

Research result and open perspective

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The NbS paradigm

Reinterpreting the role, presence, and meaning of nature in cities constitutes, today more than ever, an essential research topic for those involved in architectural, landscape, and urban planning and design. This book aimed to explore it by connecting different disciplinary perspectives and approaches.

The concepts of «urban biodiversity» and Nature-based Solutions were placed at the center of an interdisciplinary exchange of ideas, critical reflections and research applications, collected in the first two sections of the volume. Furthermore, the Nature-based Solutions paradigm guided the creation of the probably most innovative part of the research, which aimed to set 'a toolbox' useful for local authorities and described in the third section.

As it is demonstrated by an increasingly substantial scientific literature, Nature-based Solutions (NbS) in fact are considered internationally as key strategic actions for implementing environmental governance processes that address, at the local level and particularly in urbanized territories, the challenge of ecological transition.

However, the urban and architectural redevelopment project is a complex issue that must take into account the multiplicity of aspects that a public administration must manage to guarantee the population the protection of rights, widespread well-being and the quality of the delivered services.

The application of naturalization projects of urban areas, therefore, must deal with issues relating to urban mobility, technological network infrastructures, existing and newly built plant systems precisely with a view to the green energy transition, the provision of cultural and social services, the citizens housing, the workplaces, the usability of green spaces and areas and everything that, in short, constitutes the essence of an urban settlement.

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Urban green structures are crucial landscape elements for the promotion and conservation of biodiversity in ever-growing urban areas. To achieve this objective, it is necessary to act through balanced planning and integrated adaptive management of open spaces, which reflects the development of a green matrix of multipurpose habitats.

This consideration suggests evaluating interventions on the natural component of urban elements (NbS) within a framework of objectives that a municipality must plan based on specific needs and priorities identified in such a way that divergences in effects or ineffectiveness of the interventions are not created.

When proposing the inclusion of NbS in an urban context, it will therefore be necessary to evaluate not only their effectiveness in terms of landscape and energy-environmental sustainability, with a view to mitigating the urban heat islands, controlling and reducing the effects of climate change, but also their compatibility and coherence, both on an economic and functional level, with the overall programme of interventions that the municipality is required to develop.

Some issues in particular are deemed relevant to make these interventions feasible and operational:

- develop site-specific and place-based projects and processes, which take into account the environmental and ecological local conditions, but also the different historical and cultural characteristics, specific heritage values, and peculiar socio-symbolic dimensions;
- dialogue with municipal administrations to develop suitable tools for the management of new urban districts from an LCA and LCCA perspective closely connected to the circular economy and the possibility of rational, thermodynamic exploitation of renewable energy;
- detect and interpret the needs of users and administrators to develop urban regeneration projects based on a systemic approach aimed at creating sustainable, pleasant, inclusive and safe multifunctional public open spaces;
- build predictive scenarios, through the use of dedicated software, according to a Multi Hazard Risk Assessment criterion, which takes into account the specific environmental and energy parameters of each individual intervention.

Urban Nature: Interpreting, Measuring, Managing

Main findings of the research are related to a variety of aspects related to both theoretical, methodological and instrumental approaches for urban regeneration through nature.

Regarding the theoretical framework, the research highlights that, since the 19th century, urbanisation has drastically altered ecological balances, creating cities that consume and fragment natural habitats. This has led to biodiversity loss, climate vulnerability, and degraded living conditions, prompting a transformation in urban planning. Integrating nature into cities is now essential to restore ecological functions and support human well-being and resilience.

Early visions, such as Ebenezer Howard's Garden City model or as the Boston Park System conceived by F.L. Olmsted, proposed parks, green belts, and self-contained neighbourhoods where natural processes and settlement could coexist. Today, internationally, in many urban areas the scarcity of green spaces intensifies the impacts of climate change and accelerates the decline of biodiversity.

NbS have thus become crucial, offering a holistic approach to urban regeneration by protecting, restoring, and creating ecosystems. Often implemented as hybrid solutions, NbS contribute to climate regulation, air purification, water management, and mental well-being.

In this context, Landscape architecture can play a pivotal role in favor of ecological transition, as demonstrated by a broad and heterogeneous international scenery of plans, projects, and interventions recognized as promising good practices.

Landscape architecture interprets cities as living systems, in which the well-planned and managed collection of diverse open spaces –including public and private, permeable and impermeable, historic or recently built, well-maintained and abandoned ones– forms an essential network for biodiversity. These spaces host ecological processes beyond human functions.

Starting from a reworking of the NbS paradigm, the concept of Landscape-Based Solutions is launched, which invites us to move from a mere ‘green’ paradigm towards systemic networks of open spaces that operate at multiple scales and time intervals, integrating ecological, historical, aesthetic and socio-symbolic dimensions.

This perspective aligns with the *UNESCO 2011 Recommendation on Historic Urban Landscape* (HUL) and the *European Landscape Convention*, which advocate for integrating natural and cultural values in planning.

In addition to that, historic gardens and archaeological sites (such as Florence’s Oltrarno system with the Boboli and Bardini Gardens), illustrate how heritage spaces can function as ecological corridors while revealing the history of urban landscapes. Dynamic conservation in these contexts requires interdisciplinary strategies that combine archival research, climatic data, and active biodiversity management to address challenges like plant pathogens and climate change.

Urban biodiversity is thus a multi-layered concept embracing genetic, species, and ecosystem diversity. Contrary to stereotypes, cities can become biodiversity hotspots if properly planned. Urban forests, green roofs, wetlands, and spontaneous vegetation patches contribute to ecological connectivity and resilience, particularly when they feature diverse species and structures. Vacant or unmanaged spaces may serve as wildlife refuges, though they require monitoring to prevent invasive species.

NbS can also represent a powerful tool to address water security challenges (such as water availability, flood risk, water quality aspects) also considering climate change which is typically increasing extreme events in both floods and droughts worldwide. NbS can thus constitute a significant evolution toward comprehensive, adaptive, and sustainable responses to the growing complexity of global water challenges.

However, substantial challenges remain, including fragmented responsibilities and difficulty in implementing integrated, measurable, and effective actions. Despite the comprehensive European and national regulatory frameworks, including the *EU Biodiversity Strategy 2030* and the *Nature Restoration Law*, Italian local policies remain fragmented and largely declaratory. Urban plans often lack operational tools, monitoring indicators, and coherent integration of biodiversity as a central infrastructure. The text calls for stronger alignment between global, European, and local policies, with more robust planning, monitoring, and civic engagement to fully embed urban biodiversity within the ecological transition.

Another useful interpretative key provided in the framework of research to critically reread the NbS paradigm, proposes an evolution of it in terms of Nature and Culture-based Solutions (NCbS), to put together ecological, social, and cultural dimensions.

This shift from a purely technocratic notion of ecological transition towards ecological conversion reflects a deeper commitment to care, reciprocity, and co-evolution between humans and nature. NCbS extend beyond technical interventions, embedding themselves within the cultural and ethical fabric of cities, to create ecosystems of shared responsibility and stewardship. The implementation of NCbS requires governance systems that are collaborative, adaptive, and multi-level. Co-production among public in-

stitutions, private stakeholders, civic organisations, and local communities facilitates the creation of eco-cultural commons and fosters long-term community engagement. Iterative processes of monitoring, feedback, and learning ensure that urban interventions remain responsive to changing environmental and social conditions. Hybrid governance structures help overcome administrative silos and enhance urban resilience, while integrated planning embeds NCBS into city structures through green-blue networks, systemic visions, and ecological standards. Complementary regulatory and financial tools, such as fiscal incentives, green bonds, and Payments for Ecosystem Services, expand the feasibility of these approaches.

Participatory instruments, including citizen science, collaboration pacts, and community monitoring, sustain ecological citizenship and moral responsibility across generations. In this context, Landscape planning and Urban design play a critical role in translating these principles into practice. Every landscape project functions as a methodical sequence, shaping a transformation process that expresses spatial, ecological, perceptual, and semantic relationships. Contemporary planning focuses on reconnecting fragmented urban spaces, enhancing biodiversity, and re-establishing connective ecological tissues. The Green and Blue Infrastructure model exemplifies this trend, providing an integrated framework for designing and managing urbanised territories in ways that advance thermal comfort, resource efficiency, and climate adaptation.

Innovative methodologies, such as thermodynamics-informed urban analysis, support the quantification of energy-environmental sustainability. By integrating applied physics, high-resolution climate modelling, and detailed vegetation characterisation, urban designers can identify priority areas for intervention, assess trade-offs, and optimise the benefits of NCbS. This scientific approach demonstrates that urban greenery reduces air enthalpy, mitigates the heat island effect, and lowers cooling energy demands, contributing directly to citizens' health and well-being.

The urgency of adopting such strategies is underscored by the environmental crises confronting cities: climate change, biodiversity loss, and resource depletion. Urban areas, which consume the majority of global energy and resources, face a moral imperative to transition from extractive, linear models of development towards regenerative and circular urbanism. Circular urban regeneration aligns ecological, spatial, and social dimensions to create adaptive, self-sustaining systems. Practices such as adaptive reuse, material recovery from the "urban mine," and flexible design enable cities to evolve while reducing emissions and preserving ecological value. Case studies such as Emscher Park, Lyon Confluence, and Berlin's North-South Green Corridor illustrate the diversity of approaches to integrating biodiversity, resilience, and human well-being. These examples reveal that no single model is universally applicable; effective solutions require transdisciplinary collaboration, context-sensitive strategies, and active community engagement.

Public Engagement (PE) emerges as a central pillar in the success of NCBS. Co-creation, co-governance, and participatory tools reconnect citizens with their urban ecosystems, bridging the gap between policy, research, and lived experience. Initiatives such as Florence's "Code4Risk" embody this ethos, linking climate adaptation and disaster risk reduction with urban liveability through workshops, installations, and serious games. Urban Living Labs provide further platforms for collaborative experimentation, where moral and material citizenship are nurtured in the pursuit of sustainable transformation.

Tools to apply

The application tools of the research (Part 3) includes the NbS CataTool, specifically developed within National Biodiversity Future Center (NBFC), as a digi-

tal Decision Support System (DSS) designed to promote the adoption of NbS in the Mediterranean context. Integrating scientific research, innovation, and practical applications, it serves as a cornerstone for biodiversity-focused sustainable development and aligns with European strategies like the *Nature Restoration Regulation*. The CataTool offers three core functionalities that bridge knowledge and practice. First, the NbS Selection Tool guides users through a four-step process: defining the type of intervention (protect, restore, or create), selecting the domain (urban, terrestrial, or marine), identifying the implementation area, and choosing societal challenges to address. Second, the Learning Tool enables free exploration of a structured NbS taxonomy, fostering education, co-design, and citizen participation. Third, the Case Study Finder provides a georeferenced database of over 100 national examples, each accompanied by synthetic cards, detailed sheets, and monitoring data, offering decision-makers evidence-based insights for restoration and resilience initiatives. The CataTool's integration of ecological data, evaluation scores for 12 global societal challenges, and practical guidance makes it a unique resource for urban planners, environmental managers, and policymakers. By mainstreaming NbS, it accelerates ecological transition and supports sustainable territorial governance.

Furthermore, the research illustrates that NbS address a spectrum of urban and environmental challenges, from heat islands to water scarcity. In cities, building-integrated solutions like extensive green roofs (EGRs) provide ecological, climatic, and social benefits. EGRs are lightweight, low-cost systems with shallow substrates supporting mosses, sedums, and stress-tolerant plants. They deliver thermal and acoustic insulation, mitigate stormwater runoff, reduce urban heat islands, and support biodiversity. Their maintenance requires only periodic inspections, weed control, and occasional irrigation during droughts. When combined with renewable energy systems, such as photovoltaic panels, EGRs enhance energy efficiency and climate resilience, while also improving visual comfort and human wellbeing. Beyond buildings, urban forestry and vegetation-based NbS strengthen ecological connectivity and urban resilience; large-scale afforestation projects create multifunctional forest ecosystems in urban and peri-urban areas, offering carbon sequestration, stormwater regulation, and recreational opportunities; tree rows and hedgerows mitigate habitat fragmentation, provide corridors for wildlife, and enhance microclimatic regulation; vegetation clusters and flower meadows foster biodiversity, enrich soil health, and deliver aesthetic and psychological benefits to urban communities. These small- and large-scale interventions together form living infrastructure that integrates nature into the urban fabric.

Water management represents another critical domain for NbS. Climate change and human pressures exacerbate both water quantity and water quality challenges: floods, droughts, and pollution increasingly threaten ecosystems and human settlements. NbS address these through Natural Water Retention Measures (NWRM) and hydrological interventions that restore ecosystem functionality while providing societal co-benefits. Riverscape NbS enhance flood and drought resilience by storing water, attenuating peak flows, and improving riverine biodiversity. They create heterogeneous ecotones that connect urban, peri-urban, and rural landscapes, reinforcing ecological corridors. Complementary to these, Sustainable Drainage Systems (SuDS) manage urban runoff by fostering infiltration, storage, and reuse, contributing to the "sponge city" model. Vegetated wetlands within SuDS trap pollutants, reduce nutrient loads, and provide rich habitats for aquatic life. Together, riverscape NbS and SuDS demonstrate how integrating green and grey infrastructure can simultaneously protect water resources and restore ecological functionality.

Towards a transdisciplinary research project

Transdisciplinarity can be understood as a collaborative, participatory, and interactive approach that aims to understand and comprehend complex problems and find ways to address critical issues. The transdisciplinary approach requires the involvement of academic and non-academic actors.

A transdisciplinary research project therefore implies that different stakeholders – scholars, practitioners, public administrations, citizens etc. - collaboratively co-produce knowledge to address a challenge.

Starting from these premises, the contributions collected in this volume and briefly recalled in this closing chapter, open to subsequent explorations in a more strongly transdisciplinary perspective.

And this even considering that the ‘nature’ of the concepts of Urban Biodiversity and Nature-based Solutions is markedly transgressive of the disciplinary and sectoral limits.

From this perspective, among the possible developments that the ‘Nature and City’ research project could have, the following stand out:

- Development of a common working glossary, to reposition key concepts, research words, and neologisms in order to create new knowledge through creative cross-fertilization between different approaches and specialized languages;
- Activation of Urban Nature Living Labs in collaboration with public administrations and local authorities, aimed at applying the NbS catalogue tools to specific urban redevelopment plans and projects involving citizens;
- Implementation of new Landscape-Approach in the contents of the cata-tools;
- Development of Natural/Cultural-based Solutions and Landscape-based Solutions catalogs considering a qualitative-quantitative approach to the NbS device;
- Integration of further skills and competences for reading and evaluating the potential benefits of NbS in relation to economic, ecological-qualitative, and socio-health aspects.

These are just some of the possible open trajectories to explore: thus moving - with ‘natural inclination’ - from the early stages reached towards a closer collaboration between research and practice on NBS as a process of crossing disciplinary boundaries.