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Case Study

Adopting a cross-scale approach for the deployment of a green infrastructure

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Abstract

The implementation of a Green Infrastructure (GI) involves several actors and governance scales that need adequate knowledge support. The multifunctionality of GI entails the implementation of a cross-scale approach, which combines assessments conducted at different levels and active stakeholder engagement.

This paper provides a methodology to implement a cross-scale approach to support the deployment of a Regional GI. The methodology was tested in Lombardy Region (north-west of Italy), considering three relevant territorial scales and relative strategic and planning policies. The continental level representing the overall policy-context; the regional level, with its key role for guaranteeing landscape coherence and connectivity and the local level where planning actions are effectively designed and implemented. The EU Biodiversity Strategy for 2030 and the EU GI strategy were used as references for the continental level; at the regional level, a proposal of Regional GI was evaluated focusing on two Provinces (Varese and Lecco), three regional parks (Ticino, Adda Nord and Campo dei Fiori). At the local scale, the new development plan of the Municipality of Cassano d'Adda (Milan metropolitan area) was evaluated considering different possible scenarios.

The regional GI was evaluated with respect to the capacity to provide Cultural Ecosystem Services (CES). CES were mapped using the ESTIMAP-recreation model. The model was adapted to the regional and local level with the active engagement of local stakeholders.

Additionally, census data were analysed to obtain an overview of the equitable distribution of the CES amongst inhabitants.

Results show that, in 78% of the census blocks of the study area, inhabitants have a high-value recreation resource within 4 km (31% within 4 km and 47% within 300 m). Unmet demand characterises 22% of the census blocks in the study area, clustered in zones with a high population density. The regional GI covers almost completely the two Provinces and the regional parks. In Varese Province: 68% of the territory is included in the regional GI, 82% of the census blocks local demand for recreation opportunities is met, but the population density is higher where the demand is unmet. The Province is characterised by a relatively old population (share of people older than 65 years 23.4%). In Lecco Province, 80% of the territory is included in the regional GI, in 96% of the blocks the local demand is met and the local population is relatively old (share of elderly population 22.12%).

The three regional parks present significant differences, strongly influenced by the territorial context. The Campo dei Fiori Park is almost completely included in the regional GI. The entire local population has nature-based recreation opportunities in their close vicinity. Nevertheless, the population density is very low and citizens are relatively old. The majority of the Parco Adda Nord is included in the regional GI providing recreation opportunities to 90% of the census blocks within the Park boundaries. A total of 70% of Ticino Park is included in the regional GI, where local residents are relatively old (share of elderly population 23.78%) and 90% of local census blocks are close to nature-based opportunities.

At local scale, we explored how the approach can be used to estimate changes in the CES potential provision and how this can be integrated into a site management plan.

This paper demonstrated that the combination of studies in a cross-scale perspective enhances the understanding of GI multifunctionality. It provides a framework to adapt CES mapping models to the local setting with active stakeholders engagement. Moreover, it demonstrates that also highly urbanised areas, such as the Lombardy Region in Italy, can play a role in the deployment of a continental GI and can support biodiversity and nature protection.

Keywords

stakeholder engagement, cross-scale approach, cultural ecosystem services, planning process, Green Infrastructure

Introduction

The deployment of a resilient, integrated and multi-scale Green Infrastructure (GI) is the backbone of policies aimed at preserving Europe’s natural environment. GI is recognised as a key instrument of territorial development, to support biodiversity conservation and

ecosystem restoration, maximising the provision of ecosystem services and avoiding territorial and ecological fragmentation (Zulian et al. 2021, European Commission 2020)

Implementing GI can be seen as a territorial strategy for enhancing ecosystem services. It combines together interrelated elements as "*natural, semi-natural and restored areas designed and managed at different spatial scales (from local to global), that encompass all major types of ecosystems (marine, terrestrial and freshwater), and that aims to conserve biodiversity, mitigate emissions of greenhouse gases, enable societal adaptation to climate change, and deliver a wide range of other Ecosystem Services (ES)*" (Silva and Wheeler 2017).

GI is composed of diverse physical features, specific to each location and very scale-dependent (European Commission 2013, European Commission 2019a, European Commission 2019b). An efficient GI is recognised as a key instrument in the EU biodiversity strategy for 2030 (European Commission 2020) to "*prevent genetic isolation, allow for species migration, and maintain and enhance healthy ecosystems. In this context, investments in green and blue infrastructure and cooperation across borders among Member States should be promoted and supported, including through the European Territorial Cooperation*". This statement requires a multi-scale framework to guarantee and monitor territorial cooperation.

The deployment of GI for enhancing ES calls for scale-appropriate information about the condition of ecosystems and the provision, use and demand of multiple (and often interacting) ES. However, choosing the appropriate scale at which ES should be assessed is not evident and often does not imply a single option.

The issue of scale is complex in ES assessment because individual ES, as well as bundles of ES, are generated, managed and used by a variety of social-ecological processes, structures and organisations, each with distinct spatial scales, logic and priorities (Raudsepp-Hearne and Peterson 2016). This condition is defined as a "scale mismatch" between ecosystems and conventional institutions that manage them, causing the lack of appropriate monitoring frameworks (Borgström et al. 2006, Folke et al. 2007 Gómez-Baggethun et al. 2013). The difficulties related to the scale of ES governance and management have precluded their implementation in the decision-making process with a potential source of conflicts in the access of ES (Gómez-Baggethun et al. 2013).

Despite the recognised importance of the added value that different ecosystem functions and services provide to society, it remains a challenge to adequately integrate ES into policy (Primmer et al. 2015). Enhanced uptake of ES in planning and policy requires bringing ES assessment and valuation into decision-making and developing "methods that pay attention to the functioning and resilient landscapes across multiple ecosystems and social-ecological systems" (Primmer and Furman 2012).

According to Scholes et al. (2013), a *cross-scale assessment* can be defined as the combination of studies developed at different scales, focusing on how different outcomes interact and on how an action percolates across different territorial and governance levels.

The interaction is defined by Young (2006) as the "vertical interplay" between or amongst regimes located at higher and lower levels on the jurisdictional scale.

Territorial strategies are intrinsically cross-scalar. For instance, the EU biodiversity strategy has strong effects on national, regional and local policies (European Commission 2011). At the same time, local strategies, especially those on ES, can relapse and impact (directly and indirectly) also at regional, national and EU scale. This double interaction requires coordination and integration (Scholes et al. 2013) of multiple knowledge sources and of multiple stakeholders who understand, manage and benefit from the services (Primmer and Furman 2012).

Several authors highlighted the need for integrated and cross-scalar approaches when dealing with the deployment of GI (Demuzere et al. 2014). An efficient GI goes beyond the administrative boundaries or the ecosystem types and comprehends elements, such as biodiversity-rich parks, gardens, green roofs, ponds, streams, woods, hedgerows, meadows at local scale; large protected natural areas, lakes, river basins, high-nature value forests, extensive pasture, low-intensity agricultural areas, extensive dune systems and coastal lagoons at a regional scale or trans-boundary features, such as international river basins, forests and mountain ranges at supra-national scale (European Commission 2013). Amongst multiple benefits derived from GI, cultural ecosystem services (CES), such as outdoor recreation or outdoor teaching resources, are often mentioned to represent functions that enhance human well-being, health and education (European Commission 2012).

This paper proposes an approach to support the deployment of a regional GI by integrating the knowledge derived from studies developed across different scales. A healthy regional GI includes a network of protected areas; traditional rural landscapes and peri-urban-urban ecosystems and, for this reason, it represents the backbone for the implementation of European policies. The EU's biodiversity and GI strategies represent the overall policy context. The methodology combines regional and local CES maps co-created with the active engagement of local stakeholders and framed according to the national planning system. The aim is to demonstrate:

1. how to implement a cross-scale assessment;
2. how the results can provide information for the different policy levels;
3. how to engage actively local stakeholders.

Methodology

Description of the case study

The research was implemented across three territorial scales. Results of studies on CES at European level (Vallecillo et al. 2019) and on the deployment of a regional GI (Arcidiacono et al. 2016, Arcidiacono and Ronchi 2021) were combined with a CES model adapted to regional and municipal settings, with the active engagement of local stakeholders. Results

were used to provide information for regional and local plans and to identify synergies with the European strategies.

Fig. 1 summarises the three territorial scales and relative policies supported.

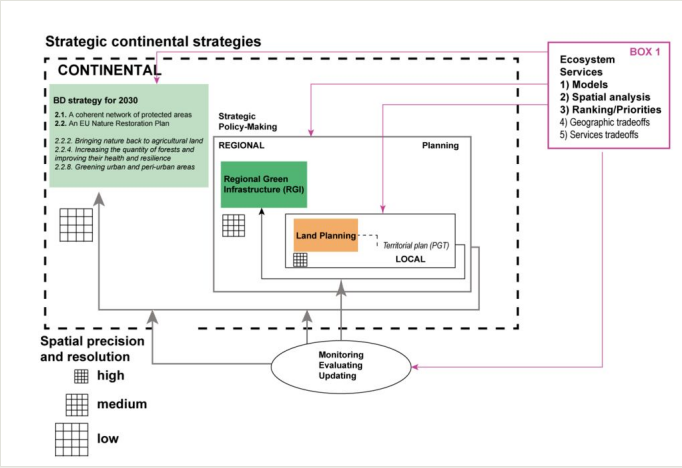

Figure 1.

Cross-scale approach to support planning policies (modified from BenDor et al. 2017).

1. Continental - EU Biodiversity Strategy for 2030 - Bringing nature back into our lives, aims at "protecting and restoring nature in the European Union (European Commission 2020). Specifically through: A coherent network of protected areas (section 2.1) and the EU Nature Restoration Plan (section 2.2) to reverse biodiversity loss. The GI is recognised as an instrument within key Ecosystem types:
    1. Agroecosystems (Section 2.2.2. Bringing nature back to agricultural land)
    2. Forest ecosystems (2.2.4. Increasing the quantity of forests and improving their health and resilience)
    3. Urban ecosystems 2.2.8. Greening urban and peri-urban areas
        1. EU Urban Greening Platform, under a new "Green City Accord" with cities and mayors.
2. Regional - the deployment of the regional GI (Lombardy Region, north-west of Italy) considering the methodology illustrated by Arcidiacono et al. 2016 and Arcidiacono and Ronchi 2021;
3. Local - for supporting the definition of strategic actions for the settlement system, the environmental resources and the infrastructure network to be included in the territorial development plan (PGT) (Municipality of Cassano d'Adda, Lombardy Region, Italy) Fig. 1.

We integrated three policy levels: continental, regional and local. We framed the approach according to the Italian planning system (see Suppl. material 1), but it can be adapted to any planning framework. We followed a rationale partially derived from BenDor et al.

(2017), who proposed a pathway for integrating the ES concept into land use and environmental planning and Cowling et al. (2008), who stated that ES applications need to be user-inspired, user-useful and user-friendly.

We started considering what is promoted at European level (continental scale in Fig. 1). In the Biodiversity Strategy for 2030 (European Commission 2020), GI is instrumental in supporting a coherent transnational ecological network of protected areas and to maintain and restore terrestrial ecosystems (European Commission 2019b). Specifically, it is important for forest and highly modified ecosystems types, such as urban ecosystems and agroecosystems (Maes et al. 2020).

At the regional level (Fig. 1), we based our work on a proposal for the GI strategy in Lombardy (north-west of Italy), structured following the directions and goals raised at EU level (European Commission 2012, European Commission 2013) developed for the regional landscape plan of Lombardy, Map PR 4.1 and published in August 2017*1. The proposal of a regional GI sets prescriptive rules for landscape regeneration and environmental improvements. Three landscape typologies were defined and derived from the combination of a set of ES indicator models, namely "Habitat quality", "Agricultural values" and "Presence of cultural heritage" (Arcidiacono and Ronchi 2021). The landscape types defined are:

1. The *natural landscape*, including forests and semi-natural areas, characterised by the presence of areas relevant for biodiversity and conservation purposes. The areas were selected also according to article 142 of the Italian Legislative Decree 22/2004 (and subsequent amendments and additions)*2 defining the Alpine and the Apennine regions above 1,600 and 1,200 metres and the territories close to lakes as protected areas;
2. The *rural landscape* characterised by the presence of elements of the traditional rural landscape: consists of a mosaic of small-scale arable fields, traditional paddy fields and rural linear elements (European Commission 2017);
3. The *anthropic landscape* characterised by the presence of historical and cultural heritage sites (according to the Italian Legislative Decree 22/2004)*2 (European Commission 2017).

The regional GI aims to become an instrument to promote multi-sectoral and multi-scale policies, incorporating actions for landscape regeneration, nature conservation and recreation activities. The policy actions include the re-organisation and restoration of the anthropic landscape; the maintenance of the ecological connection in the natural landscapes; the enhancement of cultural and historic landscapes (Arcidiacono and Ronchi 2021) (Fig. 2).

The operability of the regional GI requires coordination across political and administrative levels ranging from regional to sub-regional (provinces in Italy) and local scale (Arcidiacono et al. 2016). Nowadays (early 2021), the regional GI has not yet been approved, the process for its definition is still ongoing and probably some changes will be made on the first proposal published in August 2017 and used in this paper. Nevertheless, we

implemented our analysis in two Italian provinces and three regional parks of Lombardy to demonstrate how a cross-scale approach could additionally provide information for the regional plan.

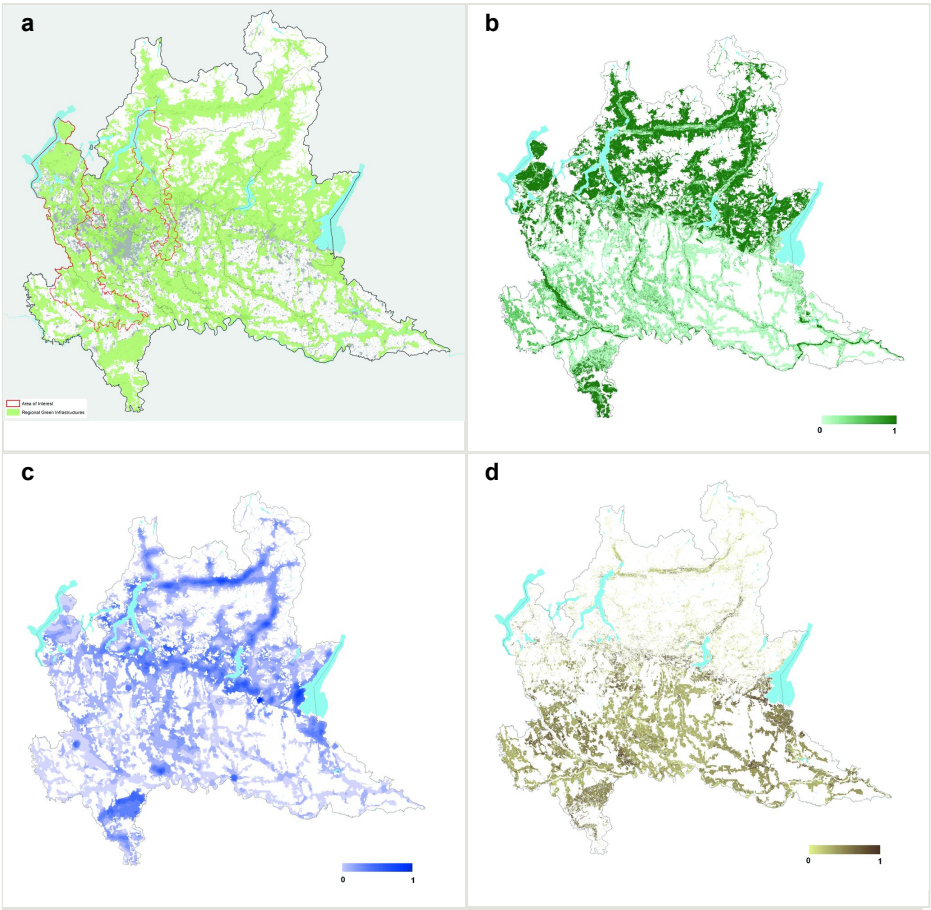

Figure 2.

The proposal for green infrastructure for the Lombardy Region and the three landscape types (natural, anthropic and rural), based on the first proposal of GI elaborated for the regional landscape plan of Lombardy, map PR 4.1, published in August 2017.

a: The proposal of green infrastructure of Lombardy
b: The natural landscape
c: The anthropic landscape
d: The rural landscape

Two Italian Provinces (Varese and Lecco) and three regional parks (Campo dei Fiori, Ticino Park and Adda Nord Park) were assessed at the regional level using information included in the GI plan. The Parks differ in size and characteristics: Campo dei Fiori is located in the primary hills of the Alps Region; Ticino Park extends across three provinces along the Ticino River including natural areas and a significant part of agricultural land; while Adda

Nord Park combines natural landscapes with different cultural and historical heritage sites close to the River Adda. Within the study area, there are 23 Sites of Community Importance (SCI) and five Special Protection Areas (SPA) established under the Habitats Directive close to, or partially overlapping with highly urbanised areas. These Natura2000 sites fall inside the three regional parks aiming to ensure the long-term survival of Europe's most valuable and threatened species and habitats.

At the local scale, we worked with the Municipality of Cassano d'Adda for defining and setting strategic actions for the settlement system, the environmental resources and the infrastructure network which could be implemented in the territorial development plan (PGT). PGT is the general municipal plan introduced in the Lombardy Region with Law no. 12 of 2005. It provides future development strategies and land use regulation (See Suppl. material 1). Cassano d'Adda is a medium-sized city of 18,725 inhabitants and covers a surface area of 18.6 km² (1,006.72 inhabitants/km²)*3. The Municipality, located along river Adda, is partially included in the Adda Nord Park and it is almost completely covered by the proposed regional GI.

Fig. 3 shows the configuration of the three governance levels and presents an overview of the Italian planning system, to clarify mutual dependencies amongst the different levels of governance.

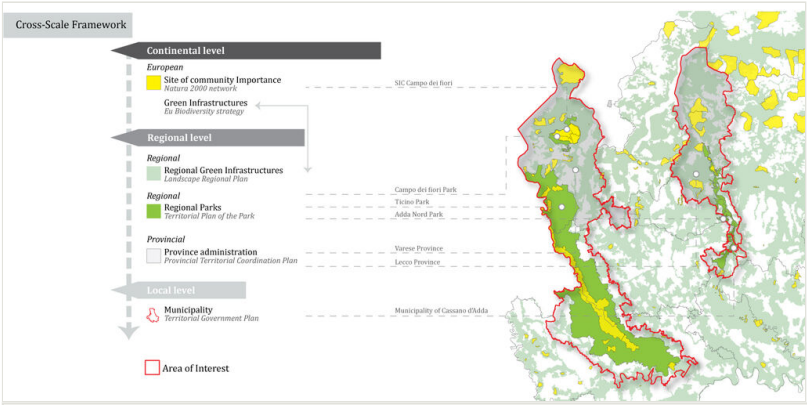

Figure 3.

The cross-scale framework, based on the three governance levels of the Italian planning system.

Model to map nature-based recreation opportunities

We mapped CES using a modified version of the ESTIMAP recreation model (Zulian et al. 2013, Paracchini et al. 2014). ESTIMAP is a collection of models originally developed for mapping ES to support European policies. The ESTIMAP recreation model consists of advanced multiple layers look-up tables and assigns values reflecting the capacity to provide ES to land units through cross-tabulation and spatial composition generated from the overlay of different thematic maps (Zulian et al. 2018). The model measures the

capacity of land to provide nature-based outdoor recreational and leisure opportunities. It consists of two basic sections:

1. The Recreation Potential (RP): which maps the potential capacity of ecosystems to support nature-based recreation activities;
2. The Recreation Opportunity Spectrum map (ROS), which combines a proximity/ remoteness indicator and the availability of facilities with the potential supply (RP) and provides a map with nine categories of recreation opportunities.

The operability of the regional GI requires coordination across political and administrative levels ranging from regional to local scale (Arcidiacono et al. 2016).

Fig. 4 provides examples of recreation activities, mapped with the ROS map. The opportunity spectrum classifies the territory into nine categories, respectively representing high, medium and low level of opportunities provided from the ecosystems combined with high, medium and low availability of facilities as infrastructures to reach and enjoy the recreation areas. Fig. 4 shows the most important nature-based recreation activities that people can enjoy in the area.

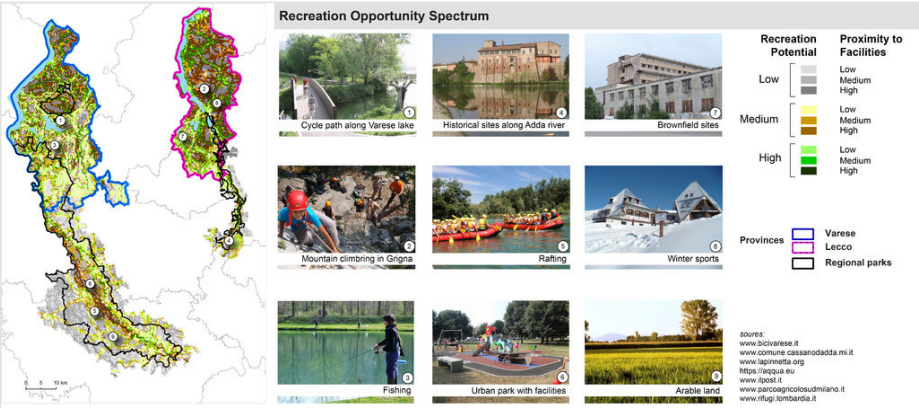

Figure 4.

Examples of recreation activities which can be done in the study area and are mapped on the ROS map.

The ROS analysis recognises areas with a high potential of ecosystems to support nature-based recreation activities and with high proximity to facilities that allow people to reach and enjoy them. An example are natural areas along rivers and lakes which are used by pedestrians and cyclists. The situation is different in areas that do not have sufficient infrastructure to guarantee easy fruition of the natural area. This is the case of mountain areas, that offer opportunities for nature-based recreation, but where there is a lack of facilities. The opposite condition is represented by the urban parks, where the extent of natural areas is relatively low, but there are facilities to reach and enjoy them. Artificial and developed areas or intensive agricultural land are not considered as direct or indirect opportunities for outdoor recreation.

At pan-European scale, the ESTIMAP-recreation model has been used to map recreation opportunities provided by all ecosystems, focusing on urban ecosystems. The model has been applied for the purpose of ecosystem services accounting (Vallecillo et al. 2018, Vallecillo et al. 2019), ecosystems assessments (Maes et al. 2020) and in several Pan-European scale studies with the aim of assessing bundles of ecosystem services in Europe (Liquete et al. 2016, Grizzetti et al. 2017, Mouchet et al. 2017). Additionally, it has been adapted to the urban setting (Baró et al. 2016, Cortinovis et al. 2018, Maes et al. 2019) as well as other settings (Zulian et al. 2018).

Through the participation of local stakeholders (described in the next section), the original version of ESTIMAP-recreation model has been adapted to support the regional GI policy of Lombardy and the territorial development plan (PGT) of Cassano d'Adda. The four steps protocol for the model adaptation were derived from Zulian et al. (2018):

1. Definition of the aim of the mapping process: a detailed description of the final uses and users of the maps, type of stakeholder engagement and the main characteristics of the study areas;
2. Selection of the scale of analysis: the spatial extent, spatial precision and attributed accuracy;
3. Model configuration: the structure of the model (how to combine the elements that play a role in the spatial availability of recreation opportunities);
4. Type of input data: the selection of data relevant to the local settings with the engagement of local stakeholders.

Stakeholder engagement

Representatives from public administrations were involved in a participatory activity, conducted between 2016 and 2017, adopting a sequential, qualitative, multi-method approach (Creswell 2003) with the aim to:

1. Engage practitioners and stakeholders in the co-production of the maps;
2. Adapt the model to fit the specific needs;
3. Obtain feedback from potential users of the CES model.

The participatory activity was organised using the world café methodology, an effective and flexible method for creating a living network of collaborative dialogue (Reason et al. 2008). In the first round, participants were invited to discuss nature and the role of daily and touristic outdoor recreation activities in the study area with the aim of providing information for and adapting the mapping approach. Key discussion issues were: the kind of recreation activities, the type of users and availability of public facilities.

In a second round, the stakeholders were asked to discuss the conceptual scheme of the model and to assign a weight that reflects the suitability of recreation activities to each element included in the model. The scores assigned by local experts are included in Suppl. material 2. The results of the interactive discussions are summarised in Suppl. material 3 and have been used to implement the regional and local recreation maps.

Catalogue of urban green areas and facilities

Data available at local scale were not detailed enough to create a recreation map, useful to support the deployment of the local PGT. For this reason, we collected qualitative data, based on direct observation and fieldwork, to improve the information available from the Municipality of Cassano d'Adda. We gathered data on the territorial context (urban, peri-urban or rural) and on the availability of facilities (lights, baskets, benches, cycle racks, playgrounds, drinking fountains, disabled access, fence for dogs, kiosks, sports facilities). Seventeen areas were included in the survey carried out during 2017 (Suppl. material 4). These data have been used to enrich the local recreation maps.

The cross-scale analysis

The demand for outdoor recreation opportunities was quantified by mapping the share of the population that lives close to "high-quality areas for daily recreation". ESTIMAP defines "high-quality areas for daily recreation" as areas that have a high occurrence of elements that can potentially provide opportunities for outdoor activities and where facilities are available to reach and enjoy the location.

As proposed by Wolff et al. (2015), we analysed a potential direct use of resources by the residents. We applied a cumulative accessibility model as suggested in Ekkel and de Vries (2017). The daily-based demand of local residents is considered fully satisfied if they live within a 300 m distance from an area with a high potential to offer nature-based outdoor recreation opportunities. This distance has been suggested as a reference in recent reviews on green spaces and health (Egorov et al. 2016) and is also considered a target at a local scale (Stessens et al. 2017). Population data have been extracted from the national census at the census block level (ISTAT 2019) and spatially allocated according to the size of buildings in each census block (Suppl. material 5). In each census block, we computed the percentage of the population that lives within 300 m from the closest high recreation opportunity (from now on called "fully-met demand"). A second level was introduced to simulate the demand of local residence using a distance of 4 km (from now on called "partially met demand"). Iacono et al. (2008) worked on the estimation of distance decay functions for different destinations and, according to this study, 4 km is a good approximation to model the individual propensity to reach a destination for recreational purposes.

The capacity to provide nature-based recreation opportunities was measured by computing the share of surface area for each ROS category within the two Provinces, the protected areas and across the proposed regional GI with respect to the degree of urbanisation of the area. Data were used at the LAU (Lower Administrative Unit) level; a map is available in Suppl. material 6. According to EUROSTAT (EUROSTAT 2019), populated areas can be classified in cities, towns and suburbs and rural areas:

- Cities (densely populated areas: at least 50% of the population lives in urban centres);

- Towns and suburbs (intermediate density areas: less than 50% of the population lives in rural grid cells and less than 50% of the population lives in urban centres);
- Rural areas (thinly populated areas: more than 50% of the population lives in rural grid cells).

For a more complete overview of the demand, socio-economic indicators were computed at the census block level, specifically: the total age dependency ratio, the share of elderly population and the population density. The total age dependency ratio is the proportion of the population not included in the work-force who are "dependent" on those of working-age (the number of dependants in a population divided by the number of working-age people. Dependants are defined as those aged zero to 14 and those aged 65 and older, working-age is from 15 to 64) (EUROSTAT 2021, OECD 2021).

The share of the elderly population is the share of people aged 65 years or above in the total population (EUROSTAT 2021, OECD 2019, OECD 2021). The two indicators, together with the population density, provide an overview of the structure size of the beneficiaries. Equal access to nature is fundamental also considering, for instance, the restrictions due to the COVID-19 pandemic. To provide a more complete overview, social surveys on recreation activities carried on in the Lombardy Region were also consulted (Cavedo 2017).

At a local scale, the results from the RP map were used to evaluate the recreation opportunities provided by considering different planning scenarios proposed in the PGT. We explored how the approach can be used to estimate changes in the ES potential provision and how this can be integrated into a site management plan.

Spatial analyses were performed using GRASS GIS (GRASS Development Team, 2018. Geographic Resources Analysis support system (GRASS) Software, Version 7.4. Open Source Geospatial Foundation. https://grass.osgeo.org) and ArcGIS (ArcGISDesktop: Release 10. Redlands, CA: Environmental Systems Research Institute).

Input data

Table 1 presents all input data used in the analysis and gives more detail on how they have been used in the study. To map recreation at regional and local scale we used publicly available data. At the local scale, the municipality of Cassano d'Adda provided the spatial information that was verified and integrated with field data.

Table 1.

Input data used in model to assess nature-based recreation.

Data	Source
Regional land use/land cover Map (DUSAF)	GeoPortale of Lombardy region
Topographic databases, Lombardy Region (DBT)	

Data	Source
Natural features: monumental trees, sites of geological and geomorphological interest, mountain peaks and passes, viewpoints, cascades, springs, river areas with high landscape value, line trees, urban green areas.	
Historical and cultural heritages sites	
OpenStreetMap – tags of interest: natural (water related); natural (inland); point of interest (viewpoint); highways (local roads, bridleway, path for cycling unspecified paths).	OpenStreetMap contributors. (2015) Planet dump, Retrieved from https://planet.openstreetmap.org
OpenStreetMap – road network	
New territorial plan (PGT), Municipality of Cassano d'Adda	Regional catalogue of Local territorial plans
Catalogue of public urban green areas (See Suppl. material 4)	Survey conducted in the Municipality of Cassano d'Adda
Degree of urbanisation	Eurostat
Italian census blocks (census data)	ISTAT
Population data	ISTAT
Residential buildings	GeoPortale of Lombardy region

Results

Adaptation of ESTIMAP-recreation

Results retrieved from the participatory activity and information gathered from the catalogue of public urban green areas and facilities were used to adapt the ESTIMAP-recreation model to fit the supra-local and local needs. Table 2 shows the relevant aspects of the adaptation process, described following the structure proposed in Zulian et al. (2018).

Table 2.

Adaptation process of the ESTIMAP-recreation model, derived from the local stakeholder engagement.

Step	Sub steps	Regional scale	Local scale
Type of knowledge and use of knowlegde	Final map users	Lombardy Region, Provinces, Regional Parks	Municipality of Cassano d'Adda
	Applications	Policy	Planning
	Type of stakeholders engagement	Interactive process of consultations	

Step	Sub steps	Regional scale	Local scale
Scale (s) of analysis	Scenarios assessment (Yes/No)	No	Yes
	Positional accuracy	(DUSAF 10,000 = 10 m) 20 m	(Cassano d'Adda 2.5/5 m) 5 m
	Attributed accuracy	Input data scores and weights have been selected and co-defined with local stakeholders.	
Conceptual schema of the model		- The *Recreation Potential map* (*) includes a correction that decreases the value of the indicator close to main roads. The experience of nature can be highly disturbed by different activities, such as noise of traffic and aeroplanes (Pröbstl et al. 2010, p. 29 and 30). - The presence of Natura2000 sites was not included in the data used to create the RP map because the interest was to map the gradient of opportunities provided within the parks.	
		- The *Proximity to facilities map* (**) depends on features to enjoy and to reach potential recreation areas	
			Detailed information on public urban green areas and facilities, see Suppl. material 4

* Recreation Potential in Fig. 5

** *Proximity to facilities map* in Fig. 6

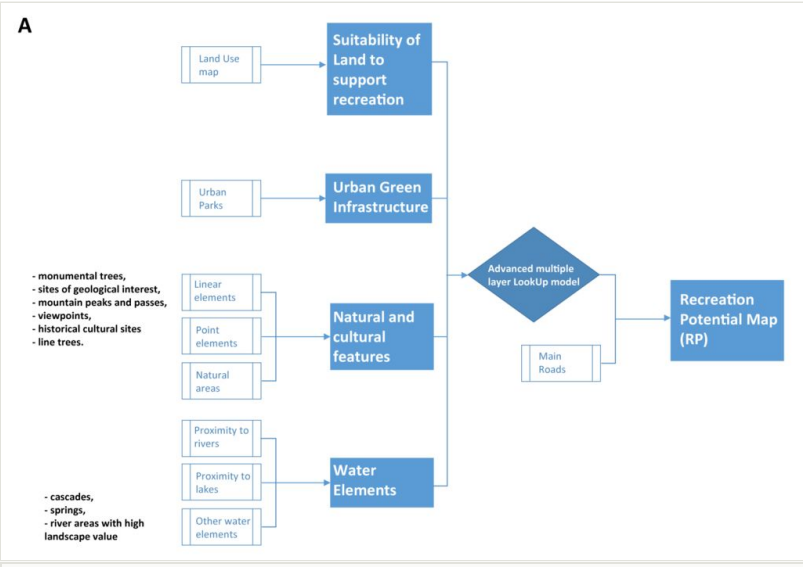

Figure 5.

Workflow of the Recreation Potential Map (RP)

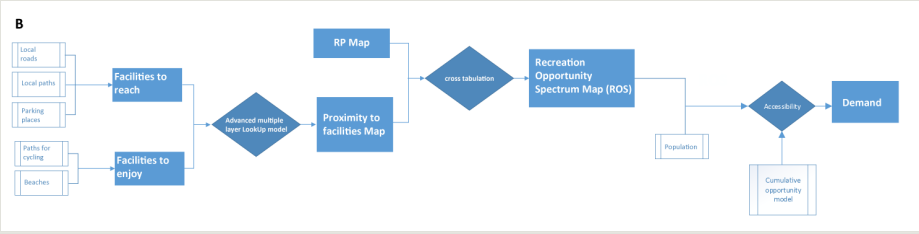

Figure 6.

Workflow to obtain the Recreation Opportunity Spectrum (ROS) and the demand for recreation

Provision of recreation opportunities

Fig. 7 shows census block classified in three categories which represent a gradient of demand satisfaction. Original maps used for the analysis are available in Suppl. material 7. Lombardy Region is characterised by a clear dual spatial pattern with reference to satisfaction of local demand for recreation opportunities. Map A shows a north-south and a horizontal gradient, which follows the main rivers and the shape of protected areas.

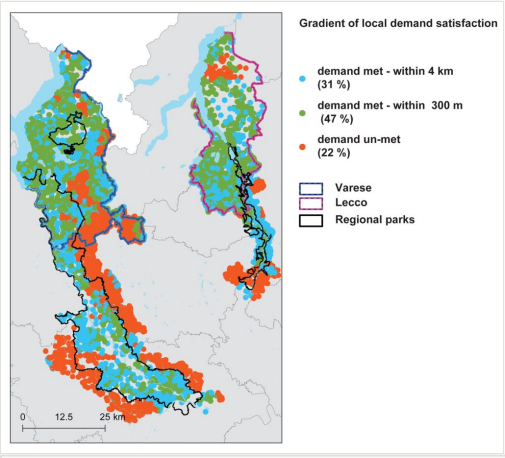

Figure 7.

Gradient of local demand satisfaction.

In our case study (see map B included in Suppl. material 7), in 78% of the census block, the demand is met and residents can reach a location which provides opportunities for recreation within 300 m up to 4 km. In 31% of the census blocks, residents have a hot spot of recreation opportunities within 4 km. In 47% of the local census blocks, the recreation demand is fully-met and local residents can reach areas with high recreation opportunities for daily use within 300 m. In 22% of the census blocks, the demand is not satisfied. Here local authorities should concentrate on improving the availability of green areas and increasing the facilities to reach them (such as bike paths). The northern part of the study area is defined as "Pre Alps district", characterised by the major lakes of Lombardy as

Lake Como, Lake Maggiore and Lake Varese, together with minor ones such as Lake Comabbio and Lake Monate. According to the rationale of the indicator and the stakeholders' preferences, the presence of lakes and rivers plays a crucial role in the selection of areas for recreation activities. Besides that, the Varese Province (as an example) invested in bike and pedestrian paths, for instance, around Lake Varese and Lake Commabbio that actually attract local users in all seasons. Fig. 8 shows the spatially explicit distribution of recreation opportunities and the share of different ROS categories per Administrative units (Provinces) and within the regional parks, considering a different degree of urbanisation.

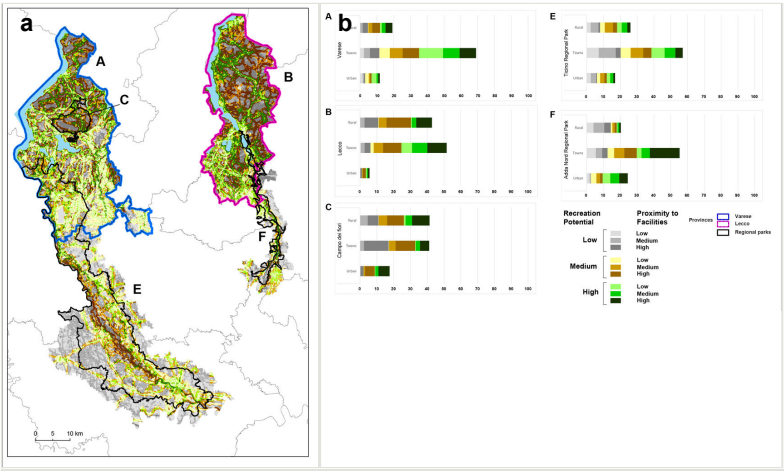

Figure 8.

The share of recreation opportunities available per province and regional park. Percentages are computed by considering the degree of urbanisation.

a: The spatial distribution of the ROS categories in the case study area
b: The histogram distribution of the ROS categories divided into Provinces (Varese, Lecco) and regional parks (Campo dei Fiori, Ticino and Parco Adda Nord)

The analysis highlights the important contribution of natural elements to the deployment of the regional GI and to the provision of CES. Natural elements are distributed in the northern part of the study area and along the main watercourses and water bodies (Ticino and Adda Rivers and Lakes Maggiore, Varese and Como). The Regional Park of Campo dei Fiori, that is also part of the Natura2000 network as a Site of Community Importance (SCI), is completely included in the regional GI (especially for the natural characterisation) and provides opportunities for recreation which depend largely on the quality of its natural landscape, but with relatively low availability of facilities (Fig. 9). In fact, despite its proximity to the Municipality of Varese (about 5 km) and other important urbanised areas, the natural condition of the Park, associated to its topography (altitude reaches 1,227 m a.s.l.), has precluded the development of facilities that could encourage sustainable uses (Fig. 9). Recreation opportunities in this area completely satisfy local needs; however, the area is characterised by a relatively old population (share of elderly population between 23.59 and 30.81%) with a low population density (See Table 3).

Table 3.

Recreation opportunities and demographics indicators reported per Territorial units. Demographics are reported only for census blocks with population. * % by territorial unit

Reporting units	**Recreation Opportunities**				**Demographics**			
	*high RP and high presence of facilities **	*high RP and low- medium-high presence of facilities**	*demand (% of census blocks)*		*total age dependency ratio*	*share of elderly population (%)*	*population density (inhab/km^2)*	*surface (km^2)*
Province of Varese	14.82	46.16	met demand (within 4 km)	31.7	68.34	24.29	887.13	240.27
			met demand (within 300 m)	50.65	65.18	23.68	815.22	448.46
			unmet demand	17.65	56.42	21.04	893.86	199.58
Province of Lecco	21.8	41.58	met demand (within 4 km)	17.26	50.89	20.83	676.63	159.63
			met demand (within 300 m)	79.6	58.62	22.13	110	448.46
			unmet demand	3.14	53,34	29.2	498.98	18.38
Parco Ticino	7.34	31.45	met demand (within 4 km)	42.32	64.43	23.35	686.83	390.12
			met demand (within 300 m)	44.43	63.04	24.4	388.42	214.14
			unmet demand	13.25	60.13	23.1	470.57	93.78

Reporting units	**Recreation Opportunities**				**Demographics**			
	*high RP and high presence of facilities **	*high RP and low- medium-high presence of facilities**	*demand (% of census blocks)*		*total age dependency ratio*	*share of elderly population (%)*	*population density (inhab/km^2)*	*surface (km^2)*
Parco Adda Nord	23.53	42,78	met demand (within 4 km)	26.9	52.52	18.45	769.98	63.74
			met demand (within 300 m)	66.21	56.92	23.14	673.2	53.58
			unmet demand	6.9	52.49	17.09	318.54	23.36
Campo dei Fiori	22.38	32.34	met demand (within 4 km)	14.29	64.17	30.81	274.61	11.85
			met demand (within 300 m)	85.71	65.05	23.59	629.74	38

However, Adda Nord Park, which is characterised by the presence of important natural elements that contribute to a high value of recreation opportunities and includes Special Protection Areas (SPAs), is located very closely to a highly urbanised area (75% of the Park is classified as urban and towns). This implies high availability of facilities to enjoy and reach recreation sites and a relatively high proportion of met demand (Table 3), with only 6.9% of census blocks far from recreation opportunities (but characterised by a relatively young population). Ticino Park, on the other hand, is mid-way between the two cases above mentioned. The Park is characterised by a strong natural component, mainly located along the Ticino River, combined with some important rural areas, as a part of the historical agricultural tradition of Lombardy and relevant historical heritage sites located in the urban areas. This characterisation has influenced the development of facilities in correspondence of the land use of the Park. A total of 70% of the Park is included in the regional GI. Nevertheless, the remaining area (which overlaps with the zones where local demand is not satisfied) is relatively densely populated (if we compare its population density with Adda Nord Park or Campo dei Fiori) with a relative dominance of elderly population. In Varese and Lecco, two Provinces of the "Region of Lakes" in Lombardy, a relatively high share of areas provide a high level of recreation opportunities (respectively 46.16% in Varese and 41.58% in Lecco). Facilities to reach and enjoy recreational sites are

well developed (14.82% of the area is close to high-level recreation sites in Varese and 21.80% in Lecco). The two Provinces are almost completely part of the regional GI (70% in Varese and 75% in Lecco, Fig. 9)

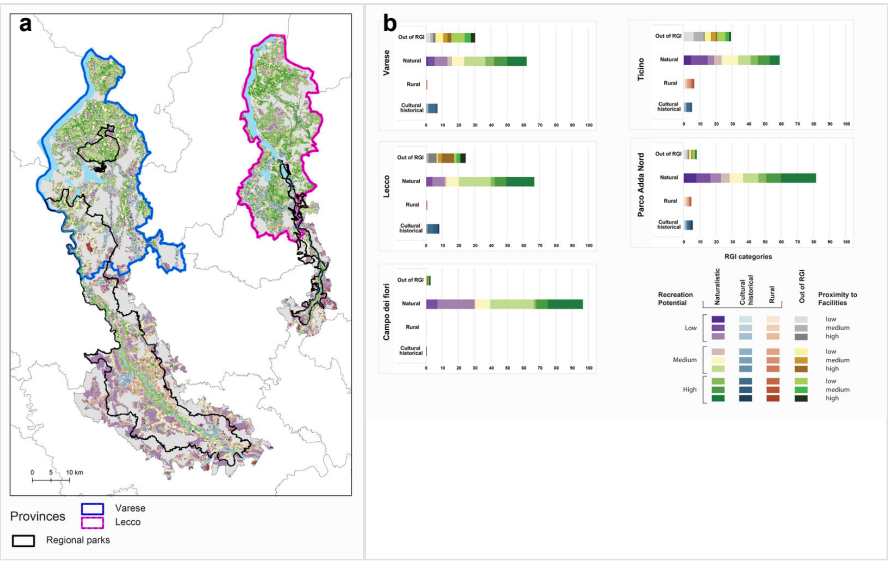

Figure 9.

The share of recreation opportunities available per province and regional park within the proposed regional Green Infrastructure (%)

a: The mapping distribution of the ROS value
b: The distribution of the ROS categories divided into Provinces (Varese, Lecco) and Regional Parks (Campo dei Fiori, Ticino and Parco Adda Nord) and considering the three landscape types of the Regional GI

In 82.35% of the census blocks in Varese, the demand for recreation is fully met (50.65% of the populated blocks are very close to an area with high potential). Nevertheless, areas, where the demand is fully met, are characterised by a relatively old population (average total age dependency ratio higher than 50 and the average share of elderly population is 24.29 and 23.68%, respectively). Vice-versa areas where the demand is not met are characterised by high population density and a relatively younger population. Small municipalities around the City of Varese benefit from the close presence of the Campo dei Fiori Regional Park, of the lakes and of the forests and that explains why demand in this area is met.

In Lecco, the demand is fully met in 96.86% of the census blocks. All of the Province is characterised by a relatively old population and a low population density.

Fig. 10 and Table 4 show the Recreation Potential Map for the Municipality of Cassano d'Adda and presents the baseline and scenario results for four selected transformation areas (TA) forecast by the PGT approved in October 2019*4. We present the RP map here for two reasons:

Table 4.

Scenarios analysis: Change in the Recreation potential in the Transformation areas define by the PGT of Cassano d'Adda Municipality.

Transformation area	Recreation potential (average)	
	baseline	scenario
Area "AT1 - Stazione" total surface area: 47,302 m^2, is the old abandoned railway station; the forecast uses are services, tertiary and commercial	0.35	0.47
Area "AT2 - ex scalo ferroviario" total surface area: 107,239 m^2, is the old abandoned railway yard, directly connected with the previous AT1 and dedicated to craft and industrial use	0.33	0.48
Area "AT3 - ex Polveriera" total surface area: 12,240 m^2, is located in the productive district of the municipality and includes an abandoned industrial site; the forecast use is craft/industrial	0.53	0.41
Area "AT19 - via Don Castellazzi" total surface area:12,023 m^2, is characterised by the presence of residential neighbourhoods and close to a historical area of Cascine San Pietro	0.55	0.48

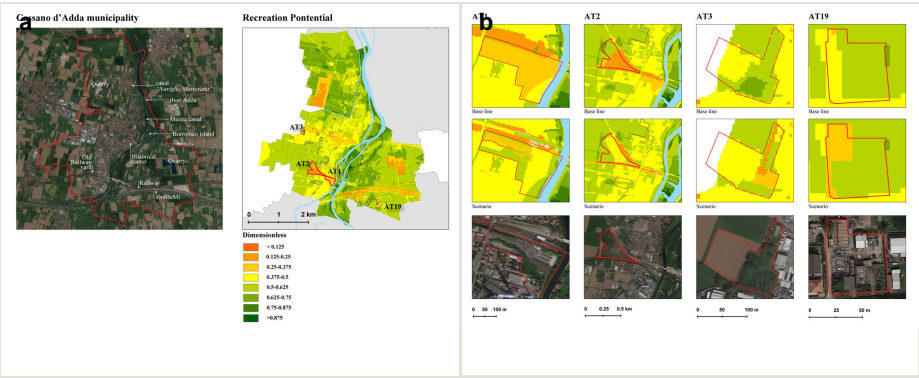

Figure 10.

The baseline and scenario analysis for Cassano d'Adda Municipality

a: The Recreation Potential map of Cassano d'Adda Municipality
b: The baseline and scenarios analysis: the changes of the Recreation Potential in the forecaste transformation areas of Cassano d'Adda Municipality

1. the small size of the TA does not allow us to measure a clear change with the ROS;
2. we wanted to concentrate on the potential ES provision and not on the presence of facilities.

Zones that tend to green and dark green colours in Fig. 10a (higher capacity to provide recreation opportunities) are the ones close to Adda River characterised by natural areas (woods, shrubs) with good environmental conditions and by diverse facilities (cycle path, dogs area, sports facilities). Moreover, the convergence between the River Adda and the

artificial canal Muzza creates a unique landscape with loops, ramps and islands (i.e. Borromeo Island) that attract numerous residents and inhabitants of the eastern side of the Milano Metropolitan area. The low RP is assigned to built-up areas or open areas covered by infrastructure, such as the old and the new station and railway track and the highways A35 Brescia-Bergamo-Milano in the southern part of the Municipality. The two large areas with low RP, located in the northern and eastern part of the Municipality, are active or partially active quarries.

We ran the model using the current land use/land cover of the TA (Baseline) and changed it according to the projects suggested by the PGT for the development of the TA (Scenario). New projects include new green areas, cycle paths, building area, vegetation elements as tree rows or possible pedestrian connection and so on. The scenario analysis presented provides an ex-ante estimation of the possible impacts on RP derived by the implementation of TA; therefore, the policy-makers of Cassano d'Adda Municipality could consider these results for the new edition of the PGT by addressing their choices on the most suitable for CES provision.

Discussion

Nature-based recreation is a key CES, especially in highly populated areas. Nature-based recreation, defined as all physical and intellectual interactions with biota, ecosystems and landscapes (Vallecillo et al. 2019), provides the opportunities to experience direct contact with “nature”, otherwise completely lost. Citizens can practise different activities, such as canoeing, swimming in open water, walking, running and biking, potentially on a daily or weekly basis. In this application, the demand for CES is quantified in terms of "*direct use*" using an indicator that accounts for proximity (Wolff et al. 2015). Demand can be analysed with a focus on local residents, in terms of short-daily recreation trips or considering several types of trip purposes (from short trips to a longer one), which is indeed very important in Lombardy Region. A recent study, which analysed recreation activities of residents in Lombardy Region, estimated 8,456,000 daily trips in 2015, of which 68.7% were within the Region (Cavedo 2017). The main travel reasons are for recreational (45.4%) or cultural (8%) purposes; therefore, a large part of the intra-regional trips involved our study area. This pattern was analysed indirectly in this study, considering the spatially explicit distribution of recreation opportunities (Suppl. material 7).

A cross-scale approach, defined as a combination of studies developed at different geographical scales, was implemented to support a number of policies intrinsically interconnected. Additionally, stakeholders were engaged as an integral part of the mapping process (Zulian et al. 2018, Cowling et al. 2008).

Stakeholders engagement and map co-production are very important elements for integrating ecosystems and their services into decision-making (European Commission 2019a). The engagement and the participatory activities allow also non-experts to be aware of the value of maps. At the same time, map co-production helps to develop new

points of view on "already known dynamics" processes and reinforce the discussions and feedbacks.

This paper highlights a number of important benefits derived from a structured cross-scale approach.

The first one is the combination of mutually supportive studies to implement interconnected policies. In the EU's Biodiversity policies (European Commission 2020), GI represents a transversal instrument for deploying a coherent ecological network across different ecosystem types, aiming at restoring degraded ecosystems or at maintaining healthy ecosystems. Additionally, the Biodiversity Strategy for 2030 includes, for the first time, a section on urban ecosystems emphasising the role of local green infrastructure for biodiversity and human health and well-being. These concepts are an integral part of the planning instruments examined in this paper.

In fact, our results support stakeholders and policy-makers of different governance levels in knowing and being aware of the opportunities and weaknesses in the provision of nature-based recreation opportunities. For example, the awareness of impacts of a specific type of recreation activities on conservation or nature protection programmes is fundamental to direct policy-makers towards appropriate development strategies or the recognition of the role of high urbanised areas as support of EU, regional and local GI (Maes et al. 2019).

A second benefit is the implementation of the approach in a real planning framework.

Here, we used the Italian planning framework (see Suppl. material 1) to show that the results can be easily integrated and used in the different existing planning system. For instance, the provincial territorial coordination plan or the metropolitan plan (in Italian: *Piano Territoriale di Coordinamento Provinciale - PTCP and Piano Territoriale Metropolitano - PT*) can include the RP analysis for the identification of new local parks with recreational functions or for the selection of landscape conservation strategies. In the same way, the PGT can use the research outputs to achieve the requirements of habitability and urban quality through the concept of public service (such as social housing, green areas and other public services). Additionally, results are useful from an inter-sectorial perspective. For instance, the cross-scale approach as a support tool for a multi-scale GI could be adopted in other planning instruments, such as the provincial forestry plan (in Italian: *Piano d'indirizzo forestale*), aiming for nature conservation or the sustainable mobility strategy, that includes orientation for territorial fruition, based on cycle and pedestrian paths at different territorial scale (supra-local and local).

The third important benefit of this approach is its replicability. In fact, the methodology can be replicated and adapted to other settings, including also other ES (not only CES, but also regulating, provisioning and supporting services) and other European strategies and policies.

Although natural capital accounts are usually compiled at the national level (United Nations, European Union, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, Group, W.B. 2014, United

Nations 2019), their framework would effectively work at subnational levels to serve different purposes. A cross-scale approach would become an operational tool to check consistency and potentially perform aggregation as appropriate at different administrative levels (i.e. from municipal to regional to national).

Conclusions

This paper provides significant insight regarding the interaction between different policy levels. It highlights how one can influence the other by establishing a mutual relationship for the implementation of a territorial development strategy, based on ES provisions. Nowadays, further advancements were done in the use of a multi-scale approach as a synthesis integration of different individual analyses (Scholes et al. 2013) and, while it is less explored, the cross-scale approach, based on the interaction between various scale (continental, regional, local).

The study has experimented with the cross-scale method by verifying how studies promoted at the regional level could relapse to the local scale within a continental strategical policy. The Italian planning framework was used as a scope of application and CES were considered as an exemplifying ES. Moreover, the co-production of maps was adopted, based on stakeholder knowledge as a crucial component of ES approach (Zulian et al. 2018, Cowling et al. 2008).

The research provides an example of how to integrate information derived from different sources and explore opportunities to be considered during the different phases of a planning process. This is not an exhaustive assessment that should include a bundle of ES and focused policies and planning actions. Nevertheless, the experiment allowed us to consider a number of research areas that normally are treated separately.

1. ES modelling and adaptation to the local context;
2. Role and importance of stakeholders engaged in the map production;
3. Integration of ES into the planning process in a cross-scale perspective.

In mapping ES, issues such as scale, data precision, resolution and accuracy certainly matter. Nevertheless, their relevance is strictly linked to the reason the map was created and is used in the assessment. In fact, the mapping could contribute to making the importance of ES evident in the decision-making process. Pan-European maps, very useful for awareness-raising and strategic policy-making, can provide a reference framework that has to be contextualised with reference to national, regional and local scales. In the meanwhile, methodologies developed at EU scale can support the adaption of models and indicators (in this case a CES) to fit very local needs. Stakeholders engagement and map co-production are very important aspects of the process of adapting ES or other territorial models that have to be integrated into the planning process. The engagement and the participatory activities also allow non-experts to be aware of the value of maps. At the same time, map co-production helps to develop new points of view on "already known dynamics" processes and reinforce the discussions and feedbacks.

The integration of ES into the planning process is actually strongly recommended by the scientific community. In addition, the Commission, as mentioned in the introduction, sustains the process through different activities (Zulian et al. 2021). What is needed is a collection of real-world experiences that demonstrate the added values of ES assessment.

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Author contributions

- Grazia ZULIAN developed and implemented all spatially explicit models;
- Silvia RONCHI produced the Catalogue of Urban Green Area with public facilities (Municipality of Cassano d'Adda) , prepared all input data and produced and implemented population-weighted density model;
- Silvia RONCHI and Grazia ZULIAN coordinated the Stakeholders engagement workshops for the co-production of maps;
- Grazia ZULIAN and Silvia RONCHI framed the assessment framework;
- Grazia ZULIAN and Silvia RONCHI drafted the text (original and final version);
- All the authors contributed in writing, reviewing and editing the manuscript.

Conflicts of interest

The views expressed in this article are personal and do not necessarily reflect an official position of the European Commission.

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Supplementary materials

Suppl. material 1: The Italian Planning System doi

Authors: Silvia Ronchi
Data type: Document
Brief description: short description of the Italian planning system
Filename: oo_200734.docx - Download file (16.13 kb)

Suppl. material 2: Distribution of the scores assigned by local experts during the stakeholder engagement activity doi

Authors: Silvia Ronchi and Grazia Zulian
Data type: Numeric tables
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Suppl. material 3: Stakeholders engagement for the co-production of maps doi

Authors: Grazia Zulian, Silvia Ronchi
Data type: Document
Brief description: Collection of data and information provided by the participants involved in Workshops used for the co-production of maps
Filename: Stakeholders engagement.docx - Download file (17.72 kb)

Suppl. material 4: Catalogue of Urban Green Area with public facilities (Municipality of Cassano d'Adda) doi

Authors: Silvia Ronchi
Data type: Document
Brief description: Catalogue with information and photos on the urban green areas with public facilities in the Municipality of Cassano d'Adda.
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Suppl. material 5: Methodology for estimating the population-weighted density according to the size of buildings in each census blocks doi

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Authors: Grazia Zulian
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Brief description: map of the degree of urbanisation classes aggregated at municipality level
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Suppl. material 7: Demand index at Regional level, inhabitants within 4 km (A) and 300 m (B) from an area with high level of opportunities for nature-based recreation. doi

Authors: Grazia Zulian
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Endnotes

*1 The Regional GI proposal used in this paper was defined and published in August 2017, it is not yet final, the process of revising the Regional Landscape Plan is in progress (current date: February 2021).

*2 For more information visit the Italian Official Gazette

*3 The resident population at 31 August 2020 (source: GeoDemo ISTAT)

*4 For more information visit the Official Website of Cassano d'Adda