

CONNECTING WATER, BIODIVERSITY AND CULTURAL ECOSYSTEM SERVICES – RESEARCH AND PRACTICE

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ABSTRACT

Nature-based solutions (NBS) are approaches where water and nature dimensions are much interconnected. Recent international recommendations advise on the importance of giving to NBS the opportunity of providing a whole range of benefits, from water management and biodiversity enhancement to promoting a spectrum of societal benefits.

This work presents an overview of these opportunities and illustrates NBS that connect water, biodiversity and cultural ecosystems services. Insights from the NATURELAB research project, with 15 experimental sites across six different countries, provide diverse natural environments and geographic contexts. This variety enables the exploration of NBS aiming at promoting health, well-being, and environmental sustainability. In parallel, the Corredor do Rio Leça (CRL) exemplifies an innovative model of governance. This association of municipalities focuses on the restoration and enhancement of the Leça River's ecosystem, specifically its riverbed and banks. By prioritizing biodiversity restoration, climate resilience, and community well-being, the CRL exhibits a practical application of NBS principles in a collaborative governance framework.

It was demonstrated, in theory and practice, how the NATURELAB and CRL approaches towards expanding NBS are both aligned and provide mutual opportunities for learning. Both showcase real examples that can inspire other regions globally to harness the full potential of NBS.

Keywords: *biodiversity, cultural ecosystem services, governance, innovation, nature-based solutions; water*

1. Introduction

1.1. Overview of the international approach to Nature-Based Solutions (NBS)

Nature-based solutions (NBS) are currently considered natural, functional systems and strategies that can contribute to sustainability, improving the environmental quality and citizens' well-being, whilst simultaneously providing opportunities for economic development (IUCN, 2020a; IUCN, 2020b; EC, 2021). International literature confirms the wide range of objectives sustaining the development of NBS: climate change mitigation and adaptation; water management; coastal resilience; green space management; air quality; regeneration and urban management; participatory planning and governance; social justice and social cohesion; public health and well-being, among others (EC, 2021; Science for Environment Policy, 2021; Biswal et al., 2022; Kõiv-Vainik et al., 2022). These outcomes validate that NBS are increasingly recognized as being of the utmost interest for the environmental, social and economic sustainability of regions, cities and communities. Although clear to some actors, the international need to boost this awareness and collaborations among distinct stakeholders is pivotal to allow the expansion of successful integration of all the important dimensions of NBS.

For the ones dealing with water related issues, there have been many steps in the long way of managing and dealing with the topic. Several rivers and river basins are examples of landscape changes in order to enhance navigation, to produce energy, or to enable agricultural production and settlements in floodplain areas (Albert et al. 2021). These transformations have led to negative impacts over centuries, such as erosion and pollution or a decrease in biodiversity and in ecosystem services provision. According to an EEA report (2018), currently only 40% of surface waters are in good ecological state and only 38% are in good chemical state. This leads to a considerable economic cost correlated to the loss of ecosystem services (Romanazzi et al. 2024).

Cook and Spray (2012) identified as one of the most important gaps in water management ‘the failure to understand the connection between water and ecological health, and the links between the health of natural ecosystems and human well-being’. Although dating from more than one decade ago, the statement is still valid. Worldwide and across distinct stakeholders, there are diverse levels of acknowledgment of the interconnections between water management, biodiversity and ecosystems services. Nature-based solutions (NBS) are approaches where water and nature dimensions are clearly intertwined. In the past, NBS focused on dealing with water related challenges, such as climate change mitigation and adaptation, urban flood and rainwater management, or reducing stormwater pollution to the level required for environmental protection (Barbosa and Fernandes, 2006; Barbosa and Rebelo 2023). Although these are valuable contributions, as previously mentioned, they are also only a portion of what NBS can deliver. The European Commission (EC, 2021) comprehensive framework proposes to assess the impacts of NBS across 12 societal areas. Among them there are the following: Climate Resilience; Water Management; Green Space Management; Biodiversity; Place Regeneration; Participatory Planning and Governance; Health and Well-being, and New Economic Opportunities and Green Jobs.

The integration of the biodiversity dimension in the restoration of rivers and river landscapes, is being carried out worldwide, with success. Floodplains are intricate systems, shaped by flows of water and sediments which are affected and affect biological processes. Often, these areas are converted to agricultural lands or used for urban development (Opperman et al. 2024). Restoring functional ecosystems, especially in the context of urban rivers, becomes crucial to reverse biodiversity loss and to better prepare for climate change resilience (Hart et al. 2023). The adoption of comprehensive approaches to river basins is expressed by the World Economic Forum Sustainable Development Goals (SDGs), which call for an ecological restoration of river landscapes, namely by SDG 14 (Life below water) and SDG 15 (Life on Land).

NBS do play a crucial role in the emerging efforts to adapt rivers, and other ecosystems as well, to extreme climate change scenarios and to improve the ecological and chemical status of water resources (e.g., Kumar et al., 2020; Oakes et al., 2021). Using NBS approaches not only help decrease flood risks in nearby and downstream urban areas but also provide benefits for biodiversity conservation and protected habitats (Albert et al. 2019), therefore enhancing ecosystems services (Orta-Ortiz & Geneletti, 2022; Neumann & Hack, 2019).

Barbosa and Rebelo (2023) conducted a simple search in the scientific literature published between 2019 and 2022, using the key words “nature-based solutions” and “guidelines”, selecting 20 representative articles to be analysed. They concluded that, in spite of NBS contributions to enhance the environmental and social sustainability of cities and communities, resilience to climate change and improved health and well-being, the majority (70%) of the studied articles did not incorporate a multidisciplinary approach to NBS. Nasrabadi (2022) indicates that NBS contribute to the sustainability of the urban landscape, with added value in several areas, namely: i) mental and physical health; ii) safety, especially in the face of natural disasters; iii) environmental education; iv) a sense of belonging; v) the aesthetic value of the place and (vi) the promotion of social interaction. In the context of the Jialing River (China), Wang et al. (2021) demonstrate that NBS can innovate conventional riparian planning. The authors used a holistic approach and five paradigms to support communication during the study, helping local government representatives and stakeholders to perceive nature and its contribution to populations, including ecosystem services.

On the other hand, Sowińska-Świerkosz and García (2021) point out the importance of adding the environmental dimension, including human health and well-being, to NBS. They also underline that the values, expectations and needs of citizens, as a stakeholder group, should be taken into account, and the indirect economic benefits brought by NBS, such as reduced healthcare costs, should be estimated. The authors suggest using qualitative indicators to assess the impact of NBS on the population, such as levels of satisfaction; a sense of belonging; social justice, social cohesion and long-term effects on health.

1.2. The NATURELAB project and the Corredor do Rio Leça interconnections

The NATURELAB project (<https://naturelab-project.eu/>) proposes an integrative and innovative approach to contributing to resilient communities, with a focus on health and care prevention. The research is being implemented at 15 experimental sites, located in five countries - Portugal, Greece, The Netherlands, Germany, and Peru. Dealing with three typologies of nature spaces - horticulture and gardening spaces, as well as with urban parks and forest and protected areas - the project enhances and expands the benefits of green and blue areas - such as resilience to climate change, the promotion of biodiversity, and urban water management - and links them to Health and Societal Pillars. The diversity of these experimental sites can be acknowledged through information provided at the project website, and by public available videos featuring the sites. Implementing a holistic approach is vital, therefore NATURELAB explores the interconnectedness of these factors with NBS. It focuses on nature spaces that, although with different space dimensions, contribute to regulating water flow and temperature, offering sustainable solutions. Green and blue spaces also contribute to mental health by reducing stress and anxiety. The project deals with already existing nature spaces, with distinct characteristics and in several countries. It promotes the importance of evaluating its sustainability and potential for providing cultural ecosystem services to communities, namely to their health and well-being. A “Framework of key indicators to assess and categorize different types of nature spaces and their impact for therapeutic indications” was already established by the project (Fernandes et al., 2024). NATURELAB is also designing and implementing three Healing Gardens, in Portugal and Peru, aiming at boosting a new awareness and showcase designing nature spaces that can accomplish a wide range of NBS benefits.

The Corredor do Rio Leça (CRL) is an association of municipalities, dealing with NBS at a local and regional level. Since the four main municipalities through which the river flows joined forces in this association, solutions can be implemented at the basin scale. CRL’s work over the last few years, financed by REACT-EU/2021, started by protecting and valorising water resources, intervening in the riverbed and banks. CRL focuses on restoring the Leça River, while enhancing biodiversity and promoting the well-being of local communities and improving their livelihoods. Under the scope of its mission, CRL understands that human-nature interactions are affected by accessibility, individual capability, and motivation to use nature (Soga et al., 2021). While access to nature can provide immediate benefits such as stress reduction or contribution to food security (Egerer et al., 2022; Levinger et al., 2022), post-COVID studies found that contact with nature increased the motivation of people to be physically active (Jenkins et al., 2021).

The NATURELAB project coordinator, established a collaboration agreement with the head of Corredor do Leça, aiming at two main objectives:

- ✓ Research and development of approaches and methodologies that combine water cycle management (quantity and quality) with the protection of natural ecosystems and the promotion of biodiversity through nature-based solutions.
- ✓ Collaboration for the study and implementation of nature-based solutions and integrated approaches that emphasise the contributions of natural areas and the presence of water to resilience to extreme climate events and to the cultural services of ecosystems, including for health and well-being of populations (cultural ecosystem services).

It is understood by the two organisations the benefits of joining efforts. Six out of the 15 NATURELAB ES are in Portugal, and although the project and CRL work at different space and geographic scales, there are several layers of the approach to NBS dimensions that can be shared. Noteworthy, NATURELAB will be preparing and delivering guidelines that are for the use of municipalities and, therefore, this collaboration is very promising for both parties.

2. Research and practice alliances allow integration and high impact for NBS

2.1. The relevance of frameworks and alliances towards NBS expansion

According to the IUCN Global Standard for NBS (2020), Nature-based Solutions use natural ecosystems and natural processes to provide benefits for biodiversity, while at the same time, promoting a full spectrum of societal benefits. Some of these benefits of NBS interventions in rivers include watershed protection, reducing risk of damaging floods, among others, and these are being addressed by CRL. Floodplain ecosystems provide a variety of ecosystem services, including supporting services, regulating services, as well as provisioning and cultural services, namely by improving downstream water quality, nutrient storage and recreational opportunities (Chambers et al. 2023). In fact, renaturalisation and rewilding of urban rivers have been shown to improve ecological quality, recreational attractiveness as well as increased capacity to provide several

ecosystem services (Veríssimo and Roseta-Palma, 2023; Suárez et al., 2024) and these features are core within the NATURELAB approach.

Table 1 provides an assessment of the NBS dimensions that are addressed by NATURELAB and CRL, according to the EC (2021) framework. A scale of three levels was established to assess the level of addressing each dimension by NATURELAB and Corredor do Leça, namely “1- CORE” (*within the main objectives*), “2- Relevant” (*very consistently addressed*) and “3-Indirect relevance” (*addressed at a secondary level*). The “Opportunities for collaboration” were measured based on the assumption that when the difference in the level of addressing is of two, there is **High** opportunity, when is of one there is **Good** opportunity and, finally, when it is the same there is **Reduced** opportunity, except when it is CORE, because it demonstrates similar values. For the latter the classification “**Alignment**” was used.

The results of the evaluation are depicted in the last column of Table 1. They demonstrate that NATURELAB and CRL deal with complementary approaches and that there is Alignment in what regards Biodiversity and Place Regeneration dimensions. This similarity is already being acknowledged to facilitate conversations and collaborative decisions. Regarding all the other dimensions, it is observed that opportunities for collaboration are High for the case of 4 dimensions, and Good in what regards 6 of the other NBS dimensions. No dimension is acknowledged as being of Reduced interest.

Table 1. Dimensions of NBS addressed by NATURELAB and Corredor do Leça and opportunities for collaboration

NBS dimensions* (alphabetical order)	NATURELAB	Corredor do Leça	Opportunities for collaboration
Air Quality	Relevant	Indirect relevance	Good opportunity for know-how exchange
Biodiversity	CORE	CORE	Alignment
Climate Resilience	Relevant	CORE	Good opportunity for know-how exchange
Green Space Management	CORE	Relevant	Good opportunity for know-how exchange
Health and Well-Being	CORE	Indirect relevance	High opportunity for know-how exchange
Knowledge building for sustainable urban transformation	CORE	Indirect relevance	High opportunity for know-how exchange
Natural and climate hazards	Relevant	CORE	Good opportunity for know-how exchange
New economic opportunities and green jobs	Relevant	Indirect relevance	Good opportunity for know-how exchange
Participatory planning and governance	Indirect relevance	CORE	High opportunity for know-how exchange
Place regeneration	CORE	CORE	Alignment
Social Justice and social cohesion	Relevant	Indirect relevance	Good opportunity for know-how exchange
Water management	Relevant	CORE	High opportunity for know-how exchange

* The EC (2021) framework was used. A scale of three levels was established to assess the level of address that NATURELAB and Corredor do Leça use towards each dimension: “CORE”, “Relevant” and “Indirect relevance”.

2.2. The Corredor do Rio Leça achievements and future challenges

So far, all interventions at Leça River were made with the first goal to renaturalize this urban river, through various NBS techniques, such as natural engineering, rewilding or restoring habitat with native riparian flora, trying to promote ecological connectivity.

Some of the interventions done by CRL include the development of a naturalised retention basin near the river bank (*c.f.*, Fig. 1). This intervention allowed the restoring of habitat previously existing on site, which before was landed, by raising the river bank, to be used for agriculture and for flood protection. The goal of this intervention was to serve as a new flood area, preventing floods in the city downstream, while at the same time build a new refuge for biodiversity, creating new habitat for fauna. NBS were used for river bank erosion control, using local stone and replanting native riparian forest. This multi purpose and multi benefit usage of plant roots as a bank erosion control, mimics perfectly, the native habitat services for society, health and wellbeing benefits of the seasonal and flood adapted habitats. Another successful intervention using NBS, was the creation of more connectivity in the river, by destroying old obsolete dams and adapting the ones that still

have a use to the passage of fish. The creation of naturalised fish passages was developed using the dynamic of the river, respecting the *genius loci*, such as the use of local rocks as well as taking advantage of the geology of each place. Finally, another intervention worth mentioning is the restoring of the river margins in 71 km. This intervention used natural engineering solutions to stabilise 9 km of the river banks that were suffering erosion, by creating new banks better adapted for the water cycle, allowing permeability, providing habitat for fauna and the colonisation of native vegetation, which will further contribute to its stabilisation and recovery process.

Regarding the future challenges, so far CRL have identified 4 main challenges. These include (i) the maintenance of the intervention areas, (ii) control of invasive species and increasing, (iii) maintaining scientific partnerships to apply the best available techniques and (iv) establishing CRL as a living lab with the scale of the natural resource and interacting with local decision makers and communities.



Fig. 1. Retention basin re-naturalized by CRL intervention. a) Before the initial intervention; b) after intervention.

2.3. Governance, co-designing NBS and following up

The urban acupuncture approach blends contemporary urban design with traditional Chinese acupuncture principles, using small-scale interventions to catalyse transformative changes in urban contexts, extending from the urban to the peri-urban and the rural. Urban acupuncture is linked to physical planning and design interventions such as playgrounds or the improvement of pedestrian and bike networks (Hemingway and De Castro Mazarro, 2022). The Healing Garden at the NATURELAB Experimental Site #13 (Puericultorio Perez Aranibar) is a NBS that promotes sustainability and health and well-being. It fits into the urban acupuncture approach for being a small-scale intervention (*cf.* Fig. 2). Puericultorio Perez Aranibar is a 100-year-old orphanage located on Lima's waterfront (Pacific Ocean, Peru), 50 m above sea level. The entire property is of 14 hectares with green areas, most of which are neglected due to budget problems. The NATURELAB project supported this small-scale intervention, where plants have been carefully selected to offer a rich sensory experience, promote environmental stewardship, attract birds and pollinators, restore soil characteristics, and clean the air. The water balance was ensured by selecting water-wise plants, that are also pest resistant, resistant to sea breeze, and requiring low maintenance. This NBS will be monitored using the project framework of indicators (Fernandes et al., 2024) as well as by evaluating the impact of the space to promote health and well-being, through assessing the implementation of Nature-based Interventions (NBI) customised to address the health issues of the community of children.



Fig. 2. Institution in Lima, Peru where NATURELAB implemented a Healing Garden. a) Before; b) After the intervention.

Other two Healing Gardens are under development in Portugal and Peru and need to be co-created and adjusted to the settings in which they are included. For instance, the Healing Garden in Portugal will be implemented

at the Quinta de Ribafria a relevant green area in the municipality of Sintra, at the gates of Lisbon city, with various species of trees and shrubs and one of the richest national areas in terms of combined natural, architectural, cultural and patrimonial heritage. The 13,3 hectares area includes hiking trails, classified national monuments, and an old manor house. Different water bodies (stream, cascade, lake) and identified biodiversity values (fauna and flora) coexist here with other uses, including cultural activities. Distinct sectors of the Sintra Municipality (a NATURELAB project partner) are working together into establishing the location and design of a Healing Garden that can facilitate NBI, and respect environmental and cultural values, as well as other local uses. The Culture Division, the Strategic Projects Division, the Environmental Sustainability and Energy Transition Office of Sintra municipality are collaborating with Cultursintra, the organisation responsible for co-managing the Quinta de Ribafria, and other NATURELAB project partners to establish the best location and design.

Under the motto “4 municipalities. One single river!” the CRL is promoting a groundbreaking approach to nature-based governance, acting in the territory associated to the ecosystem scale of the river basin, breaking abstract municipal borders to act on a cooperative, coordinated and complementary effort to depollute, recover and act on the Leça River from the spring to the ocean. This effort is anchored by multiple interactions and inclusion of private landowners, local governance, local industry, schools, academic institutions, NGO’s, municipalities and the national environmental agency (APA). The public participation that preceded all the CRL interventions have been a key element to access the private margins, schedule works between crop cycles, raise awareness for the global objectives and introduce the NBS as the best option, having the best advantages in terms of cost/benefit implementation, landscape qualification, future gains on biodiversity and facilitated management practices with use of local knowledge.

Governance and interventions at basin scale, provides not only scale benefits, coordination, coherence and complementarity of interventions, but can also allow the identification and promotion of regional green corridors that provide wider ecological and territorial potential, as well as connection for biodiversity and populations.

Public use and contact with this green and blue corridor allow a deeper connection with biodiversity cycles, better understanding of natural processes such as water cycle and climate variability, which is a powerful environmental perception tool to trigger awareness, higher sustainability standards and cultural preferences related to sustainable consumption, way of life and political demands. Moreover, populations health and well-being will benefit from this contact and interaction with nature, all of these being cultural ecosystem services.

Small scale interventions in urban parks, at the municipalities of CRL will directly benefit from the NATURELAB outcomes and guidelines. Similarly, the successful experiences of CRL will be disseminated by NATURELAB and will enrich the project approach towards the promotion of innovative NBS, aligned with high principles of environmental and social sustainability. The NATURELAB reports that will be published during the second semester of year 2027 include: “Portfolio for the classification of the therapeutic potential of nature spaces”; “Recommendations for the selection of nature spaces for therapeutic use”; “Guidelines for analysing the health benefits of green areas conform the requirements of natural capital accounting”; and “Guidelines for the creation and management of private and public healing gardens and horticulture and gardening spaces”. All the know-how that is already being built to support these outcomes will be expanded through the discussions and joint collaborations, including implementation of NBS solutions at the CRL municipalities.

3. Conclusions

Whether in the context of natural areas without anthropogenic intervention - such as a forest or a coastal ecosystem - or in the context of urban areas, NBS should incorporate the assumption that healthy and balanced ecosystems provide multiple benefits and services. NBS can restore urban settings and urban rivers, promoting ecosystem services and enhancing biodiversity. During the last century, urban rivers have been highly degraded due to urban development and growth (and not so good decisions) losing capacity to provide ecosystem services needed for water and nature balance, as well as for the society's well-being.

It has been proved that working towards high impact NBS must take place based on collaborative processes of transdisciplinary co-creation, through the active involvement of the population and relevant stakeholders. Each urban context, as well as geographic and climate location, should be inspired and supported by the international scientific knowledge, and work on sound solutions customised to its reality. Moreover, NBS implementations should be followed up and monitored with the involvement of all interested parties.

The joint work of an international EU funded project (NATURELAB) and an alliance of four municipalities (CRL) can raise improved awareness from local and regional decision makers and stakeholders allowing new perceptions of nature and its contribution to populations, including benefits of cultural ecosystem services. The use of indicators to assess the impact of NBS on the sustainability of the sites and the population are promising fields to be explored.

This article demonstrates the relevance of researchers, decision-makers and local stakeholders working side by side, promoting the implementation of sound NBS, at different space scales, that connect water, biodiversity and cultural ecosystem services, and reciprocally learning from the collaboration, as well as being able to demonstrate and inspire others.

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