Chapter 9
From "Landscape DNA" to Green Infrastructures Planning

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9.1 "Landscape DNA" as a Basis for Sustainability

According to the theory of Landscape Ecology, landscapes are co-evolutionary systems that are complex and adaptive (Kauffman, 1991; Rescia et al., 2012). They are characterized by spatial heterogeneity, that can change greatly during the time (Pickett and Cadenasso, 1995).

Nevertheless, such heterogeneity originates from some main structures and processes that act as invariants: the deep-rooted interdependencies between the original structures of the landscapes (particularly latitude, climate and hydro-geomorphological characters), and, even more notably, local resources.

Landscape has also been described as a "resource interface" in order to explain the use that communities make of landscape over time, and the co-evolution between landscapes and humans (Farina, 2008).

The changed landscape alters human needs as well as the type and use of resources that are requested by humans. New human needs drive new landscape transformations.

This process links the environmental issues related to resource consumption to the concept of "common good" that regards both use and community. In this sense, landscape is strongly linked not only to environmental resilience but also to social resilience and sustainability.

Landscape evolution can be told as the history of the domestication of nature by humans (Zeller & Göttert, 2019), in which the relationships between *available*

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information and energy on the one hand, and used information and *energy on the other,* are critical in shaping landscape in different ways throughout the centuries.[1].

Information plays a substantial role within landscape dynamics. Information can be defined as the total memory of the natural and cultural history of a place, and as the capacity to organize a system (Farina, 2006).[2]

Throughout this history, landscapes accumulate over time the signs and the memory of their evolution (Turri, 2003), in terms of main structures (typically hydro-geomorphological and pedological) and population behaviors (the results of the co-evolution between nature and culture), that remain as "marks" through the centuries.

These marks act as a continuous condition that is driving the evolution and the organization of landscape, their regeneration and/or conservation, despite the enormous transformations prompted by humans.

The evolution of landscapes is oriented by the great heritage of information that they accumulate over time and from the different needs that populations try to satisfy by exploiting resources and energy.[3]. We could think of this heritage as the genetic pool that drives the development of an organism and that acts as the "landscape DNA".[4]

Losing "landscape DNA" means to lose a part of the total amount of the accumulated information or some items that permit information exchange within the landscape, organizing it.[5]

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[1] In 1990 Zev Naveh coined the term "total human ecosystem", meaning that every ecosystem on the planet is now conditioned by human activities. Today, we call it "Anthropocene", describing the current period as the period during which human activity has been the dominant influence on climate and the environment.

[2] Types of information fluxes through time:

- the immaterial part of the landscape that drive its evolution, as cycles, events, species presence and interactions memory;
- the biophysical exchanges between geomorphological items and primaeval vegetation that drove the evolution of soils, the evolved vegetation and, at last, ecosystems including the human's,
- the actual immaterial and material exchanges between landscape items. In this case, the exchange acts as the main link of landscape systems in the form of the vital relationships between biotic and abiotic elements, between the land mosaic and the organism, and finally between different organism. Information theory help to understand the concept of suitability: not all landscape items can exchange information with each other; not all the landscape can easily adapt to a relationships system.

[3] As an example, the vast (huge) transformations that began with the Industrial revolutions are well explained by this concept, strictly linking information and energy in an entropic process.

[4] The "landscape DNA" concept is highly promising to explain ancient processes and structures that play important roles in the actual patterns.)

[5] This is the case of (that) infrastructures, (able) capable to interrupt the main biotic fluxes within a landscape, but also of the loss of traditional relationships between city and country, that is reflected in the actual resource consumption-based policies (actual policies based on resource consumption), as well as in the difficulty to improve material and immaterial synergies within town and territory. Is part of this loss, the missing of knowledge of the natural cycles underlying some critical process for the landscape.

The loss of "landscape DNA" is directly linked with the loss of landscape resilience, cities unsustainability, "landscape consumption".

These dynamic landscape trends cannot be foregone or controlled, but they can be influenced or driven to preferable directions by plans, projects and activities.

Understanding the "landscape DNA" is therefore a prerequisite of landscape sustainability.

9.2 Metropolitan Landscapes

Metropolitan landscapes are critical as they present the fastest shifts in evolutionary dynamics when compared to other landscapes.

They also show deeper transformations in the previous spatial patterns that are based on natural resources, such as soil, surface water, groundwater, biodiversity and the knowledge and culture that originates from them.

Nevertheless, metropolitan landscapes generally retain some structural elements like hydrological and geomorphological characters, the Environmental DNA (Ruppert et al., 2019), and some main characters of the populations that form the "landscape DNA".

Today, such structural elements play a strategic function in ecosystem and landscape development, in terms of their role in the co-evolutionary history of a given territory. To take into account the structural elements of the landscape sits at the base of a real sustainable planning, aming towards an equilibrium of the urban metabolism where urban areas are able to produce resources.

Recognizing these elements is a necessary step in developing plans and projects that make full use of the natural dynamics, rather than opposing them, while also "making nature work" according to human needs and tendencies. In this way plans and projects can promote sustainability and resilience.

Landscape Ecology metrics are tools that can be used to better the understanding of the above-mentioned landscape patterns and elements, as well as the influence of these patterns on different functions and processes over time.

These tools have key functional roles, such as describing the past, highlighting vulnerability and resilience factors and helping to develop future scenarios.

The case study of the Torino Metropolitan Area will be used in this paper to explain the principle foundations of space-time scaling and landscape transformation, as well as the different methods of studying and planning the metropolitan landscapes altogether.

9.3 The Case Study

The widespread growing attention for Green and Blue Infrastructures (GBI, EU, 2013) and for their capability to provide benefits to the human ecosystems and to address adaptation goals, is forcing urban planners to innovate landscape governance.

The inclusion of GBI in planning instruments, at different levels of governance and in different planning tools, is critical for implementing the European Strategy on Green Infrastructures. GBI inclusion in planning instruments reveals the strong interaction between the social and the ecological systems.

This paper presents a multiscale and multidisciplinary method aimed at developing a sustainable landscape plan for the Turin metropolitan area (i.e. the Green Crown of Turin).

The project has been developed within the interregional project LOS_DAMA!, driven by Piedmont region, aimed at integrating the landscape dimension, Ecosystem Services (ES), GBI and Nature Based Solutions (NBS) into planning policies.

The methodology used relies on the analysis of the genetic characters of the metropolitan landscape to highlight its diversities and vulnerabilities, applying the ES paradigm within a participatory process.

9.3.1 Principles and Methods

We rooted our analysis in the understanding of landscape vulnerability (Adger, 2006) as the opposite of the robustness and resilience ensemble (Gallopin, 2006; Janssen et al., 2006).

We consider *Resilience (R)* as the ability of groups or communities, or ecosystems, to cope with external stresses and disturbances as a result of social, political and environmental change. In landscape, resilience is the ability of response to a certain disturbance with a new configuration and equilibrium.

Robustness is the ability of a landscape to maintain its dynamic equilibrium and features facing novelties. Therefore, resilience and robustness together represent different strategies for a landscape to evolve.

We consider *Vulnerability (V)* as the probability that a landscape unit disappears, survives or changes its own characters, functions and equilibrium when exposed to different disturbances and stresses.

Vulnerability, Resilience and Robustness depend on the state of health of the set of ecosystems that characterize a specific landscape, including humans as part of the ecosystems.

Vulnerability, resilience and robustness usually coexist in a system and are intended as a characterizing property of a landscape itself.

Reducing Vulnerability and improving Resilience is the final goal of our work. This goal is reached through the development of a participated plan integrating ES (Costanza et al., 1997; Costanza, 2008; Haines-Young & Potschin, 2018) and GBI.

In this process, ES play a dual role:

- ES as a tool to describe the Landscape Units (LU) and their diversity, helping understanding the LU DNA, their vulnerability and their own role within the overall landscape mosaic;
- ES as tool to orient the plan, highlighting those related ES able to reduce vulnerability itself. In this approach each LU has its proper priority ES (Table 9.1).

The method has been tested and refined through a participatory process aimed at the development of a governance tool for an area comprising 49 municipals, through the following steps (see Figs. 9.1, 9.2, 9.3, 9.4 and Table 9.2).

Table 9.1 The main issues developed within the project

Principles	Uses
Landscape approach	Integrating analysis and plan to reach sustainability
Multi-scale approach on three study area. This approach is useful to characterize the three study areas with different levels of details and information	The upper scale, regarding the overall landscape "Green Crown of Turin (CV)"
	The medium, regarding the planning scale: 14 Landscape Units (LU)
	The lower regarding the project scale: a local area included in three LU.
Vulnerability and resilience properties at the three scales	They help to highlight the peculiar diversities of LU, their proper roles within the pilot area, understand the priority ES within each LU; orient the plan and the monitoring of the landscape mosaic dynamics
Application at the different scales, of spatial indicators borrowed by landscape ecology (see paragraph dedicated)	They act as a proxy of some soil ES and are used to highlight the main vulnerabilities and the priority soil ES of each LU
Development of the "water map" (see paragraph dedicated)	Understanding the water cycle linked to land transformation and definition of the the main vulnerabilities and priority water ES of each LU
ES (and the proper GBI), significant for the overall landscape, and the ones that are significant within the different LU	They are analysed to set policies suitable either for the large scale and the LU
Participation as a structural element to exchange information and in the definition of the multiple values	Build a share scenario of GBI planning, to be implemented with suitable NBS, based on the landscape and communities needs

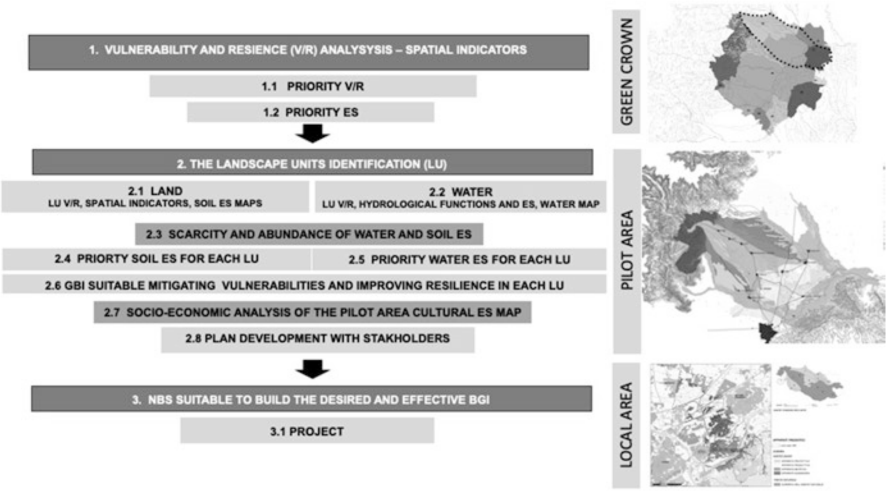

Fig. 9.1 Multi-scale approach to planning and designing effective Blue and Green Infrastructures

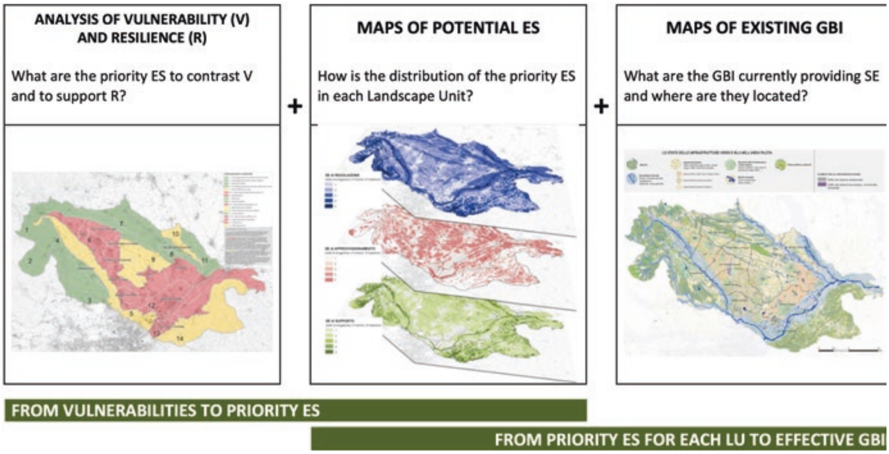

Fig. 9.2 The three phases of the pilot area development plan

9.4 The Tools

Specific metrics and spatial indicators have been used to estimate landscape loss, Vulnerability increase, and cultural and ecological ES that the agricultural landscapes can provide.

Spatial indicators describe the structures and the function of the landscape mosaic and are used as a proxy for vulnerability factors and dynamics.

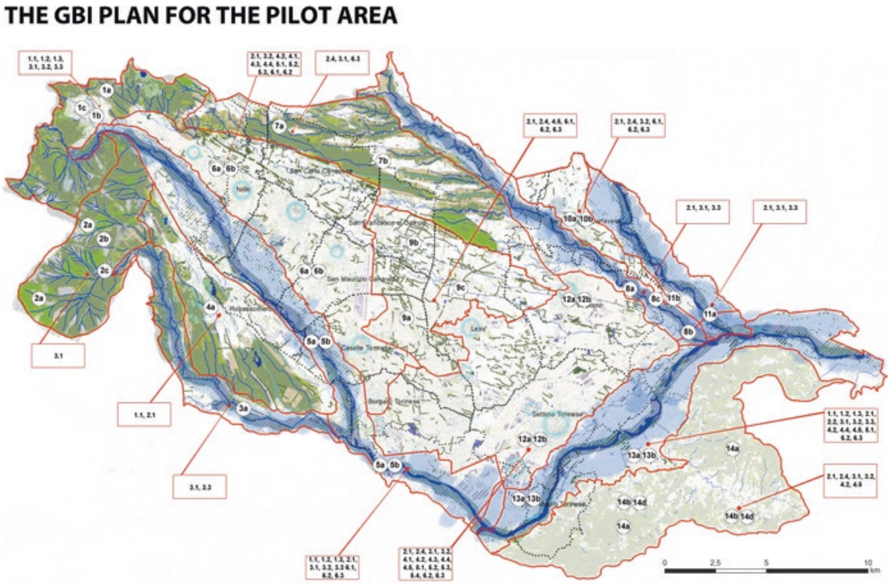

Fig. 9.3 The final map of the GBI plan for the pilot area

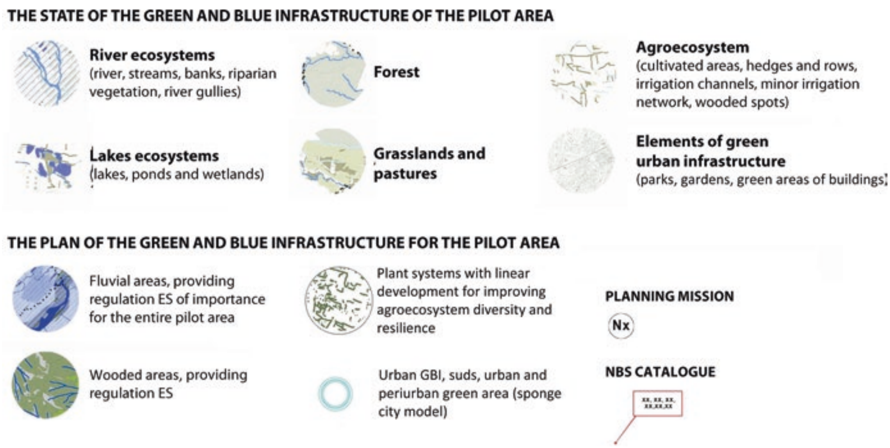

Fig. 9.4 Legend of to the map Fig. 9.3: the legend is organized in such a way as to differentiate the elements of the existing conditions, which form the basis of the plan, and the elements of the project are developed through the planning missions and the catalogue of the NBS

Table 9.2 Short description of methodological approach phases for the plan instrument, integrated by the evaluation of the Ecosystem Services and the identification of actions to increase resilience

Phase	Short description
1	The preliminary evaluation of the landscape vulnerability of the Green crown and its Land Units (LU). Such evaluation has been developed with suitable spatial indicators.
1.1	Highlighting the priority factors of Vulnerability (V) and Resilience (R). Resilience specifically, is linked with landscape "DNA".
1.2	Identifying the Ecosystem Services (ES) to reduce the main vulnerabilities of the Green crown. The selected ES are part of the priority ES, as their improvement at the lower scales, helps to reach sustainable goals for the overall landscape.
2	The identification of the LU depending from the overall main structures (Hydrogeological items, main patterns and physical relationships) and the medium scale analyses.
2.1	The development of the landscape mosaic, the soil ES maps and the implementation of the spatial indicators within the LU, in order to study the soil ES, to characterize the LU and their V/R linked to land cover and its patterns and dynamics, and, at the end, to sustain the GBI plan (see the paragraph "Measuring the total impact of soil consumption").
2.2	The development of the "water map". It considers the hydrological functions of the different elements of the land cover different elements, in order to study the water's ES, characterize the LU and their V/R linked to water distribution and dynamics, and, at the end, better integrate the water cycles with the plan of land (see the paragraph "Mapping Water").
2.3	The assessment of the scarcity and abundance of the ES able to reduce vulnerability.
2.4, 2.5	The identification of the soil and water ES able to reduce the main vulnerabilities, for each land unit: this phase allowed to define the set of the prior ES for each land unit, throw the assessment of the scarcity and abundance of the ES able to reduce vulnerability.
2.6	From the ES that are priority and scarse, are outlined the effective GBI, able to mitigate vulnerability and improve resilience within the LU
2.7	A socio-economic analysis of the pilot area, including the mapping of cultural ES, their providers and beneficiaries, and the identification of governance tools fitting with the ES enhancement the economic evaluation of the GBI in the pilot area. This step has been developed using the contingent valuation methodology, the sole able to capture non-use and indirect values in a Total Economic Value framework
2.8	The participated plan development on the pilot area. The participation process has been developed with a diversified group of stakeholders and it was a tool to share either the analysis and the planning phasis.
3	The shared choice of the Nature Based Solutions (NBS) able to implement the ES needed form each land unit.
3.1	Development of the project al the local scale.

Moreover, they are useful to explain vulnerabilities to stakeholders and to monitor future evolution of the landscape mosaic. Such indicators are based on data derived from the Land Cover Map.

The next paragraphs describe two indicators, one for detecting the loss of landscape functions due to soil sealing, the other related to the need to join the soil policies with the water ones: The Water Map.

9.4.1 Measuring the Total Impact of Soil Consumption

Soil sealing is a well-known topic. Nevertheless, current soil sealing metrics and management still lack a spatial strategical overview. They need to better take into consideration the ES provided by fertile soils and the urbanization dynamics effects on soil loss and degradation.

Such impacts are strictly linked to the patterns of urbanization.

We can assess direct impacts caused by sealed areas, and indirect impacts caused by disturbances derived from urbanization or by the loss of previous functions because of landscape fragmentation and patches size reduction.

These phenomena are especially visible in urban fringes, where the structural changes go hand in hand with the issues caused by the accelerated speed of human processes. Such phenomena undermine the provided ES, and the persistence of local “landscape DNA” and local knowledge, as well as the adaptation strategies of the ecological system.

Taking into account different case studies, we developed a spatial indicator able to describe the total impact of widespread urbanization on the landscape (Fig. 9.5, 9.6 and 9.7).

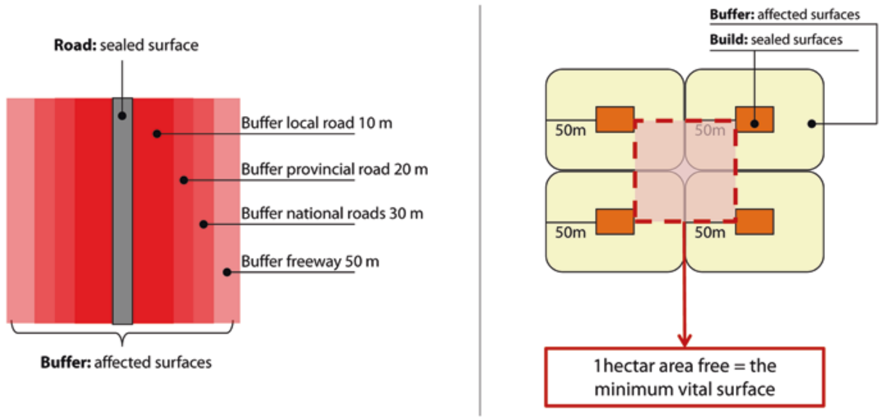

Fig. 9.5 The buffer around the road (left) and the buildings (right) is the affected surface by direct and indirect impacts. In these areas, soil ES can’t develop their potential performances because of the limited size of the patches
The width of the roads0 buffers comes from Forman (2003), the one for the building comes from Dinetti (2005), and Gibelli (2003): 1 h free area seems to be the minimum vital surface suitable for birds habitat and to maintain agricultural activities in urban fringes

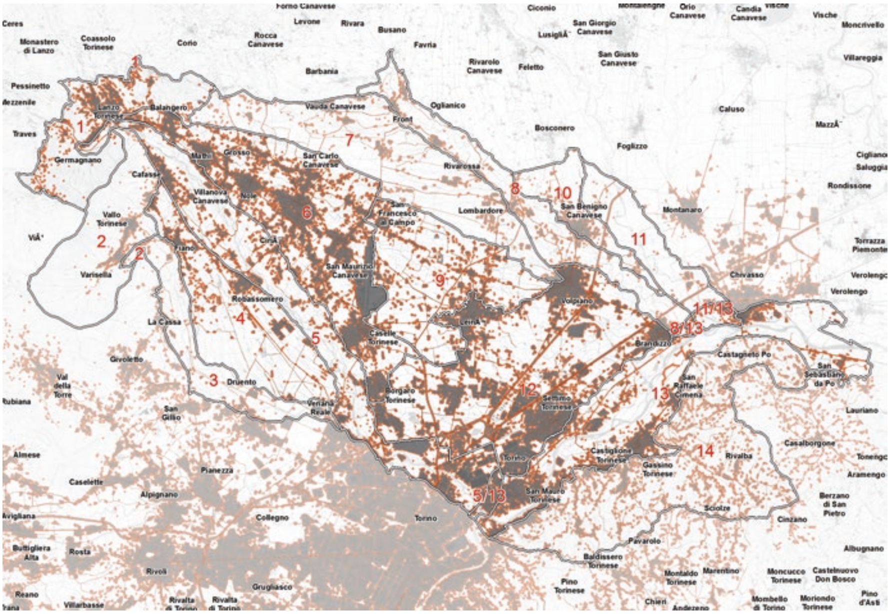

Fig. 9.6 Mapping the indicator at the scale of 14 LU

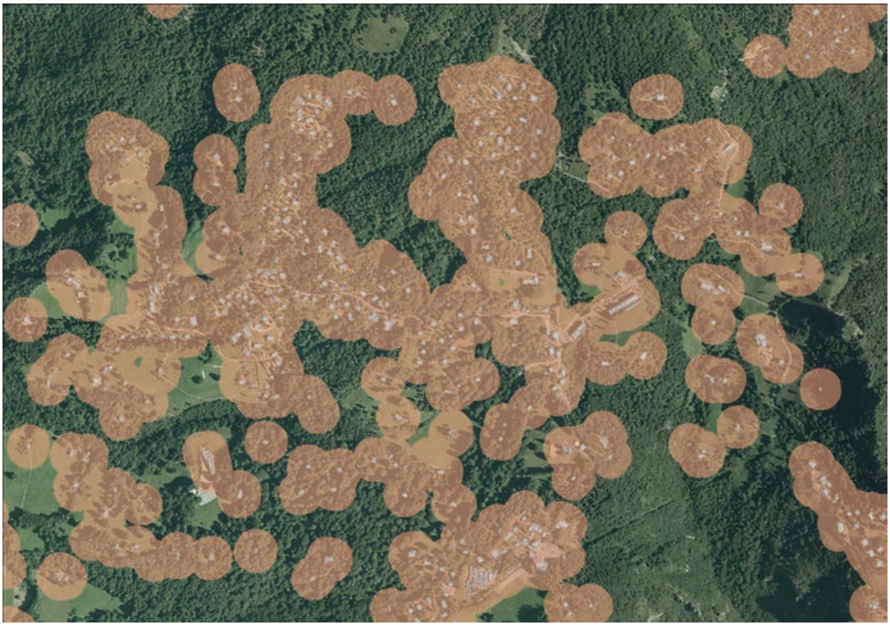

Fig. 9.7 Mapping the indicator: zoom level for the map

LU	Settlement Form Index [SFI]		Total Impact Index [TII] (%)		Settlement Sprawl Index [SSI]	
	dimensionless value	Icon that represent the ratio: - Black label represents total sealed surface of LU - Orange label represents total affected surface of LU	value (%)	Icon that represent the ratio %: - Black part represents total affected surface of LU - Green part represents total free surface of LU	dimensionless value	Vulnerability level class
8.	1,15		26%		30,27	
2.	2,89		11%		31,64	
11.	3,31		16%		51,98	
7.	3,61		20%		72,64	
4.	3,05		24%		73,54	
3.	3,40		22%		74,64	
10.	2,65		29%		75,81	
1.	2,81		27%		77,05	
13.	2,15		40%		85,82	
Green Crown	2,18		40%		86,06	
5.	2,16		42%		91,17	
12.	1,83		54%		98,23	
9.	3,58		32%		112,87	
6.	1,87		61%		113,51	
14.	4,33		36%		153,91	

Fig. 9.8 The results of the spatial indexes for the overall landscape "Green Crown of Turin (CV)" and for each 14 LU: the icons represents the ratio between the area sealed by buildings and infrastructures (black) and the affected area (orange). The LU presenting the largest orange buffers present the main vulnerabilities

The indicator is easy to use, implementable, comparable and communicable. It consists in three spatial indexes (See Fig. 9.8) based on the ratio between the sealed areas and the ones interfered from buildings and infrastructures.

The dimensions of the interfered areas (buffer) has been defined on the basis of the minimum ecological functionality of the land mosaic tesserae. The indexes are based both on experimental analysis and scientific literature related to lowland agroecosystems in temperate climate.

These three indexes allow to:

– take into account not only the soil consumption, but also the effects on the ES, considering both the sealed area and the surrounding area affected by the indirect impacts as fragmentation, pollution, aesthetical damage and so on;
– have a set of 3 indicators, working as a "proxy" for the missing ES, to be easily used in territorial planning;

  - define areas in which the sprawl growth can increase landscape vulnerability.

– be used to build an aggregate indicator for the classification of peri-urban landscapes (Fig. 9.9).

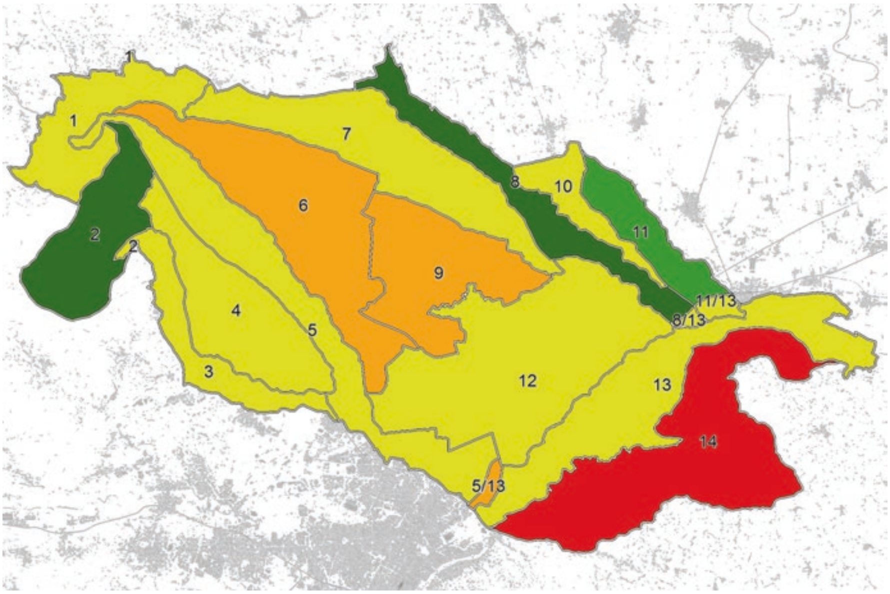

Fig. 9.9 The 5 vulnerability classes within the 14 units: 5 classes of vulnerability where found: the low level vulnerability (value < 35); medium low (35 < value < 60); medium (60 < value < 100); medium high vulnerability (100 < value <120); high vulnerability (value > 120)

9.4.2 Mapping Water

Fresh water availability is one of the main challenges of the current century: water is both a critical resource and a responsibility now and in the near future.

Climate Change affects the hydrological balance and the current standard water management policies increase the vulnerability of the water system.

Each land transformation affects the hydrological cycle, including effects on ground water: indeed, every time that a plan is approved water is threatened.

Typical planning tools fail to consider water as a structural element of the territory at the scale of the river basin. Therefore, urban growth can damage the water resources, adding vulnerability to the landscape and to the whole territory.

The "Water Map" has been developed with the aim to build a tool to help planners to understand the importance and the role of water, similarly to the land cover map for the soil.

The Water Map highlights the links between the main hydrological/ecological functions and the land cover elements. It allows to understand the specific role of each landscape tesserae in relation to water and to highlight the ES that derived from the water cycles. It is completed by a map of the existing pressures on water.

The Water Map shows the relationships between water and soil and it is a useful tool to characterize hydrographic basins, to assess scarcity and abundance of

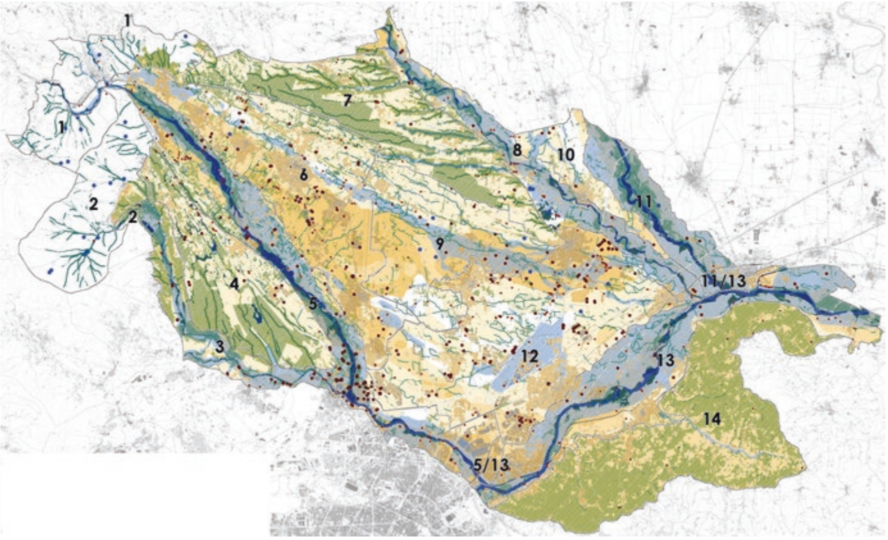

Fig. 9.10 Water Map: spatial distribution of the landscape elements that perform hydrological functions. The Map highlights the land landscape elements able to provide Ecosystem Services linked to the water cycles and the hydro-ecological functions

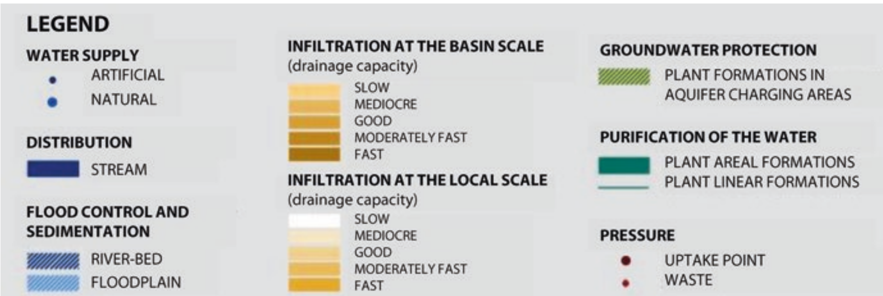

Fig. 9.11 Legend of Water Map: "hydrological functions"

hydrological functions, to understand the relationships between settlements, human activity and water, to orient GBI plans and plans in general, choose suitable NBS.

Furthermore, putting water as a central topic of planning, helps to increase the stakeholder's consciousness of water (Fig. 9.10 and 9.11).

9.5 The Results

The output of the project is a strategic plan oriented at solving or mitigating the current issues, through encouraging and implementing effective sustainability practices, based on GBI and efficient projects. A flexible plan “to do well”, based on the local development of GBI and of a new Governance model.

The project implementation gave the opportunity to test some technical tools as the Water Map and the spatial indicators that where also used within the participatory process. The participatory process was able to improve the understanding of the local landscape and of its resources for the community.

Moreover, it facilitated the joint work between municipalities, public and private actors. Such forms of cooperation could take up a leading role within the phase of strategy implementation, as well as promoting the cooperation between different institutions and different governance levels.

The actors shared a common interest in the recommended implementation actios, also because the plan was capable of enhancing local diversities, understood as synergic parts with their specific role.

Some of these actions are suitable to promote local circular economies that could develop from from multifunctional GBI.

The result is an articulated proposal built through a participatory process and using different tools, precisely to support a self-regenerating process capable of including larger communities by improving their knowledge.

9.5.1 The Tools for the Implementation of the Plan

The plan provides the strategies and the guidelines for the local development of actions. Therefore, it is rich in tools to communicate the local landscape characters and vulnerabilities. The plan also provides the strategy to help to design an effective GBI.

- *The knowledge: Descriptive sheets of LU*

Each LU is accompanied by a sheet synthetizing the characters of the LU itself through a synthetic description and the results of the analyses on which the planning and project scenarios are based.

Each sheet includes information related to:

- the main Landscape structures, that have an effect on its evolution;
- the Vulnerability and Resilience drivers;
- the results of the indicators used to describe V/R (maps and data) and the highlighted criticalities;
- the hydrological functions used to describe V/R (maps and data) and the highlighted criticalities;
- the priority ES;

– the effective GBI to improve priority ES and the planning missions suitable to develop the local GBI linked to the overall scenario.

These tools provide a set of instruments for technicians and stakeholders to orient actions at different scales and to monitor them.

- *The Planning missions*

Planning missions are the result of the process in its entirety. They are represented on a map and explained in the LU descriptive sheets.

The planning missions map is completed by sketches useful to communicate the priorities of the missions in each LU and by written sentences related to the same priorities.

- *Economical estimate of the expected scenarios*

This part was developed during the participatory process workshops by using the "Willingness To Pay" (WPT) method (Derkzen et al., 2017).

The activity took into consideration two different scenarios.

Scenario 1 assumed the provided GBI could mitigate the temperature increase and the flood effects.

Scenario 2 assumed that the provided GBI could achieve the goals set in Scenario 1 and furthermore could save agricultural land and their products as well as the open-air recreational activities.

The results are synthetases in Table 9.3.

The results show a significant engagement of people, specifically regarding the vulnerability of their landscape facing Climate Change, and a remarkable willingness to pay to improve ES and GBI to reduce vulnerability.

Moreover, it shows that people generally do not care significantly about agriculture loss and open-air spaces. It must be noted that this work has been developed before the COVID-19 pandemic and now the perception regarding these elements has probably changed.

However, the majority of the people attending the participatory process were urban citizens without a complete perception of the importance of the rural and natural landscapes. Such landscapes are important for maintaining the resources and ES that sustain the life of the city life and that have a main role in regulating vulnerability and quality.

- *Governance instruments for GBI development and management*

The tools are developed in two documents.

The first is a specific written document including the actions directed to the different sectors of the regional Administration, and a list of different economical

Table 9.3 The WTP in the different scenarios

	WPT (€ per family per year)	Annual value (MLN /year)	10 years value (MLN)
Scenario 1	43	3,6	36
Scenario 2	36	3,1	31

resources, suitable for the GBI improvement. ES and GBI are a transversal concepts and objects, and quality and benefits depend on different causes that reside in different operative sectors and policies.

Therefore, it is critical to address the administrative sectors that could have actual effects on the ES and the GBI, such as Agriculture and Forestry, Infrastructures and Public Works, Social Services, Basin and Town Planning, Climate Adaptation, Energy, and to indicate what kind of policies could consider the implementation of GBI.

The second document is the NBS abacus. A work tool that explain with words and graphic how to choose the best NBS to design an effective GBI with the priority ES and the vulnerability.

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