Green Infrastructure and Ecosystem Services to Guide the Revision Process of Land-Use Plan. A Methodological Framework

Green Infrastructure and ecosystem services to guide the revision process of Land-use Plan. A methodological framework.

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Abstract. Nowadays, several experiences in the spatial planning show that a performance-based planning approach that introduces the ecosystem services provided via green infrastructure can positively influence the social dynamics and contribute to improve the quality of life in rural and urban environments.

Despite the need to introduce ES and GI concepts and paradigms into the spatial planning process, in the Italian planning system the green component in cities is still planned at the municipal level by the Land Use Plan, which is based on prescriptive model of zoning.

The paper analyses a research project developed for two case studies on different urban contexts in the Marche region (Central Italy) through a comparative method based on a multiscale planning approach to evaluate ecosystem services related to land uses and land use suitability. In both cases, this approach has positively influenced the revision process of the current Land Use Plan in supporting the design of green infrastructure to improve the environmental performance of cities.

Keywords: green infrastructure, ecosystem services, urban green standard for public facilities, land use suitability

1 Introduction

Nowadays, several experiences in the international literature show that a performance-based planning approach that introduces the ecosystem services (ES) paradigm in the city planning and design process can positively influence the social dynamics and contribute to improve the quality of life in rural and urban environments [2, 3].

In this scenario, one possible way to guarantee the provision of ES via spatial planning is based on the strategical planning and design of Green Infrastructure (GI) [4], seen as the "conceptual tool" [5] to manage ecological resources in cities.

In this framework, the union of natural resources and landscape on a territorial scale with the urban scale system of Green Spaces (UGS) [6] represents a key element to

guarantee habitats connectivity [7] conservation of biodiversity [8] and the provision of regulating and cultural ES [9] [10].

Despite the need to introduce ES and GI concepts and paradigms into the spatial planning process, in the Italian planning system the green component in cities is still planned at the municipal level by the Land Use Plan, which is based on prescriptive model of zoning, without considering the provision of expected ES.

With this study, we analyze two of the main critical aspects to overcome.

The first concerns the absence of a sectoral wide-range plan that integrate the ES conceptualization and analysis at the national and regional level, to guide the planning process at the local and consequently the municipal level [11].

The second one consists in the unsuitability of the existing Land-Use Plan structure, where the design of public spaces is merely based on a minimum quantity of 'prescriptive standards' to guarantee public facilities for citizens, instead of qualitative and performing instances [12]. The result of this approach in the main Italian experiences is an overall picture of a fragmented and non-cohesive framework of green areas, which must be included in the GI strategic vision to maximize multifunctionality and benefits of the ecosystems within the city [13].

To this end, a multiscale planning approach based on the design of GI can be effective to guide the decision-making process and governance in land-use planning, with particular attention to environmental aspect, soil uses and land use suitability [1].

In this scenario, the aim of this paper is to define a methodological framework that represent a way to transfer the concepts of ES and GI to the current practices of spatial planning, replicable in different Italian contexts.

To do this, the paper analyses a research project developed for two case studies on different urban contexts in the Marche region (Central Italy). Section two report a comparative method adopted for the case studies that is based on a multiscale and multilevel planning approach. Section three illustrate the main results. Section four discuss how the adoption of new environmental strategies based on the ES provided via GI have positively influenced the process of revision of the current Land Use Plan to enhance the environmental performance in two different ways. Section five provide some concluding remarks.

2 Materials and methods

2.1 Case studies

The municipality of Falconara Marittima is a small town located in the terminal part of the Esino river valley on the Adriatic coast and close to Ancona, the regional capital of the Marche region (central Italy).

The total land area extends for 25.81 km^2, with a residential population of 25,727 and a population density of 996.78 (inhabitants/ km2).

The municipality of Osimo, (second case study) is in the south-west part of Ancona between 17 and 360 meters above sea level, in the hills between the sea and the Apennines of the Marche region. The total land area extends for 105.4 km^2, with a residential

population of 33,991 and a population density of 322.4 (inhabitants/ km^2, ISPRA, 2022a; ISTAT 2021).

The main difference between the case studies is represented by spatial settlement. The urban area of Falconara Marittima is divided in three urban contexts a) city center, Castelferretti, Rocca, b) two periurban contexts: Esino river, Barcaglione hills; while the municipality of Osimo is divided in a) the historical center of and three urban contexts: Osimo Ovest, Osimo Sud, Osimo Stazione, b) eleven peri-urban areas: Abbadia, Aspio, Campocavallo, Casenuove, , Padiglione, Passatempo, San Biagio, San Paterniano, San Sabino, Santo Stefano, Villa.

Investigations have been developed to identify the environmental strategies to a) draw up the Green Masterplan for the municipality of Falconara Marittima, b) develop the green strategy for the implementation of the New Land Use Plan for the municipality of Osimo, and future development of the strategic Environmental Plan of the city.

2.2 Methodological approach

Methodology is divided in two steps: a) assessment of the large-scale ecological network; b) assessment of the green component of the Land Use Plan (UGS at the city scale) based on the recognition of the green standard for public facilities in line with the Italian law on urban planning standards (Ministerial Decree n. 1444/1968).

Point a) consisted in:

1. Downscaling of environmental elements from the current spatial planning instruments (prescriptive and non) that manage landscape and natural resources at the territorial scale (PPAR; REM; PTC) [16–18]
2. Geospatial census of different rural areas.

The downscaling of the spatial planning levels from the regional to the local scale was based on the definition of the inter-municipal cooperation starting from geospatial localization of the Ecological Functional Units (UEF) defined by the Ecological Network of Marche Region (REM).[16]

These contexts summarize the environmental system by integrating information of a vegetational, fauna and anthropic nature, to characterize the ecological fabric in its different structural and functional articulations.

To define the first local cluster of five municipalities: a) Falconara Marittima, b) Montemarciano, c) Monte San Vito, d) Chiaravalle, e) Camerata Picena, we selected the following UEF: n.16 *Colli costieri di Senigallia*; n.76 *Valle dell'Esino*; n. 82 *Ancona*; n.21 *Colline tra Santa Maria Nuova ed Osimo*. To define the second local cluster of six municipalities: a) Osimo, b) Castelfidardo, c) Camerano, d) Offagna, e) Polverigi, f) Santa Maria Nuova; we merged the UEF: n. 21 *Colline tra Santa Maria Nuova ed Osimo*, n. 25 *Fascia basso collinare tra Musone e Potenza*, n.77 *Fondovalle del Musone* (Fig. 1).

The downscaling has been summarized in the following four steps.

Step one: we defined the Local Ecological Network (Rete Ecologica Locale, REL) starting from the two clusters of municipalities. Then we selected the spatial layers from the regional planning instrument and georeferenced them from the 1:50.000 regional scale to provincial and then municipal scale (scales details 1:10.000 and 1:2.000).

Step two: we overlapped the environmental resources ("invariants" elements) of the network defined by Regional and Provincial planning tools (Piano Territoriale di Coordinamento Provinciale PTC) such as: a) naturalistic continuity strips, b) respect strips, c) axes of the ridge, for both Municipalities and scaled them to define the Ecological Network on the municipal scale (Rete Ecologica Comunale, REC), as the 'common ground' to design of green infrastructure.

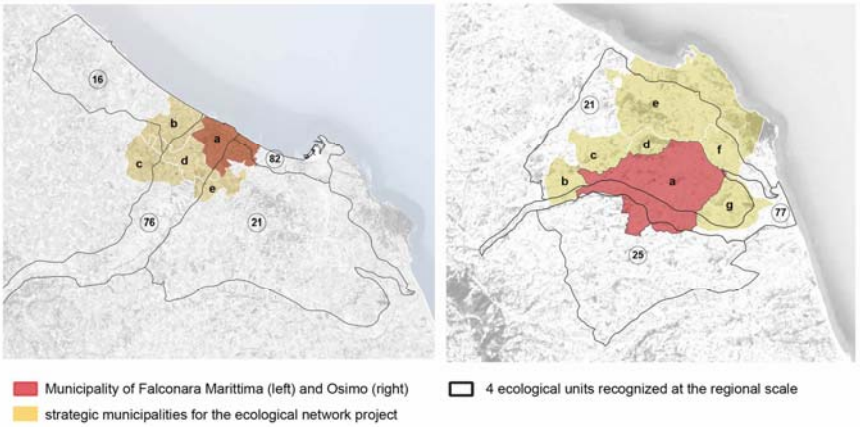

Fig. 1. Municipality of Falconara Marittima (top) and Osimo (down). UEF defined by REM and localization of municipalities interested by the downscaling process.

Step three: we overlayed selected level of knowledge from the Regional Landscape Plan (Piano Paesistico Ambientale Regionale, PPAR) form the specific categories ("*categorie costitutive del paesaggio"*) related to the three thematic sub-systems that describes the entire regional territory i.e. (a) geological/geomorphological/hydrogeological system; (b) botanical and vegetational system; (c) historical and cultural system (Tab.1).

In line with Regional Council resolution n. 1287/1997, in Osimo municipality we added a specific cathegory called "Elements of the traditional agricultural landscape" from the (b) botanical and vegetational system of the PPAR (article 38), as essential elements to preserve in planning process:

- row of trees with native species;
- road and farming hedges of native species;
- forests with a majority of native species;
- individual plants of landscape value (species, size, location).

Data have been processed in GIS environment.

Table 1. The spatial levels selected from the landscape and territorial planning instrument (regional and provincial scale).

Planning instrument	legal framework	scale	Spatial levels selected
Regional Landscape Plan (Piano Paesistico Ambientale Regionale *PPAR*)	D.A.C.R. n. 197 of 3 November 1989	regional	a, b) coastal dune, uncultivated area, panoramic area, rivers, coast, slopes, agricultural landscape, rows of trees; c) historical cores and centers, historical buildings, archeological zones
Ecological Network of Marche Region (Rete Ecologica Marche *REM*)	Regional Law n. 2 of 5 February 2013	regional	nods - buffer, connection system of regional interest, local connection system not connected, stepping stones
Territorial Provincial Plan (Piano Territoriale di Coordinamento *PTC)*	D. C. P. n.177 of 28 July 2003	provincial	naturalistic continuity strips, respect strips, axes of the ridges

The second phase consisted in the survey of the rural areas. For the municipality of Falconara Marittima the census was based on the "Carta della Natura Habitats", developed by ISPRA [19]. This map georeferenced and classified the natural capital of Italy, identifying the protected areas to be preserved, for this it contributes to support the decision-making process in the planning and design of ecological networks.

For the municipality of Osimo, we developed a census of the peri-urban area to define an overall picture of the existing botanical and vegetational elements. The geolocation was carried out in collaboration with the expert team of botanists and agronomists appointed by the Municipality.

Point b) consisted in the assessment of the green component of the Land Use Plan (UGS at the city scale) based on the evaluation of the urban green standard for public facilities deriving from the Italian Ministerial Decree n. 1444/68 for urban planning regulation.

In both case studies analyzed, the Plan a) identifies the existing public and private UGS, b) provides planning standards for public facilities related to development plans in urban and peri-urban areas, based on quantitative indicators for the achievement of a 'minimum amount of greenery per capita'.

Specifically, in line with the Regional Law of Marche Region n.34/92 "Rules on urban planning, landscape and territorial planning" we investigated the development of green standard inside: a) the overall project (minimum surface required :12(9+3) m2/inhabit. of green standard for public facilities); b) the urban design projects of green standard for public facilities for new urban settlements or transformations (same minimum surface required).

In both cases, the overall project guarantees the minimum standards of green areas provided for the citizens.

To do so, we firstly investigated the green standards (divided into forests, green mitigations, urban parks, private green areas) using the Informatic territorial system (SIT) database developed by the municipality and manageable by open-source software Qgis.

Next, we verified the implementation of green standards within the urban design projects that constitute the second level of spatial planning tools.

Then, we evaluated the total UGS starting from the recognition of the green census set up by the Municipalities by open-source database, visual survey, and improved by sampling RGB-NIR multi-spectral images (year 2019) developed by AGEA (Italian Agricultural Payments Agency) in a Gis environment.

Finally, we overlayed the total of green standards on the existing public green areas to investigate private green area not yet implemented from the land-use plan, which must be considered through the development of specific public-private contract. This is essential to complete the overall picture of UGS as the basis of the GI design.

The sum of these areas to the unimplemented standards defined the total of (public and private) green areas to be included in the overall green project for urban areas.

On the other hand, for the municipality of Osimo the balance was verified between the overall project and the distribution of green standards i.e., historic center, urban and peri-urban areas.

3 Results

a) The assessment of the large-scale ecological network led to characterize the natural and cultural value of the territory in terms of ecosystem services [20].

From the overlaying of spatial levels derived from the downscaling of the Regional Ecological Network (REM) the spatial definition of core areas and corridors (Fig.2) and their consistency was obtained.

Results show a percentage of about 7.7% and 9.5 % of natural elements on the total land area, respectively for the Municipality of Falconara Marittima and Osimo. Data highlight the functionality and naturalistic value of land use characterized by a prevalence of regulating ecosystem services to preserve (Tab.2).

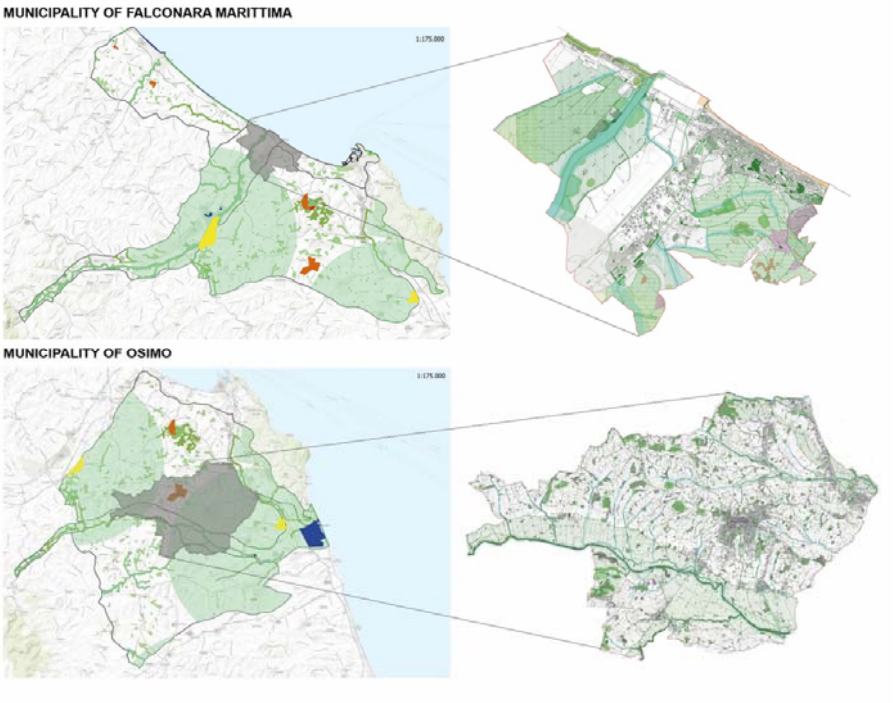

Fig. 2. Definition of the Local Ecological Network (REL, left side) and the framework of the Ecological Network for the Municipal scale (REC, right side)

Table 2. The components of the ecological network derived from REM on the municipal scale.

Municipality	Typology	Color reference	Name/location	area (km^2)	Tot. EN (km^2)*	Tot. EN/Municipality Land Area (%)
Falconara Marittima	Connection system (regional scale)	dark green	Esino river	1.67	5.33	7.7
	Buffer zones	light green	Garzaia	3.34		
	Stepping stones		scattered	0.32		
Osimo	AF (floristic area) node	red	Santa Paolina forests	0.32	10.04	9.5
	OPF (faunistic protection areas) node	orange	San-Paterniano-Santo Stefano	2.16		
	Connection system (regional scale)	dark green	Cingoli - Potenza -Fiumicello ridge	31.60		
	Connection system (local scale, not connected)	olive green	Fiume Musone tra Staffolo e Osimo	0.45		
			Foce Musone e bacino dell'Aspio	0.25		
	Buffer zones	light green	Garzaia	63.32		
			Garzaia	11.22		
	Stepping stones		scattered	4.27		

*Excluding buffer zones and overlapping

The overlaying of thematic levels from the Regional Landscape Plan (PPAR) allowed to spatially define and quantify land uses mainly based on the provision of cultural ecosystem services (CES, Tab.3)

For the two case studies, the land characterization of PPAR define a percentage of 50% and 43% of land area with a recognized cultural value of landscape and territory, with CES provided from both the natural and the anthropic elements.

Table 3. Spatial levels selected by the regional landscape plan (PPAR) to define the suitability of the land use according to cultural ecosystem values.

	Municipality			
	Falconara Marittima		Osimo	
Typology	CES land use (km^2)	CES land use/ Municipality Land Area (%)	CES land use (km^2)	CES land use /Municipality Land Area (%)
panoramic area[1]	0.5		7.69	
slopes[2]	0.17		3.68	
agricultural landscape[3]	7.81		29.51	
landscape value[4]	4.46		5.28	
total	12.96	50	46.16	43

[1] protecting areas of panoramic roads - article n. 43 historical and cultural system of PPAR.

[2] article n. 31 PPAR geological and geomorphological system of PPAR

[3] article n. 38 historical and cultural system of PPAR

[4] Areas with recognized landscape-environmental value – article n. 20 PPAR

The census of the rural areas led to define a quantitative and qualitative characterization of green spaces, and a spatial definition of landscape typologies (Fig. 4). Both municipalities have a low percentage of land suitable for the provision of regulating ES provided by environmental elements to implement the GI.

On the contrary, the high percentage of agricultural areas, especially in the Municipality of Osimo, highlight most of the land use characterized by the supply of provisioning type of services (Tab.4).

Table 4. Land use suitability in the rural areas.

		Municipality			
		Falconara Marittima		Osimo	
Municipality	land use	area (km^2)	Percentage on the Municipality land area (%)	area (km^2)	Percentage on the Municipality land area (%)
	natural	4.57	17	7.40	7
	agricultural	9.93	38	79.98	75
	coast	0.398	1.54	-	-
	Total	14.89	57	87.38	83

b) The assessment of the green component of the Land Use Plan defined two opposite conditions for the implementation of green standards expected:

While in Osimo 74% of green standards are public areas developed and managed by the Municipality, 16% of green standards in Falconara Marittima highlights a potential growth of public green services with a growing capacity to provide ecosystem services.

In Osimo, the historic center measures 27% of the green standards implemented in line with 31% of the three urban contexts and peri-urban areas. This data confirms a fair distribution of public green services in the municipal area.

Comparing the two cases, private green areas to confirm or not in the land-use plan (overall project) are 89% for the Municipality of Falconara and 22% for the Municipality of Osimo (Tab. 5).

This means that the two Municipalities must adopt equalizing and rewarding criteria with citizens to implement the environmental project supported by GI at the city scale.

In this scenario, planners must give priority to the development of the areas that are essential to the overall GI design project by defining design guidelines and strategies to maintain, enhance or regenerate natural capital, maximizing the multifunctional aspect of green areas and ES provision within the city.

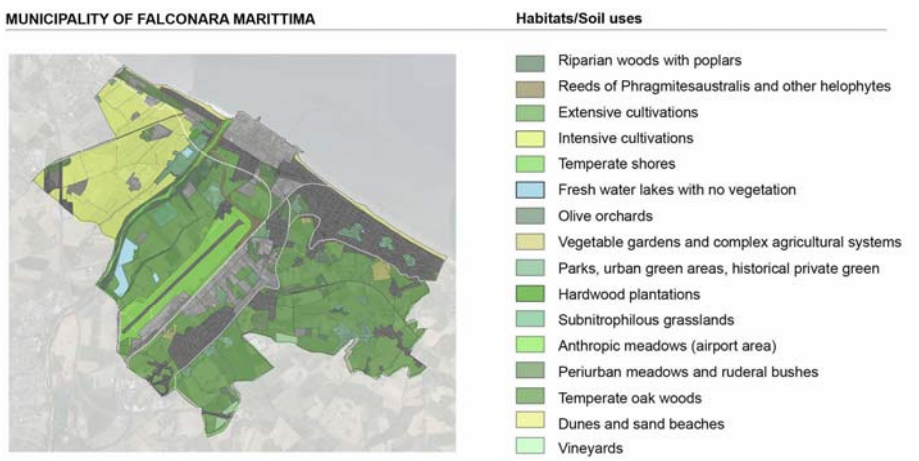

Fig. 3. Municipality of Falconara Marittima (top). **"**The Carta della Natura Habitats". Descriptions of habitats for cartography at 1: 50,000 scale (top). Source: ISPRA, Italian Institute for Environmental Protection and Research and graphics modified the authors. Habitats classification is based on CORINE Biotopes.

Table 5. Evaluation of the urban green standards for public facilities on the two-case studies Land-use Plans

Municipality of Falconara Marittima								
Land use Plan – overall project						Land use Plan – urban design project		
	Green Standards (S)[1] on Municipality land area	Green Standards Implemented (SI)	Green Standards Not implemented (SNi)	Areas with declined constraints	Private green areas (To redefine)	Green Standards (S)[2]	Green Standards Implemented (SI)	Green Standards Not implemented. (SNi)
		(IS/total S[1])	(SNi/total S[1])	(DC)	(SNi+DC)/GS	(S[2]/total GS)	(IS/total S[1])	(SNi/total S[1])
land area (km^2)	2.6726	0.436	2.236	0.147	2.383	0.157	0.048	0.109
%	-	16	84	41	89	19	8	11

Municipality of Osimo							
Land use plan – overall project				Distribution of GS for public facilities on the municipality land area			
				Historical center		Other contexts	
	Green Standards (S)[1]	Green Standards Implemented (IS)	Green standards Not implemented	Green Standards Implemented	Green Standards Not implemented.	Green Standards Implemented	Green Standards Not implemented.
	(S/total GS)	(SI/total S[1])	(NiS/total S[1])	(SI/total S[1])	(SNi/total S[1])	(SI/total S[1])	(SNi/total S[1])
land area (km^2)	1.449	0.873	0.576	0.40	0.38	0.46	0.18
%	-	78	22	27	26	31	12

Fig. 4. Municipality of Falconara Marittima (left), and Municipality of Osimo (right). Urban green areas ("standards" Italian low M.D. 1444/68) for public facilities to design GI at the city scale.

4 Discussions

This contribution describes a methodological framework that standardizes a series of simple steps that can be replicated in different geographical and environmental contexts at the national level.

Based on large-scale geomapping of the existing functionality and land use suitability [21], and the evaluation of green standard implementation at the city scale, this method can represent a) an essential knowledge base support for planning potential implementation of ES through the development of specific planning policies, b) support the design of GI helping in the management of existing environmental resources and the planning of potential growth of green facilities.

Furthermore, this approach can help to define policies to contrast the loss of agricultural land due to soil sealing, with negative impact in ES supply [22], food and biomass production [23].

Moreover, to consolidate a city-scale recognition and spatial definition of the existing green urban areas is essential for the municipality for the feasibility of GI in a defined time [24].

In fact, planners can provide design action and hierarchical priority ladder to a) maintain, b) enhance, c) regenerate the natural capital represented by the green standard as essential components for the GI project (Fig. 6).

On the other hand, the green standard not implemented represent a limit for the development of GI planning actions which needs to adopt specific equalization and rewarding criteria through public-private cooperation actions.

Regarding the limitations of this study, the availability of regional and local data integrated with site survey are essential to obtain good results.

Finally, international replicability requires adaptability to different systems and planning rules.

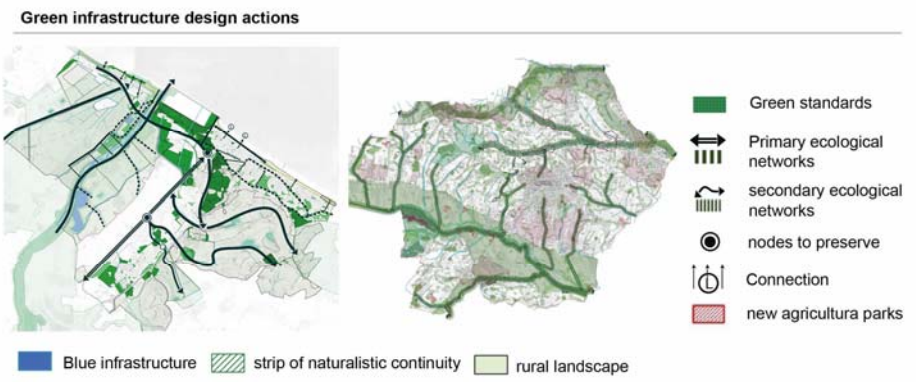

Fig. 5. Master Plan of the GI strategical actions framework based on the spatial definition of the large-scale spatial levels and the urban green areas.

5 Conclusion

A multiscale method to introduce the concepts of ES and GI in spatial planning can be effective to improve the quality of life in rural and urban environments.

The comparison between the two case studies provides a method based on the union of a large-scale ecological network assessment and the investigation of the standard for public facilities of the Land Use Plan, in line with the Italian law on urban planning green areas ("standards" Ministerial decree n. 1444/1968).

Based on the spatial definition, quantification, and qualitative characterization of the two scales spatial levels, urban planners can define a hierarchical scale of governance to introduce GI strategy in planning processes, providing guidelines to start the revision of the Land-Use Plan through appropriate zoning variance based on environmental strategies.

References

1. Tóth G, Stolbovoy V, Montanarella L (2007) SOIL QUALITY AND SUSTAINABILITY EVALUATION
2. Kendig L (1980) Performance zoning. APA Planners press, Chicago, Illinois
3. Cortinovis C, Geneletti D (2020) A performance-based planning approach integrating supply and demand of urban ecosystem services. Landsc Urban Plan 201:103842. https://doi.org/10.1016/J.LANDURBPLAN.2020.103842
4. EU (2013) Green Infrastructure (GI) - Enhancing Europe's Natural Capital
5. Ronchi S, Arcidiacono A, Pogliani L (2020) Integrating green infrastructure into spatial planning regulations to improve the performance of urban ecosystems. Insights from an Italian case study. Sustain Cities Soc 53:. https://doi.org/10.1016/j.scs.2019.101907
6. Chatzimentor A, Apostolopoulou E, Mazaris AD (2020) A review of green infrastructure research in Europe: Challenges and opportunities. Landsc Urban Plan 198:. https://doi.org/10.1016/j.landurbplan.2020.103775
7. Boitani L& CF& FA& IM& MM& MA& OD& GR& RC (2002) Rete Ecologica Nazionale. Un approccio alla conservazione dei vertebrati italiani. Relazione finale.
8. Casavecchia S, Allegrezza M, Biondi E, Tesei G ZL (2020) Conservation and management of biodiversity and landscapes: A challenge in the era of global change. In: The First Outstanding 50 Years of "Università Politecnica delle Marche": Research Achievements in Life Sciences. Springer Nature Switzerland AG 2020, pp 483–503
9. Gómez-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecological Economics 86:235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019
10. Gómez-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecological Economics 86:235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019

11. Di Marino M, Tiitu M, Lapintie K, et al (2019) Integrating green infrastructure and ecosystem services in land use planning. Results from two Finnish case studies. Land use policy 82:643–656. https://doi.org/10.1016/J.LANDUSEPOL.2019.01.007
12. Coppola E. (2016) Infrastrutture sostenibili urbane. Inu Edizioni – Collana Accademia
13. Millennium Ecosystem Assessment (Program) (2005) Ecosystems and human well-being : synthesis. Island Press
14. ISPRA (2022) Consumo di suolo, dinamiche territoriali e servizi ecosistemici, Edizione 2021
15. ISTAT 2021 No Title
16. Marche Region (2013) Regione Marche: Rete Ecologica Marche (REM) – Normativa. https://www.regione.marche.it/Entra-in-Regione/Rete-Ecologica-Marche-REM/Normativa
17. Marche Region (1989) PPAR, Piano Paesistico Ambientale Regionale. https://www.regione.marche.it/Regione-Utile/Paesaggio-Territorio-Urbanistica-Genio-Civile/Paesaggio
18. Province of Ancona (2003) Piano Territoriale di Coordinamento. http://www.provincia.ancona.it/Engine/RAServePG.php/P/980810030300/M/956210030372
19. ISPRA Carta della Natura. https://sinacloud.isprambiente.it/portal/apps/webappviewer/index.html?id=885b933233e341808d7f629526aa32f6. Accessed 16 Jun 2023
20. Haines-Young R, Potschin M (2018) CICES V5. 1. Guidance on the Application of the Revised Structure. Common International Classification of Ecosystem Services (CICES) 53
21. Vrščaj B, Poggio L, Marsan FA (2008) A method for soil environmental quality evaluation for management and planning in urban areas. Landsc Urban Plan 88:81–94. https://doi.org/10.1016/J.LANDURBPLAN.2008.08.005
22. EC (2002) COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Towards a Thematic Strategy for Soil Protection
23. Tóth G (2012) Impact of land-take on the land resource base for crop production in the European Union. Science of The Total Environment 435–436:202–214. https://doi.org/10.1016/J.SCITOTENV.2012.06.103
24. Monteiro R, Ferreira JC, Antunes P (2020) Green Infrastructure Planning Principles: An Integrated Literature Review. Land (Basel). https://doi.org/10.3390/land9120525