Earth Syst. Dynam. Discuss., 3, 1159–1190, 2012
www.earth-syst-dynam-discuss.net/3/1159/2012/
doi:10.5194/esdd-3-1159-2012

Earth System Dynamics Discussions

Urbanization susceptibility maps: a dynamic spatial decision support system for sustainable land use

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Received: 20 September 2012 – Accepted: 27 September 2012 – Published: 4 October 2012

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Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

Recent developments in land consumption assessment identify the need to implement integrated evaluative approaches, with particular attention to the identification of multidimensional tools for guiding and managing sustainable land use. Policy decisions defining land use are mostly implemented through spatial planning and related zoning, and this involves trade-offs between many sectoral interests and conflicting challenges aimed at win-win solutions. In order to identify a decision-making process for land use allocation, the paper proposes a methodological approach for a Dynamic Spatial Decision Support System (DSDSS), named Integrated Spatial Assessment (ISA), supported by Geographical Information Systems (GIS) combined with Analytic Hierarchy Process (AHP). Through the empirical investigation in an operative case study, an integrated evaluative approach implemented in a DSDSS helps to elaborate "urbanization susceptibility maps", where spatial analysis combined with a multi-criteria method proved to be useful for facing the main issues related to land consumption and minimizing environmental impacts of spatial planning.

1 Introduction

Urban development and land consumption are two of the major conflicting forces driving land use and land cover change, characterizing cities growth and their sustainability. The problematic expansion of development at the expense of open space and natural resource lands has sparked intense interest and conflicting debate over the critical aspects and potentials of territorial transformations (Weber et al., 2006; Potschin, 2009; Walter and Stützel, 2009; Schetke et al., 2012; Terzi and Bölen, 2012).

If we consider the European reality, it is evident that Europe is one of the most urbanized continents in the world (EEA, 2009). Cities are economic engines and also the context of environmental, cultural and social quality of life, but the open conflict between economic growth and cultural, social and environmental development determines many

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different consequences in urban and territorial transformations, as urban sprawl and the spread of low-density settlements, increasing the pressure on greenfield land.

The ongoing urbanization and conversion of territory is perceived as one of the main challenges facing in the definition of transformation strategy. At the same time, a general lack of consideration of the value of soil, which is not recognized as a limited and non-renewable resource, implies many different territorial criticalities, related to the impoverishment of agricultural land, urban dispersion, spatial and ecological fragmentation, etc., and imposes the need to consider land consumption as an essential aspect that has to be supported by suitable modalities for its measurement and assessment at all different levels of urban and territorial planning (Hasse and Lathrop, 2003; De La Rosa, 2005; Tsai, 2005; Huang et al., 2007; Peng et al., 2007; Torrens, 2008; Jones et al., 2009; Lobley and Winter, 2009; Gerundo and Grimaldi, 2011).

Soil is an extremely complex, variable and living medium, a non-renewable resource which performs many vital functions: it is the interface between the earth, the air and the water, and it has a role as a habitat and gene pool, serves as a platform for human activities, landscape and heritage, and acts as a provider of raw materials. These functions are worthy of protection because of their socio-economic as well as environmental importance. Today soil degradation (erosion, loss of organic matter, compaction, salinization, landslides, contamination, sealing, etc.) is accelerating, with negative effects on human health, natural ecosystems and climate change, as well as on economy (EC, 2012). Indeed, soil degradation is exacerbated by human activities, such as certain agricultural and forestry practices, industrial uses, tourism and urban development (COM, 2006a). In particular, “land take”, also referred to land consumption, describes an increase of settlement areas over time. This process includes the development of scattered settlements in rural areas, the expansion of urban areas around an urban nucleus (including urban sprawl), and the conversion of land within an urban area (densification). Depending on local circumstances, a greater or smaller part of the land take will result in actual soil sealing (EC, 2012).

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At present, approximately 75 % of the European population currently lives in urban areas, and by 2020 it is estimated that this will increase to 80 % (EEA, 2010a); but since the mid-1950s the total surface area of cities in the EU has increased by 78 %, whereas the population has grown by only 33 % (EEA, 2006). Today, the European areas classified as "peri-urban" have the same amount of built-up land as urban areas, but are only half as densely populated (Piorr et al., 2011). According to data published by the European Environment Agency in the context of Corine Land Cover for the years 1990, 2000 and 2006 (CLC, 2012), it has been estimated that detected land take between 1990 and 2000 was around 1000 km^2 per year in the EU, and settlement areas increased by nearly 6 % (Prokop et al., 2011). From 2000 to 2006, the rate of land take decreased slightly to 920 km^2 per year, while the total settlement area increased by a further 3%. This corresponds to an increase of almost 9 % between 1990 and 2006 (from 176 200 to 191 200 km^2). But, in the same period, the population increased by only 5 %, though there is a wide difference in population growth across Europe and within regions (EC, 2012). It has been configured a growth of urbanized areas much more complex and confusing, which was further accentuated by the progressive and concomitant expansion of the long-distance mobility basins and threatens to irreversibly alter the polycentric character of many European urban regions.

Urban sprawl, exploded city, urban nebula, urbanized landfarm, peripheralization of countryside, etc., are just some of the definitions that identify the most significant phenomenon in the territory transformation and evoke the idea of a more indefinite and unstructured space, without an effective system of planning. In general, urban areas have expanded further at the expense of all other land-cover categories, with the exception of forests and water bodies. Urbanization and expanding transport networks are fragmenting habitats, and affecting ecosystem services, playing a crucial role because they influence water, nutrient and carbon cycles too. Indeed, soil organic matter is a major terrestrial sink of carbon and thus important for mitigating climate change. Peat soils represent the highest concentration of organic matter in all soils followed by extensively managed grassland and forest: soil carbon losses thus occur when these

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systems are converted. Loss of these habitats is also associated with decreased water retention capacity, increased flooding and erosion risks and reduced attractiveness. While the slight forests increase is a positive development, the decline of natural and semi-natural habitats (including grassland, bogs, heaths and fens) is a major cause for concern (EEA, 2010a, b, c). The long-term sustainability of Europe's land use was a focus of the *European Spatial Development Perspective* (EC, 1999). Its vision has been carried forward and supplemented with new priorities by the *Territorial Agenda* of the EU and the *Action Programme* for its implementation (COPTA, 2007) which defined an intergovernmental programme of work up to 2011. Indeed, in Europe there are a variety of initiatives that have been developed over the past years aiming at the collection of soil information. These initiatives were developed over a time frame of several decades and were coordinated by actors at different levels: Global (FAO, UNEP, etc.), European (EU, ECE/ICP Forest, FOREGS), National, Regional and Local. Different approaches are required for each of the recognized threats to European soils. While some of the threats may require systematic monitoring, other threats need a more focused approach taking into account the fact that they do not occur everywhere in Europe. Indeed, stratification of the European soils according to susceptibility to each of the single threats would allow developing targeted monitoring approaches for each of these (Van-Camp et al., 2004).

Different EU policies (for instance on water, waste, chemicals, industrial pollution prevention, nature protection, pesticides, agriculture) are contributing to soil protection. The Commission adopted a *Soil Thematic Strategy* (COM, 2006a) and a proposal for a *Soil Framework Directive* (COM, 2006b) with the objective to protect soils across the EU and how use it in a sustainable way on the regional and local territory. About five years after the adoption of the *Soil Thematic Strategy*, the European Commission published a policy report on the implementation of the Strategy and ongoing activities (COM, 2012). The report provides an overview of the actions undertaken by the European Commission to implement the four pillars of the Strategy, namely awareness raising, research, integration, and legislation in order to protect European soils and

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ensuring their sustainable use. According to this perspective, the European Commission has elaborated the *Guidelines on best practice to limit, mitigate or compensate soil sealing* (EC, 2012) in order to identify the impacts of soil sealing, to recognize some common aspects, to limit the soil sealing phenomenon and mitigating and compensating the effects. The *Commission Staff Working Document* describes approaches based on three main strategies:

1. *Limiting*, that means preventing the conversion of green areas and the subsequent sealing of (part of) their surface. The re-use of already built-up areas, e.g. brownfield sites, can also be included in this concept. Targets have been used as a tool for monitoring as well as spurring progress, and creating incentives to rent unoccupied houses has also helped in limiting soil sealing.

2. *Mitigating*, that means identify some appropriate mitigation measures in order to maintain some of the soil functions and to reduce any significant direct or indirect negative effects on the environment and human well-being. For example, these include using permeable materials instead of cement or asphalt, supporting green infrastructure, and making wider use of natural water harvesting systems.

3. *Compensating*, that means to select some compensation measures, considering, however, that sealing cannot be exactly compensated for. Indeed, the purpose is to sustain or restore the overall capacity of soils in a certain area and to fulfill (most of) their functions.

The on-going urbanization and conversion of landscape and territory is perceived as one of the main challenges, and the *Roadmap to a Resource Effcient Europe* (COM, 2011) proposed that by 2020, also recognizing that land take is generally connected with soil sealing. The Roadmap proposes that EU policies take into account their direct and indirect impact on land use in the EU and globally, and that the rate of land take is on track with an aim to achieve no net land take by 2050. In this perspective, spatial planning can play an important role in achieving a more sustainable land use by taking

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account of the quality and characteristics of different land areas and soil functions against competing objectives and interests, in a long term view.

Through the empirical investigation in an operative case study elaborated during the Strategic Environmental Assessment (SEA) for the City Plan of the municipality of Montecorvino Rovella in the Province of Salerno, in Southern Italy, it was structured an integrated evaluative approach implemented in a Dynamic Spatial Decision Support System (DSDSS), named Integrated Spatial Assessment (ISA). This approach, supported by Geographical Information Systems (GIS) combined with Analytic Hierarchy Process (AHP), helps to elaborate urbanization susceptibility maps, where spatial analysis joined with multi-criteria methods allows to identify the main issues related to land consumption, also minimizing environmental impacts of City Plan strategies.

2 Integrated approaches and tools

Policy and planning decisions shaping land use involve different and several trade-offs between many sectoral interests (industry, transport, energy, mining, agriculture and forestry, etc.). These trade-offs can be tackled through integrated programmes and integrated approaches for land use, spatial planning and land management practices, that include the implementation of renewable energy targets, forest and agricultural land use, the role of green infrastructure, the re-use of land and a more general land resource management (EEA, 2010c).

According to the above perspective Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) are important tools for evaluating plans, programmes and projects which have impacts on land resources. Indeed, their implementation has shown that they can improve the consideration of environmental aspects, contributing to a more systematic and transparent planning, and increasing participation and consultation of stakeholders (public, NGOs, associations, different authorities at all levels, etc.). However, the effectiveness of the tools, in particular the SEA, is strictly linked to the approach followed regarding screening criteria, identification of

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alternatives, and an improved data situation (EC, 2009). The European Commission has noted (COM, 2009) that the effect of SEA and EIA Directives could be further improved by better guidance regarding impact assessment. As regards the SEA Directive, it would become more effective if it was also applied to policies or voluntary plans and programmes, stressing the need for sustainable and efficient use of soil resources, and considering the demographic and regional situation and the vast potential for inner urban redevelopment.

Indeed, the existing relationships between zoning and physical structure of urban environments suggest that the evaluation of the environmental consequences has to be an integral part of the planning process. This means that it is essential to identify suitable approaches, instruments and indicators for land consumption assessment in order to implement principles and models of local sustainable urban development. Increasing attention to the SEA process and its articulation shows that it is necessary to apply SEA in the earliest stages of the plans and/or programmes decision-making process so that it can be truly effective in improving the organization of different phases and make the evaluation operational. It also becomes necessary to determine the stage of the decision-making that is most appropriate for the integration of SEA approaches and techniques. In particular, complete integration of SEA within the planning process requires correct understanding of the decision-making process in its different phases, along with the need to identify specific contributions of the different professional fields involved. Decisions are made after considering a number of different and sometimes conflicting points of view and variables in which environmental issues are only one of the aspects taken into account in an interdisciplinary approach. Developing a SEA process in an integrated and participatory way means considering how different points of view, components and values can contribute to understand the key issues and select alternatives.

The structure of the SEA process as a tool to support decision-making should adapt to the type and content of the plan or program in question and the relative procedural phases without compromising the specific nature of the approach itself. At the

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same time, it is essential to combine different techniques and tools within the same framework, integrating various evaluation tools in order to define a multi-methodological framework that can analyze and tackle the different issues. In particular, some methods offer the possibility of combining Multi-Criteria Analysis and Multi-Group Analysis with Geographical Information Systems (GIS), Internet Technology, Spatial Decision Support Systems, Cellular Automata Models, contributing to the construction of a Dynamic Spatial Decision Support System (Cerreta and De Toro, 2012a; Fusco Girard and Torre, 2012; Perchinunno et al., 2012). A great variety of territorial information can be easily combined and related to the characteristics of the different land use options, facilitating the construction of appropriate indicators and improving impact forecasting, leading to a preference priority list of the various options.

In particular, integration of Multi-Criteria Analysis, Multi-Group Analysis and GIS can be useful in the presence of strong environmental and social conflicts as land consumption or land take, in which the role of local resources and social actors, their relations and objectives can be considered structuring elements in the development of a dynamic spatial evaluative model. In this process, spatial analysis, performed using spatial data, can include methods able to explore the spatial relationships between features both real and theoretical, extracting or creating new information about a set of geographic features (techniques to determine the distribution of a spatial feature, the relationships between two or more features, etc.), and the study of the locations and shapes of geographic features and the relationships between them. Integration of Multi-Criteria Analysis, Multi-Group Analysis and GIS supports the definition of a spatial multi-criteria decision-making process, able to involve a set of geographically defined alternatives compared respect to a given set of evaluation criteria and taking into account decision-makers' preferences (Cerreta et al., 2012; Cerreta and Mele, 2012). This means that results of the analysis depend not only on the geographic distribution of attributes but also on the value judgments involved in the decision-making process. Spatial analysis combined with multi-criteria methods has been used in recent years

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to support evaluation, especially in the field of land use planning, and can be a useful approach for facing the main issues related to land consumption.

According to the above perspective, the proposal of a multi-methodological evaluative framework can help generate more efficient and effective results than sector-specific approaches. The Integrated Spatial Assessment (ISA) (Fusco Girard and De Toro, 2007; Cerreta and De Toro, 2010, 2012b) can be useful for the recognition of tangible and intangible values, including the development and definition of goals, the sharing of knowledge, negotiation and compromise, and the evaluation of needs. The proposed approach can help communities clarify values, be more adaptive and proactive, respond to change, set personal and collective goals, and participate in the decision-making process. At the same time, the application of spatial tools is useful in identifying territorial references linking values and planning choices.

3 Integrated Spatial Assessment (ISA) approach for Montecorvino Rovella City Plan

3.1 Urbanization susceptibility maps

The Integrated Spatial Assessment (ISA) approach was applied to the new City Plan of the municipality of Montecorvino Rovella in the Province of Salerno, in Southern Italy. Throughout the experimentation, the aim was to build a new methodology that could help recognize the main values, create a greater cohesion about environmental protection and the safeguard of local resources, and stimulate the reduction of soil consumption for a more sustainable use of the territory. The ISA approach can also support to identify territorial impacts deriving from plan strategies and actions.

In order to structure a Dynamic Spatial Decision Making-Process, the environmental complexity has been explored taking into account a smaller number of essential elements, able to provide the useful strategic information that schematizes the

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multidimensional character of the territory. Therefore, the tools used in this process are the following:

1. for an oriented knowledge construction of local resources, was identified a system of suitable environmental indicators, able to analyze both the status quo, considering the "current values", and the scenarios of a possible development of the territory, identifying the "foreseen values";

2. for the analysis of territorial and environmental characteristics, was realized a GIS containing the data of the geological system, the agricultural land use, and the general territorial system;

3. for the assessment of the plan alternatives, the multicriteria method of Analytic Hierarchy Process (AHP) (Saaty, 1980) was integrated within the GIS to foresee, in spatial terms, the impact of the plan on the different environmental characteristics and to identify sustainable strategies of action.

In order to analyze the opportunity for the plan to reduce land consumption through the multicriteria method AHP integrated with the GIS, were generated "urbanization susceptibility maps", which expressed the big or small attitude of the territory to "receive" an urbanization process, considering its potential impacts.

The application of the AHP method is particular relevant for structuring the decision-making process in hierarchical form (Saaty, 1980, 1992). This approach consists of three main phases:

1. construct a suitable hierarchy;

2. establish priorities between elements of the hierarchy by means of pairwise comparisons;

3. check logical consistency of pairwise comparisons.

The first step is based on findings indicating that when elaborating information, the human mind recognizes objects and concepts, and identifies relations existing between

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them. Because the human mind is not able to perceive simultaneously all factors affected by an action and their connections, it helps to break down complex systems into simple structures: this simplification is possible by means of a logical process which aims at the construction of suitable hierarchies.

The second step is represented by pairwise comparisons (i.e. comparing elements in pairs with respect to a given criterion), which are used for establishing priorities (or weights) among elements of the same hierarchical level. They are compared in pairs with respect to the corresponding elements in the next higher level, obtaining a matrix of pairwise comparisons.

In order to represent the relative importance of one element over another, a suitable evaluation scale is introduced, called also "Saaty's scale". It defines and explains the values 1–9 assigned to judgments in comparing pairs of elements in each level with respect to a criterion in the next higher level. Pairwise comparisons are organized in adequate matrices, for each of them are calculated the so-called "vectors of priorities" (expressed on the scale 0–1, by means of the normalization of principal eigenvector of the matrix) which, when aggregated, provide a complete ranking among alternatives.

The third step considers that, in comparing elements, inconsistency of a certain degree can arise: in the AHP approach a "consistency ratio" of each matrix of pairwise comparisons is computed for checking the inconsistency degree, using the calculation of the principal eigenvalue of the matrix. Indeed, a consistency ratio of 0.10 or less is considered acceptable; if this ratio is more than 0.10, it is necessary to reformulate the judgments by means of new pairwise comparisons.

In the present case-study, the urbanization process of the territory is analyzed considering the assessment of the land consumption according to different criteria and indicators. Evaluation criteria were organized according to a three levels hierarchical structure (Table 1).

To the criteria of the third hierarchical level were associated some spatial indicators linked to a value judgment, expressed through a six points scale:

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– high urbanization susceptibility (score 5);
– medium-high urbanization susceptibility (score 4);
– medium urbanization susceptibility (score 3);
– medium-low urbanization susceptibility (score 2);
– low urbanization susceptibility (score 1);
– no urbanization susceptibility (score 0).

To each urbanization susceptibility class, a numerical value (score) and a chromatic scale were associated with the six judgments. To produce the graphic representation of the results, the color given to every pixel is related to every score according to the conventional range from dark green to red (Table 2).

To conduct "spatial assessment" an extension of the AHP method within ArcGIS was used (Marinoni, 2004; Marinoni and Hoppe, 2006), obtaining "urbanization susceptibility maps". According to this approach it is possible to obtain not only a simple overlay of the different themes, but to make a pairwise comparison of the criteria of every hierarchical level, giving a weight (expression of an expert judgment) on a scale 0–1 to each criterion through the calculation of the principal eigenvector of the pairwise comparison matrixes.

It can be highlighted that a first pairwise comparison matrix contains the criteria of the first hierarchical level ("geomorphology" and "natural resources and ecological network").

For the second hierarchical level are necessary two pairwise comparison matrixes: "geology" and "morphology"; "natural resources" and "ecological network".

In the same way, for the third hierarchical level are necessary four pairwise comparison matrixes: "slopes stability", "soil permeability" and "seismic zoning"; "slopes classes" and "altimetry"; "agriculture land use" and "soil fertility"; "natural park", "site of community importance" and "special protection areas".

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In each pairwise comparison and for every pixel it is possible to obtain a total value as a linear combination of weights of criteria by the score related to the urbanization susceptibility.

For “geology” we obtained the maps of Fig. 1a, b, c, that show the scores given to the respective criterion (slopes stability, soil permeability and seismic zoning).

In making a linear combination among weights and scores relative to these three criteria (i.e. calculating the priority vector in the AHP method), we have the results of Fig. 1d. It is possible to apply the same process to the criterion “morphology” and the results (Fig. 2b) can be combined with those related to “geology” (both belonging to the second hierarchical level) obtaining the urbanization susceptibility for the criterion “geomorphology” (belonging to the first hierarchical level) as it can be seen in Fig. 3a.

In the same way we obtained the maps for “natural resources and ecological network” as shown in Figs. 2c, d and 3b. Therefore, considering all the criteria of the hierarchy and combining the data of all criteria belonging to the first hierarchical level, we obtained the map of Fig. 4a, in which the colors from dark green to red express the urbanization susceptibility (from high to none) of the territory of Montecorvino Rovella.

According to the above approach, the assessment can really support the planning process, enhancing the potentials of each area and, most of all, localizing new urban transformations where territorial and environmental impacts can be minimized. Taking into account the susceptibility maps obtained, the planner can design the plan in coherence with them, reducing the consumption of new soil and of local environmental resources.

3.2 Land consumption, indexes and indicators

In the context of territorial policies the deepening of the knowledge system is a high priority for the identification of planning tools, and for the selection of approaches and methods for assessing and monitoring the effects of the expected transformations.

As was pointed out land consumption is one of the main phenomena on which it has focused research and theoretical and operational studies in recent years, in order to

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define actions able to achieve the right balance between the development prospects and the need to preserve the soil resource, unique and non-renewable.

In particular, the initial attention given to the measurement of the total land used was followed by studies able to link land use to the different themes and disciplines that affect it. Indeed, from the land consumption due to the city development, we moved to also consider the land used for infrastructures, for technical services related to energy production, for technological settlements or occupied by mining activities.

In this way, the knowledge of issues related to this phenomenon has been progressively expanded, both in quantity and in quality terms, not only with reference to the expansion process of urban areas, but also to its impact on agricultural activities, and on the natural resources and landscape (Fichera et al., 2012; Vizzari, 2011).

The complexity of this issue requires the need to establish shared methodologies for the measurement of the phenomenon, in order to ensure the possibility to compare the data examined in relation to the policies undertaken, to the planning models to be implemented at all government levels and to the evaluation processes associated to the different types of plan.

In compliance with the requirements by the European Union, it is possible to identify an appropriate set of indexes and indicators, which are useful to direct intervention strategies and plan choices to an effective limitation of land consumption. As indicated by the Organization for Economic Co-operation and Development (OECD), the indexes/indicators are parameters related to an environmental phenomenon, able to provide information on the characteristics of the event as a whole (OECD, 2003).

Their function is to indicate the status (or the change of state) of a complex phenomenon which is not subjected to direct measurement: through the use of indexes/indicators it is possible to represent synthetically problems investigated, maintaining unchanged the content of the analysis conducted.

These properties make indicators and indices technical tools of knowledge and control, communicable and understandable, which can play a strategic role in facilitating

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and making more objective, effective and transparent decision-making processes oriented to planning.

The need to express in exhaustive terms the complexity of the phenomena analyzed has lead to the identification of an evaluative approach focused on different indicators and indexes, correlated from the logical and functional point of view, able to describe and relate the different connotations that land consumption can assume and, at the same time, the processes of territory transformation connected to it.

Land consumption must be considered as a dynamic process, which alters the nature of a territory, from natural to artificial conditions, of which soil sealing is the last stage (EEA, 2005). Based on the guidelines and procedures developed by the European Environment Agency (EEA), active to support the European Union in assessing land use sustainability, monitoring and definition of strategies (EEA, 2001), it was possible selecting some suitable indicators and indexes.

In particular, despite the abundance of indicators illustrated in literature (Ochola and Kerkides, 2004; Montrone et al., 2010; Weiland et al., 2011; Mattila et al., 2012; Selicato et al., 2012; van Oudenhoven et al., 2012), in order to define the land use strategies for the territory of Montecorvino Rovella we identified only that able to assess the contribution of the different environmental components. Taking into account the results obtained from processing urbanization susceptibility maps, it was assessed the land consumption before and after the City Plan implementation. In this way it was possible to analyze the effects of the City Plan strategies on land consumption.

In particular, taking into account the characteristics of the territory and the actions of the plan, five main indexes were selected (Regione Piemonte, 2012):

1. Land Consumption index by Infrastructures (LCI): it allows to assess the percentage of land area consumed by infrastructures outside the urbanized area.

2. Land Consumption index by Urbanized areas (LCU): it allows to assess the percentage of land transformed for the realization of urbanized areas at the expense of agricultural or natural uses.

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3. Reversible Land Consumption index (RLC): it allows to identify the percentage of natural land area converted to activities that modify land use without soil sealing (as urban parks, sports facilities, etc.).

4. Irreversible Land Consumption index (ILC): it is the sum of Land Consumption index by Infrastructures (LCI) and Land Consumption index by Urbanized areas (LCU), and identifies the overall percentage of land consumed in an irreversible way.

5. Total Land Consumption index (TLC): it is the sum of Reversible Land Consumption index (RLC) and Irreversible Land Consumption index (ILC).

In Table 3 are the five indexes calculated by analyzing the present situation and what might happen after the implementation of the City Plan strategies.

It is possible to observe how the value of LCI increments with the realization of City Plan strategies, going from 0.67 % to 0.97 %; while the value of LCU is reduced considerably, going from 3.74 % to 1.25 %. An interesting aspect is also represented by the positive increase of RLC, which goes from 0.64 % to 2.27 %. Therefore, it is possible to highlight how the City Plan decided to increase interventions that transform the territory in a reversible way. In any case, the value of ILC increases from 4.40 % to 6.22 %, and the value of TLC is changed from 5.04 % to 8.50 %. It is evident that the City Plan territorial transformations lead to an increase in land consumption, but it is equally important to note that one of the objectives is focusing more on interventions that involve reversible land consumption.

Moreover, new urbanization and reversible land uses are localized in areas characterized by greater urbanization susceptibility, identified by the combined approach of the AHP method and GIS as “high”, “medium-high” and “medium” (Fig. 4b). According this integrated approach of methods and tools (Fig. 5) it is possible to localize new transformations where territorial and environmental impacts can be minimized, and support a transparent and dynamic decision-making process, taking into account multidimensional criteria and the specificity of local resources.

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4 Discussion and conclusions

According to *The European Environment – State and Outlook 2010* (EEA, 2010c), today's main environmental challenges are characterized by a systemic character and need to be tackled taking into account their interactions. Indeed, the assessments of four environmental priority areas (climate change, nature and biodiversity, use of natural resources and waste, and environment and health) point to a series of direct and indirect links between environmental challenges. Then, many of the links are direct, i.e. changes in the state of one environmental issue can translate directly into pressures of another, or indirect when changes in one environmental issue resulting in feedbacks on another and vice versa. In particular, land use and land-cover changes exemplify such indirect links: they can be seen to be both a driver and an impact, not only of climate change, but also of biodiversity loss and the use of natural resources; for example, any change in land use and land cover, resulting from urbanization or converting forests to agriculture (Di Fazio et al., 2011; Fichera et al., 2011), affects climate conditions as well as biodiversity. At the same time, many changes in the state of the environment are due to unsustainable consumption and production patterns. The land use and land cover are the principal drivers of environmental change, influencing landscapes and the distribution and functioning of ecosystems, answering to our demands for food, forest products, renewable energy and urbanization (CLC, 2012).

Any policy or strategy for the land conservation and sustainable management is not possible without a careful and thorough process of analytical knowledge, in order to monitor the phenomenon in terms of quality and quantity, to understand their causes, to recognize the results and to develop effective mitigation measures to be integrated in concrete instruments of territorial government. It is necessary, therefore, a system of spatial and dynamic knowledge, with reliable and easily comparable data, able to guide and support the decisions of planners and policy makers need to limit the consumption and waste of soil resource.

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Existing best practices designed to limit, mitigate and compensate soil sealing show that sound spatial planning follows an integrated approach, requiring the full commitment of all relevant public authorities, in particular those governance entities (e.g. municipalities, regions, etc.) which are normally responsible for land management. Another relevant aspect is that specific regional approaches are developed, taking into account unused resources at local level (for example, a particularly large number of empty buildings or brownfield sites). Furthermore, existing funding policies for infrastructure development have been carefully reviewed, leading to a reduction of those subsidies that act as drivers for unsustainable land take and soil sealing, considering also the aim of lowering the share of urbanization fees in municipal budgets (EC, 2012).

The aim of limiting land consumption, therefore, requires a multidisciplinary approach, which allows tight integration between the policies of the government of the territory that operate at different levels and sectoral policies, including spatial planning and scheduling of strategic sectors including legal instruments, plans, programs, and evaluation tools.

Land use monitoring, as well as to consider his state of health, can help to define appropriate policies that, through planning activities, permit to implement a sustainable land management, and contribute to building a collective consciousness to consider soil as a common good, so that its protection should be preferred to transformations.

With the present case study a selection of useful spatial and territorial indicators are proposed, based on available data sources and using a different approach by introducing environmental reporting units as the basis for the calculation and representation of the information. The indicators are created by means of spatial analysis of different information layers using GIS combined with AHP method.

The aim of this approach was to better illustrate the territorial diversity of the natural environment and assess the related impacts of the urbanization process. The specificity of the spatial and territorial indicators obtained is that they address the environmental information in relevant terms for the local resources. The present case study is an attempt in the direction of territorial indicators able to describe the potentials and

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critical aspects of the urbanization process, in a field of investigation which requires consolidation and further development. Indeed, the development of dynamic spatial indicators, and the use of maps for reporting and assessment of soil sealing and land consumption is considered a powerful way of communicating to planners and policy-makers, and should be part of the tools used in a territorial and urban transformation process.

Acknowledgements. The authors thanks all the components of the working group for the elaboration of the new City Plan of Montercorvino Rovella: Michelangelo Russo (Urban planning); Giuseppe Guida (Project coordination); Annie Attademo, Alessandro Formisano, Tiziana Vitiello (Collaboration to urban planning); Gemma Belli (Historical studies); Luigi Daina (Agronomy); Luigi Pisapia (Geology); Paolo Carrafiello, Maria Cerreta, Pasquale De Toro (Strategic Environmental Assessment); Giuseppe Ricco, Signum Civitatis Architetti Associati, Valeria Palo (Office Plan).

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Table 1. Hierarchical structure of criteria and indicators for urbanization process.

Criteria of the 1st level	Criteria of the 2nd level	Criteria of the 3rd level	Indicators	Susceptibility	Scores
Geomorphology	Geology	Slopes stability	Very high degree of danger	None	0
			High degree of danger	Low	1
			Medium degree of danger	Medium-low	2
			Moderate degree of danger	Medium	3
			Stable zones	High	5
			Quarries	None	0
		Soil permeability	Low-permeable and impermeable soils	High	5
			Permeable soils (porosity)	Medium	3
			Permeable soils (fractures and carsism)	Low	1
		Seismic zoning	Rocks	High	5
			Conglomerates	Medium-high	4
			Clay soils	Medium	3
			Alluvium	Medium-low	2
			Screes	Low	1
	Morphology	Slopes classes	Zones with less than 10 % gradient	High	5
			Zones between 10 % and 20 % gradient	Medium	3
			Zones between 20 % and 30 % gradient	Low	1
			Zones between 30 % and 50 % gradient	None	0
			Zones with more than 50 % gradient	None	0
		Altimetry	Zones between 17 and 250 m a.s.l.	High	5
			Zones between 250 and 500 m a.s.l.	Medium	3
			Zones between 500 and 1178 m a.s.l.	Low	1
Natural resources and ecological network	Natural resources	Agriculture land use	Grazing, grassland and wood	None	0
			Grazing and grassland	None	0
			Maquis	None	0
			Olive grove	None	0
			Tree cultivation and grazing	Low	1
			Tree cultivation and olive grove	Low	1
			Tree cultivation	Low	1
			Arable farming and tree cultivation	Medium-Low	2
			Arable farming	Medium	3
			Uncultivated land	High	5
			Non agriculture land	High	5
		Soil fertility	Good fertility	Low	1
			Sufficient fertility	Medium	3
			Low fertility	High	5
	Ecological network	Natural Park	Zones in the Park	Low	1
			Zones outside the Park	High	5
		Site of Community Importance	Zones in the Site of Community Importance	Low	1
			Zones outside the Site of Community Importance	High	5
		Special Protection Areas	Zones in the Special Protections Areas	Low	1
			Zones outside the Special Protections Areas	High	5

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Table 2. Scores and colors given to the different urbanization susceptibilities.

Urbanization susceptibility	Score	Color	
High	5	Dark green	
Medium-high	4	Light green	
Medium	3	Light Yellow	
Medium-low	2	Dark yellow	
Low	1	Orange	
None	0	Red	

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Table 3. Indexes of land consumption.

1. Land Consumption index by Infrastructures (LCI)	
Current values	Plan implementation
In = Infrastructures = 28.1 km^2 Ta = Total land area = 4208 km^2 LCI = In/Ta × 100 = 0.67 %	In = Infrastructures = 40.8 km^2 Ta = Total land area = 4208 km^2 LCI = In/Ta × 100 = 0.97 %
2. Land Consumption index by Urbanized areas (LCU)	
Current values	Plan implementation
Ua = Urbanized land area = 157.2 km^2 Ta = Total land area = 4208 km^2 LCU = Ua/Ta × 100 = 3.74 %	Ua = Urbanized land area = 221.1 km^2 Ta = Total land area = 4208 km^2 LCU = Ua/Ta × 100 = 1.25 %
3. Reversible Land Consumption index (RLC)	
Current values	Plan implementation
Ra = Reversible land area = 26.9 km^2 Ta = Total land area = 4208 km^2 RLC = Ra/Ta × 100 = 0.64 %	Ra = Reversible land area = 95.6 km^2 Ta = Total land area = 4208 km^2 RLC = Ra/Ta × 100 = 2.27 %
4. Irreversible Land Consumption index (ILC)	
Current values	Plan implementation
ILC = LCI + LCU = 4.40 %	ILC = LCI + LCU = 6.22 %
5. Total Land Consumption index (TLC)	
Current values	Plan implementation
TLC = RLC + ILC = 5.04 %	TLC = RLC + ILC = 8.50 %

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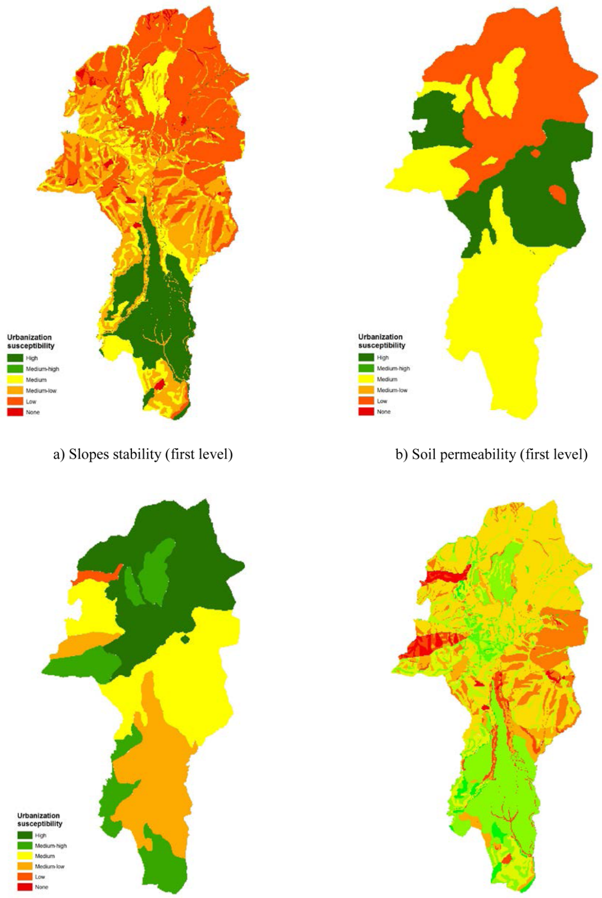

a) Slopes stability (first level) b) Soil permeability (first level)

c) Slopes stability (first level) d) Geology (second level)

Fig. 1. Urbanization susceptibility maps for geology.

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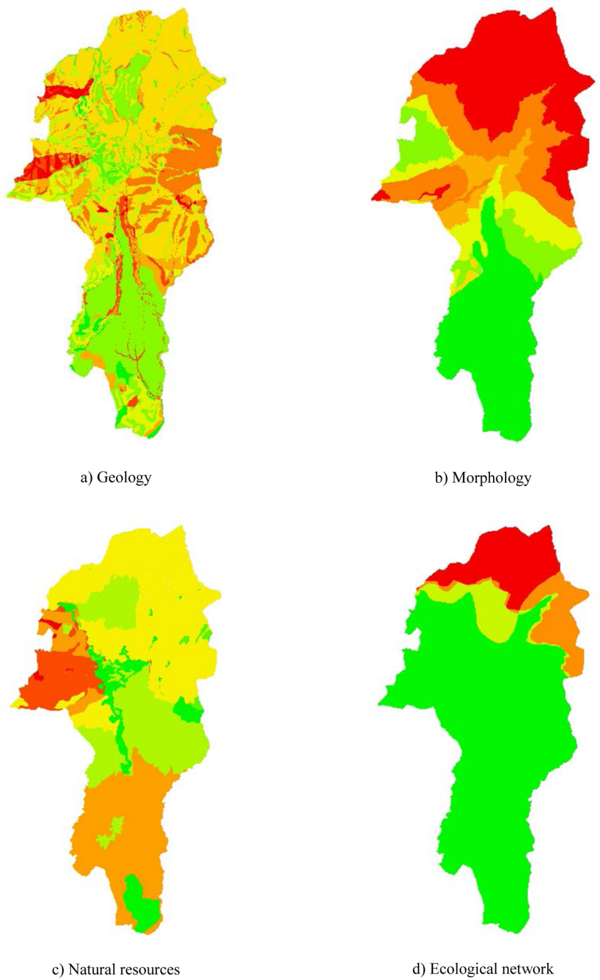

Fig. 2. Urbanization susceptibility maps for the second hierarchical level.

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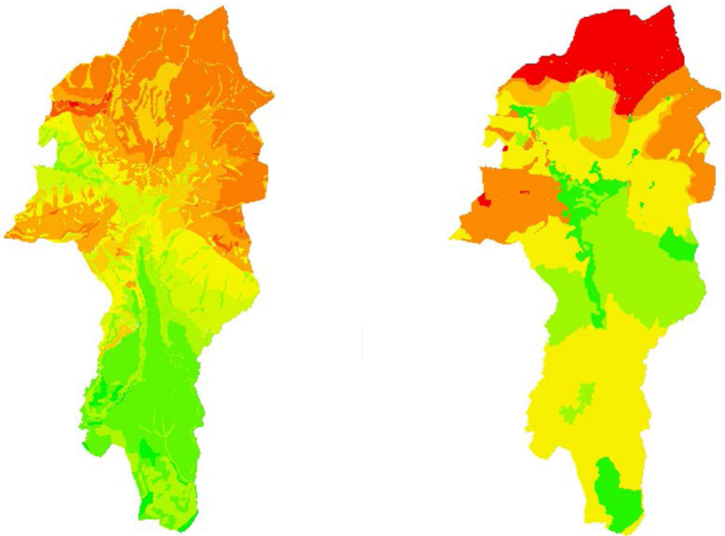

a) Geomorphology

b) Natural resources and ecological network

Fig. 3. Urbanization susceptibility map for the first hierarchical level.

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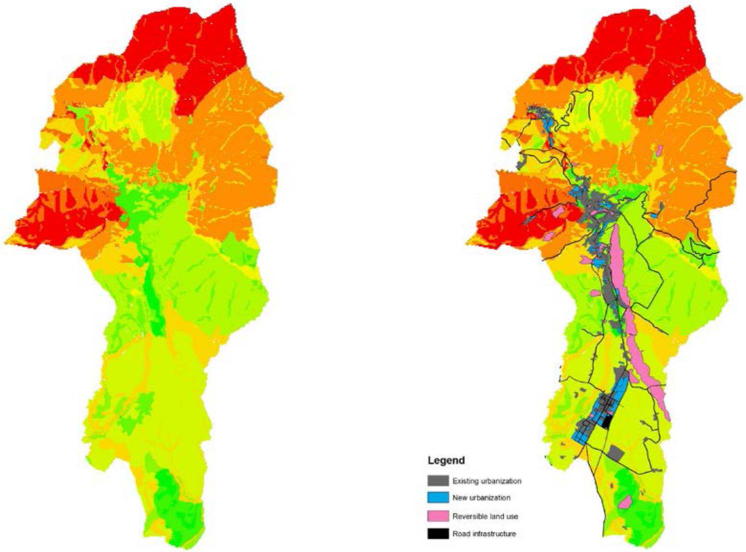

a) Overall urbanization susceptibility

b) City Plan

Fig. 4. Overall urbanization susceptibility map and the City Plan.

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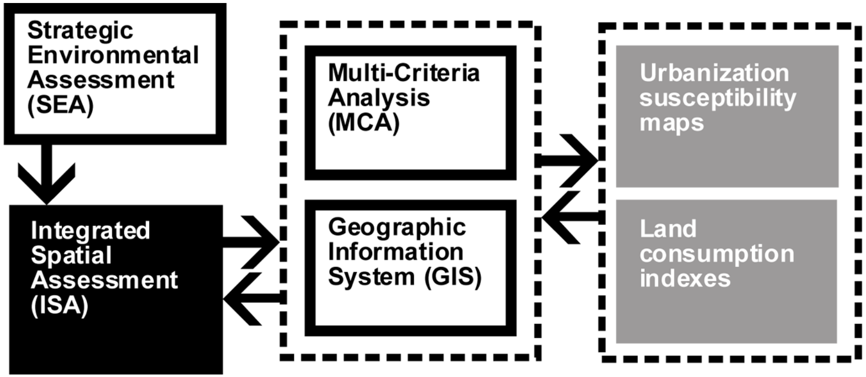

Fig. 5. The methodological approach.

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