Ecosystem Service Assessment in Land Use Planning Decreasing Territorial Vulnerability. A Critical Exploration of Planning Problems Starting from the Land Take Regulation in Piedmont Region, Italy

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key words: ecosystem service, strategic environmental assessment (SEA), urban standards, land use planning, biodiversity, territorial vulnerability, land take

Abstract

Ecosystem Services (ES), e.g., benefits that the soil provides to communities, represents a new paradigm that supports the transition of land use planning towards environmental consideration. The application of ES during the decision-making process is crucial to make the ex-ante evaluation of the environmental and socioeconomic effects of land use changes. ES assessment supports the preliminary measurement of ecosystemic trends due to land use changes both biophysically and qualitatively. Nonetheless, even if the biophysical analysis of ES achieved optimal results, it has been less explored how to fill the gap between the theoretical evaluation of ES and its practical implementation for urban design. At the international and academic stage, the significance of ES is therefore high since one of the most prominent critics that come from the debate is that ES assessment is practically weak and insufficient to provide an operational framework for *effective utilization in land use planning in adapting to territorial vulnerabilities.*

The paper will consider the issues mentioned above analysing the land take regulation in the Piedmont Region, e.g., Law no. 302/2018 "Norme urbanistiche e ambientali per il contenimento del consumo del suolo". The paper intends to a theoretical reflection on how the operational application of ES can be actively and practically used to support land use planning especially performing ecological compensation for new urban development. In the methodological section, the General Land Use Plan of the city of Moncalieri, a city near Turin (Italy) will be evaluated testing the ecosystem performance based on the evaluation of three ES (Habitat Quality, Carbon Sequestration, Water Yield) of each land use zone. The calculation forwards an assessment of the most common regulative soil ES in Moncalieri finding a homogeneous distribution in the whole city both public and private on). The main findings of the research indicate that ES can be proactively used to increase the knowledge and the ecosystemic condition of the communities through their utilization for land use planning processes.

1. AN ECOLOGICAL PERSPECTIVE FOR SPATIAL PLANNING[1]

The global socioeconomic changes that are affecting cities require a radical reconsideration of the complex relations of urban system in order to address future challenges better (Gabellini, 2018)[2]. The crisis that under-stresses contemporary cities is mainly due to the progressive and uncontrolled "planetary urbanization"[3] (Brenner and Schmid, 2011) that increases both territorial and social vulnerabilities of cities (Brunetta e Caldarice, 2019).

The traditional emphasis posed to the city, as an accelerator of economic system (Jacobs, 1969), engine of globalization (Sassen, 1991) and attractor of innovation (Glaeser, 2011), today leaves the stage to the emerging the awareness of the importance that urban areas implies for environmental balance (Elmqvist *et al.*, 2013). Nowadays, there is growing attention to ecological issues that are crucial to addressing healthier conditions of the environment and citizens (Seto *et al.*, 2013). Synthetically, this perspective requires to a new cognitive approach on spatial planning and urban design – such as the growth control, the land take limitation and the application of urban regeneration at urban scale (Albrecht, 2017).

A crucial contribution to this emerging perspective comes from the field of Ecosystem Service (ES) studies that represents a new discipline aimed at consider the soil as a limited resource which play an essential role to the collective well-being limiting anthropic noises and generating new performances (Costanza *et al.*, 2017; Maes *et al.*, 2012; Partidario e Gomes, 2013). ES gained success in the early Nineties when referred to the environmental assessment of specific land use changes[4] (McPhearson *et al.*, 2015; Meerow e Newell, 2017), and therefore their importance was associated with their capacity of aiding the decision-making process for territorial government in addressing territorial vulnerabilities (Mooney *et al.*, 2009).

In this perspective, the ES can be necessary support for spatial planning and urban project as they allow understanding and evaluating the environmental effects deriving from the transformation of land use and their indirect economic and social consequences. The evaluation of SEs (Maes *et al.*, 2012; Pulighe *et al.*, 2016; European Commission 2016) needs to address the ecosystem value differences both in quantitative (biophysical and economic) and qualitative terms (trade-off between optimal functions and propensity to land uses), managing to evaluate the quality instead of the only amount of the transformed soil.

Unfortunately, the connections between the theoretical knowledge of the ES and their practical use in planning are still weak (Meerow & Newell, 2017). In particular, the methodologies for the quantification and mapping of the ES are not systemically oriented to the evaluation of the forecasted land use transformation in the Strategic Environmental Assessment (SEA) process. In this direction, analyses related to the implementation of the ecological effectiveness of land use plans should,

[1] This paper is the result of the combined research activity of the authors. Nonetheless, Ombretta Caldarice authors the final version of sections 1 and 4, while sections Stefano Salata authors 2 and 3.

[2] Contemporary cities are under challenging socio-economic changes (economic and financial crisis, emerging inequalities, poverty and social instances) and environmental too (land take and soil sealing, climate change, noise and pollution that affect human health). This situation requires a new role of spatial planning to find adequate solutions (Ponzini, 2016).

[3] In the United Nations Report entitled World Urbanization Prospects, in 2014 the 55% of the world's population is living in urban areas with a rising trajectory that will reach 66% in 2050. This data increases if compared with European cities (73% in 2014 and 82% in 2050) and in Italy (69% in 2014 and 78% in 2050).

[4] Ecological mitigation and compensation measures were not considered in the traditional planning procedure during the Seventies to the Nineties. Few examples in Italy (after the Nineties) considered environmental mitigation. An example is the Land Use Plan of Reggio Emilia (designed by Giuseppe Campos Venuti in 1999) that introduced as major innovation urban equalization and ecological compensation for urbanizations.

therefore, be innovated through the addition of criteria for guiding the ecosystem processes to integrate and support the tools that build the sustainable city project.

In this direction, the main innovation of mapping and assessing ES is therefore related to the capacity of understanding and also quantify socially and economically the effects of land use change. In a nutshell, ES are a" bridging concept" (Braat e de Groot, 2012) that lead to overcoming the simplistic vision of the nature against the human-made world, assuming that natural ecosystems are integrated with anthropic areas in its broad and inclusive meaning.

Within this context, the Piedmont Region recently approved the proposed legislation named "Norme urbanistiche e ambientali per il contenimento del consumo del suolo (Law no. 302/2018). The Law aims at pursuing a sustainable urban development limiting the land take and favoring, as an alternative, actions to restore the permeability and filtering capacity of soils, while not the urban regeneration and requalification of the existing built-up stock. The new Law integrates the rules defined by the Regional Plan giving priority to the land take limitation (with the objective to reach a no net land take on 2040). To reach this target, the Law introduces some limiting thresholds that define the amount of allowed urban transformations in specific sites with the temporal decay of building rights for planned but unrealized urban transformations. To what concerns ES, article 8 introduces the "urban/environmental standards"[5], here intended as the portion of the public city that has to be devoted to environmental ecology and ecosystem provisioning.

On the light of this new institutional framework, this contribution is focused on measuring and assessing the ecosystem performance of the City of Moncalieri (TO) with the support of spatial georeferenced maps of three ES[6] (Habitat Quality, Carbon Sequestration, Water Yield), that are selected to meet the principal soil supporting and regulative functions generated by the land use plan. Results are ecosystem indexes distributed for each functional parcel-based zone of the land use plan that are summoned up by a synthetic indicator that provides an average ES value for each regulative zone.

Discussions are focused on the distribution of the ES provisioning capacity of each functional area, taking into account the capacity of the land use plan to generate a healthier and sustainable city.

The study addresses two main issued: i) the quantitative knowledge of the ES delivering capacity for each functional zone and ii) the efficacy of the new Law no. 302/2018 to define the minimum amount ES for each functional zone.

The paper is structured in three parts: after the introduction, the first part introduces the practical application of ES in planning, the second describes the methodology for the spatial ES assessment in the city of Moncalieri, while the third provides a discussion around the results obtained forwarding some guidelines for spatial planning in an ecological perspective.

2. ECOSYSTEM SERVICES IN PRACTICE

ES paradigm stems from the academic literature of the Seventies on urban ecology (Sukopp, 2008) but has spread, from the Nineties onwards, with the aim of giving an economic weight to the contribution of ecological processes to human life that, traditionally, has been considered cost-free and unlimited. The logic behind the notion of ES then, is that the quantification of their economic value would encourage greater awareness of their indispensable role, would allow to consider them as components to be generally taken into consideration in the context of decision-making and, therefore, would foster social and political choices that are more environment-friendly and sustainable.

Despite several interpretations[7], in the urban planning framework the most suitable one links ES to the soil modification that, in turn, is one of the most influenced components by the impact of human activities (Pickett *et al.*, 2011) and their altering actions[8]. From this perspective, it can be said that soil has a good "ecosystem quality" when it provides ecological, economic and social functions, guaranteeing an adequate supply of ES (Borgogno-Mondino *et al.*, 2015).

From the taxonomic point of view, the European Environmental Agency (EEA) ranks the ES by the CICES classification (Common International Classification of Ecosystem Services). As Haines-Young and Potschin (2011) point out, «For the purposes of CICES, ecosystem services are defined as the contributions that ecosystems make to human well-being. They are seen as arising from the interaction of biotic and abiotic processes, and refer

[5] The Piedmont spatial planning law no. 56/1977 (updated by the Law no. 372013) defines urban standard as "the minimum public space per inhabitant that has to be provided for new urban areas" (Falco, 1987). Notably, the Law defines that for each new theoretical inhabitant the plan has to provide at least 25 sqm of public areas, updating the Italian Law no. 1444/1968 that fixed this amount at 18 sqm/inhabitant. In the Piedmont Region, this differential amount can be developed in private areas for public uses by an agreement between the Public Administration and the private owners (Caldarice, 2018).

[6] The methodology here employed has been experimented in the European project LIFE SAM4CP. For a synthetic view of this approach see Barbieri and Giaimo (2017).

[7] However, there is not yet an agreement about a standard definition of ecosystem services at the scientific level (Boyd and Banzhaf, 2007) as scholars provide definitions according to their research fields. The meaning issue is particularly relevant as it relates to ways the concept is understood, considering that ES do not relate to any natural phenomenon, but rather to a human interpretation.

[8] In short, urban soils are "substances sink" (Sauerwein, 2011).

specifically to the 'final' outputs or products from ecological systems».

CICES classifies ES in:

- provisioning services that supply goods and raw materials such as food, water, fuel, and biomass;
- regulating services that affect climate, air and water quality, soil formation through carbon sequestration and storage, erosion and nutrients control, regulation of the water quality, protection and mitigation of hydrological phenomena, genetic reserve and biodiversity conservation;
- cultural services that include non-material benefits, such as cultural identity, ethical and spiritual functions, aesthetic and recreational values, landscape and natural heritage.

Over the last ten years, moreover, the discussion on ES has broadened, both to orient a more precise determination of ecological and economic value and use of this paradigm in the decision-making process. On the first side, the assessment methods usually applied and approved base on the clear distinction between monetary and non-monetary techniques: the former aim to achieve a quantification in terms of ES money-value, while the latter aim to bring out quantities or qualities that cannot be quantified in terms of money and that can extend the values-spectrum considered. Monetary methods are predominant, as their results can be applied more easily in the decision making. On the contrary, non-monetary techniques are less common (Mononen *et al.*, 2016) but more diverse from the point of view of practices and outputs, being based on the principle that ES are "spatially explicit" (Haase *et al.*, 2014) and that it is therefore not possible to consider them without geographical references. In contrast with commodities, indeed, ES are not exchangeable, and therefore their location is a crucial characteristic for their value.

On the other side, instead, a wide and growing area of study focuses not only on the typological ES classification but also on the possible impact that they might have on planning tools, as it is now evident that changes in land use can crucially influence ES provision (Delphin *et al.*, 2016, Salata, 2014) and that spatial planning play a key role in protecting, safeguarding or improving them (Arcidiacono *et al.*, 2017).

However, today's knowledge on ecosystem values primarily aims to define the status indicators related to the statistical evaluation of the ecosystem-mean-value among land use classes (the current state) and addresses much less the values of the administrative zones of the local plan at the parcel-based level.

In order to make the land use plan an essential element for the ecological perspective, both analytical-assessment and designing dimensions require innovation in terms of contents, technique, and training process, in line with the new paradigm of ecosystem-proprieties of soils (Partidario and Gomes, 2013). This approach can proactively respond to the European Strategy for the Integration of Climate Change and Biodiversity (EU, 2013) in the process of Strategic Environmental Assessment-SEA for Plans and Programs. Briefly, we can state that the ES assessment in spatial planning and urban design is one of the challenges that scientific knowledge and administrative practice will have to face in the coming years in order to strengthen the universal awareness about environmental resources protection for ecosystems balance.

3. THE ECOSYSTEMIC PERFORMANCE OF THE CITY OF MONCALIERI

The City of Moncalieri, directly south from Turin, is located in the south-east axis that from the main town follows the Po river course along both the Turin-Piacenza-Brescia and Liguria directions, in line with Alessandria and Genoa. The town has a population of 57.234 inhabitants (ISTAT, 2017) and consists of about 6,200 buildings (as pointed out by the BDTre Digital Topographical Database of Piedmont Region).

Moncalieri territory has a quite diverse orography and consists of a flat part that develops mainly in the southern and western sectors of the municipal boundaries, and of the Po river basin that from the City of Moncalieri enters in Turin along the Turin hill ridge. In Moncalieri settlement has developed transversely to the longitudinal axis of the river, approaching to the bay which signals the Turin entrance. However, Moncalieri has also extensively expanded in the hilly northern part of the municipal territory, where settlements mainly distribute along the main streets that provide access to the Turin hill, also with high-density levels of land use. This high accessibility and infrastructure level is precisely what determines Moncalieri peculiarity: the city is located at the entrance of the North-Italian highway system and directly linked to the Turin beltway network. For this reason, the city has historically seen the development of large industrial areas, as the Vadò area, one of the largest in the metropolitan area. On the other hand, the Po River crossing has historically represented a limit to the development of settlements. Thus, in summary, the geological, morphological and hydrographic characteristics of Moncalieri make its municipal territory naturally susceptible to high levels of vulnerability.

The analysis on the macro categories of land use, according to the regional digital topographic database (2018), indicates that 34% of the territory consists of the anthropic system (including urban green spaces and urban free spaces), 39% comprises agricultural land, while the woodland occupies 14% of the territory. A remaining part of extra-urban green areas covers the 4% of the territory; the infrastructure system occupies the 6% while bodies of water represent the remaining 3%. The anthropic system, although no representing the majority of land uses, covers a significant ecological and landscape impact. The rate of impermeable soil, calculated with the spatial interpolation of data from the High-Resolution database built up area Imperviousness (2012), is about 26%, but the comparison with the anthropic system (permeability index of anthropic soil), shows that approximately 78% of urban land is impermeable (Table 1 and Figure 1 and Figure 2). This percentage expresses a remarkable critical level considering that in the stock of 1,638 hectares of urban land almost the 80% consists of impermeable material and therefore it is exposed to complete soil degradation, the consequent increase in hydrogeological risk and surface run-off, depletion of ecosystem functions and the increase of heat islands. The current land use plan (approved in 1997 and upgraded with several variations until the 2016 final version) is an instrument that has almost finished its building capacity. As the document review shows, the land use plan still has few zones that need to be completed, either through direct interventions with built-up permissions, or through new built-up expansion zones to design with new masterplans.

Primarily, the land use plan of Moncalieri has designed and regulated the current structure of the city based on a central settlement system laying on the Po river body and expansions along Corso Savona and Strada Torino axis, while industrial settlements are located in the south part of the city.

Table 1 - *Land use and land cover*

	Land use/cover type	Surface (ha)	Land use inex (%)
Land use	Antropic	1.638,87	34,48%
	Agricultura	1.838,60	38,68%
	Natural and Seminatural	654,44	13,77%
	Other (green)	173,21	3,64%
	Infrastructures	294,33	6,19%
	Water	153,54	3,23%
		4.752,99	100,00%
Land cover	Impermeable	1.276,94	26,87%
	Permeable	3.476,05	73,13%
		4.752,99	100,00%

Ecosystem assessment is developed according to three methodological steps:

1. *the mapping of the ES Habitats Quality, Carbon Sequestration and Water Yield in the Moncalieri area with the use of the Integrated Evaluation of Ecosystem Services and Trade-offs software (InVEST,http://naturalcapitalproject.stanford.edu/invest/) (see section 3.1);*
2. *the standardization of the values resulting from ES mapping and the GIS overlay analysis through the use of the Weighted sum function (Esri ArcGis 10.6), which considers the same weigh for the three variables to assess the distribution of ecosystem performance in comparison with the regulatory areas of the land use plan (see par. 3.2);*
3. *the review of PRG functional zoning, and the assessment of the relationships between regulatory areas and ES delivery capacity (see section 3.3).*

3.1 Mapping ES

The first methodological step is the ES mapping in relation with Habitat Quality, Carbon Sequestration and Water Yield[9] with the InVEST software (Sharp *et al.*, 2018). The program consists of a package, freely downloadable, which allows mapping different ES scales, starting from the statistical and cartographic data-collection in different formats (such as CSV tables, vector- polygons shape files with related table-specific fields, and geo-dataset raster files with cell values and excel dataset).

The three selected ES are defined as follows:

- *Habitat Quality* (HQ)[10] relates to the service of the ecosystem function that support habitats provided by the soil and its land use. This service is a good proxy of the ecological biopotentiality levels (BTC), that has been modelled without considering the "specific-species" quality;
- *Carbon Sequestration* (CS)[11] relates to the carbon-storage service of soils and of both underground (roots) and topsoil (stem and foliage) biomasses. This service is associated with the ability of soil and subsoil

[9] The selection of these three ES follows an extensive survey on regulation services that also consider nutrient retention services (Nutrient Retention) and sediment retention (Sediment Retention). However, when observing the orographic conditions of Moncalieri territory, these two ES do not allow to quantify the biophysical performance of the PRG zones, since the values referring to an area usually depend on the interaction of several landscape factors. Thus, it has been decided to limit the analysis just to those ES that can provide specific features of the areas, avoiding then ambiguous interpretations. Furthermore, it has to be said that when the study started (September 2018), both recreational and cultural values were not available for the Moncalieri as the data collection for the functions modelling was not yet completed.

[10] As pointed out form the InVEST User Guide, "*the habitat quality refers to the ability of the ecosystem to provide conditions appropriate for individual and population persistence, and is considered a continuous variable in the model, ranging from low to medium to high, based on resources available for survival, reproduction, and population persistence, respectively*".

[11] As pointed out form the InVEST User Guide, "*the model maps carbon storage densities to land-use or land-cover rasters, which include types such as forest, pasture, or agricultural land. The model summarizes results into raster outputs of storage, value, as well as aggregate totals*".

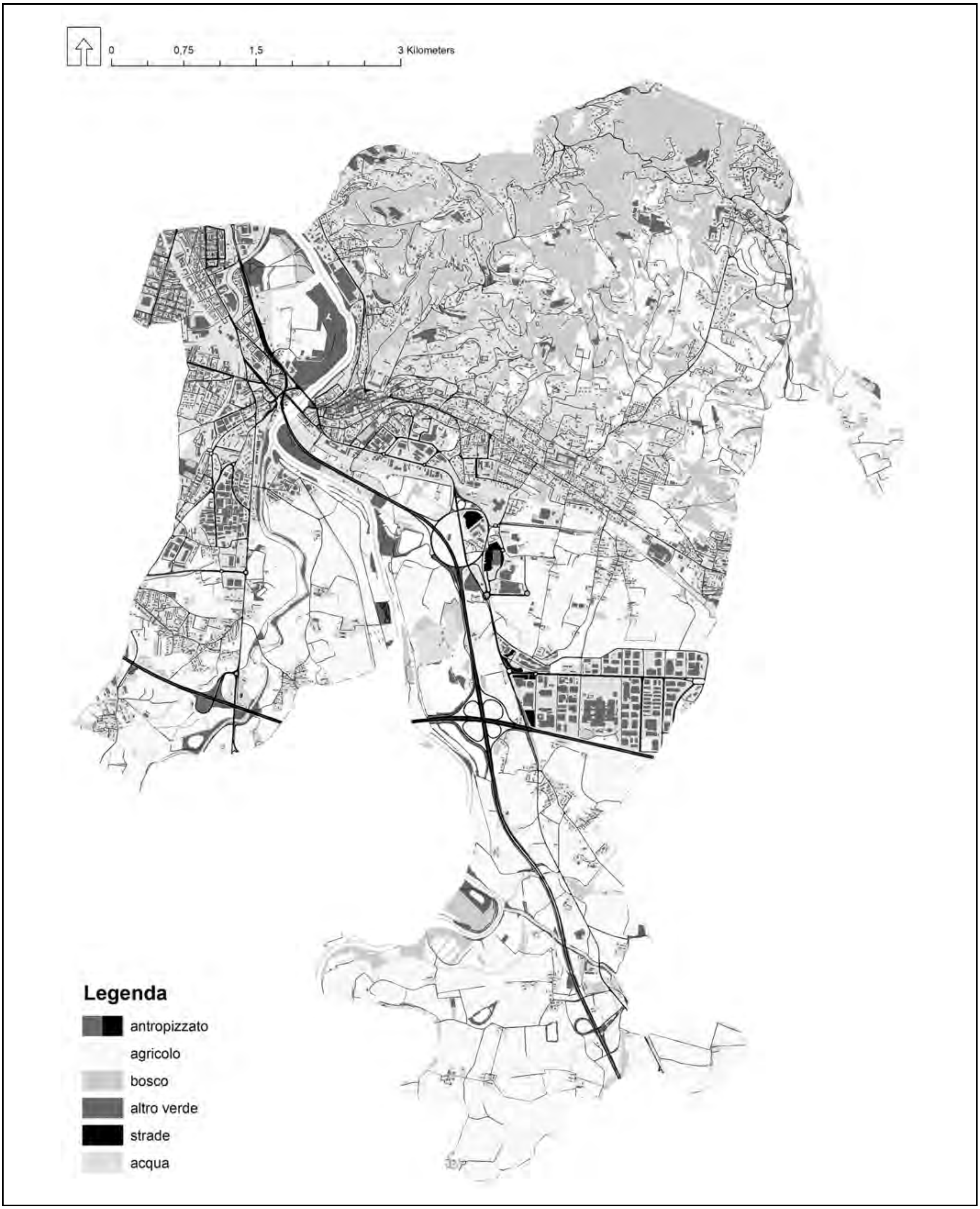

Figure 1 - *Land use in Moncalieri*

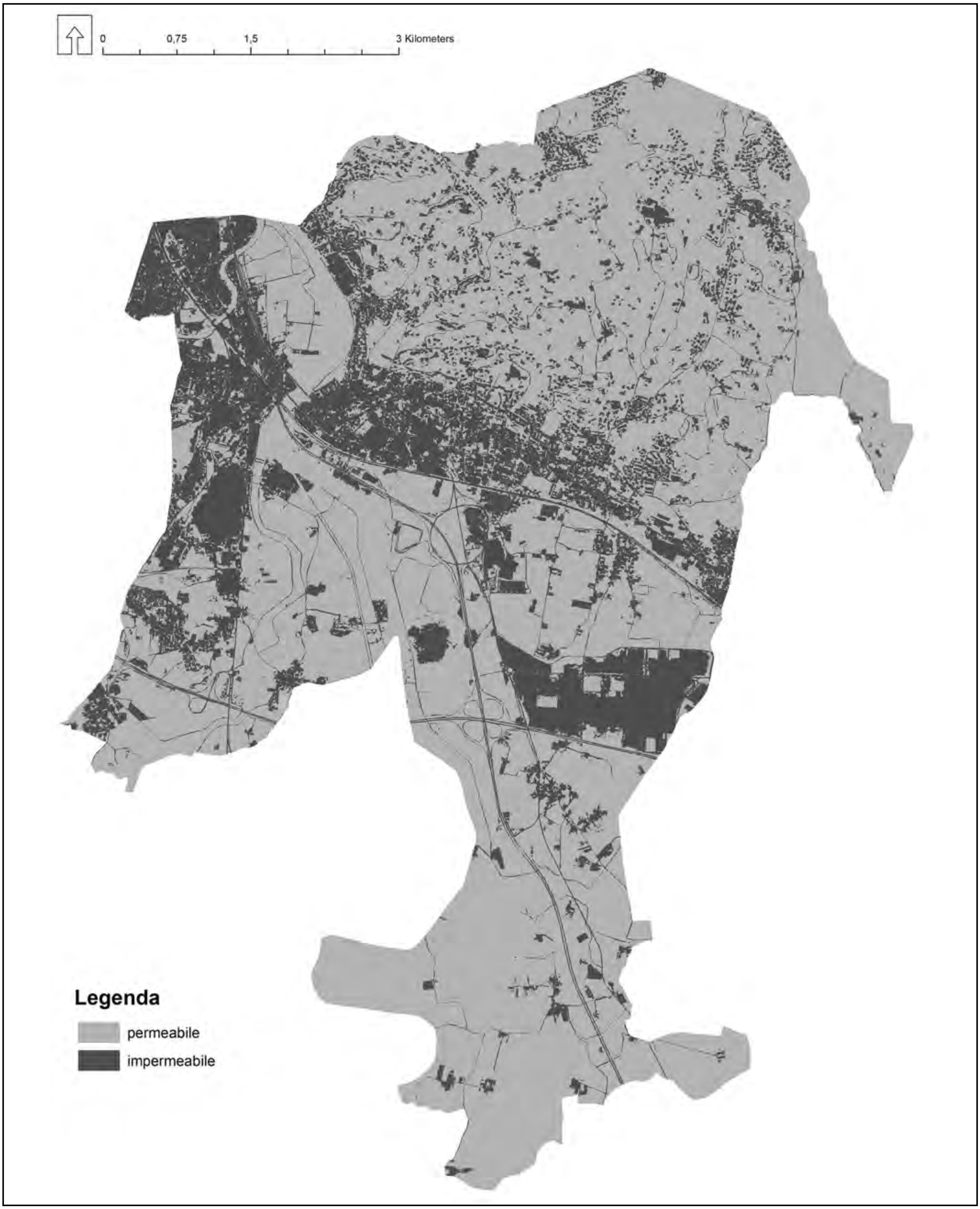

Figure 2 - *Land Cover in Moncalieri*

components to store organic carbon in the superficial layers of soil and in the litter;

- *Water Yield* (WY)[12] relates to the soil service of water retention due to its saturation capacity. This ES represents the water amount that can be retained and become available for evapotranspiration processes, hence avoiding flowing into fresh or groundwater. WY represents the "retention" function carried out by the soil about the annual average rainfall of the model.

The inputs related to the three models are

- land use, according to the Piemonte Land Use Cover 2010 and some additions at the local scale;
- nature-values related to land use: REP/ENP values (Ecological Network of the Province) with the integration of anthropic areas;
- threats and related interference with habitats (anthropic system together with agricultural areas and infrastructure network classified in primary, secondary and local roads);
- carbon storage values associated with land use classes as soil, litter, hypogaeum phytomass and epigeal phytomass (values are referred to the National Inventory of Forests and Carbon Foresters);
- the average depth of soil;
- average roots depth by vegetation typology;
- average annual rainfall in the area;
- Plant Available Water Content fraction (water portion that can be collected from the ground about the pedogenetic characterization of plants);
- the mean level of evapotranspiration in the area compared to the hydrographical basin baseline;
- potential evapotranspiration coefficient for vegetational species.

The outputs, represented in raster maps with 20-meter pixels, have been assessed according to:

- HQ spatialization, with values related to the analysis context (from 0 to 1);
- CS spatialization, with absolute values of stored carbon per pixel;
- WY spatialization, with absolute values of water, both retained by the annual soil and evapotranspirated per pixel.

3.2 Standardization and overlay with regulatory areas

InVEST software outputs have then been processed with an overlay analysis in order to compare the analytical results of the cartographic outputs with the different regulatory areas of the PRG. In this case, the process relies on the intersection between the information layer of the PRG homogeneous zones and the single layers of the three ES.

Before proceeding with the intersection, the outputs were firstly digitalized and then statistically normalized considering the maximum value provided by the references, i.e., the Metropolitan City of Turin.

Once elaborated the three HQ, CS and WY maps, they have been intersected with the land use plan-layer of regulatory zones and eventually dissolved with a statistical process based on the mean ecosystem value for each zone about the three services analysed. The whole procedure resulted in an analytical table about the ES average values in comparison with the (current) PRG regulatory areas.

This output shows the spatialization of the mean values for the three ES delivering capacity in the different zones of the plan and presents a comparative assessment of ES behaviours according to their spatial distribution. The Ecosystem Service Value (ESV) has been precisely calculated for this purpose (being the mean value for each homogeneous zone of HQ, CS, and WY) and represents a synthetic indicator of the total ecosystem performance in the area.

3.3 The Moncalieri ecosystemic performance

Overlaying the regulatory areas on the municipal topographic Dbtre-database, it is possible to verify the effective execution of the current PRG. As previously said, the ecosystem analysis extends to every PRG areas under the Implementing Technical Standards:

- A Zones, characterized by urban settlements, smaller centres, buildings, and buildings with historical-artistic, environmental or documentary value, and organised in Ar1 (urban settlements forming the historical centres), Ar2 (minor centres with environmental value) and AV (hill areas with environmental interest);
- B Zones, characterized by high density of buildings, and divided into Br (residential areas mainly or built entirely up), Bp (industrial, traditional, commercial and services areas), Bpr1 (transformation areas from industrial use to tertiary, commercial and dwelling ones) and Bpr2 (transformation areas from industrial to dwelling);
- C Zones, dominated by the not built part of the city, and organized in Cr (predominant residential destination), Crs (transformation areas from public services to public services-dwelling uses), Crc (transformation areas from public services to shopping mall, business services and dwelling) and Cp (partially built-up areas for industrial, business and tertiary use);
- special areas of transformation, distinguished in TCR

[12] As pointed out form the InVEST User Guide, "*the InVEST Reservoir Hydropower model estimates the relative contributions of water from different parts of a landscape, offering insight into how changes in land use patterns affect annual surface water yield and hydropower production*".

(transformation areas from service-use to tertiary activities, dwelling and services), TR (tertiary activities integrated with residential areas) and TE (tertiary areas where exhibition, administration and hospitality sectors are predominant);

- E Zones, set to agricultural functions, and articulated in Ee (empty or scarcely built-up areas in the rural flat territory and in the hilly side east of Strada Revigliasco), Ep (built-up areas, buildings and barracks located in the agricultural areas, but used for extra-agricultural productive uses), Es (plant nurseries) and Es1 (areas used for permanent greenhouses within residential areas);
- S Zones, meant for public spaces, community, public green spaces or parking as defined in the National Law 1444/1968, and distinguished in Sr (services for dwellings), Sp (services related to production centres, and to commercial, tertiary and hospitality activities) and Srp (services related to private settlements).
- F Zones, areas of general interest, articulated in FV (public parks or public urban and interurban uses), FH (social and healthcare facilities in the public dimension), FI (equipped areas for high-education), Ft (technological system areas of general interest), Frp1 (Regional PTO area for sports and free time), Frp2 (accommodation facilities and public park), Fg (general equipment of public interest) and Fe (religious purpose uses);
- the "Variante di Vadò", such as the urban reorganization project in the south-east industrial area of Moncalieri.

Considering the ecosystem assessment of Moncalieri, and in particular the detailed ES data-analysis, it emerges that regulatory areas of the land use plan can provide ES homogeneously (Table 2 and Figure 3a, Figure 3b, Figure 3c, Figure 3d). This becomes particularly evident in the ES amount for the A Zone (residential areas with historical, artistic and environmental value) because it coincides with the ES amount for C zones (PRG expansions areas). This condition relates that the ecosystem value in A Zone is strengthened by the disaggregated value of the hilly areas (Av Zones), while the C Zones (those areas where the land use plan imagines future expansions) are already located in the hilly part of the city next to the old town or along the main roads. Furthermore, it appears clear that the B Zones provide weak ecosystem performance (especially when relating to the Habitat Quality) because of their high soil-sealing values. The E Zones (agricultural lands representing the 38% of Moncalieri land use) are characterized by low ecosystem values (the lowest after the B zone soils) because of the high presence of plant nurseries and permanent greenhouses, which in fact undermine both the Habitat Quality and Carbon Sequestration performances (and in fact, the E Zones show the lowest HQ and CS performances of the Municipality, together with the FH ones). On the other hand, both S and F Zones (mainly public spaces) provide high ecosystem values, especially in the Frp2 hilly areas close to the Maddalena Park and in the FV urban and interurban public park areas where both hydrogeological reorganization and protection, improvement and promotion measures of natural-landscape resources are allowed.

4. TOWARDS AN ECOLOGICAL DIMENSIONING TO ADDRESS TERRITORIAL VULNERABILITY?

This article shows the main results of an ongoing research project that aims to question how the ES paradigm can be applied to local policy definition, starting from measurements and assessment of Moncalieri ecosystem performance. At the local scale, this application may guarantee the proper use of soils and consequently a response to territorial vulnerability. The underlying assumption of the study is that land use changes generally involve ES turnover and that consequently, urban planning may contribute to the ecosystems protection and the ES balance through a reasoned distribution of land uses in the plan.

In other words, the article provides a relevant contribution to the empirical knowledge about spatial planning, since it analyses and assess how the normative zone of the Moncalieri land use is able to give EC in an ecological perspective.

Besides the previous paragraph, it is evident that the ecosystem analysis points out that the so-called Private City, through its texture regulation and control and its land parameters for A, B and C Zones, provides an ecosystem input that is equal to the one provided by the so-called Public City (mainly located in S and Z Zones). In other words, this simulation highlights that not only the Public City, with the public areas and public use regulation, can contribute to the ES welfare provision with high ecosystem performance (as reported by the Regional Law 302/2018 of Piedmont Region).

Some methodological reflections may follow starting from the empirical results about the significance of the ES assessment within the land use plan, but also from the operational implications on its contents, techniques, and development process. First of all, the integration of the ecosystem dimension into the urban plan is not a simple operation because the performance of the soil related to one or more ES is not directly "standardizable" as it depends from the complex relationships between ecological and other variables. That is to say that the "ecosystem sizing operation" does not seem to have an action-dimension that can be easily pursued.

Law no. 302/2018 of Piedmont Region focuses precisely on these topics and tries to decline the environmental issue in a new operational perspective for urban planning that guarantees the recognition of the ecosystem functions for free, natural and rural areas, but also the transformations compensation, recovery, and environmental mitigation. In

Table 2 - *ES-mean-values related to the Regulation Zones of Moncalieri land use plan*

Regulation Zones	Area (ha)	HQ	CS	WY	ESV
ZONA A – Insediamenti urbani con carattere storico-artistico o ambientale	**851,6**	**0,181**	**0,231**	**0,512**	**0,337**
Ar1 – Centro storico	31,5	0,193	0,217	0,489	0,300
Ar2 – Nuclei minori con valore ambientale	41,7	0,169	0,245	0,534	0,300
Av – Aree collinari di interesse ambientale	778,5	0,393	0,281	0,558	0,411
ZONA B – Parti del territorio in gran parte o totalmente edificate	**389,0**	**0,114**	**0,200**	**0,470**	**0,246**
Br – Aree residenziali in gran parte edificate	284,0	0,100	0,217	0,490	0,269
Bp – Aree a destinazione produttiva	86,8	0,167	0,186	0,452	0,268
Bpr1 – Aree di trasformazione a prevalente terziario	10,5	0,097	0,177	0,444	0,239
Bpr2 – Aree di trasformazione a prevalente residenziale	7,7	0,039	0,169	0,417	0,208
ZONA C – Parti del territorio di completamento o di nuovo impianto	**353,7**	**0,278**	**0,231**	**0,503**	**0,337**
Cr – Aree a destinazione residenziale	293,2	0,280	0,286	0,577	0,381
Crs – Aree per residenza e pubblici servizi	11,2	0,286	0,229	0,507	0,341
Crc – Aree per centro commerciale integrato	2,5	0,194	0,191	0,451	0,279
Cp – Aree edificate a produttivo, commerciale e terziario	46,8	0,350	0,217	0,479	0,349
VARIANTE VADÒ	**196,0**	**0,270**	**0,198**	**0,469**	**0,312**
ZONE T – Aree speciali di trasformazione	**31,8**	**0,153**	**0,182**	**0,438**	**0,259**
TCR – Aree per attività terziarie, residenza e servizi	17,3	0,126	0,165	0,413	0,235
TR – Aree per attività direzionale e terziaria	4,4	0,149	0,180	0,452	0,260
TE – Aree a terziario prevalentemente espositivo	10,1	0,191	0,203	0,449	0,281
ZONE E – Parti di territorio destinate ad uso agricolo	**1.602,2**	**0,207**	**0,207**	**0,502**	**0,306**
Ee – Aree libere del territorio rurale di pianura	1.594,9	0,397	0,264	0,557	0,406
Ep – Aree edificate adibiti ad usi extragricoli	6,5	0,275	0,294	0,628	0,399
Es - Vivai	0,6	0,103	0,133	0,378	0,205
Es1 – Serre fisse	0,2	0,054	0,138	0,447	0,213
ZONE S – Spazi pubblici (art. 21 LUR 56/77)	**165,8**	**0,310**	**0,236**	**0,512**	**0,353**
Sr – Servizi residenziali	151,3	0,269	0,235	0,511	0,339
Sp – Servizi produttivi, commerciali, terziari e ricettivi	9,7	0,436	0,193	0,458	0,362
Srp – Servizi residenziali di tipo privato	4,8	0,225	0,279	0,567	0,357
ZONE F – Attrezzature ed impianti di interesse generale (art. 22 LUR 56/77)	**537,0**	**0,331**	**0,267**	**0,519**	**0,372**
FV – Aree a parco pubblico	484,7	0,540	0,291	0,548	0,460
FH – Attrezzature socio sanitarie ed ospedaliere	1,4	0,041	0,208	0,459	0,236
FHP - Attrezzature socio sanitarie ed ospedaliere di tipo privato	3,1	0,604	0,304	0,453	0,454
FI – Attrezzature per istruzione superiore	6,0	0,238	0,256	0,538	0,344
Ft – Aree per impianti tecnologici	19,1	0,227	0,218	0,490	0,311
Frp1 – Area del PTO destinata a uso sportivo e tempo libero	6,6	0,284	0,240	0,535	0,353
Frp2 – Aree per attrezzature ricettive e parco pubblico	0,6	0,697	0,422	0,628	0,582
Fg – Aree per attrezzature generali di interesse pubblico	3,6	0,098	0,198	0,461	0,253
Fe – Aree a destinazione religiosa	11,8	0,253	0,265	0,555	0,358

Figure 3a - *Ecosystem performance of Moncalieri Municipality: Habitat Quality*

Figure 3b - *Ecosystem performance of Moncalieri Municipality: Carbon Sequestration*

Figure 3c - *Ecosystem performance of Moncalieri Municipality: Water Yield*

Figure 3d - *Ecosystem performance of Moncalieri Municipality: Ecosystem Service Value* other words, the DDLR 302/2018 supposes that the 7 sqm/ per capita of planning obligations (corresponding with the spread between the national minimum size of 18 sqm/ per capita - introduced by National Law no.1444/1968- and the Piedmont Law no. 56/1977 size of 25 sqm/per capita), can be defined as "environmental planning obligations"[13], his issue allows to consider them as public areas where compensation interventions from land consumption, recovery, settlement and environmental mitigation can be located, hence providing a good quality amount of environmental, ecological and ecosystem services able to reduce vulnerabilities. As defined in DDLR 302/2018, ecosystemic performances shall be evaluated by the PRG through its land use regulations referred to the Public City, assuming that minimum quality objectives and sustainable requirements should be met. However, it is now evident that the simple relation between the ecosystem dimensioning and the planning obligations as a paradigm of the "land take regulation" /"limiting soil consumption", is a narrow perspective. Indeed, what emerges from the PRG regulatory zones assessment is that high levels of ES arise not only from normative areas, but also from the Private City. This last one actually contributes to high levels of soils-environmental performance especially in the hilly areas (PRG Zone A) and in the agricultural ones (Zones E). To summarise, the pure quantitative dimensioning of ecosystem performance of soil-public-functions does not seem to be a favourable perspective for the correct ecosystem compensation. On the other hand, the present proposal seeks two other more general elements. The first one, in line with the DLLR 302/2018, expects that, together with the ecosystem dimensioning, qualitative parameters are introduced in any public property projects. This step might favour the interpretation of the ecosystem components needed to achieve: good percentages of soil permeability, satisfactory numbers of trees and shrubbery according to the species-ecological-functions, standard rules for open spaces, and wetlands prediction. The second one, instead, calls for a rethinking in the ecosystem-oriented approach as reported by the Guidelines for the Integration of Climate Change and Biodiversity in the Strategic Environmental Assessment (SEA) of the European Union (2013). This document considers the SEA as the mandatory instrument for introducing ES into the planning process with a holistic approach which overcomes the sectorial nature of traditional environmental assessments (Brunetta, 2006). In practice, the ES could be applied in the SEA both in the baseline and scoping phase in order to collect data from the baseline scenario and to identify the assessment key issues; and also in consideration of the project alternatives (as they represent the objectives and evaluation criteria). For instance, with this new perspective, the general purpose of "protecting and increasing biodiversity" could be reformulated according to the ecosystem logic as "considering a certain transformation, which kind of effects will result from ES biodiversity?".

In this view, despite mapping ES supports the definition of SEA targets, the knowledge of land use ES performance is an asset to understand which is the real suitability of uses in urban and rural areas comparing existing uses and their coherence with the optimal ones. This knowledge should support the decision that regards an optimization/upgrade of uses where actual utilizations does not reach an efficient performance in terms of ES delivering capacity.

Closer integration and reciprocal dialogue between ecosystem analysis, zoning tools, and SEA procedures would thus allow overcoming the general extension to the whole municipal territory of mitigation and compensation responses to territorial vulnerabilities, focusing instead on different and specific solutions in line with the regulatory areas of the Plan. This new cognitive dimension might mainly work for an urban planning doctrine that can develop and adopt new and renewed tools, which in turn express a more flexible, resilient and ecologically oriented paradigm.

[13] Article 8 paragraphs of Law no. 302/2018 specify that this perspective can also be applied to those standards related to both production and commercial functions and the additional areas provision for public facilities of general interest related to housing uses. In this way, an extra-amount of 15 sqm/per capita for urban and public parks, may be used as a location space for those interventions directly derived from compensations in order to improve the territorial ecological connectivity and biodiversity.

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References

Albrechts L., "Some ontological and epistemological challenges", in Albrechts L., Balducci A., Hillier J. (eds.), *Situated Practices of Strategic Planning. An international perspective*, Routledge, London and New York, 2017, pp. 1-11.

Arcidiacono A., Ronchi S., Salata S., *Un approccio ecosi-*

stemico al progetto delle infrastrutture verdi nella pianificazione urbanistica. Sperimentazioni in Lombardia, Urbanistica, No. 157, 2017, pp. 102-110.

Barbieri C.A., Giaimo C., *Paradigmi ecosistemici, piano urbanistico e città contemporanea. L'esperienza del progetto LIFE SAM4CP*, Urbanistica, No. 157, 2017, pp. 114-121.

Boyd J., Banzhaf, S., *What are ecosystem services? The need for standardized environmental accounting units*, Ecological Economics, No. 63, 2007, pp. 616-626.

Borgogno-Mondino E., Fabietti G., Ajmone-Marsan F., *Soil quality and landscape metrics as driving factors in a multicriteria GIS procedure for peri-urban land use planning*, Urban For Urban Green, No. 14, 2015, pp. 743-750.

Braat L., de Groot R.S., *The ecosystem services agenda : bridging the worlds of natural science and economics, conservation and development , and public and private policy*, Ecosystem Services, No. 1, 2012, pp. 4-15.

Brenner N., Schmid C., "Planetary urbanisation", in Matthew G. (eds.), *Urban Constellations*, Jovis, Berlin, 2011, pp. 10-13.

Brunetta G., Caldarice O., "Putting Resilience into Practice. The Spatial Planning Response to Urban Crisis", in Brunetta G., Caldarice O., Tollin N., Rosas-Casals M., Morató J. (eds.) *Urban Resilience for Risk and Adaptation Governance. Theory and Practice*, Springer, Cham, 2019, pp. 27-41.

Brunetta G., *Valutazione e pianificazione. Verso l'integrazione?*, Scienze Regionali – Italian Journal of Regional Science, Vol. 5, No. 3, 2006, pp. 119-126.

Caldarice O., *Reconsidering Welfare Policies in Times of Crisis. Perspective for European Cities*, Springer, Cham, 2018.

Campos Venuti G., *Le innovazioni del piano: perequazione ed ecologia*, Urbanistica, No. 112, 1999, pp. 66-74.

Costanza R., de Groot R., Braat L., Kubiszewski I., Fioramonti L., Sutton P., Farber S., Grasso M., *Twenty years of ecosystem services: How far have we come and how far do we still need to go?,* Ecosystem Services, Vol. 28, 2017, pp. 1-16.

Delphin S., Escobedo F.J., Abd-Elrahman A., Cropper W.P., *Urbanization as a land use change driver of forest ecosystem services*, Land Use Policy, No. 54, 2016, pp. 188–199.

Elmqvist T., Fragkias M., Goodness J., Güneralp B., Marcotullio P.J., McDonald R.I., Parnell S., Schewenius M., Sendstad M., Seto K.C., Wilkinson C. (eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, Springer, Dordrecht, 2013.

European Commission, *Mapping and Assessment of Ecosystems and their Services*, Luxembourg, 2016.

European Union, *Guidance on integrating climate change and biodiversity into strategic environmental assessment,* Luxembourg 2013.

Falco L., *I "nuovi" standard urbanistici*, Edizioni delle Autonomie, Roma, 1987.

Gabellini P., *Le mutazioni dell'urbanistica. Principi, tecniche, competenze*, Carocci Editore, Roma, 2018.

Glaeser E., *The Triumph of the City*, Macmillan, London, 2011.

Jacobs J., *The Economy of Cities*, Random House, New York, 1969.

Haase D., Frantzeskaki N., Elmqvist T., *Ecosystem Services* in Urban Landscapes: Practical Applications and Governance Implications. Ambio, No. 43, 2014, pp. 407-412.

Haines-Young R., Potschin M., "The links between biodiversity, ecosystem services and human well-being", in Raffaeli D., Frid C. (eds.), *Ecosystem Ecology: A new Synthesis*, Cambridge University Press, Cambridge, 2011, pp. 110-139.

Maes J., Egoh B., Willemen L., Liquete C., Vihervaara P., Schägner J.P., Grizzetti B., Drakou E.G., La Notte A., Zulian G., Bouraoui F., Paracchini M.L., Braat L., Bidoglio G., *Mapping ecosystem services for policy support and decision making in the European Union*, Ecosystem Services, Vol. 1, No. 1, 2012, pp. 31-39.

McPhearson T., Andersson E., Elmqvist T., Frantzeskaki N., *Resilience of and through urban ecosystem services*, Ecosystem Services, Vol. 12, 2015, pp. 152-156.

Meerow S., Newell J.P., *Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit*, Landscape and Urban Planning. Vol. 159, 2017, pp. 62-75.

Mononen, L., Auvinen, A.P., Ahokumpu, A.L., Rönkä, M., Aarras, N., Tolvanen, H., Kamppinen, M., Viirret, E., Kumpula, T., Vihervaara, P., *National ecosystem service indicators: Measures of social-ecological sustainability,* Ecological Indicators 61, 2016.

Mooney H., Larigauderie A., Cesario M., Elmquist T., Hoegh-Guldberg O., Lavorel S., M Mace G., Palmer M., Scholes R., Yahara T., *Biodiversity, climate change, and ecosystem service,* Current Opinion in Environmental Sustainability, No. 1, 2009, pp. 46-54.

Partidario M.R., Gomes R.C., *Ecosystem services inclusive strategic environmental assessment*, Environmental Impact Assessment Review, Vol. 40, 2013, pp. 36-46.

Pickett STA, Cadenasso ML, Grove JM, Boone CG, Groffman PM, Irwin E., Kaushal SS. Marshall V. McGrath BP. Nilon CH, Pouyat RV, Szlavecz K., Troy A., Warren P., *Urban ecological systems: Scientific foundations and a decade of progress*, Journal of Environmental Management, Vol. 92, No. 3, 2011, pp. 331-362.

Ponzini D., *Introduction: crisis and renewal of contemporary urban planning*, European Planning Studies, Vol. 24, No. 7, 2016, pp. 1237-1245.

Pulighe G., Fava F., Lupia F., *Insights and opportunities from mapping ecosystem services of urban green spaces and potentials in planning*. Ecosystem Services, No. 22, 2016, pp.1-10.

Salata S., *Land take in the Italian Alps,* Management of Environmental Quality: An International Journal, No. 25, 2014, pp 407-420.

Sassen S., *The Global City: New York, London, Tokyo*, Princeton University Press, Princeton, 1991.

Sauerwein M., "Urban Soils-Characterization, Pollution, and Relevance in Urban Ecosystems", in Niemelä J., Breuste J., Thomas E., Glenn G., Philip J., McIntyre N.E. (eds.), *Urban*

Ecology, Oxford University Press, Oxford, 2011, pp. 45-58.

Seto K.C., Parnell S., Elmqvist T., "A Global Outlook on Urbanization". Elmqvist T., Fragkias M., Goodness J., Güneralp B., Marcotullio P.J., McDonald R.I., Parnell S. Schewenius M., Sendstad M., Seto K.C., Wilkinson C. (eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, Springer, Dordrecht, 2013.

Sharp R., Tallis H.T., Ricketts T., Guerry A.D., Wood S.A., Chaplin-Kramer R., Nelson E., Ennaanay D., Wolny S., Olwero N., Vigerstol K., Pennington D., Mendoza G., Aukema J., Foster J., Forrest J., Cameron D., Arkema K., Lonsdorf E., Kennedy C., Verutes G., Kim C.K., Guannel G., Papenfus M., Toft J., Marsik M., Bernhardt J., Griffin R., Glowinski K., Chaumont N., Perelman A., Lacayo M., Mandle, L., Hamel P., Vogl A.L., Rogers L., Bierbower W., Denu D., Douglass J., 2018.

Sukopp H., *On the early history of urban ecology in Europe*, in Marzluff J.M, Shulenberger E., Endlicher W., Alberti M., Bradley G., Ryan C., Simon U., ZumBrunnen C. (eds), Urban Ecology, Springer, Boston, 2008.