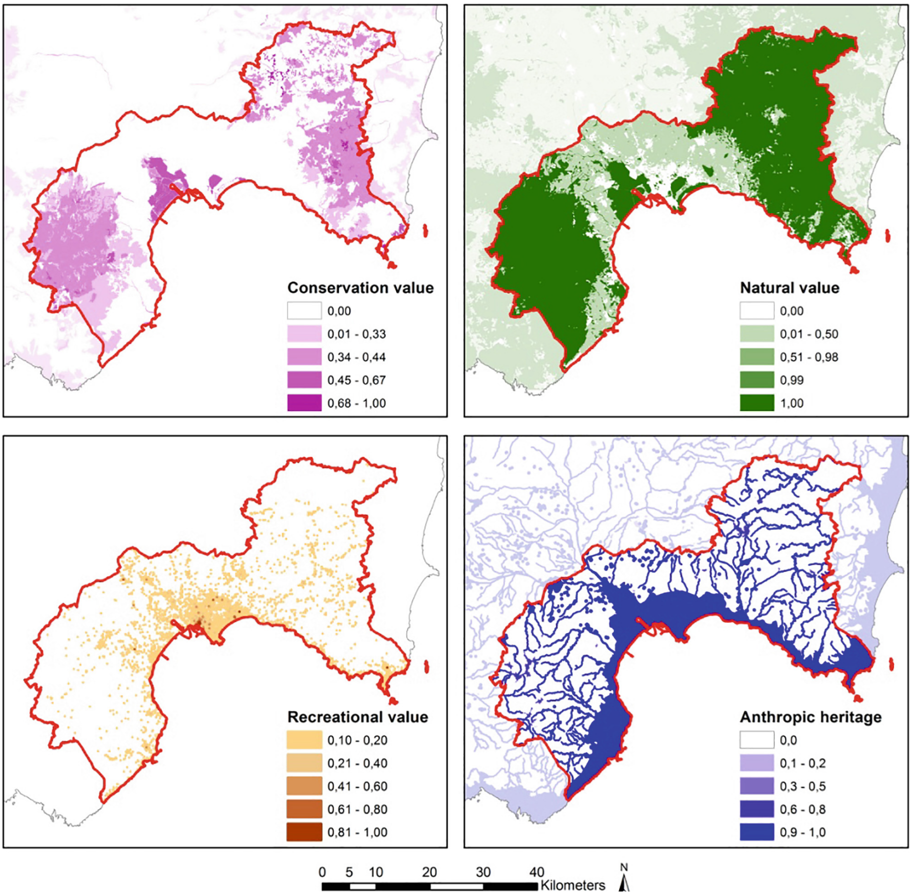

Fig. 2. Spatial distribution of the four values within the study area

Areas taking non-zero values in conservation value are mostly, but not exclusively, located within Natura 2000 sites and highly spatially clustered in their immediate surroundings.

As for natural values, two large clusters taking extremely high values are notable in the eastern and western parts of the study area, as well as two smaller clusters in the middle (corresponding to two wetlands surrounded by the built-up core of the metropolitan city); contrary to what happens with conservation values, the rest of the area does not have a zero value, meaning that, although not of Community interest, some middle-quality habitats act as "bridges" between areas having highest values.

With regard to recreation value, approximately 96% of the cells display zero value, meaning that for the vast majority of the study area the average PUD value is zero. Cells taking non-zero values, and especially cells taking the highest values, are highly clustered within the city of Cagliari; moreover, a linear constellation of non-zero values is clearly visible along the coastline, while the rest of the study area only shows scattered non-zero values.

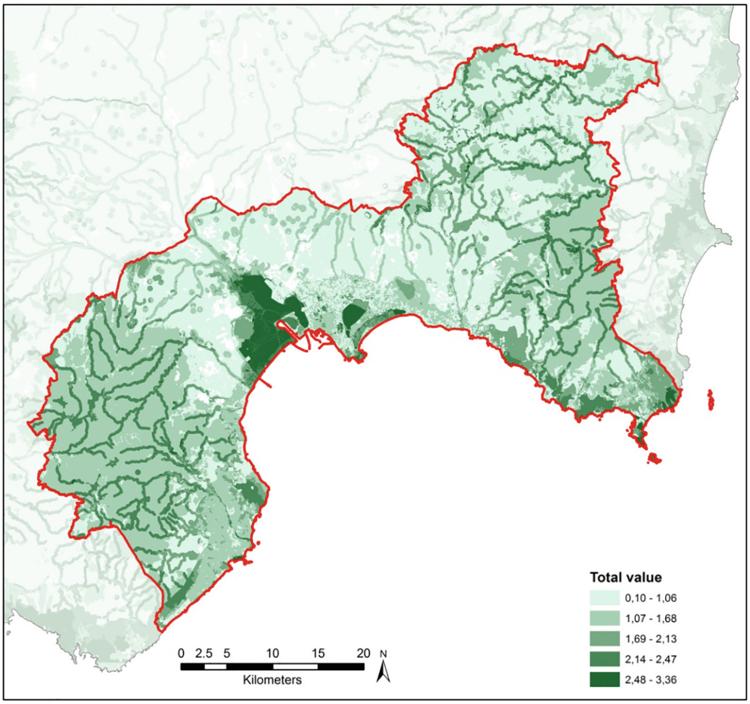

Fig. 3. Spatial distribution of the total value within the study area (classification: Jenks algorithm)

Finally, the anthropic heritage map shows that the most part of the study area takes either the minimum (0) or the maximum (1) value; only some small scattered areas take intermediate values. Moreover, areas taking the maximum value are largely dominated by two main environmental assets, characterized by strict restrictions on new development and land use changes. The first type, "Coastal strip", is protected under the RLP (article 20 of the plan implementation code), which forbids any kind of new development while allowing restoration or renewal of existent buildings. The second type, comprising "[listed] Rivers, creeks and their 150-m buffers", is protected under national law, whereas the RLP merely makes it clear which areas are to be preserved and protected as belonging to this type. A third type of asset that brings about the maximum value, but less significant in terms of size, comprises both "Listed archaeological heritage" and "Areas with prehistoric, historic, cultural remnants".

The total value map (Fig. 3) shows that no land parcel achieves the maximum total score (i.e., 4), which also implies that no land parcel simultaneously achieves the maximum score in each of the four values above presented. Areas taking the highest values consist mainly of rivers and creeks together with their 150-m buffers, wetlands, as well as large forest areas and bits of coastal areas.

5 Discussion and Conclusions

In this study we attempted to make spatially explicit a multifunctional GI by mapping four constituents that correspond to as many functions that the GI should support and ensure, hence addressing an open issue on how to account for multifunctionality [43] in designing a GI.

The results from the methodological approach tested in this study highlight that the four values vary differently across space, which is pretty straightforward, since each value captures a specific aspect or function relevant to landscape planning.

Moreover, it is also not surprising that no land parcel simultaneously achieves the maximum score in each of the four values that express as many single functions (high-quality biodiversity conservation, supply of ecosystem services, recreation, landscape protection). This supports the view that multifunctionality is an ideal (or "elusive" [44]) goal when designing a GI, because in reality different areas tend to perform one (or more than one) dominant function and complement each other, hence some spatial tradeoffs between areas performing different functions need to be understood and agreed upon when deciding which areas are to be included in a spatially-designed GI to be managed through a spatial planning tool such as a landscape plan. As a consequence, rather than the map representing the spatial configuration of a GI, the total value map in Fig. 3 should be thought of as a tool to support the choice about possible areas to be included in a GI within a normative regional spatial plan.

By doing so, this methodology addresses a major issue highlighted by Lovell and Tayor [36], that of a "limited success" in institutionalizing GI, because in Italy landscape plans are to be prepared and adopted by an institution to fulfill an obligation by law through a process in which participatory processes are mandatory in the strategic environmental assessment framework as per European Directive 2001/42/EC. Such participatory processes would engage ecosystem services beneficiaries [45], which include but are not limited to local communities. Ecosystem services beneficiaries' knowledge, expectations, and priorities were not included in the methodology here implemented, which is solely grounded on official, scientific datasets (e.g. as for the selection of threats when assessing NAT_VAL) or on expert judgment (e.g. on prioritizing threats or assessing sensitivity weights, again in connection with NAT_VAL). Therefore, future research could address the issue of taking ecosystem services beneficiaries into account, for instance as regards possible weights to assign to each constituent value to reflect their priorities.

Finally, Habitats Directive's objectives have been incorporated in the methodology primarily via CONS_VAL and secondarily via NAT_VAL, with the aim to help integrate biodiversity conservation objectives into spatial planning, so as to ease implementation of article 10 of the Habitats Directive, which states that relevant features of the landscape should be managed to improve the ecological coherence of the Natura 2000 network. Future researches could therefore explore how the methodology would work at a larger scale, compatible with Natura 2000 network's spatial layout (for instance, biogeographical regions or disconnected parts thereof) and what the relationship is between the multifunctional GI as here identified and the ecological network connecting Natura 2000 sites as implied in article 10 of the Habitats Directive, comprising linear and continuous structures as well as stepping stones.

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