

Article

Assessment of Municipal Masterplans Aimed at Identifying and Fostering Green Infrastructure: A Study Concerning Three Towns of the Metropolitan Area of Cagliari, Italy

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Abstract: Building upon a recent piece of research that maps a regional green infrastructure (RGI) in relation to four components (natural value, conservation value, landscape value, and recreational value), this study aims at identifying planning policies that can foster the enhancement of the RGI by increasing one or more of its components at the sub-regional scale. To this end, the RGI suitability map is overlaid with the planning schemes of the municipal masterplans (MMPs) of three towns belonging to the Metropolitan City of Cagliari (Italy), and multiple linear regressions are performed. The outcomes of the study imply that the eligibility of a land parcel to be part of the RGI depends on several factors related to planning policies entailed by the zoning schemes of the MMPs, such as presence and spreading of conservation and safeguard areas within urban fabrics, improved accessibility of historic and natural landmarks, planned use of nature-based solutions within the regulating codes of MMPs, improvement of habitat quality in the spatial context of rural areas. Main limitations of the proposed methodology concern the fragile theoretical foundations concerning the assessment of the recreational value, and the need for structured integration of nature-based solutions into the proposed methodology.

Keywords: green infrastructure; ecosystem services; Natura 2000 Network; environmental planning

1. Introduction

The concept of green infrastructure (GI) arises within the international debate at the end of the 1990s as a distinctive approach to landscape planning [1]. GI is considered as a reference category in the contexts of several disciplines, e.g., landscape ecology [2], greenway planning [3], and management of water resources [4]. Moreover, different functions of GI are identified, e.g., biodiversity conservation [5], or benefits provided to local communities and to civil society as a whole [6]. Therefore, several definitions of GI are available in the literature. Among many, Benedict and McMahon's [5], Wright's [7], Weber et al.'s [8] and the European Commission's [9] are the most relevant. Benedict and McMahon [5] define GI as the ecological system that supports environmental, social and economic health, emphasizing the socio-economic approach to GI. According to Wright [7], although connectivity, multifunctionality and green areas represent the core ideas as regards the category of GI, a deterministic definition is somewhat questionable because, on the one hand, such definition would be inconsistent with a progressively evolving conceptual framework concerning GI, and, on the other hand, its intrinsic interoperability would imply the opportunity of using the GI

conceptual framework in a number of research and technical fields related to environmental and spatial studies, which would entail a preference to a flexible, non-deterministic definition. Weber et al. [8] stress the environment-related character of the GI concept, conceived as a system of natural and semi-natural areas spread over the landscape. Broadly speaking, from the above-cited literature GI can be understood as a network of natural and semi-natural areas that play a key role in supporting ecological, social and economic activities.

This study takes as a reference the definition by the European Commission [9] (p. 3), which describes GI as “a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings.” This definition stresses two fundamental characteristics of GI, that is, provision of ecosystem services and protection of biodiversity [10].

Habitats located in the countries of the European Union are characterized by growing fragmentation and deterioration due to human pressures on the environment and the ecosystems [11,12]. The spatial identification of GI is a key element of the European Union biodiversity strategy to 2020 since the second target states that “By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems” [13] (p. 5). Consequently, GI represents a spatial planning tool that significantly enhances the quality of life through environmental, social and economic values generated by multifunctional uses of the ecosystems [12].

A number of authors highlight the importance of the inclusion of GI within spatial planning practice [14,15]. Lennon and Scott [15] target the identification and the expansion of GI as one of the most important strategies to implement the ecosystem-based approach into spatial planning. The use of GI in urban contexts entails the development of spatial processes whose planning and management involve particular attention to the impact of non-ecological benefits generated by urban contexts on natural (non-urbanized) environments [16]. According to Kambites and Owen [6], GI planning should be (1) holistic, related to both human and ecological functions; (2) strategic, reflecting a forward-looking view that goes beyond administrative boundaries; (3) inclusive, involving different stakeholders; and, (4) qualitative, assessing biodiversity value and natural resources quality.

However, the implementation of the GI category and related principles is still limited in planning practices, partially due to the limited understanding of the GI concept by planners [17], whose knowledge and information concerning GI is not supported by adequate scientific foundations [18]. Moreover, the implementation of the GI concept into policy-making is problematic because of the complexity of planning processes, which deal with environmental, social, and political contexts and the related regulatory framework [17].

Several studies discuss benefits generated by GI, but they seldom take account of the critical relationships between theoretical assumptions and practices derived thereof as regards the planning framework at stake [19]. Davies et al. [20] investigate the implementation of GI at the urban and regional levels, in relation to twenty European case studies, by using data derived from a number of sources such as official planning documents, questionnaires, Internet analysis, and statistical archives. Davies et al.’s study reports that only seven out of 32 analyzed plans mention the term GI and that only in four cases (Edinburgh, Liverpool, Bristol, and Barcelona) references to connections between GI and spatial planning can be identified. In the work of Artmann et al. [21], GI is the key concept to propose guidelines on how landscape plans can make urban networks of green spaces consistent with compact city spatial frameworks. From this point of view, particular attention should be paid to how local plans should address GI planning [22], and to the lack of models that assess synergies and tradeoffs between ecological and social benefits generated by the spatial identification and planning of GI [23,24]. Under this perspective, this study aims at proposing a methodological approach to include and implement GI within spatial planning at the city level, hence it addresses an outstanding gap concerning scientific and technical research on GI.

As regards these questions, this study builds upon a few recent articles, related to Sardinia, concerning the identification of a spatial taxonomy of areas eligible to be part of a regional green infrastructure (RGI) [25,26] on the basis of four factors, namely the natural, conservation, landscape and recreational values. This study aims at defining and analyzing the relationship between the RGI, identified through the implementation of the methodology proposed in the above-cited articles, and the rules of municipal masterplans (MMPs).

In order to achieve this goal, a methodology based on the overlay mapping of the spatial taxonomy of areas eligible to be part of the RGI and the zoning layouts of MMPs, and on the analysis of correlations between the spatial taxonomy and the zoning rules, is proposed. Correlations are identified through regression analysis. The methodology is applied to the MMPs of three municipalities belonging to the Metropolitan City of Cagliari (MCC, Sardinia, Italy). The outcomes of the study offer important suggestions as regards the definition and implementation of the planning policies of the MCC, based on the general goal of strengthening the GI-related characteristics of the towns located within the metropolitan boundaries, with a view to a future expansion of the RGI within the MCC. The proposed methodology can be easily applied to other national and international urban contexts, and the results of its implementation into the towns of the MCC are important comparative references as regards analogous studies.

This study is structured as follows. This introduction (Section 1) has identified the wider context and the debates that the study is contributing to. Next, Section 2 describes the proposed methodological approach and the spatial context for the implementation of the case study, that is, the towns of Cagliari, Assemini and Capoterra. The results coming from the regression analysis which explores and detects correlations between the RGI and the spatial zoning rules of the MMPs of the three towns are presented in Section 3. In Section 4, implications for spatial planning policies related to the urban contexts of the MCC are discussed. Finally, directions for future research and concluding remarks are proposed in the Section 5.

2. Materials and Methods

2.1. Case Study

Municipalities are, in Italy, in charge of programs and plans, ruling on land development and land-use changes, hence they draft, adopt and approve their own MMPs, which simultaneously lay down a strategic policy for the concerned territory and provide the setting for the management of small scale land-use transformation [27]. Due to the hierarchic nature of the Italian planning system [27] (p. 35), MMPs must conform to a number of higher level plans, the most prominent of which are regional plans, and especially the Regional Landscape Plan (RLP).

This study takes the towns of Assemini, Cagliari and Capoterra, in Sardinia (Italy) as case studies. Each town is a municipality, with its own elected local government and mayor, and it is also part of the MCC, recently established under national law no. 2014/56 and regional law no. 2016/2 (Figure 1). Cagliari, with its approximately 150,000 inhabitants and 85 km² in size, is the regional capital and the metropolitan center; Assemini (having around 27,000 inhabitants and 118 km² in size) and Capoterra (with about 23,000 inhabitants and 69 km² in size) are two medium-sized towns both geographically and economically close to the regional capital, since they belong to the same travel-to-work area, in that a good share (approximately 30 percent [28]) of their populations commutes to Cagliari on a daily basis.

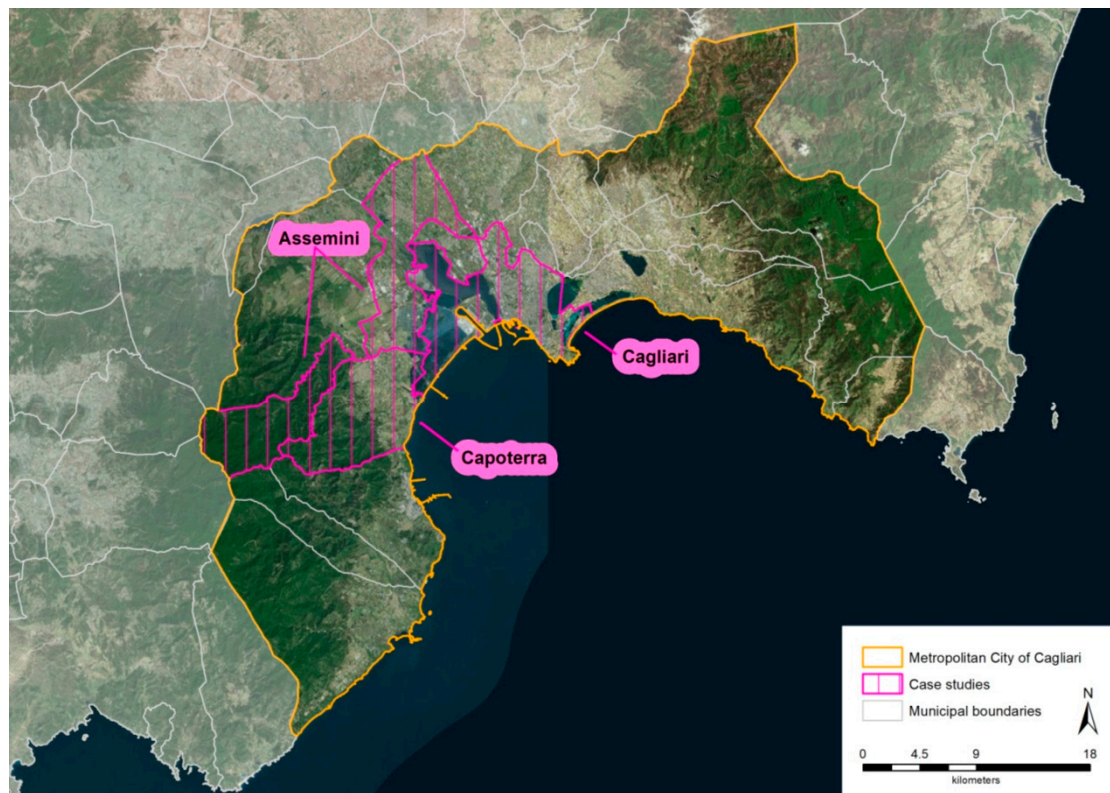


Figure 1. The study area.

The three above-mentioned towns were deemed useful as case studies because, notwithstanding their geographic proximity (which implies similarities in natural, social, and landscape features which lay the basis for the identification of the RGI) and their common planning framework (due to their belonging to the same region, their MMPs are subject to the same regional planning laws and must conform to the same RLP), some outstanding differences can be found that make the comparison interesting. The first difference has to do with the share vegetated (hence, natural and semi-natural areas, which are a necessary, but not sufficient, condition for the presence of a GI as defined by the European Commission [9]) versus urbanized area, since in Assemini and in Capoterra a large portion of the municipal land cover is either natural or agricultural, contrary to what happens in Cagliari, where artificial land covers dominate, if wetlands are not taken into account. A second difference concerns the concentration of the resident population, which in Cagliari amounts to about 1,760 residents per square kilometer, about seven times as much as that of Capoterra (339.5) and eight times as much as that of Assemini (225.3), which in terms of GI implies significant differences in municipal demand for ecosystem services, and, possibly, delocalization of the supplying areas. A third difference regards the land-use plans in force: only two of them (Assemini's and Capoterra's) conform to the RLP in force, while the third (Cagliari's) has very recently started the adjustment process [29] to the RLP, hence in principle for Cagliari there might be more room for improving nature and landscape protection policies and therefore for enhancing the supply of ecosystem services and ultimately the GI. Finally, a common feature of the three municipalities is the presence of several natural protected areas, including various Natura 2000 sites and two regional natural parks, which can constitute core areas for an RGI provided that their inter-connections are properly identified, safeguarded and managed through appropriate planning actions.

2.2. Zoning Schemes

Within both the municipalities of Assemini and Capoterra, an MMP recently approved and compliant with the Sardinian RLP is in force; their planning documents and zoning schemes, approved

in August 2015 and May 2016, respectively, are available on the municipalities' official web pages [30,31]. As for the municipality of Cagliari, a much older MMP, dating back to 2004, is in force; such plan was approved under the former landscape planning system, hence the complex and conflictual process of adjustment to the RLP [29] has not taken place yet. The planning documents and zoning scheme for the municipality of Cagliari are available on its official webpage [32] and geoportal [33].

For each of the three municipalities, the zoning schemes were retrieved and analyzed in the light of their respective technical implementation norms. Next, the schemes were simplified on the basis of the provisions contained in the norms, so as to reduce as much as possible the number of zone types, for instance, by joining together sub-zones belonging to the same zone type, or by merging zones with similar planning or building rules. This simplification led to identifying ten types of planning zones; out of the ten types, listed in Table 1, type "E" is not included in Cagliari's zoning scheme, while types "GS" and "IC" are not included in Assemini's and Capoterra's ones.

Table 1. Homogeneous zones identified by the zoning rules of the municipal masterplans (MMPs) of Cagliari, Assemini and Capoterra: simplified and detailed zone types.

Simplified Zone Types		Detailed Zone Types		
Type	Description	Cagliari	Assemini	Capoterra
A	Historic districts.	PQCS	A1; A2	A1; A2.1
B	Residential completion zones.	B1; B1*; B2; B2*; B2R1; B2R2; B2R3; B3; B3*; B3R1; B3R2; B3R3; B4; B4*; B4R1; B4R2; B4R3; B5; B5*; B5R1; B5R2; B6; B6*; B6R1; B6R2; B7; B7R1; B7R2; B8; B8*; B8R2; B8R3; B9; B9R1	B1.a/B1.b; B2; B3; B3	B1; B2
C	Residential expansion zones.	C*; C1; C1*; C2*; C3*; C4*; C5*; ER	C1; C2.1; C2.2; C3	C1a; C1b; C1c; C1d; C2; C3
D	Industrial and commercial zones.	D; DG; DR	D1; D2.1; D2.2; D2.3; D2.4; D2.5; D2.6	D2a; D2b; D2c; D2PIP
E	Agricultural zones.	—	E1; E2; E5	E1; E2; E3; E4; E5
G	Collective service zones.	G1; G2; G3; G4; G5I; G6; G7; GA1; GA2; GH; GI; GI/S; GIT; GM; GM*; GM*/GI/S; GOM; GP1; GT; GT*/GA2; GT*/GI; GT*/GS; GTS; D*/G	G1.1; G1.2a; G1.2b; G1.2c; G1.2d; G1.2e; G1.3; G1.4; G1.5; G1.6; G1.7; G1.8; G1.9; G1.10; G1.11; G2.1; G2.2; G2.3; G2.4a; G2.4b; G2.4c; G2.5; G3.1; G4.1a; G4.1b; G4.2; G4.3; G4.4; G4.5; G4.6	G1a; G1b; G1c; G1d; G2a; G4
GS	Collective service zones: green parks significant at the city level.	GS	—	—
H	Conservation and safeguard zones.	AR; AS; H; HG; HS	H1; H2a; H2b; H3	H1; H2; H3
EZ	Enterprise zones.	BS3*; IC; PI1; PI2; D*/GI; D*/GI1; S3*	—	—
S	Public spaces reserved for collective activities, green areas, or parking lots at the district level.	S1; S1*; S1-S2; S2; S2*; S2/E; S3; S4	S1; S1/S2; S2; S2/S3; S3; S4; SBpr	S; S2; S3; S3*; S4

"A" zones coincide with historic districts (sometimes, as in Cagliari, featuring buildings dating back to the Middle Age, and mostly comprising built-up areas developed before World War II), although sometimes they also include other built-up areas with distinctive historic or artistic features.

“B” zones are built-up areas generally developed from the 1950s onwards. They are usually completely developed (meaning that the full housing capacity in terms of cubic meters per square meter of land has already been built), although some partially developed areas can also be included, provided that roads and other infrastructures have already been realized and that at least 10 percent of the allowed housing volume has been developed.

“C” zones are bound to be residential areas; they comprise both undeveloped or partially developed parts of a town that do not qualify as “B” zones (either because they lack infrastructures or because the built volume does not reach the minimum threshold).

“D” zones are reserved for new commercial and industrial buildings, also including processing, storage and selling of agricultural and fishing products.

“E” zones are allocated for agricultural uses, and comprise five sub-zones depending on the importance of agricultural and farming activities that can be carried out, hence ultimately depending on the land suitability for crop production, grazing, or farming. In these areas, residential buildings are allowed only if connected to, and necessary for, the maintenance of the agricultural plot of land in which they are built.

“G” zones are meant to host buildings and facilities, both public and private, of collective interest; they include, among others, high schools, universities, hospitals, sports facilities, water treatment plants, waste incinerators.

“GS” zones identify large green areas that are reserved for urban parks, in which only low-density public facilities (for sports or recreation) can be built.

“H” zones comprise areas where development is almost completely forbidden; they include fragile and sensitive areas, such as beaches or buffer zones around wetlands and rivers, as well as areas to be preserved for their archaeological or speleological or landscape relevance, and also buffer zones around major infrastructures (e.g., roads or railways) that must be left undeveloped.

“EZ”, zones, the so-called “enterprise zones” [34,35], are undeveloped or partially-developed parts of the city of Cagliari where integration of different functions (residential buildings, public facilities and recreational areas) must be guaranteed.

“S” zones are areas that must be surrounded by the developer to the municipality when a private detailed development plan (be it for housing, or for industrial or commercial development) is implemented; such areas are therefore public and can be turned into primary schools, public facilities or green spaces for the district, or parking lots.

2.3. Methodology

This study builds upon a methodology applied in previous studies [25,26,36,37], where a potential RGI is mapped taking an Italian region as a case study: Lombardy in [36], and Sardinia in [25,26,37]. In the Sardinian case, the suitability of each patch of land to belong to an RGI is assessed based upon four factors expressing as many functions provided by a GI, as follows:

- natural value (NatVal), which represents habitats’ quality notwithstanding pressures and threats exerted on biodiversity, and hence the GI’s capacity to provide ecosystem services. NatVal is assessed and mapped through the tool “Habitat quality” of the software “InVEST” [38] that uses as input: i. data on land covers, retrieved from the regional geoportal [39]; ii. threats to biodiversity identified in the Natura 2000 Standard Data Forms of the European Environment Agency [40] and weighed by experts in the field; iii. a sensitivity matrix of each land cover type to each threat;
- conservation value (ConVal), which accounts for the fact that green infrastructures are, in the definition provided by the European Commission [9] and quoted in Section 1, “a network of high quality natural and semi-natural areas”. Hence ConVal accounts for the presence of natural and semi-natural habitats protected under the European Union legislation because rare, or in danger of disappearance, or providing outstanding examples of typical characteristics of one of the European biogeographical regions;

- recreation value (RecVal), which provides an indication of the extent to which landscapes are attractive for recreational uses and hence provide recreational ecosystem services; RecVal is assessed and mapped through the tool “Visitation: Recreation and Tourism” of the software “InVEST” [38] which retrieves spatial and quantitative information from geotagged pictures uploaded by users on the social media Flickr;
- landscape value (LandVal), which accounts for the quality of landscapes as implied in the RLP’s normative framework. In compliance with the European Landscape Convention of the Council of Europe [41], landscape in the plan is regarded as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factor” (article 1) and a “foundation of people’s identity” (article 5); therefore, depending on their quality, landscapes are providers of cultural ecosystem services. From the spatial dataset of the plan, available on the regional geoportal [42], the location of each landscape good was retrieved and, through an expert-based approach, a score was assigned to each good; the higher the score, the stricter the rules contained in the plan so as to protect and preserve the good, and ultimately, the higher the quality of that good.

The suitability of each patch of land to belong to an RGI is then assessed by summing up the above four values, which all vary in the range (0–1), and it is therefore represented by the total value (TotVal): the higher TotVal, the greater the suitability.

The suitability map representing the Sardinian RGI (Figure 2) is next overlaid with the zoning schemes of the MMPs provided in Figure 3. Through a spatial intersection between the two layers, for each resulting polygon a vector having components (Zone, NatVal, ConVal, RecVal, LandVal, TotVal) is produced, where “Zone” represents the zone type assigned by the MMP and can take one of the ten values listed in Table 1.

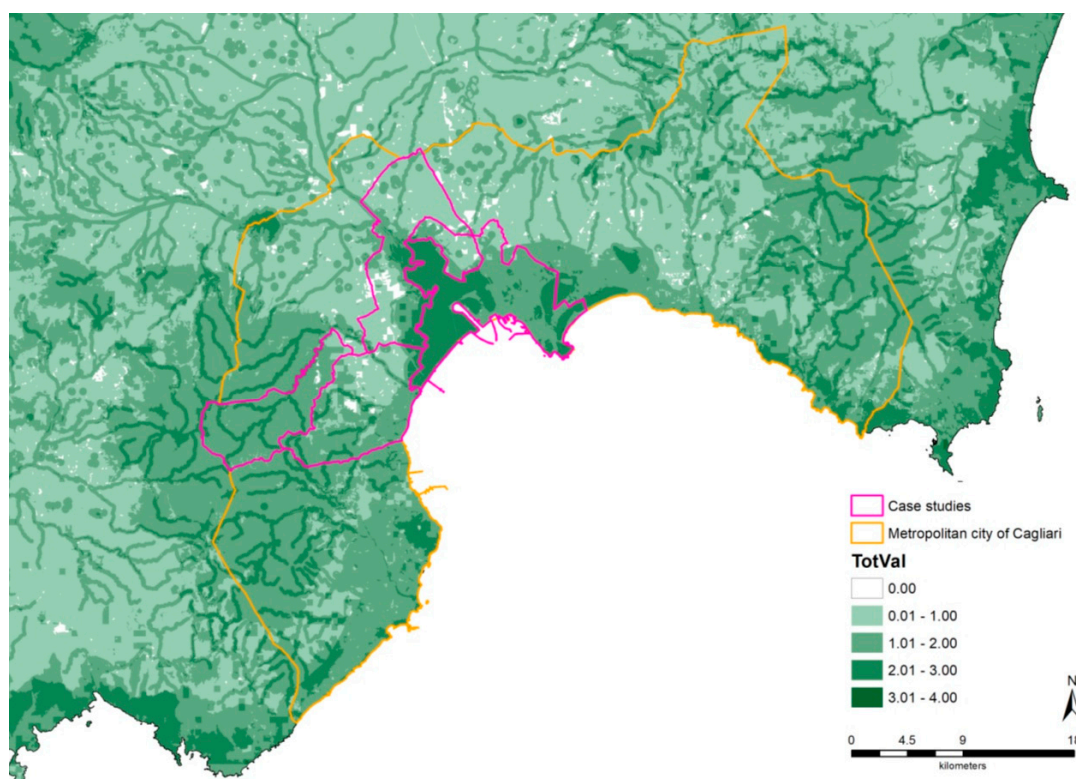


Figure 2. Map of the total value, which identifies the eligibility of patches to be included in the Regional green infrastructure.

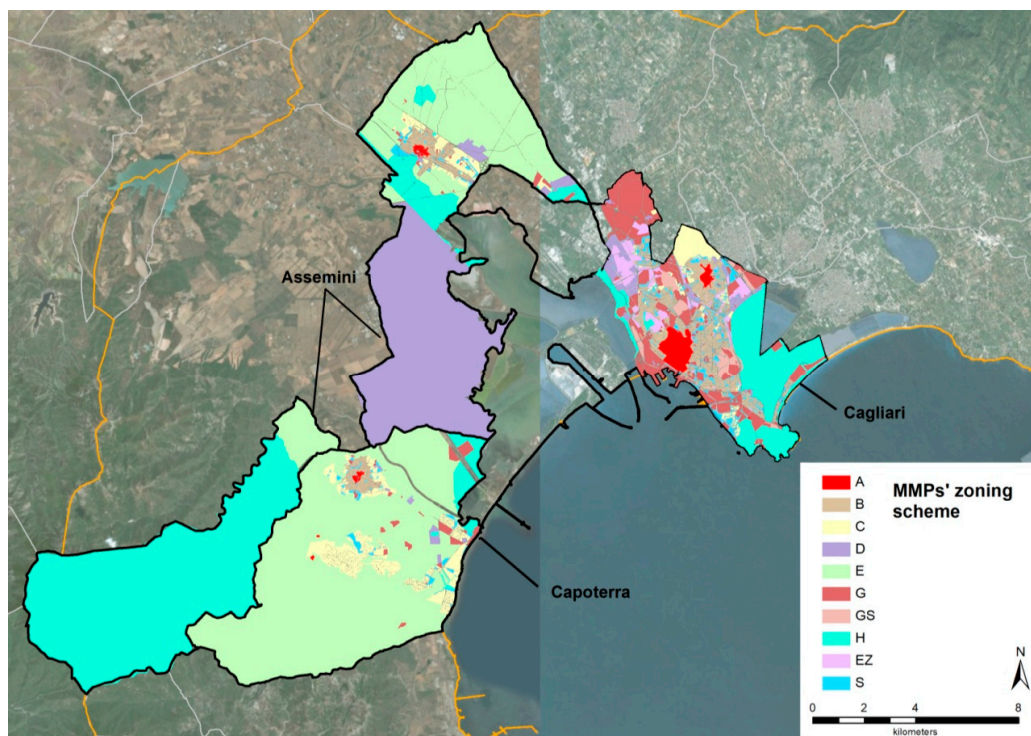


Figure 3. The zoning layout of the MMPs of Assemini, Cagliari and Capoterra.

Next, for each of the three municipalities here taken as case studies a multiple linear regression is performed:

$$\text{TotVal}_k = \beta_{0,k} + \beta_{1,k}A + \beta_{2,k}B + \beta_{3,k}C + \beta_{4,k}D + \beta_{5,k}E + \beta_{6,k}G + \beta_{7,k}GS + \beta_{8,k}H + \beta_{9,k}EZ + \beta_{10,k}\text{Area}, \quad (1)$$

where

- “k” is the municipality;
- explanatory variables representing the zoning scheme (“A” to “EZ”, see Table 1) are dichotomous, or Boolean, variables; each dichotomous variable can take only two values, 1 or 0, according to the following rule: if a patch is classed under the A zone type, the variable A equals 1, otherwise it equals 0; if a patch is classed under the B zone type, the variable B equals 1, otherwise it equals 0, and so on; each coefficient estimated by regression (1), β_i , $i = 1, \dots, 9$, identifies the change in TotVal related to a patch in case it is classed under the zone type identified by the variable associated to the coefficient β_i (i.e., A, B, etc.) with respect to the basic condition that the parcel of land under consideration was classed as “S” zone; the coefficients estimated by regression (1), β_i , $i = 1, \dots, 9$, define a taxonomy of the zone types based on the quantitative contribution to TotVal expressed by the values of β_i , $i = 1, \dots, 9$;
- “Area” is the size of the parcel of land under consideration, resulting from the spatial intersection between the zoning map and the RGI suitability map;
- results from the multiple linear regression are finally used to develop, for each municipality, an ordered list of the planning zones; for each municipality, the order depends on the value of the coefficients β_i , $i = 1, \dots, 9$, of regression (1).

As in several studies concerning urban and regional phenomena characterized by multiple factors, the use of multiple linear regression models is based on the grounds of the lack of identified predetermined relationships between the variables representing the factors (among many, [43–46]). Since no a priori interpretive hypothesis is available, the unknown surface, located in an n-dimensional space, which represents the functional relationship between n variables that characterize an urban

phenomenon, can be approximated, point by point, by the small region identified by the tangential plane. The small region shared by the (unknown) surface and the (known) tangential plane is identified by a local linear relationship between the variables, which is a linear local approximation of the unknown general relationship between the variables. The tangential plane represents the trace of the local linear relationship between the variables over the unknown surface in the n -dimensional space. The equation of this plane can be estimated through a multiple linear regression like (1), where the trace of TotVal over the unknown surface is a ten-dimensional plane [47,48].

The variable Area is used to control the possible effect of the size of land parcels; if the estimated coefficient β_{10} were significant in terms of p -value hypothesis testing, this would imply that “TotVal,” that is the eligibility of a parcel to be included in the RGI, is influenced not only by the zone type of a patch, but also by its size, or, that either an agglomeration ($\beta_{10} > 0$) or a dispersal effect ($\beta_{10} < 0$) is detected. A two-tailed significance test based on t -statistic is implemented in the estimated regressions in order to check if the estimated coefficient of Area is significantly different from zero (p -value $< 5\%$). If the p -value is greater than 5%, this would imply that the correlation between TotVal and Area can be confidently excluded, or, that no agglomeration or dispersal effect does show up.

3. Results

The estimates of the regressions related to Cagliari, Assemini and Capoterra define the features of the effects of a zone type on the eligibility of a patch to be included in the RGI. Indeed, each coefficient of the dichotomous variables estimated in the regressions identifies the effect on the eligibility of a patch to be included in the RGI as a consequence of it being classified as a homogeneous zone type from “A” to “H,” or as “EZ” or “GS” (only for the MMP of Cagliari, which does not show any “E” type zone) types, with respect to the basic situation of a patch being classified as “S” homogeneous zone type. This estimated effect equals the difference in TotVal, everything else being equal. Accordingly, a ranking of the homogeneous zone types can be defined, on the basis of the estimated effects, from the highest to the lowest.

Tables 2–4 show the results of the regression estimates related to Cagliari, Assemini and Capoterra.

Table 2. Regression results related to Cagliari.

Explanatory Variable	Coefficient	Standard Deviation	t-Statistic	p-Values	Mean of the Explanatory Variable
A	0.693	0.068	10.123	0.000	0.0096
B	−0.035	0.020	−1.731	0.083	0.2637
C	0.014	0.030	0.486	0.627	0.0660
D	−0.100	0.038	−2.624	0.009	0.0346
G	0.021	0.023	0.897	0.370	0.1481
GS	0.568	0.036	15.779	0.000	0.0400
H	0.750	0.022	34.883	0.000	0.2031
EZ	0.003	0.029	0.116	0.907	0.0706
AREA	0.000	0.000	−1.583	0.114	7925.00

Dependent variable: TotVal: Mean: 1.498; Standard deviation: 0.549; Adjusted R-squared: 0.337.

Table 3. Regression results related to Assemini.

Explanatory Variable	Coefficient	Standard Deviation	t-Statistic	p-Values	Mean of the Explanatory Variable
A	0.206	0.118	1.746	0.081	0.0125
B	−0.300	0.065	−4.649	0.000	0.1043
C	0.029	0.068	0.419	0.675	0.0771
D	0.851	0.057	14.914	0.000	0.3393
E	0.268	0.060	4.497	0.000	0.1960
G	0.095	0.094	1.009	0.313	0.0229
H	0.988	0.060	16.585	0.000	0.1991
AREA	0.000	0.000	−1.197	0.231	35505.19

Dependent variable: TotVal: Mean: 1.115; Standard deviation: 0.808; Adjusted R-squared: 0.304.

Table 4. Regression results related to Capoterra.

Explanatory Variable	Coefficient	Standard Deviation	t-Statistic	p-Values	Mean of the Explanatory Variable
A	−0.072	0.119	−0.601	0.548	0.0106
B	−0.713	0.055	−13.023	0.000	0.0769
C	0.007	0.042	0.169	0.866	0.2652
D	−0.086	0.111	−0.778	0.436	0.0124
E	0.263	0.040	6.587	0.000	0.3672
G	0.306	0.062	4.951	0.000	0.0525
H	1.159	0.051	22.939	0.000	0.1020
AREA	0.000	0.000	1.056	0.291	24266.91

Dependent variable: TotVal; Mean: 1.034; Standard deviation: 0.743; Adjusted R-squared: 0.317.

The estimates of the coefficients of the area of the patch are not significant in terms of *p*-value hypothesis testing. As a consequence, as put in evidence in Section 3, there is no sign of a marginal effect of the highly volatile size of patches on their eligibility to be included in the RGI. In other words, no agglomeration or dispersal effect is detected, which makes inferences and implications based on the estimates of the three regressions straightforwardly connected to the variables representing the zoning type (from “A” to “EZ”).

In the rest of this study, we adopt the same test described in Section 3 as regards the significance of the estimated coefficient of AREA in order to assess the significance of the estimated coefficients related to the variables representing the zoning type (from “A” to “EZ”). By so doing, if the *p*-value is greater than 5%, this would imply that correlation between TotVal and the zoning type-related variable at stake can be confidently excluded. If this is the case, the variable is labeled as not significant (NS) in Table 5, based on the results shown in Tables 2–4, columns “*p*-values.”

The regression estimates put in evidence that the “H” zone type always shows the highest effect on patch eligibility, whereas the “C” zone type, namely the residential expansion type, does not influence eligibility in any of the three regression estimates. The effect of the “EZ” zone, only identified in the zoning layout of the MMP of Cagliari, also related to residential expansion with an additional endowment of public services integrated into the residential areas, is not significant as well. In two out of three cases (Cagliari and Assemini), the effect on the eligibility of the “G” zone type, that is, general public services, is not significant, whereas its influence is positive as regards Capoterra, where the impact of the “D” zone type (industrial, craftsmanship and hypermarket areas) is not significant.

On the contrary, the impact of the “D” zone type is significant as regards Cagliari and Assemini, even though it is much more important, as regards its size, in the case of Assemini. The negative estimate of the coefficient of “D” (−0.100) indicates that, in the case of Cagliari, the effect of this zone type is lower than the effect of the “S” zone type (publicly-owned public service areas) by about one-tenth. The marginal effect of the “B” zone type is weakly significant in all of the three cases as well. This finding stresses that the areas showing large and pervasive land-taking processes, such as the “B”, “C”, “G” with the exception of Capoterra, “D” with the exception of Assemini, and “EZ” zone types, are almost totally inadequate to be included in the RGI. The highly urbanized “S” zones, which are targeted as already, or bound-to-become, publicly-owned public service areas, show very low influence as well.

The zone types which mainly help to characterize a patch as being eligible to be part of the RGI are (1) the “A” type, that is, historic and artistic center, featured by environmental values related to the built environment, with the exception of Capoterra, whose “A” zone is, by the way, less attractive and valuable than Cagliari’s and Assemini’s corresponding areas; (2) the “E” type, which identifies rural and agricultural areas, characterized by the lowest levels of soil sealing and land take (this type of zone is not present in the zoning layout of the MMP of Cagliari); and, above all, (3) the “H” type, which is characterized by patches which the MMPs identify as worth protecting because of their environmental and landscape-related features. The effect on the eligibility of the “GS” zone type, which identifies

open spaces and recreational areas, that is, almost-totally unbuilt areas, and which is only included in the zoning layout of the MMP of Cagliari, is consistent with the effect of the “H” zone type as well.

Table 5 highlights the ranking of the zone types as regards their influence on the eligibility of patches to be included in the RGI, and the corresponding means of NatVal, ConVal, LandVal and RecVal, in order to identify the factors’ influence in a comparative way.

Table 5. Ranking of the homogenous zones based on the contribution to TotVal implied by the regression results, and average values of the four factors which determine TotVal, related to each homogeneous zone (NP: the homogeneous zone is not present in the MMP’s zoning rules; NS: the regression *p*-value entails that the coefficient is non-significant).

Zone Type	Cagliari					Assemini					Capoterra				
	Rank	Average Values: NatVal, ConVal, LandVal, RecVal				Rank	Average Values: NatVal, ConVal, LandVal, RecVal				Rank	Average Values: NatVal, ConVal, LandVal, RecVal			
A	2	0.432	0.000	1.000	0.573	4	0.000	0.000	0.722	0.087	NS				
B	6	0.030	0.000	1.000	0.261	6	0.038	0.000	0.200	0.065	5	0.049	0.000	0.027	0.068
C	NS					NS					NS				
D	7	0.233	0.000	0.952	0.039	2	0.644	0.162	0.636	0.010	NS	NS	NS	NS	NS
E	NP					3	0.482	0.028	0.352	0.006	3	0.529	0.061	0.523	0.010
G	NS					NS					2	0.448	0.057	0.639	0.019
GS	3	0.607	0.024	1.000	0.262	NP					NP				
H	1	0.675	0.204	1.000	0.195	1	0.748	0.187	0.647	0.005	1	0.696	0.282	1.000	0.038
EZ	4					NP					NP				
S	5	0.101	0.001	1.000	0.225	5	0.316	0.000	0.258	0.030	4	0.288	0.022	0.513	0.034

With reference to the “A” and “H” (and “GS,” in the case of Cagliari) zone types, the average values of LandVal are comparatively high, since they are always higher than 0.6. The average values of NatVal of the “E” zones are lower than the “A” and the “H” zones’ values, even though they are higher than the remaining zones. Moreover, the “H” zones show the highest average values of ConVal in all of the three cases, although there is room for improvement, since they are never higher than 0.3.

On the other hand, the conservation value on average equals zero as regards patches located in the “A” zones, whereas it is very close or equal to zero in already-urbanized areas or in areas characterized by ongoing advanced urbanization processes, such as “B,” “C,” “D,” “G,” “EZ” and “S”, which is consistent with expectations, since it is very unlikely that habitats protected under the provisions of European Union rules can be found in these areas.

The results of the regressions show that the “A,” “E” and “H” zone types are the most important in terms of impact on the eligibility of patches to be part of the RGI. Moreover, Table 5 stresses that there is still large room for improvement as regards all the zone types. For example, the almost-totally urbanized areas classed as “B,” “C,” “D,” “G,” “EZ” and “S” zone types show non-null NatVal and RecVal, and often comparatively not so low, in each of the three MMPs, especially with reference to the recreational profile (RecVal), which gives credit to possible scope for improving RGI-related features of areas located in the three towns of the MCC.

Particularly relevant is the improvement margin related to agricultural areas (“E” zone type) and to the protection areas (“H” zone type) as regards all of the four values. This implies that the ruling framework related to these zone types would be worth exporting to other parts of the municipal land in order to increase the eligibility of patches to be included in the RGI.

4. Discussion

The study analyzes the relations between the land uses, defined in the MMPs of three local municipalities included in the MCC, and the RGI whose identification is based on the methodology proposed by Lai and Leone [37].

According to the results presented in Section 3, the “H” zones are the areas that mainly positively affect the eligibility of patches to be part of the RGI in the three study areas. In particular, in relation to “H” zones, the average values of the four factors show the following similar trends (1) NatVal is higher than 0.5; (2) ConsVal and RecVal are lower than 0.5; and (3) LandVal equals 1 (maximum value) in the case of Cagliari and Capoterra and is lower than 0.7 in the case of Assemini. As a consequence, there is plenty of room for improving two out of the four factors (ConVal and RecVal).

ConVal is mainly influenced by the presence of habitat of community interest. “H” zones are conceived as areas of particular environmental and natural interest; thus, they may represent buffer zones to protect high-quality sites, such as Natura 2000 sites, or stepping stones along migration routes. A possible policy recommendation aims at extending the environmental protection regimes related to habitats and species beyond the boundaries of protected areas by identifying those patches that, in relation to their characteristics, could be suitable for species and habitats. Therefore, advancements of scientific knowledge related to habitats and species within “H” zones and awareness-raising activities are preliminary necessary steps in order to increase the size of protected areas. In line with this recommendation, Maiorano et al. [49] suggest that integrated management of Natura 2000 sites and of their neighboring areas may improve the effectiveness of conservation measures within protected areas due to control over human-induced activities in the surrounding areas.

Acting on elements that influence RecVal shows more room for improvement than ConVal due to its lower values in relation to “H” zones in the three study areas. RecVal is calculated on the basis of geotagged information retrieved from the social media Flickr, representing the attractiveness of a certain area to visitors in a defined time period. Several studies [50–52] show that recreational attractiveness of an area, conceived of as the demand for recreational activities, is influenced by different factors, such as accessibility and accommodation availability. Therefore, a possible recommendation concerns making these areas more accessible through infrastructures that, on the one hand, support slow mobility (such as cycle and pedestrian paths) and, on the other hand, do not increase habitat fragmentation. In fact, increased fragmentation of habitats is likely to result in decreasing values of ConVal and NatVal.

In relation to NatVal, although its average values are quite high (between 0.67 and 0.75) in all of the three case studies, there is still some room for improvement. NatVal is mainly influenced by land uses and threats to habitats, identified through standard data forms of regional Natura 2000 sites. From this standpoint, two types of policy actions should be taken into account as particularly effective: reduction of threat and mitigation of land-taking processes. Both these actions can include measures aiming at restoring ecosystems, also through the use of nature-based solutions (NBSs). The concept of NBSs was coined by the European Commission [53] to define techniques and solutions based on the use of nature in urban areas. NBSs are designed to address effectively several social challenges in terms of effective resources management, and, at the same time, to provide economic, social and environmental benefits. NBSs are more efficient and cost-effective solutions than traditional approaches [54]. The European Commission [53] identifies a series of NBSs to make cities more livable and sustainable, such as the restoration of abandoned and degraded areas, the use of permeable surfaces and of rain gardens to manage and control rainwaters within urban settlements. For example, in the city of Cagliari a significant and troubling phenomenon, represented by agricultural uses and informal settlements, characterizes a particular “H” zone, called “AR—Is Arenas” within the regional “Molentargius-Saline” park. In these areas, specific measures to mitigate threats caused by urban settlements are necessary.

Moreover, due to the positive influence of “H” zones on the eligibility of patches to be part of the RGI, both the increase of the existing “H” zones and the definition of new “H” zones at the expense of other zones could represent a possible policy action.

In relation to Capoterra and Assemini, “E” zones also influence positively the eligibility of patches to be part of the RGI. The average values of NatVal, ConVal, LandVal and RecVal are lower than those that can be found in “H” zones and, for this reason, there might be more room for improvement, in particular in relation to NatVal and ConVal. Natural value is mainly influenced by the quality of land

covers, frequently threatened by intensive agricultural use and by habitat fragmentation due to rural settlements and infrastructure. He et al. [55] in a recent work, where they study the impacts of land covers on habitat quality, suggest improving habitat quality through agricultural policies that promote a more sustainable use of land, with particular attention to isolated rural settlements. In relation to ConVal, as promoted by the 2014–2020 Sardinian regional Rural Development Program, a possible policy could include sustaining agri-environment-climate commitments, comprising, among others, incentives to support those farmers who allocate part of their farmland for wildlife (e.g., establishing grass swards along wetlands, keeping unharvested conservation lands for wildlife, or maintaining hedgerows and drywalls for small vertebrates).

5. Conclusions

This study aims at identifying a methodological approach to include and implement GI within spatial planning at the city level. For this purpose, relations between the land uses defined by MMPs and the factors related to the spatial identification of the RGI are analyzed and assessed.

The study highlights two important aspects. First, as suggested by Mell [56,57], GI implementation is strongly influenced by the sometimes lacking continuity between what is proposed by the national and regional administrations and what is implemented by the municipalities. The lack of models that assess synergies and tradeoffs between different functions and benefits that GI can provide is a significant aspect [23,24]. According to Davies et al. [20], the social role of GI is strongly related to three issues: “where,” “which interventions” and “in what circumstances.” These three aspects require, on the one hand, accurate knowledge of the involved urban contexts, and, on the other hand, an adequate understanding of the available planning tools [18]. In relation to the implementation of the methodology proposed in this study, regarding three towns of the Metropolitan City of Cagliari, MMPs establish spatial taxonomies of the municipal lands based on land cover categories. In Italy, and in the regional context of Sardinia, the integration of GI within planning practices is strongly influenced by the expertise of the technical staff working in local administrations, and by political pressures from representatives of the municipal councils, which should be based on local communities’ expectations and perceived needs related to land uses. However, under the provisions of the laws in force, direct participation of local communities in decision-making processes concerning the approval procedure of MMPs is limited and rather ineffective.

The second aspect focuses on the implementation of spatial transformations. In urban contexts, characterized by a weak ecosystem structure and by pressures and impacts generated by high-building-density settlements, ecosystem restoration measures play an important role in integrating GI within local planning [58]. Therefore, as highlighted by the findings of this study, consistently with the provisions of Action 6 of the Target 2 of the Convention on Biological Diversity 2020 Strategic Plan, GI should represent a significant tool to promote ecosystem restoration in urban and rural areas. Moreover, GI plays an important role in economic terms as well, since it increases the attractiveness of urban environments [20]. On the other hand, a collaborative approach to policy-making concerning local spatial planning procedures, which would imply an effective cooperation effort involving technical structures and representatives of the local administrations, and direct participation of the local communities, is likely to produce regulations which may eventually identify the most adequate decisions concerning the spatial taxonomy of land uses on a non-deterministic, multi-functional basis. Furthermore, other studies [17,57] analyze how GIs are implemented in spatial planning. For example, Mell [57] assesses the implementation of GI in the United Kingdom and in the United States through a comprehensive review of the existing literature. Di Marino et al. [17] investigate this issue through the analysis of policy and planning documents and by interviewing regional and city planners. This study goes beyond the traditional analysis of planning documents to understand, as suggested by Davies et al. [20], where, what type of interventions and in what circumstances the implementation of GI is likely to impact local (municipal) planning processes.

In conclusion, the proposed methodology can be regarded as a tool in support of decision-makers that can be exported to other European contexts, where Natura 2000 Network is established in compliance with the Habitat Directive. The main advantage of the proposed methodology is its flexibility, which makes it possible to add new values in order to include normative, social and economic aspects that characterize other European contexts. A first most significant limitation concerns the assessment of place attractiveness (RecVal) based on social media only, although some research has argued that social-media retrieved information can be used as a reliable proxy for visitation data (see for instance Wood et al. [59], Sessions et al. [60], Heikinheimo et al. [61]). A second limitation stems from the fact that the methodology for assessing natural value (NatVal) does not take NBSs (such as green roofs or green walls) into account, hence possibly underestimating the natural value in built-up areas. These limits could be addressed in future research.

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Glossary

ConsVal	Conservation value
GI	Green infrastructure
GIS	Geographic information system
LandVal	Landscape value
NatVal	Natural value
MCC	Metropolitan City of Cagliari
MMP	Municipal masterplan
NBS	Nature-based solution
NP	Not present
NS	Not significant
RecrVal	Recreation value
RGI	Regional green infrastructure
RLP	Regional landscape plan

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