RETHINKING THE ECOLOGICAL NETWORK PROJECT CONSIDERING NEW QUESTIONS RAISED BY URBAN COMPLEXITY

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Abstract

Environmental integrity and ecological continuity have become central issues for promoting sustainable territorial development in the context of the ecological transition.

Beyond addressing the fragmentation of natural spaces and biodiversity loss, contemporary spatial planning and ecological network design are increasingly required to enhance ecosystem services, support climate change adaptation and mitigation, and respond to emerging community needs.

The opportunity to test an integrated and complex approach highlighted the need to reread and reinterpret the constituent elements of the ecological network project. Focusing on the ongoing revision of the Territorial Governance Plan and the Ecological Network Plan of the Municipality of Mantua, originally adopted in 2012, the research explores how ecological network planning can be updated today to reflect new environmental priorities and planning paradigms.

The paper is structured around a critical reinterpretation of the conceptual paradigms that have accompanied the evolution of ecological network planning. These paradigms provide the analytical framework through which the Mantua case study is examined, allowing the identification of three key design directions that characterise contemporary ecological network planning. Building on the dialogue between theoretical reconstruction and empirical evidence, the study ultimately suggests the emergence of a new landscape-centred paradigm intended to support the future evolution of ecological network planning.

Keywords: ecological network, ecological transition, continuity, multifunctional connections, renewed challenges, landscape, cultural identity.

The Evolution of the Concept of Ecological Network

In recent years, the ecological network project has undergone a profound transformation. Created as a specialised response to habitat fragmentation and often translated into plans perceived as a technical device or a set of constraints, it has progressively become a structural mechanism of territorial governance, an integrated way of reading and organising cities, the countryside and natural systems, guiding transformations and, more recently, dealing with the climate crisis, loss of biodiversity and quality of life. In this process, not only has the sophistication of analytical tools evolved, but above all the idea of what a network should be has changed. A significant shift has occurred from conceiving it as a connection between prestigious areas to understanding it as a territorial infrastructure capable of producing ecological continuity, landscape value and environmental performance.

As a premise for a report on this type of design-based investigation, it is useful to reconstruct this evolution by distinguishing a few phases, not as rigid periods, but as trajectories of a reflection on culture and operations. These trajectories overlap and are still recognised today as constituting the different design experiences. In this reading we can recognise three main stages:

- an initial phase that we could call experimental and foundational, extending up to the first five years of this century, which favoured conservation strategies and the recognition of systemic frameworks of areas dedicated to conserving and protecting the existing natural value;
- a second stage that we could call territorial and landscape integration (spanning 2005 to 2015) in which the focus of the ecological network project was expanded to integrating the ordinary matrix of the rural landscape and planning tools;
- a third phase in which the ecosystem and multiple functions were characterised, introducing elements of reflection on the role of ecosystem services and their social benefits. The last stage featured greater attention to the climate crisis and the opportunities offered by applying regenerative strategies, in which the network became infrastructure for resilience and a platform for interventions oriented around nature-based solutions.

Each step corresponds to an ‘expansion’ with respect to approaches that present a variety of complementary aspects. It starts with habitat defence and a focus on protecting species recognised as important, followed by a transition to a landscape-territorial dimension, arriving at an ecosystem-performance vision with a strong focus on climate-adaptive aspects.

In the first phase, the ecological network is built around a clear and simple objective: combating the effects of fragmentation produced by widespread urbanisation and linear infrastructures and combating such agricultural simplification that reduces the ability of ecosystems to evolve. The scientific references are landscape ecology and conservation biology (patch mosaics and corridors, meta populations, isolation thresholds), while the European regulatory framework — the *Habitat Directive 92/43/EEC*, *Birds Directive* and *Natura 2000* — offers a set of objectives, categories and

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perimeters to guide the protection of values present in the territory. In terms of design, a composition consisting of a set of recurring 'elements' prevails core areas (highly natural nodes), ecological corridors and buffer areas. The first applications favour a large-scale approach with the identification of existing or potential continuity, often using ground cover readings and identifying barriers and permeability. The main limitation of this approach lies in the distance between interpreting the existing features and implementing the interventions. The network is frequently designed around complex analytical readings, but it struggles to develop designs from indications and operational strategies that can restore ecological values in ordinary contexts.

In this first phase, a decisive part of the conceptual structure of ecological networks stems from the junction — and partial overlap — of conservation biology and landscape ecology. While the former introduces the urgency of combating biodiversity loss and the isolation of populations in fragmented territories, the latter offers a true 'spatial grammar' for reading and designing the territory: the patch–corridor–matrix mosaic, the notions of matrix permeability/resistance, measuring discontinuities and thresholds, attention to margins and ecotones. This disciplinary fusion enables an important step from considering individual prestigious sites to considering territorial structure and flows. These connections and processes also cross ordinary spaces (agricultural, periurban, infrastructure-based). On an operational level, landscape ecology helps to translate ecological concepts into representations and planning tools (land coverage maps, fragmentation analysis, identification of potential barriers and corridors), feeding the idea that protection cannot be limited to protected areas but must involve the overall matrix. At the same time, it is precisely this 'analytical-structural' origin that explains a typical limitation of this phase. The network tends to be designed as the result of complex readings, while translation into projects and rules for implementation, especially in ordinary contexts, is often weaker and discontinuous.

One important example of this approach is the International Union for Conservation of Nature (IUCN) publication entitled *Integrating biodiversity conservation and sustainable use: lessons learned from ecological networks*, developed to verify the implementation status of current initiatives and consolidate the initial experimental results (Bennett, 2004). The publication presents a scheme, which, in its simplicity, can be used effectively as a reference for describing the elements constituting the network as understood in the first phase of conceptual development (Figure 1). As Bennett (2004, p.6) highlights: "More importantly, the approaches also share a common understanding of how this model should be applied on the ground, namely through the allocation of specific functions to different areas, depending on their ecological value and their natural-resource potential." As explained in the text, these functions are linked to a complex system of territorial components. Bennet refers, in fact, to central areas, where the key focus is the conservation of biodiversity; corridors, which act as links between the various areas; buffer zones, which filter out

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potentially harmful external influences and are essentially transition zones where compatible land uses can be found; and areas for sustainable use, where a certain balance can be found between the exploitation of natural resources and the safeguarding of ecosystem functions.

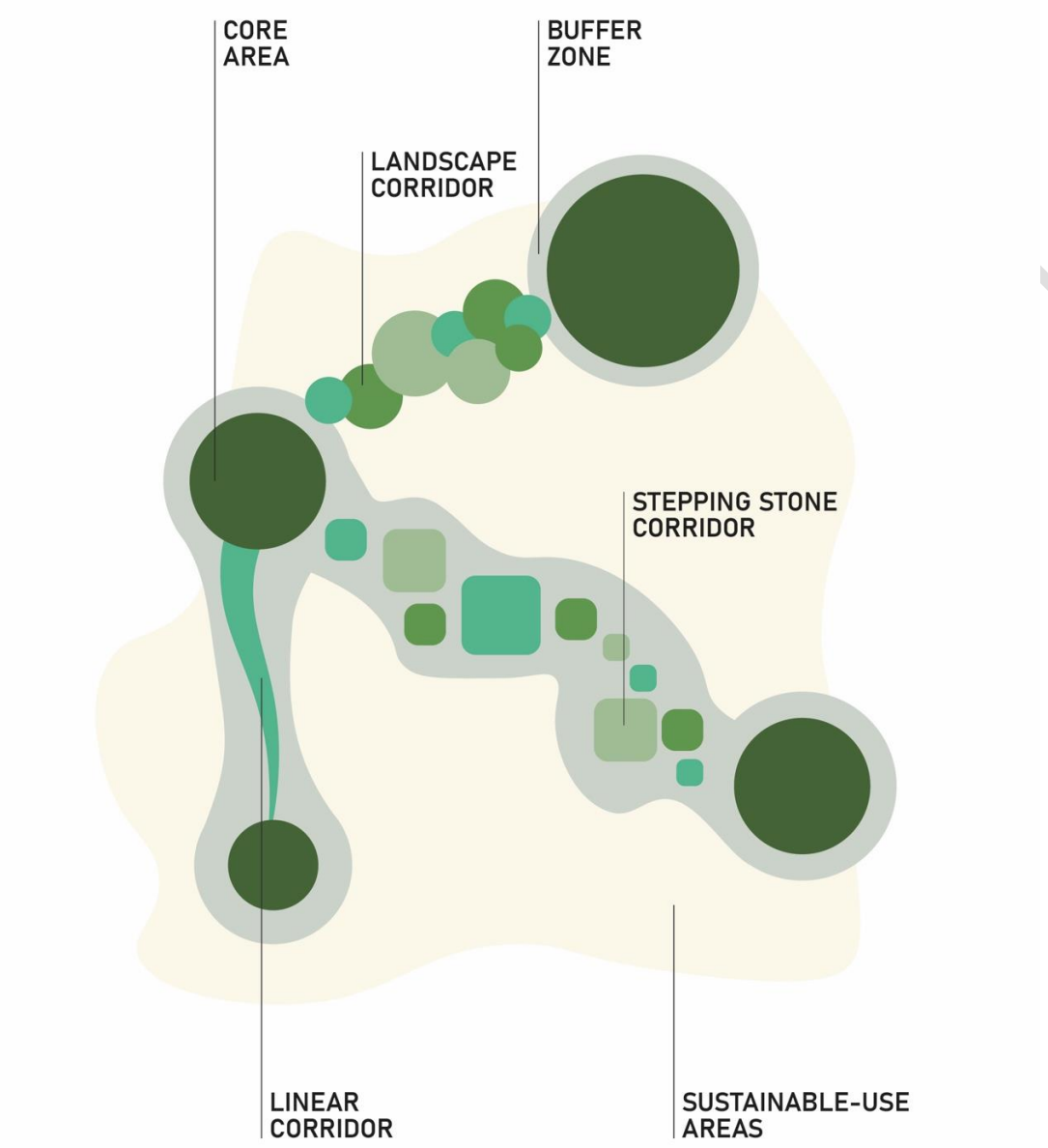


Fig. 1: Spatial representation of the ecological network building blocks (Source: authors' graphic elaboration base on Bennett, 2004)

The second phase is marked by the progressive implementation of the ecological network project in spatial and landscape planning. The ecological network no longer aims to connect protected areas or sites of ecological value. It is understood that connectivity depends on the quality of the territorial matrix as a whole and that ecological processes also cross agricultural, periurban and infrastructure landscapes. The European Landscape Convention and its progressive cultural influence push us to consider the network as an element capable of structuring the landscape, giving shape and meaning to transformations, mitigating impacts and mending discontinuities (Council of Europe, 2000). From

a methodological point of view, the use of GIS systems and connectivity analysis (network and graph modelling) is growing, but the challenge is also institutional. To coordinate different actors and make management continuous throughout a structure that crosses fragmented skills.

In this second phase (roughly 2005–2015), the ecological network gradually moved out of its specialist enclosure and the main challenge became integration, which could be summarised by the prefix ‘multi’. Multidisciplinary, because the network could no longer be built using only biological categories. It had to interact with urban and landscape planning, hydraulics and water management, agronomy and forestry, slow mobility and public space, up to issues of health and wellbeing. At this stage, the network ceased to be merely an object to ‘map’ and became a governing device, which required design criteria and rules capable of holding ecological quality and territorial transformations together. Multiscale, because connectivity did not coincide with administrative boundaries. Ecological corridors followed river basins, ridges, agricultural and infrastructure networks, requiring coherence between superordinate levels (regional/provincial) and local (municipal) translation into rules, projects and priorities. Multi-institutional, because implementation depended on fragmented skills: planning, public works, green management, basin authorities, consortia, park authorities, farmers and infrastructure managers. The result was a paradigm shift in which the network was no longer concerned solely with ‘planning’, but also with governance – that is, coordination, agreements, action plans and ongoing management. This is where ‘multi’ becomes the real test: turning shared knowledge into concrete actions that can be financed and maintained over time.

In the second phase, the lexicon and conceptual structure of ecological networks progressively shifted towards green infrastructure, which can be read as a true evolution. There was a change not only in name, but also in the role assigned to the network. While the ecological network in the first phase was primarily a tool to combat fragmentation and habitat isolation, green infrastructure was developed and established as a planning approach to deliberately integrate nature and natural processes into territorial development. It emphasised the ability of green and blue systems to provide multiple, measurable benefits, integrating ecological corridors, open spaces, river systems, slow mobility networks and multifunctional agriculture.

This transformation occurred for two main reasons. The first was operational. Locally, space is limited and skills are fragmented; the idea of infrastructure makes it possible to treat green areas not as residual or ‘standard’, but as a strategic network comparable (in importance) to grey infrastructure, capable of guiding investments, rules and maintenance. This step is exemplified by the approach of Benedict and McMahon (2006), who proposed green infrastructure as a planned network of natural and semi-natural spaces that support ecological functions and human needs, while providing a language that is more understandable to decision-makers and more usable in planning processes.

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The second reason is conceptual. In the second phase, the focus on multifunctionality increased. The network serves both biodiversity and health and wellbeing, urban quality, water management, landscape continuity and slow mobility. The literature of those years insisted on this transition. Urban and periurban green space systems were read as infrastructure that simultaneously supports ecosystems and quality of life and requires connections between different components and scales. The establishment of green infrastructure as a European framework matured up to the 2013 European Commission Communication, which defined Green Infrastructure (GI) as an approach based on integrating nature protection and enhancement in territorial planning and development, emphasising complementarity, or an alternative, with grey infrastructure and the value of natural solutions when they are the best option (European Commission, 2013).

At this stage, therefore, the ecological network tended to focus less on corridor design and more on a framework of guidelines: types of connection and open space, performance requirements, rules for transformation and regeneration, and governance criteria. This is where the evolution towards green infrastructure makes the network more 'oriented': because it ties into recognisable territorial functions, benefits for communities and verifiable investment choices. This perspective was consolidated in the European Commission's Green Infrastructure Strategy, which emphasises that "Human society depends on the benefits provided by nature" (European Commission, 2013, p.1). Starting from this premise, the Communication argues that ecosystem services are often undervalued and treated as if they were unlimited resources, leading public authorities to favour grey infrastructure over nature-based solutions. Consequently, the continued degradation of natural capital undermines both long-term sustainability and the resilience of territories to environmental shocks.

The third phase introduced a further step relating to the affirmation of the sustainability paradigm, with reference to the SDGs (United Nations, 2015) and ecosystem services. The idea that natural factors provide measurable and relevant ecosystem performance for communities was established. Such factors include microclimate regulation, air quality, water management, soil stability, support for pollinators, enjoyment and wellbeing. The ecological network was thus reinterpreted as a multifunctional infrastructure that produces services. It was no longer just a design for continuity in an extra-urban area, but a set of elements used to plan interventions, priorities and maintenance. Applications grew in urban areas, where the network is intertwined with parks, public spaces, water networks, residual agricultural land and green-blue corridors.

At the same time, the focus on management was strengthened. Without rules for use, consistent agricultural practices, control of invasive species, care of riverbanks and maintenance continuity, the network project risks remaining fulfilled only in name, incapable of expressing any ecological value. In recent years, the ecological network project has played a decisive role in climate adaptation and regeneration strategies. More frequent extreme events, heat islands, waterproofing and hydraulic

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vulnerability, together with the new framework of European strategies (*Green Deal* and *EU's Biodiversity Strategy for 2030*), urge us to consider the network as an infrastructure of resilience and platform for nature-based solutions. The network project incorporates adaptation and mitigation objectives: urban shading and cooling, water basins and infiltration, renaturalization of riverways and minor networks, recovery of land and infrastructure margins and increasing ecological continuity and habitat quality. The need for a more 'performative' approach is clear, in which the network is called upon to contribute to improving the complex relationship between ecosystem elements and anthropic action: reducing risk, improving health, increasing accessibility to green spaces and contributing to regeneration strategies and environmental compensation. This new approach also leads to a change in overall governance. The network requires programmes, resources, partnerships and monitoring in addition to boundaries.

In this third phase, the centre of gravity shifts from the conceptual approach to implementing and measuring the effects. The ecological network becomes credible if it can produce verifiable effects and guide investments and management choices. In this step, the issue of ecosystem value is key, not only with the presence of natural elements, but also the services they offer the territory and communities: microclimate regulation, air quality, water infiltration and basins, ground stability, support for functional biodiversity, enjoyment and wellbeing. Measuring these benefits serves three operational purposes: (1) defining the intervention priorities with the greatest impact (heat hotspots, areas with water-related risk, neighbourhoods with green deficits); (2) justifying and making choices comparable, strengthening the ability to intercept resources and integrate the network into regeneration programmes; and (3) governing the network as infrastructure over time, linking design and maintenance to performance objectives. As a result, the network project is enriched with assessment tools (indicators, targets, scenarios) and monitoring devices, shifting the focus from the mere identification of ecological corridors to the definition of expected outcomes and the methods for verifying them. In this phase, the ecological network becomes a platform of solutions based on nature and restoration, in which effectiveness is not only declared, but demonstrated through simple and shared metrics capable of connecting biodiversity, climate and quality of life.

This concept is also supported by Cortinovis and Geneletti (2018), who identify two major challenges for the operationalization of ecosystem services in urban planning. The first concerns the mismatch between the scales at which ecosystem services are analysed and those at which planning actions are implemented. The second relates to the multifunctionality of urban green infrastructures, arguing that assessment methods should better account for the simultaneous provision of multiple ecosystem services under alternative planning scenarios.

Taken together, these three trajectories reveal a gradual reorientation from the network of nature nodes to the network as widespread quality of the territorial matrix; from protection as the dominant

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objective to integrating protection and transformation; from map design to the infrastructure being managed; from a static vision to adaptive and resilience criteria extended throughout the territory and urban system.

This awareness forms the basis for the proposed reflections, which aim to understand how this evolution can strengthen the work conducted in previous years to recognise an existing network and build a strongly integrated and feasible working strategy upon it. This involves defining a multiscale structure consistent with ecological dynamics and settlement needs. It is therefore necessary to select priority interventions and measures for mending and naturalisation, specifying the expected performance, management requirements and monitoring indicators. In other words, it is necessary to consider the ecological network, recognising its different components as a design structure capable of accompanying transformations and measuring its effectiveness over time.

Research approach

The research adopts an interpretative and design-oriented approach aimed at understanding how the concept of ecological networks has evolved and how this evolution has influenced planning practice. The first aim of the research, condensed in the first part of the paper, corresponds to the critical reconstruction of the conceptual evolution of the ecological network project by identifying a limited number of major developmental trajectories. These trajectories serve as interpretative frameworks for understanding the evolving role and scope of the ecological network, highlighting a changing perspective from a conservation tool to an integrated framework for planning and governance.

As highlighted in the introductory paragraph, there are three main paradigm shifts which this research aims to explore. The first conceives the ecological network as a conservation-oriented and analytical tool, primarily aimed at restoring ecological continuity between habitats. The second marks the transition towards an integrated planning and governance device, characterized by the interaction between disciplines, spatial scales, institutional actors and territorial functions, anticipating the paradigm of green infrastructure. The third redefines the ecological network as a performative infrastructure, capable of supporting climate adaptation and territorial regeneration through ecosystem services, monitoring and performance-oriented management.

These paradigms constitute the analytical framework adopted in the research. Rather than providing a purely historical reconstruction of the evolution of ecological networks, they define the interpretative lens through which the empirical investigation is conducted.

The framework is subsequently applied to the Mantua case study, where the conceptual evolution is examined through a long-term planning experience. The longitudinal analysis of provincial, regional and municipal planning instruments, together with the ongoing revision of the Municipal Territorial Governance Plan, makes it possible to investigate how different, and at times overlapping, conceptual

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paradigms have been translated into planning practice over time. The emphasis therefore shifts from the evolution of ideas to the evolution of planning instruments, revealing how changing ecological objectives have progressively reshaped design principles, governance mechanisms and implementation strategies within a specific territorial context.

By comparing the theoretical trajectories with their concrete application in Mantua, the research identifies both the continuities and the discontinuities that have characterized this process of transformation. This comparison ultimately allows the emergence of a set of design questions that extend beyond the case study itself and provide the basis for reinterpreting the role of ecological networks within contemporary territorial planning.

The outcome of this process is not merely the interpretation of the Mantua experience, but the identification of a set of design questions that can support the contemporary reinterpretation of ecological network planning beyond the specific case study. Although these design issues largely reflect themes that are already well-established in planning literature and practice, the research argues that their sequential and integrated analysis highlights a broader evolutionary trajectory. It is precisely the gradual convergence between these design approaches that suggests the emergence of a new conceptual trend, in which landscape represents the organising principle capable of integrating ecological processes, social practices and territorial transformations within a single interpretative framework.

By combining conceptual reconstruction, empirical evidence and theoretical reinterpretation within an iterative research process, the study aims to contribute to the current debate on ecological network planning. This iterative dialogue between theory and practice (Figure 2) provides a framework through which established planning themes can be reconsidered and emerging territorial challenges critically addressed.

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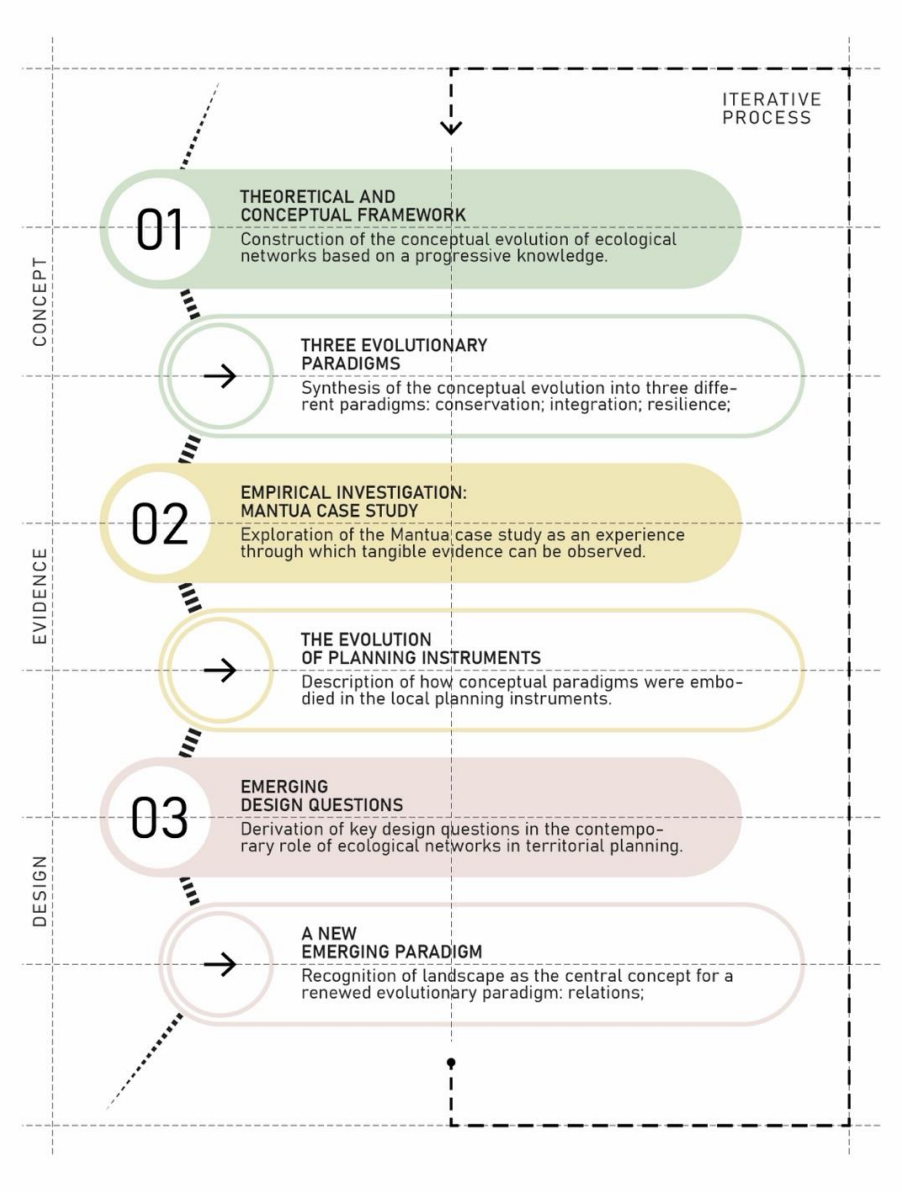


Fig. 2: An outline of the research approach, illustrating the iterative relationship between theoretical reconstruction, empirical investigation and theoretical reinterpretation for the design of the ecological network. (Source: authors' graphic elaboration)

The Experience in Mantua — Milestones along the Journey

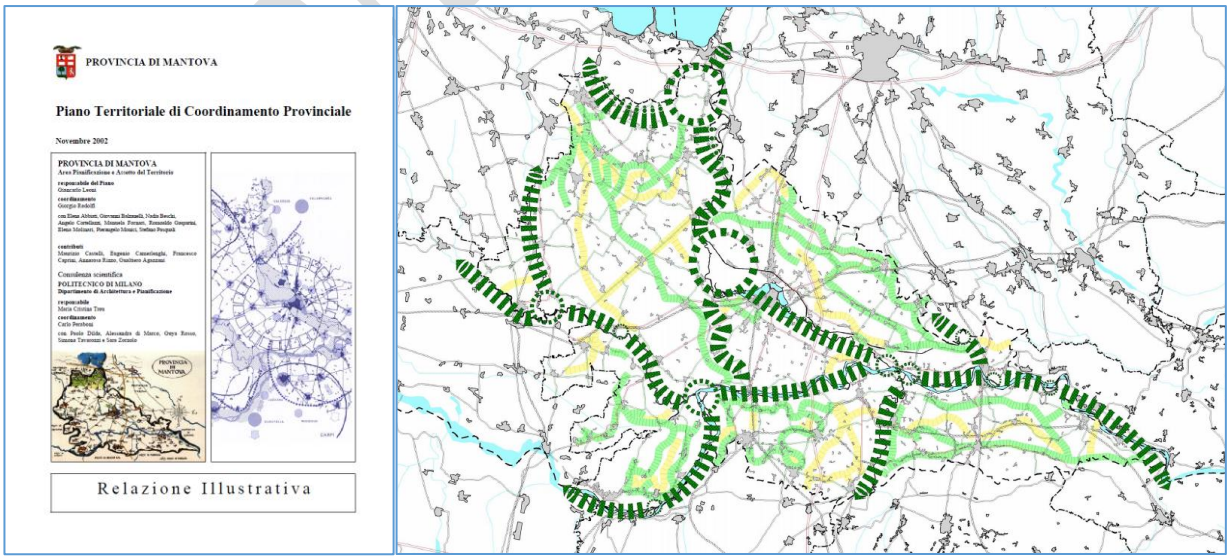
The reflections that we present were inspired by the research we undertook at the Politecnico di Milano Mantua campus starting in the early 2020s. During this period, we had the opportunity to help the Mantua City Administration redesign the system of green areas and, more in general, articulate strategies to strengthen and enhance the system of areas with high natural value in the city. This reconsideration involved the need to reconstruct the different passages defining the protection and enhancement strategies proposed by the City of Mantua. The research made it possible to focus on a number of tools that have represented milestones in the evolutionary path outlined in the first part of this contribution. Their analysis also highlights the permeability of the temporal boundaries between these lines of development. In the Mantua context, some concepts and approaches emerged relatively

early and coexist within the same planning instruments with elements associated with different trajectories. For example, the Provincial Plan – as will be discussed in more detail later in this section – not only incorporated the ecological network into the planning framework, demonstrating how issues that later became central to subsequent planning debates had already been addressed in Mantua in the early 2000s, but also set the stage for some rather topical considerations that we now associate with the issues of climate change and community wellbeing.

In various ways, these tools have constituted an evolution towards strategies to enhance more structured natural values. The tools were prepared at different scales and with different levels of prescriptive capacity as the result of reading the natural characteristics present in the territory, over which a variety of design initiatives have progressively been superimposed, not always coherently or capable of defining congruent working trajectories.

The experience in Mantua began with approval of the *Provincial Spatial Coordination Plan*[1] approved by Provincial Council resolution no 61 of 28 November 2002 (Figure 3).

With this resolution, the Province of Mantua included an organised ecological network design in its planning tool to define a design-based reference scheme in line with the regional legislative framework in order to identify an ecological network extending throughout the province. This choice anticipated the work on the regional level and built a systemic vision of ecological corridors useful for connecting the existing protected areas in its territory.



[1] Throughout the paper, english translations are used for the main italian planning instruments to facilitate readability for an international audience. The original Italian denominations of the main planning instruments are reported below, in the order in which they appear in the text: *Provincial Spatial Coordination Plan* corresponds to *Piano Territoriale di Coordinamento Provinciale* (PTCP); *Lombardy Regional Territorial Landscape Plan* that is *Piano Paesaggistico Regionale* (PPR); *Regional Ecological Network* is the italian *Rete Ecologica Regionale* (RER); *Regional Territorial Plan* refers to *Piano Territoriale Regionale* (PTR); *Territorial Governance Plan* responds to *Piano di Governo del Territorio* (PGT); *Service Plan* is the so called *Piano dei Servizi* (PdS); *Municipal Ecological Network* coincides with *Rete Ecologica Comunale* (REC); *Rules Plan* is the *Piano delle Regole* (PdR);

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Fig. 3: Diagram of the Province of Mantua Ecological Network (Source: *Provincial Spatial Coordination Plan*, Mantua, 2002).

The experience stemmed from an integrated process that spanned three complementary phases, resulting in the development of the so-called *Atlas of Environmental Information*, which is a collection of maps for analysing the Mantua area (Figure 4).

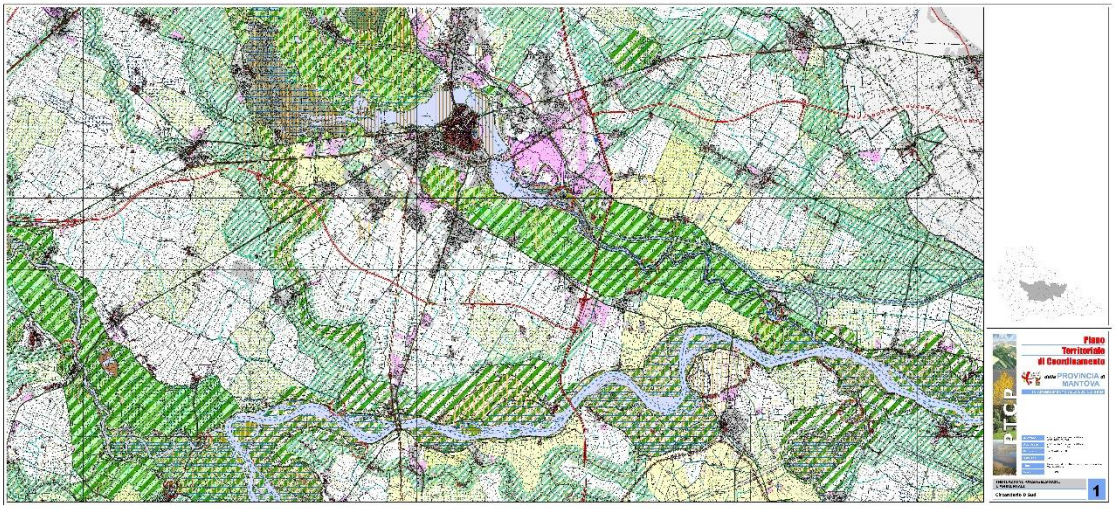


Fig. 4: Landscape and environmental indications: District D South (Source: *Provincial Spatial Coordination Plan*, Mantua, 2002)

In the first phase, the elements of landscape-environmental value around Mantua were identified and the results were summarised in a series of thematic maps containing information on the characteristic elements of the physical-natural system. Specifically, a series of maps were produced regarding altimetry, land use and coverage, landscape units, aquifer vulnerability, agricultural land use capacity, the main hydrographic network and irrigation systems.

The second phase focused on identifying factors of disturbance and environmental degradation due to human intervention, which were analysed in a thematic map. The map of urbanised and critical areas was prepared to identify possible crises and highlight where the most suitable interventions should be implemented in the future to improve and salvage the most critical situations.

Finally, the third phase looked at a number of superordinate plans – such as *Lombardy Regional Territorial Landscape Plan*, *Territorial Park and Nature Reserve Coordination Plans*, the first version of the *Mantua Provincial Territorial Coordination Plan, Provisional River Plan*, etc – to adopt possible indications, with particular reference to environmental choices and requirements.

The work followed up on the references provided in relation to the first evolutionary phase of the network concept, defining an ecological network understood as a system of core areas. These areas contain high-value habitats, ecological corridors that facilitate connections between habitats, and

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areas designated as buffer zones to protect the natural assets found in the areas of the highest ecological quality.

The theoretical reference for the experience was *Landscape planning and ecological networks* (Cook, van Lier, 1994), which highlighted the need to systematise the topics of landscape planning and landscape ecology to make the construction of ecological networks operational. In this sense, the book has fostered a dialogue between different disciplinary perspectives by integrating the ecological interpretation of landscape structure — based on concepts such as the patch-corridor-matrix mosaic, ecological processes and multiple spatial scales — with the planning dimension, which focuses on land-use regulation, design criteria and decision-making processes. In doing so, it anticipated one of the central challenges that still characterises the planning of ecological networks today: bridging the gap between ecological analysis and the operational implementation of planning and design solutions.



Fig. 5: Report of the *Regional Ecological Network* (Source: *Regional Ecological Network*, 2010)

The debate and broad disciplinary discussion initiated at the beginning of the 21st century on the role of ecological networks and their potential in terms of connecting the constituents of protected natural areas led to approval of the *Regional Ecological Network* project in December 2009. A few months later, in June 2010, the final version of the work was published, and this regional instrument was recognised as 'priority infrastructure' in the *Regional Territorial Plan* and an element to use as a guideline for municipal planning (Figure 5). The final documentation includes a definition of the criteria to use when implementing the *Regional Ecological Network* in projects by the individual municipalities; it provides a framework of existing priority natural sensitivities and a drawing of the characteristic elements of the regional ecosystem.

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This network becomes a reference for assessing strengths and weaknesses, opportunities and threats in the region. It supports the implementation of the *Regional territorial Plan* by coordinating *Provincial Spatial Coordination Plan* and municipal *Territorial Governance Plan*, while ensuring coherence with regional plans and programmes in the sector. Finally, it identifies priority sensitivities and sets specific targets to consider the need for ecological rebalancing.

In this sense, the *Regional Ecological Network* provides regional actors with a nature and ecosystem orientation framework to identify compatible planning actions while providing the relevant offices with indications on spatial priorities to improve the system overall.

One text that significantly summarises the Ecological Network as a multipurpose structure was *Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes*, in which Opdam and the other authors indicate how the concept of ecological network can be used as a methodological basis for including biodiversity conservation in sustainable development strategies (2006). The paper theorises that in multifunctional landscapes dominated by humans, biodiversity conservation requires a coherent large-scale spatial structure capable of connecting different ecosystems. Theoretical and empirical knowledge of ecological networks provides a framework for designing such structures. This is why ecological networks can bridge the existing paradox between conservation strategies for protected areas (which conserve natural structures in space and time) and peaks in development, which imply the progressive change and transformation of habitats. By definition, the structure of networks can change without losing their potential for connection and conservation capacity.

In the final part of their essay, the authors recall that "Another challenge is to determine the added value of the use of ecological networks in the planning process, both from the point of view of more effective decision-making and a more sustainable outcome for biodiversity" (Opdam et al., 2006). In terms of Potschin and Haines-Young (2003), the ecological network could be used to develop an ecologically viable future based on biophysical needs as well as on societal needs and aspirations. The range of possible sustainable solutions for a network demarcate the "room to maneuver" (Potschin and Haines-Young, 2003). The role of networks in linking ecological scales across landscapes, regions, nations and continents also needs to be explored, for example, in the context of adapting the landscape to the effects of climate change on biodiversity (Opdam, Wascher, 2004). These ecological scale levels are paralleled with administrative scale levels (Jongman, Pungetti, 2004), and one of the main challenges will be to have administrative units cooperate across ecological scales (Opdam et al., 2006).

A few months after final approval of the *Regional Ecological Network*, the City of Mantua issued Resolution n. 60 of 21 November 2012 approving its urban planning tool, known in regional law as the *Territorial Governance Plan*. The issue of incorporating the *Regional Ecological Network* into

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the territorial governance tool developed on the municipal level is addressed in two different sections: a section based on the recognition, planning and cognitive framework of reference for the economic and social development of the City and the section of *Service Plan*. In the first section, reference is made to understanding the role that the *Regional Ecological Network* can play in defining environmental redevelopment and reconstruction objectives. The document incorporates three strategic objectives: protection, aimed at safeguarding the existing importance with regard to the biodiversity and ecosystem functions still present in Lombardy; enhancement, intended to strengthen the existing importance, increasing its capacity as an ecosystem service in the territory and usability by human populations without affecting the level of the resource; and reconstruction, focused on actively increasing the existing natural heritage and biodiversity through new multipurpose regeneration projects capable of increasing the service capacities for sustainable development. Weaknesses in the current ecosystem can be strengthened to offer greater prospects for rebalancing.
The *Service Plan*, the tool entrusted by regional law with defining strategies to enhance and design ecosystem values, indicates that the locally identified ecological network should:

- incorporate regional and provincial indications, along with their adaptation on the municipal scale;
- recognise valuable areas and habitats (current and future) that must be subject to a protection regime or at least specific land use to guarantee its conservation and correct transformation over time, also in terms of ecosystem functionality;
- define concrete actions to implement the ecological network project, their location, and solutions that enable their implementation (for example, by purchasing areas or targeted agreements with owners), quantifying the cost of the different options;
- specify the tools needed to guarantee their economic sustainability (thereby introducing mechanisms for equalisation and compensation and possible conventions to implement the projects).

The municipal ecological network is therefore defined in light of regional and provincial indications and represents a priority area for implementing compensation and naturalisation interventions designed to counteract major territorial transformations. It serves as a reference for the territorial structure and in particular for defining rules and protections in agricultural areas, as well as a tool for assessing transformations. With this reasoning, the general outline of the *Municipal Ecological Network* is incorporated into the planning strategy map and subsequently developed in greater detail within the *Service Plan*, where its implementation is regulated in coordination with the *Rules Plan*.
The municipal ecological network is conceived as service infrastructure, with various design interventions planned for its implementation, consistent with the ecological structure.

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The project addresses the need to create a network of ecological nodes of supra-local importance and arranges a series of ecological corridors useful for enhancing ecological systems in the territory. Along these corridors, the project indicates the gaps to bridge and the agricultural areas recognised as holding landscape value, as well as the extent of the protective band of the water network.

The design is structured around a system of ecological connections extending east of the city, in line with the *Regional Ecological Network* guidelines and the *Framework Agreement for Territorial Development* coordinated by the Lombardy Regional Government. The plan envisages a subsequent phase to work on the low course of the Diversivo di Mincio canal up to its confluence with the Fissero canal, thus fully connecting the protected areas of Bosco della Fontana and the Mincio Valleys.

The *Service Plan* (Figure 6) also provides that for all interventions with a high environmental impact in the municipal area, compensation must be located within the municipal ecological network, contributing to its implementation and improvement.

With regard to areas of transformation and areas affected by urban regeneration projects, operators must plan to implement renaturalization projects equal to at least 10% of the land area affected by the intervention.

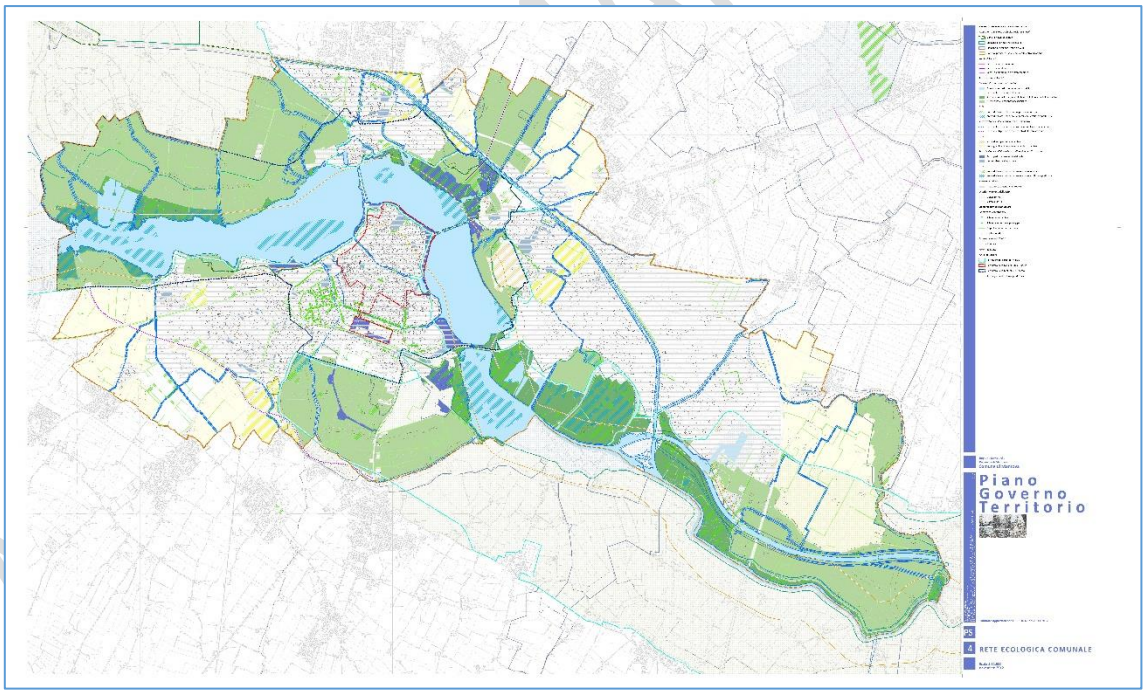


Fig. 6: Graphic elaboration of the Service Plan (PS4): Municipal Ecological Network (Source: *Territorial Governance Plan*, Mantua, 2012)

The New Municipal Ecological Network Project

In recent years, and especially in Europe, ecosystem protection and restoration has been firmly embedded in climate policies, not only as an environmental objective, but also as a condition of

resilience for the territories. The idea of an 'ecological network' can therefore be reinterpreted as infrastructure that supports crucial services relating to urban security and liveability: temperature regulation, water management, ground stability, ecological continuity, air quality, wellbeing and health. Since 2012, these concepts have shaped the document *Living well, within the limits of our planet* (European Commission, 2012) and the document *Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change* (European Commission, 2021). In the first one the European Commission (2012, p. 11) states that to live well "in the future, urgent, concerted action should be taken now to improve ecological resilience and maximise the benefits environment policy can deliver for the economy and society" The programme frames this objective within the broader transition towards an inclusive green economy trat promotes economic development while safeguarding human well-being, reducing inequalities and investing in natural capital.

This document follows another strategy approved by the European Commission in 2012 entitled *Our life insurance, our natural capital: an EU biodiversity strategy to 2020*, in which member states are explicitly asked to monitor and evaluate the state of ecosystems and their services and integrate them into accounting and decision-making systems by 2020. This is the step that 'institutionalises' ecosystem services in Europe, reminding us that "mapping and assessing ecosystem services in the EU […] will enable targeted and efficient measures to be taken to halt the degradation of biodiversity and ecosystem services" (2012, p. 2).

The comparison between the conceptual evolution of ecological networks and the longitudinal analysis of the Mantua case study makes it possible to identify a set of recurring design questions. These do not constitute new planning themes; rather, they reinterpret well-established issues within a coherent analytical framework derived from the iterative dialogue between theory and practice developed throughout this research. The outcome is set out in three interrelated design guidelines that contribute to redefining the contemporary role of ecological networks. In this sense, the combination of these different inputs contributes to give substance to a broader and already established planning issues, allowing them to be reconsidered within a coherent framework for the contemporary development of ecological networks.

- *Orienting the project around defining strategic guidelines for sustainable and resilient development, understood as a possible response to the need to adapt and mitigate the effects of climate change.*

On the municipal level, the ecological network can no longer be considered a mere protective device or the simple representation of corridors connecting prestigious areas. In the 'new' vision, it becomes green-blue infrastructure capable of guiding territorial transformations towards sustainability and resilience in a unified way. Indeed, climate change is not revealed as an abstract phenomenon but

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rather arises through localised cumulative effects — heat waves, water stress, intense rainfall and flooding, erosion and loss of soil fertility — which interact with the urban form, soil sealing, ecological fragmentation and the quality of open spaces. In this respect, the municipal ecological network can be viewed as a strategic response because it relies on multifunctional logic to combine territorial elements that reduce vulnerability and exposure: permeable and continuous land, water networks and riverways, wetlands, forests and rows of trees, urban parks, agricultural margins and small diffuse connections.

Orienting the project around strategic guidelines means moving from the network 'design' to defining principles and criteria for implementation: where to preserve and where to mend, which land to avoid consuming, how to integrate greenery into regenerating the existing fabrics, how to manage storm water with widespread solutions, which quality standards to require for new transformations and which priorities to assign to hotspots of climate risk and distress. At the same time, mitigation must be situated in a realistic but not marginal way: increasing plant cover and carbon sequestration in the soil, reducing energy needs through shading and passive cooling and supporting active mobility when the network is integrated with cycling-pedestrian paths. Understood in this way, the ecological network becomes a framework for coherence between sector policies, specific projects and calls for verification relating to measurable objectives, simple indicators (permeability, canopies, green-blue continuity, accessibility to greenery) and rules for management and monitoring over time. This ability to translate ecological knowledge into design indications and directions into effective action enables the municipal network to act as a guide for truly sustainable and resilient development, while strengthening biodiversity and landscape quality.

- *Strengthening the identity of the territory and local characteristics, encouraging community involvement in the design, development and management of a network of infrastructures and places that meet the different needs of the territory.*

On the municipal level, strengthening the identity means recognising that the ecological network is not just a technical device for biological continuity, but also an 'infrastructure of meaning', a system of spaces, paths and places that makes local characteristics legible and enhances the daily relationship between community and territory. It is not a question of 'museumifying' the territory, but of recognising its invariants and emerging characteristics to guide change without sacrificing quality, memory or recognisability. In this perspective, the network must be built starting from the structure and distinctive features — morphology and land, minor waterways and networks, agricultural plots and rows of trees, margins between urban areas and the countryside, forests, wetlands, panoramas and historical paths — enhancing them as elements of a shared territorial narrative and not as a mere 'backdrop' for transformations. Community involvement thus becomes a condition of design; not a formal fulfilment, but a way of integrating local knowledge (uses, critical issues, agricultural

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practices, places of care and use), perceptions (what is recognised as distinctive) and differentiated needs (children, elderly people, athletes, farmers, businesses) into coherent spatial and managerial choices. Listening, participatory mapping and co-design help to identify 'key locations' in the network — banks and canals, parks and gardens, cycling-pedestrian paths, tree-lined squares, vegetable gardens and agricultural margins, renaturalized areas — and define functions, accessibility levels, ecological requirements and maintenance methods for each. The result is a truly multifunctional network of infrastructures and places capable of supporting biodiversity and ecological continuity, while offering spaces for proximity, health and social interaction, improving microclimate comfort, strengthening equity in access to greenery and supporting compatible local economies (agroecology, short supply chains, slow mobility). To be credible, this direction requires operational attention, translating identity into criteria (materials, plant species, types of margins, water network continuity), ensuring inclusion and transparency in decision-making processes and above all building governance for territorial care (agreements with farmers and managers, collaboration pacts, educational programmes, civic monitoring) that ensures continuity over time. In this way, the ecological network not only meets territorial needs, but also becomes shared heritage, increasing social acceptability, management effectiveness and overall landscape quality.

- *Integrating different territorial components to build multifunctional green infrastructure capable of combining ecological values and community activities.*

At the municipal level, one of the main challenges of contemporary ecological network design no longer lies in simply connecting natural areas, but in the ability to integrate diverse territorial components within a coherent and multifunctional system. Ecological effectiveness no longer depends solely on the presence of natural corridors or nodes, but on the ability to interrelate ecological processes, water systems, public spaces, agricultural areas and the community's everyday practices within a single adaptive territorial project.

From this perspective, Green Infrastructure represents the primary operational mechanism through which such integration can be achieved. Its role is not simply to link natural elements, but to organise a territorial system capable of simultaneously delivering multiple benefits: ecological continuity, water regulation, climate adaptation, ecosystem services, soft mobility, territorial quality and public enjoyment. A watercourse can therefore function simultaneously as an ecological corridor, a flood retention basin and a cycle and pedestrian path; an agricultural field margin can incorporate habitats for pollinators, visual continuity and water filtration; a row of trees can serve as an element of ecological connectivity, climate mitigation and a distinctive feature of local identity. This type of stratification therefore requires managing the coexistence of potentially conflicting elements (intensive use versus ecological tranquillity, 'ornamental' maintenance versus ecological

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management, hydraulic safety versus renaturalisation), by defining gradients of use intensity, seasonal rules, protective measures and consistent maintenance criteria.

All this implies moving beyond sectoral planning. Multifunctionality does not mean the indiscriminate overlapping of different uses, but requires the conscious design of their interactions through gradients of naturalness, differentiated levels of accessibility, maintenance criteria and management rules capable of maintaining a balance between ecological conservation and social use. Green Infrastructure thus becomes the mechanism through which ecological knowledge is translated into design choices, enabling the various levels of the territory to interact rather than come into conflict.

At the same time, the project must introduce redundancy, complementarity and a plurality of connections, avoiding the reliance on a single corridor for the network's functioning and increasing the adaptive capacity of the entire territorial system. Municipal guidelines must therefore specify not only where to restore ecological continuity, but also how to integrate the various territorial components, what outcomes are expected — ecological continuity, biodiversity, water regulation, climate adaptation, accessibility and landscape quality — and through which management and monitoring tools to assess their effectiveness over time.

From this perspective, the ecological network evolves from a specialist conservation tool into a multifunctional territorial infrastructure, capable of simultaneously supporting ecological resilience, landscape quality and the day-to-day functioning of the territory.

A new emerging landscape-centred paradigm

Today, in the context of urban planning, contemporary challenges – such as climate change, economic instability, identity crises and the quest for a better quality of life – make the implementation of new paradigms and approaches increasingly urgent.

The design trajectories outlined in the previous section suggest that the current theoretical framework is only partially adequate for describing the contemporary role of ecological networks. Building on the three evolutionary phases discussed at the beginning of this essay, a critical analysis of their evolution now highlights the need for a broader paradigm, capable of integrating the various dimensions that currently characterise the design of ecological networks.

In light of the issues outlined above, the design of ecological networks must now necessarily move away from the conservative logic that characterised its early formulations and must be conceived as a multifunctional, adaptable and constantly evolving tool, capable of responding to the growing complexity of environmental, territorial and social challenges.

It is on the basis of this interpretation that the proposal for a new conceptual paradigm emerges. Along whit this change there is a gradual shift in focus from the network as a multifunctional infrastructure

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to the network as a relational system. This new paradigm, that takes the landscape as a reference point, concerns ecological processes, nature-human interactions and social practices.

Within this paradigm, the ecological network takes on an operational function: a tool for overcoming territorial fragmentation, integrating contrasting elements to strengthen ecosystems, promote the conservation and enhancement of biodiversity, and enhance the perception of the landscape.

Overcoming territorial fragmentation is now a necessity that simultaneously concerns ecological functioning, quality of use and the recognisability of places. In fact, on the municipal scale, discontinuities are not just 'habitat interruptions', but ruptures produced by urbanisation, infrastructure, agricultural simplification and the marginalisation of open spaces. These discontinuities result in a loss of biodiversity, but also in barely legible landscapes, degraded margins, an absence of slow connections and reduced daily perceptual quality. In this context, the landscape can play a decisive operational role, as it is the dimension in which ecology becomes form, and form becomes behaviour (crossing, stopping, caring for), leading to durable network choices.

An initial step is to assume that in order to be truly effective and feasible, the ecological network cannot remain a specialised design separate from social practice but must become a structure to develop a landscape vision. The European Landscape Convention defines the landscape as an "area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000). This definition is not only cultural, but also a methodological indication. It means that for the network to be strengthened, it must not only be ecologically correct, but also recognisable and 'habitable' in its all its parts: riverbanks, margins, agricultural plots, paths, trees and small diffuse nodes. Perception is not an ornament. It is a factor that influences consent, conflict, maintenance and, ultimately, the possibility to preserve and increase biodiversity over time.

Hence the need to integrate contrasting elements, not by eliminating differences, but by designing transitions and 'seams' that can turn barriers into thresholds: urban-rural margins, infrastructure escarpments and partitions, smaller canals and watercourses, production areas and isolated spaces. Landscape ecology has long shown how the spatial structure (patch mosaic, corridors and matrix) conditions flow of species, energy and material, and therefore the overall ecosystem functionality. In municipal practice, however, continuity almost never coincides with a single 'perfect' line. It is often built with a combination of redundant connections, microhabitats, stepping stones and diffuse matrix quality, i.e. with an increase in system complexity. This vision is consistent with the ecological network and greenway approaches, which express the need to translate ecological principles into planning and design choices that cross ordinary and hybrid contexts.

In this respect, the landscape is not only a desirable outcome, but a design criterion. It helps to identify where it is most urgent and effective to rebuild connections. For example, water lines and their

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riparian belts can be interpreted as ‘backbones’ that intertwine ecological continuity, water management, slow use and local identity. Likewise, rows of trees and hedges become minute but decisive infrastructure for ecological permeability and the recognition of agricultural plots. The literature on corridors and connectivity emphasises that linkages are not just transitions but can also constitute habitats and support ecological processes if designed and managed correctly. In parallel, the greenways strand highlights how connection can be conceived as a planning strategy to combine ecological, recreational and cultural objectives, building perceptible and usable continuity.

Ultimately, overcoming fragmentation through ‘smart landscape’ integrations means building a network that works on two inseparable registers: ecology (connectivity, habitat, processes) and perception/society (readability, identity, compatible use, care). Addressing the landscape in an operational key is precisely what makes the network more stable. What is recognised as a value — a continuous path along the water, an orderly agricultural margin rich in biodiversity, a system of planted margins that mends neighbourhoods and the countryside — tends to generate greater acceptability, monitoring and maintenance. Without these conditions, biodiversity conservation and improvement remain fragile or episodic.

In other words, addressing the loss of territorial continuity means looking at the complexity of everyday life from an evolutionary perspective in which the landscape acts as a catalyst. The relational quality of the landscape, which was universally recognised by the European Landscape Convention in 2000, places the landscape on a different level, in which environmental demands and anthropic issues do not appear as independent aspects but blend into a broader need for culture and identity.

Unlike the concept of heritage, which views the landscape is a resource to be evaluated and framed among its different physical variations, this research intends to anchor itself to a more detailed perspective, the same vision promoted by the European document, which focuses on the issue of the quality of places as a fundamental condition for people’s quality of life (IASLA, 2022). In a mutually dependent relationship, places not only influence people’s lives; their future development is also strongly tied to the way in which people perceive and assess the different architectural, historical and cultural features of the place. The idea that building the identity of a single aspect or entire communities passes through experience, and therefore through the direct relationship between people and place, inevitably calls for a reflection on the decisive role of perception and the senses in territorial enhancement processes. “Involving populations […] is not only considered a formal act, but also an integral part of the protection, management and planning/design processes” (IASLA, 2022, p. 24).

In defining a new network model in which different issues align in the search for a balanced relationship between safeguarding nature and protecting people’s physical and mental wellbeing, this research proposes a step forward not only in tracing the distinctive characteristics, but also in identifying a name that can collect and enhance all the complexity involved.

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To provide an operational and communicative expression of this emerging paradigm, we propose the term ‘Living Landscape System’ to describe a complex network in which ecological processes and human needs interact through a continuous process of integration, mutual adaptation and co-evolution. In other terms, the ‘Living Landscape System’ provides an interpretative and operational model through which it is possible to assess the effectiveness of ecological networks not only in terms of connectivity, but also on the basis of their capacity to generate ecosystem services, strengthen landscape identity, improve the accessibility and quality of public spaces, promote community engagement and increase the adaptive resilience of territories.

In practical terms, the transition from green infrastructure to the ‘Living Landscape System’ entails introducing renewed ways of combining and utilizing existing tools. By introducing a relational and evolutionary dimension, this framework requires that ecological performance, landscape quality, and social practices be assessed in an integrated manner and monitored over time. This implies supplementing conventional indicators with criteria regarding landscape character and perception, accessibility, and active community engagement and stewardship.

At the current stage, the ‘Living Landscape System’ should be understood as an experimental conceptual framework, developed in continuity with the evolution of previous concepts such as Ecological Networks and Green Infrastructure. Rather than replacing these established approaches, it seeks to integrate and reinterpret them within a broader landscape-centred perspective (Figure 7).

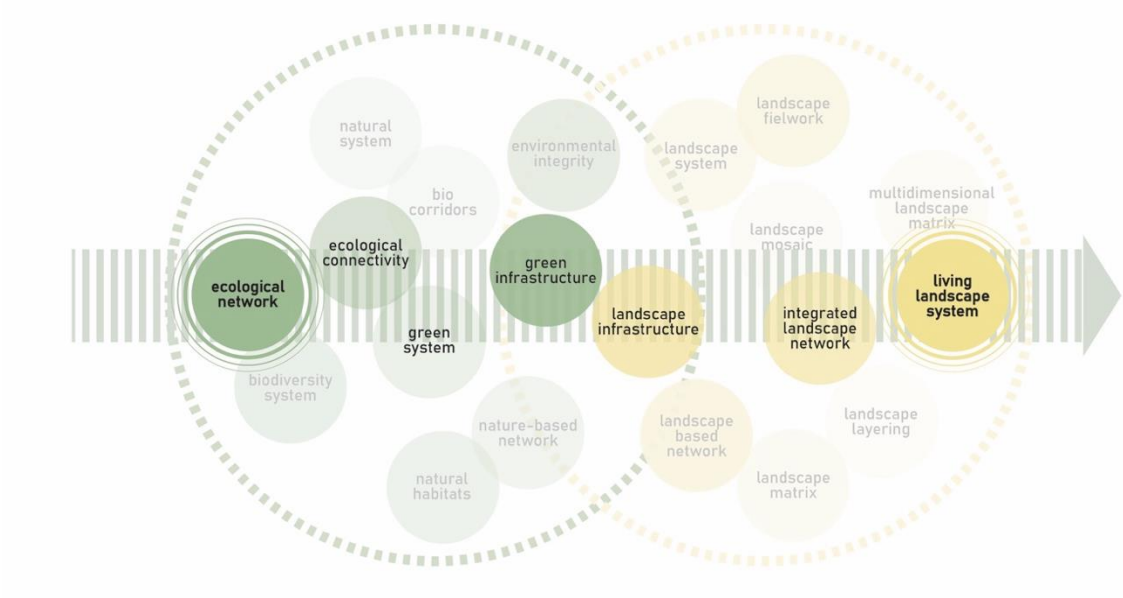


Fig. 7: Towards a new concept of network that integrates nature and culture (Source: author’s elaboration)

More specifically, the term ‘infrastructure’, long considered a key concept for restoring the complexity of ecological processes, now highlights new critical issues that can be summarised as a partial ability to represent the potential entrusted to the new network model. The notion of

infrastructure, which effectively conveys the idea of multifunctionality and support for various processes but is literally a structure interposed between other systems, tends to further highlight the aspect of connectivity to the detriment of its ability to act as an area for synthesis and co-evolution among different components.

In contrast, the concept of 'living landscape system' shifts the focus from being a tool for connection to a medium for a new relational quality, bringing renewed considerations to the fore in developing a dynamic and adaptive network capable of reacting to change. In particular, the combination of the three words derives from the strong desire to hold fast to very different and complementary shades of meaning. The word 'system' emphasises the scope of the network and its strongly integrated character while the word 'landscape' denotes the system as a multidimensional sphere resulting from human-nature interaction. Finally, the word 'living' states the continuous variability of this relationship, as an inconstant and not always predictable relationship. In this new conception, the ecological network can be understood as a real service for the population, a space for mediation between protection and transformation, an active device to produce value and support the construction of sustainable development scenarios.

Although the European Landscape Convention in some respects established a new vision that the European community could use to anchor its ideals of landscape development, it seems to have introduced new sensitivity regarding the issue that, over time, has stimulated the development of new needs and the launch of new processes in reappropriating spaces for living. Since the 2000s, as many texts testify (Cannon Ivers, 2021; Colafranceschi, 2007; Doherty, Waldheim, 2015), various researchers, academics and professionals have launched in-depth explorations regarding the landscape, reflecting on its condition, meaning and connection to the project. While all these publications stress that it is impossible to reach an unambiguous view of the subject, instead favouring a patchwork of possible interpretations, this is not an indication of a weakness in the interpretative framework, but a clear sign of innate complexity, which should continue to be promoted, pursued and explored.

This changing nature, which is never definite or assertive, validates and supports the choice to integrate the key concept of the 'landscape' in a new possible network model conceived as an open structure, one that, over time, tends towards configurations that are progressively more consistent with its hybrid nature.

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References

Benedict, M.A., McMahon, E.T. (2006). *Green Infrastructure: Linking Landscapes and Communities*, Island Press.

Bennett, G. (2004). *Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks*, IUSN, Gland.

Cannon Ivers, B. (eds.) (2021). *250 Things a Landscape Architect Should Know*, Birkhauser, Basel.

City of Mantova. (2012). *Territorial Governance Plan (Italian version: Piano di Governo del Territorio)*, <https://www.provincia.mantova.it/context_docs.jsp?ID_LINK=175> (02/2026).

Colafranceschi, D. (2007). *Landscape +: 100 words to inhabit it,* Editorial Gustavo Gili, Barcelona.

Cook, E. A., van Lier, H. N. (1994). Landscape planning and ecological networks: an introduction, in E. A. Cook, H. N. van Lier (eds.), *Landscape planning and ecological networks*, Elsevier, pp. 1–11.

Cortinovis, C., Geneletti, D. (2018). Ecosystem services in urban plans: What is there, and what is still needed for better decisions. *Land Use Policy*, n. 70, 298-312.

Council of Europe. (2000). *European Landscape Convention*, Firenze.

European Commission (n.d.). *The Habitats Directive*, in Energy, Climate change, Environment <*https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive_en*> (02/2026).

European Commission (n.d.). *The Birds Directive*, in Energy, Climate change, Environment <https://environment.ec.europa.eu/topics/nature-and-biodiversity/birds-directive_en> (02/2026).

European Commission (n.d.). *Natura 2000*, in Energy, Climate change, Environment <https://environment.ec.europa.eu/topics/nature-and-biodiversity/natura-2000_en> (02/2026).

European Commission. (2013). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Green Infrastructure (GI) – Enhancing Europe's Natural Capital*, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52013DC0249> (02/2026).

European Commission (n.d.). *Biodiversity Srategy for 2030*, in Strategy <https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en> (02/2026).

European Commission (n.d.). *Green Deal*, in Priorities 2019-2024 <https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en> (02/2026).

European Commission. (2012). *Living well, within the limits of our planet*, Brussels, <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0710:FIN:EN:PDF>

European Commission. (2021). Forging a climate-resilient Europe – the new EU Strategy on Adaptation to Climate Change, Brussels, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN>

ACCEPTED MANUSCRIPT

European Commission. (2012). *Our life insurance, our natural capital: an EU biodiversity strategy to 2020*, < https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2013_258_E_0099_01>

Doherty, G., Waldheim, C. (eds.) (2015). *Is Landscape...?: Essays on the Identity of Landscape*, Routledge.

Forman, R.T.T., Godron, M. (1986). *Landscape Ecology*, Wiley.

Forman, R.T.T. (1995). *Land Mosaics: The Ecology of Landscapes and Regions*, Cambridge University Press.

IASLA. (2022). *Paesaggio Europa. Linee guida per l'attuazione della Convenzione europea del paesaggio*, Derive Approdi, Rome.

Jongman, R.H.G., Pungetti, G. (eds.) (2004). *Ecological Networks and Greenways: Concept, Design, Implementation*, Cambridge University Press.

Lombardy Region. (2010). *Regional Territorial Plan* (Italia version: Piano Territoriale Regionale), <https://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioRedazionale/servizi-e-informazioni/enti-e-operatori/territorio/pianificazione-regionale/piano-territoriale-regionale-ptr/piano-territoriale-regionale-ptr > (02/2026).

Lombardy Region. (2010). *Lombardy Regional Territorial Landscape Plan* (Italia version: Piano Paesaggistico Regionale), <https://www.provincia.mantova.it/context_docs.jsp?ID_LINK=175> (02/2026).

Opdam, P., Wascher, D. (2004). Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels inn research and conservation. *Biological Conservation*, vol. 117, n. 3, 285-297.

Opdam, P. et al. (2006). Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes. *Landscape and Urban Planning*, vol. 75, n. 3-4, 322–332.

Potschin, M.B., Haines-Young, R.H. (2003). Improving the quality of environmental assessments using the concept of natural capital: a case study from southern Germany. *Landscape and Urban Planning*, vol. 63, n. 2, 93–108.

Province of Mantova. (2002). *Provincial Spatial Coordination Plan* (Italia version: Piano Territoriale di Coordinamento Provinciale), <https://www.provincia.mantova.it/context_docs.jsp?ID_LINK=175> (02/2026).

United Nations. (2015). *Resolution adopted by the General Assembly on 25 September 2015. Transforming our world: the 2030 Agenda for Sustainable Development.*

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