Designing Environments

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Chapter 7
Urban Regeneration with Nature-Based Solutions: Human and Nature Perspectives

Katia Perini and Enrica Roccotiello

Abstract Urban ecosystems are complex, fragmented, densely populated areas, characterized by high level of anthropic pressure, lack of green spaces, habitat fragmentation and local biodiversity loss. In addition, most urban areas face important issues, among which the heat-island effect, poor air quality, and, overall, the deterioration of water resources and ecosystems. Sustainable urban regeneration represents a unique opportunity for city re-development with the aim to reinvent and rethink spaces, specifically underused, distressed, or decaying buildings or areas. Nature-based Solutions can play a significant role in such regeneration process, being able to provide various ecosystem services for the improvement of urban ecological and environmental quality. The present chapter describes the example of the Genoa (Italy) EU H2020 funded UNaLab pilot project and related monitoring activities, implemented in the field of human wellbeing and support to local biodiversity.

Keywords Biodiversity · Ecosystem services · Ecosystem disservices · Invasive alien species · Monitoring · Pilot project · Social benefits · Sustainability · Urban areas · Wellbeing

7.1 Introduction

Urban ecosystems are complex, fragmented, densely populated areas, characterized by high level of anthropic pressure, lack of green spaces, habitat fragmentation and local biodiversity loss (Grimm et al. 2000; Wu 2008). In addition, most urban areas

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face important issues, among which the poor air quality, heat-island effect and, overall, the deterioration of water resources and ecosystems (Di Giulio et al. 2009). Sustainable urban regeneration represents a unique opportunity for city re-development with the aim to reinvent and rethink spaces, specifically underused, distressed, or decaying buildings or areas (UN 2021).

Resilient and sustainable cities can be achieved through the restoration of ecological processes and functions, the increase of biodiversity in terms of quantity and quality (native species) and the equilibrium of the biological community (Capotorti et al. 2020; Pinho et al. 2021). The introduction of natural elements in urban environments allows the establishment of multitrophic interactions, that means interactions that link several trophic levels, including plants, herbivores, and predators, parasitoids, or pathogens (Brodie et al. 2018).

Specifically, biodiversity can be defined as the variability of living beings of all origins including, among others, aquatic ecosystems, and the ecological complexes they are a part of; this includes diversity within species and the diversity of ecosystems (UN 1992 Convention on Biological Diversity). In addition, several key international regulations were created to provide the knowledge and rules to manage, support, promote, restore biodiversity of natural and anthropic habitats like CE 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (European Union 1992), World Summit on Sustainable Development (UN 2002), the European Green Deal (European Commission 2019), the EU Biodiversity Strategy for 2030 (European Commission 2020) and the nature restoration law (COM/2022/304) (IPBES 2022).

Since the two main causes of extinction are related to habitat loss and occurrence of invasive alien species (IPBES 2023), a key aspect at the urban level is the creation of habitat through Nature-based Solutions (NbS, i.e., actions to protect, sustainably manage, and restore natural or modified ecosystems providing benefits to human well-being and biodiversity (IUCN 2016) and the use of native plants to protect, restore and enhance the local biodiversity. To this aim an adequate planning should be consider the use of feeding plants for pollinators birds, and little mammals in NbS.

NbS can play a significant role in such regeneration process, being able to provide various ecosystem services (ES), i.e., the benefits people obtain from ecosystems (Millennium Ecosystem Assessment (Program) 2005). ES (Fig. 7.1) were divided into four main categories: provisioning, regulating, cultural and support services for a human-centred perspective (Maes et al. 2016). All the ES—like the provision of food, clean air, water, and resources as wood or medicine—can only be provided by healthy ecosystems and play a crucial role in supporting local livelihoods. NbS should be smartly designed avoiding the use or the occurrence of ecosystem disservices i.e., the negative effects of nature on human wellbeing (e.g., occurrence of invasive alien species, damage of buildings and infrastructures, and allergies) (von Döhren and Haase 2019; Tian et al. 2020).

Citizens show a keen interest in urban parks, viewing them as areas where they can connect with nature (Andersson et al. 2014). While utilizing an urban park, individuals may directly experience and appreciate certain ecosystem services, such as the cooling effect provided by plants (Mosca et al. 2021). However, they may not

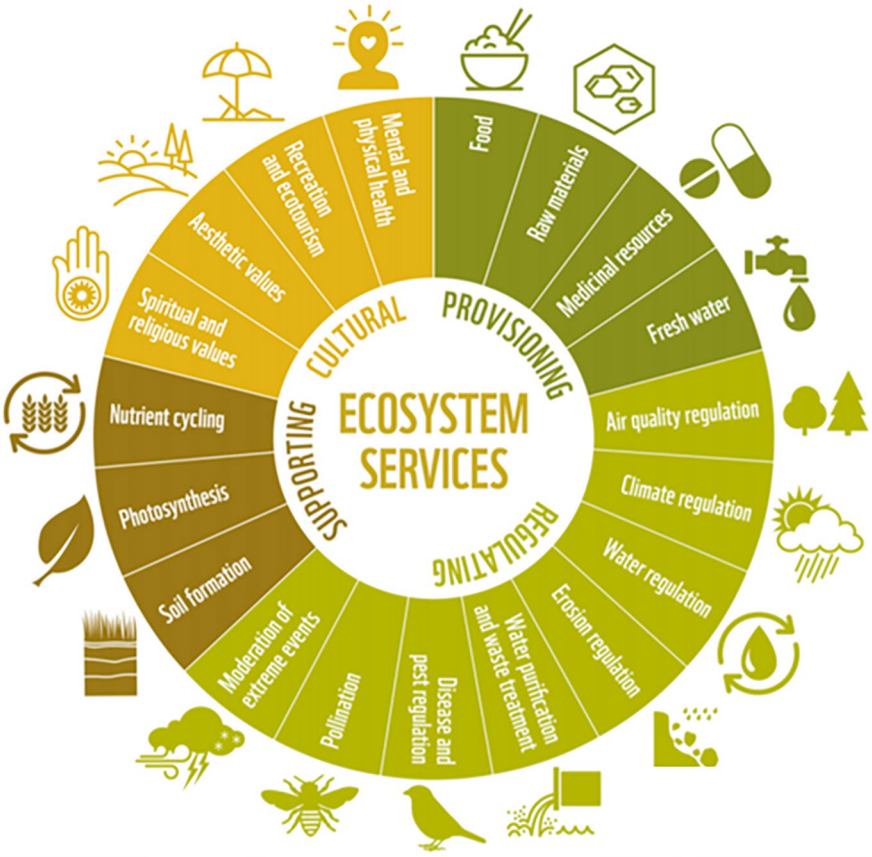

Fig. 7.1 Ecosystem services provided by nature to humans. WWF, 2016 (Adapted from Millennium Ecosystem Assessment 2005)

be immediately aware of other services, such as carbon sequestration and storage by park trees (Buchel and Frantzeskaki 2015).

While the benefits of urban ecosystems may not always be explicitly evident to city dwellers, it is essential to identify which ecosystem services are recognized by them. This understanding helps evaluate the perceived value and quality of existing urban green spaces. The belief is strong that fostering more sustainable cities involves not only enhancing the abiotic and biotic aspects of urban life but also addressing the social aspects, including people's satisfaction, experiences, and perceptions of the quality of their daily surroundings (Chiesura 2004).

In the past years, many projects were funded (e.g., through the H2020 programme) with the aim of reclaiming, redeveloping, and co-creating with local population abandoned urban spaces. Among them, the UNaLab project can be mentioned. The UNaLab project (UNaLab 2017), funded by the European Union's Horizon 2020 research and innovation programme aims at contributing to the "development

of smarter, more inclusive, more resilient and increasingly sustainable cities through the implementation of nature-based solutions".

The chapter outlines strength and weakness related to urban areas in relations with the potential services and disservices by Nature based Solutions, considering the case study of one of the UNaLab pilot projects, built in Gavoglio former military barrack (Genoa, Italy) with the aim to evaluate the biodiversity and human wellbeing in the area before and after the creation of a large public area with NbS.

7.2 Nature-Based Solutions

Nature-based Solutions "are inspired and supported by nature", "are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions." (European Commission 2023).

NbS address societal challenges by drawing inspiration from and receiving support from nature, answering to the increasing needs of tangible solutions to increase urban biodiversity (Weisser et al. 2023). These solutions are characterized by their cost-effectiveness, offering concurrent environmental, social, and economic benefits while contributing to resilience-building. NbS involve the integration of a greater variety of nature and natural elements into urban areas, landscapes, and seascapes. This integration is achieved through locally tailored, resource-efficient, and systemic interventions. Consequently, NbS not only promote biodiversity but also enhance human well-being (Cohen-Shacham et al. 2016) (Fig. 7.2).

NbS provide a wide range of ecosystem services. According to (Babí Almenar et al. 2021), these solutions can be divided into: built structures, such as green roof or green wall, land media, as tree groups, meadows, orchard, and water media, as draining pavement, rain garden or infiltration basin. The ecosystem services provided by built structure mainly regard food provision (green roof especially), local climate and air quality regulations (Coma et al. 2018; Rowe 2018), carbon sequestration and storage, runoff mitigation (green roof) (Palla and Gnecco 2018). Green roof (Fig. 7.3) and green wall (Fig. 7.4) also provide habitat for species (Köhler and Ksiazek-Mikenas 2018; Pianta et al. unpublished) and improve recreation and mental and physical heath (Kotzen 2018). Tree groups and other land media NbS provide local climate and air quality regulations (Akbari et al. 2001; Lazzari et al. 2018), carbon sequestration and storage (Field et al. 2020), erosion prevention and maintenance of soil fertility (Gonzalez-Ollauri 2022), provide habitat for species (Atkins 2018), and improve recreation and mental and physical heath (Kim and Miller 2019). Finally, water media NbS, managed by e.g., raingarden (Fig. 7.5), play a key role in the moderation of extreme events and runoff control/mitigation (Ballard et al. 2007; Woods Ballard et al. 2015).

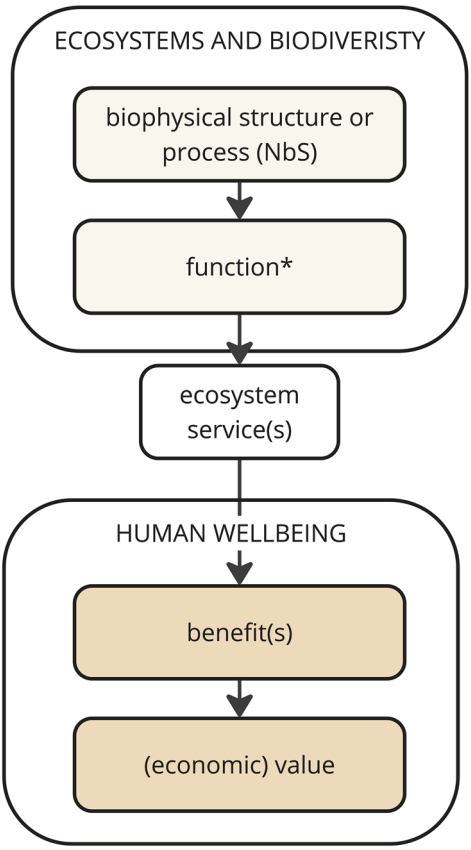

Fig. 7.2 Framework linking ecosystem to human wellbeing (de Groot et al. 2010), modified. *function: a subset of biophysical structure or process providing the service

7.3 Quantifying the Performances of Nature-Based Solutions: The Case of UNaLaB

The UNALAB-URBAN NATURE LABS (UNaLab) project, funded by the European Program "HORIZON 2020" call. Smart and sustainable Cities—SCC—02-2016-2017: Demonstrating innovative Nature-based Solutions in Cities (topic SCC-02-2016-2017 type of action IA), aims at developing smarter, more inclusive, more resilient, and increasingly sustainable cities through the implementation of NbS.

One of the three front runner cities of the project is Genoa (Italy). Genoa, with approximately 600.000 residents, features a slender coastal area bordered by hills and steep mountains in the hinterland. The city encounters various environmental hurdles linked to frequent flooding which has resulted in significant destruction in the past, primarily due to intense rainfall on a highly urbanised landscape, including challenges in water management, heat stress, and issues of water and air pollution.

Fig. 7.3 Green Roof in Genoa (Italy) on DICCA, University of Genoa, with low management and high level of biodiversity

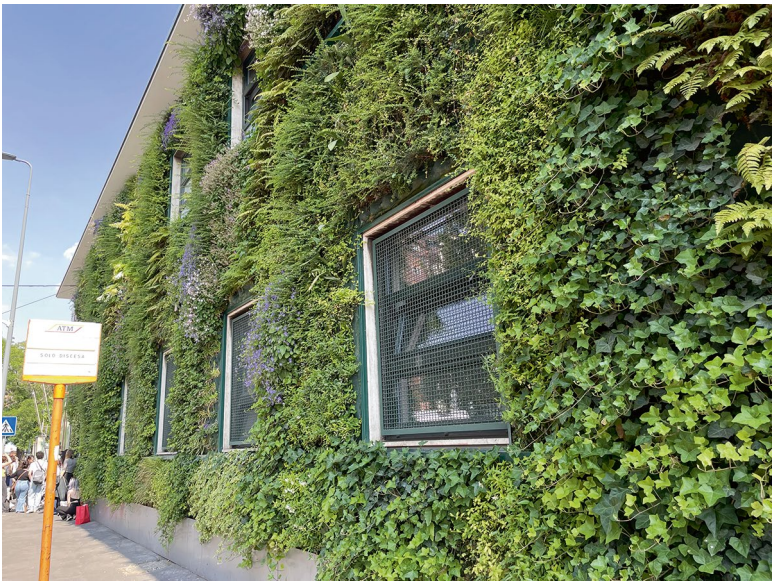

Fig. 7.4 Living wall on Giambellino's district, Milan (Italy) for particulate matter capture (H2020, Clever cities project)

Fig. 7.5 Rain Garden in Campomorone (Genoa, Italy), pilot project of Proterina3Evolution (Interreg IT-FR), photo Gianluca Porcile

Fig. 7.6 Gavoglio Urban Park with 12 NbS in the city of Genoa (Italy, 2023), northern area

The UNaLaB project partially funded the construction of a new multifunctional public park on the site with 12 different NbS in the former Gavoglio barracks, located in the Lagaccio district, a densely populated residential area (UNaLab 2017), in an intensely artificialized urban environment (Figs. 7.6 and 7.7).

Fig. 7.7 Gavolgio Urban Park with 12 NbS in the city of Genoa (Italy, 2023), southern area activities are implemented to evaluate the performances in terms

UNaLaB Genoa pilot project monitoringof ecosystem services provision. An interdisciplinary group is monitoring the performances of NbS in improving ecological, environmental, and economic condition of a district. Monitoring and data collection is related to the key performance indicators:

- Mitigation of the Urban Heat Island effect
- Capture of PM_{10}, $PM_{2.5}$, NO_2 and O_3 in ambient air
- Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)
- Active involvement of citizens
- Real estate value increase of buildings
- Biodiversity (plants)
- Pollinator insects
- Evapotranspiration rate
- Carbon sequestration
- Stormwater retention
- Water used for irrigation.

In this chapter, we focus on the key performance indicators listed in Table 7.1.

Table 7.1 UNaLaB Genoa pilot project monitoring activities developed by the University of Genoa in the field of Architecture/psychology, Environmental botany, Key Performance Indicators, and related measurement unit in relations with ecosystem services

Key Performance Indicators	Measure unit	Ecosystem services
Citizen wellbeing associated with environmental conditions (microclimate, psychological wellbeing, social cohesion)	N° of people, % satisfaction	**Cultural services** Recreation and mental and physical health Aesthetic appreciation and inspiration for culture, art, and design Social cohesion
Biodiversity	Shannon's index (H′), F%, NP/P	**Habitat or supporting services** Species richness and diversity (plants and birds)
Pollinator insects	Shannon-wiener index (H′)	**Habitat or supporting services** Pollination
Evapotranspiration	ET_0 (mm/day)	**Regulating services** Local climate and air quality regulation
Carbon sequestration	% increase; t/ha/year	**Regulating services** Carbon sequestration and storage

7.4 Citizen Wellbeing

Analysing the public's perception and enhancing well-being associated with the utilization of NbS in public areas involves examining how individuals perceive these solutions at both the individual and community levels. This assessment is crucial for gauging the positive impact on human well-being resulting from the ability to enjoy green spaces within urban environments (Chiesura 2004). The monitoring process related to the KPI Citizen wellbeing associated with environmental conditions aims to evaluate, both qualitatively and quantitatively, citizens' perceptions of ecosystem services provided by various NbS. It considers the levels of well-being and satisfaction expressed concerning the characteristics of the urban context. To conduct this assessment, data were gathered through a questionnaire, compiled by approximately 600 citizens living in the area. In this chapter we focus on the public perception of ecosystem services provided by the NbS. More specifically, we consider the relationship man-nature within the city and perceived performances of a selected number of NbS, among the ones used in the Genoa pilot project:

- Raingarden
- Infiltration basin
- Tree groups
- Drought-resilient orchard and meadows
- Green wall

- Natural engineering for slope securing.

The results of the monitoring activity show that the function of NbS is generally recognized as positive, specifically for tree-lined areas, rain gardens and infiltration basins. In the case of green walls, the most recognized effect is reduction of urban heat island (ecosystem service microclimate regulation). Also, in the case of tree groups this is the most recognized effect, along with increase of biodiversity, and rainwater management. Rain gardens are considered more for biodiversity increase than for rainwater management. This latter is correctly considered by most of the citizens as main benefit of infiltration basin.

Finally, different issues have been raised by local population: from one side having more access to green spaces for leisure and higher demand for more liveable cities, on the other, a lack of recognition of the potential environmental and ecological benefits of the park, respect to the potential ones (e.g., biodiversity improvement, CO_2 capture, etc.), was noticed.

7.5 Biodiversity

Alteration of the biodiversity in terms of species occurrence, richness (and related network) and ecological functions in the urban context is frequent, and result in a disruption and decrease of different living species (Hillebrand et al. 2018). In addition, the occurrence of exotic species that are or can become invasive (because of the absence of predators, the availability of food and the increasing temperatures) could affect the performances and effectiveness of NbS. The pre-opera monitoring on the whole area, that was subsequently reclaimed, was done to evaluate the state-of-the-art and the risk of occurrence of invasive alien species.

The monitoring after park construction was focused on the NbS realized after the reclamation process and specifically: raingarden, infiltration pond, bioswale, tree groups and green areas, drought-resilient orchard and meadows, slope afforestation, green wall, and natural engineering for slope securing. For all these NbS, the plant diversity was evaluated with the Shannon-Weiner Index (H′), that is one of the most widely used for this purpose (Shannon 1948).

The monitoring preceding and during park construction showed a total of 91 *taxa*, 73 of which are autochthonous (indigenous) and 18 allochthonous (exotic). Allochthonous species represent all those species present in an area that does not correspond to their regular range of distribution, but they have been dislocated there by volunteer or inadvertent human actions. Among the 18 alien species recorded, 12 are invasive, and 6 non-invasive, where invasives optimally adapt to specific habitat out of their natural range, causing damage to the whole ecosystem. Considering the high ratio between invasive and non-invasive species recorded we can consider these results coherent with the conditions of the area, typical of a construction site with excavated and incoherent terrain, where the previous balances were modified due to the continuous human disturbance. The occurrence of exotic, invasive or

potentially invasive species can eventually affect the effectiveness of the NbS to be realized, thus it is important to list them to plan eradication or mitigation actions.

The first monitoring, immediately after the park opening, showed that plant biodiversity, considering a pre-existing plant coverage reduced to a minimum and an area recently planted and seeded, consists of 52 *taxa*. The decrease in the number of plant *taxa* is related to the eradication of invasive species and establishment of new plant communities. The choice of numerous native herbaceous and shrub species, typical of the Mediterranean environment, and the replacement of the forest species envisaged by the project with some forest trees more coherent in terms of climate and representing pre-existing plant populations, will result in more resilient plant communities, able to better resist to environmental stresses. As regards the plant biodiversity indices, they are NbS-dependent because of the species choice and related coverage, and relatively high, but details on invasive species occurrence should complement such findings in the future. A subsequent monitoring with respect to time zero (park opening) is recommended to evaluate a possible increase, remembering that natural vegetation dynamics will establish in decades.

7.6 Summary and Future Perspectives

The monitoring of NbS is a key aspect that allow evaluating the performances of such solutions in relation to a specific context. In the portrayed case study, we monitored NbS performances based on small-scale indicators that can be used to evaluate ecosystem services provision in a degraded urban area (a former military barracks). This approach was implemented by Genoa, Tampere and Eindhoven, i.e. the frontrunner cities of the UNaLaB project, and also by the seven following cities, to help creating the knowledge base for developing a standardized set of indicators for the implementation of urban NbS that can be used at EU level, summarised in the "Nature-Based Solutions Implementation Handbook" (Dubovik et al. 2022).

What emerges from the monitoring activities is that the construction of the new park on the abandoned Gavoglio Barracks has overall a positive effect on the surrounding area. The citizens participating in the monitoring activity show an adequate knowledge of the ecosystem services provided by the single NbS analysed.

Plant diversity recorded before and after NbS realization highlighted the importance of a constant monitoring since natural dynamics require time for a more inclusive evaluation of such structure in terms of quantity and quality of the results through time, thereby providing data to manage site colonization by invasive species in the future.

It is well known that urban biodiversity positively impacts citizens' wellbeing by enhancing mental health, providing recreational spaces, improving air quality, and fostering social connections. Urban parks, like the one presented in this chapter, provide diverse ecosystems in cities, and offer residents opportunities for relaxation, exercise, and interaction with nature, leading to healthier, happier, and more resilient urban communities.

According to these results, it is possible to assume that the positive effects of the UNaLab Genoa pilot project are well understood. Further monitoring activities are under implementation to assess the perception of users in terms of wellbeing and biodiversity improvement in different areas of the UNaLab pilot project built in Genoa (construction was completed in August 2022), over time. Indeed, the perception of citizens will change in the coming months and years as the vegetation grows and the park becomes more established. Further monitoring activities are even more important when speaking about biodiversity.

Since vegetation is naturally dynamics and communities tend to evolve and change over time, monitoring the biodiversity of NbS in the park must be conducted consistently over time to understand if and how the area's biodiversity is changing, identifying the main drivers of change. This information will allow for differentiated and sustainable management of the area, creating a stable network of living organisms, also benefiting the resident population.

In addition, care should be taken where the urban green areas, like parks, are surrounded by native vegetation or are located closed to urban-rural transition areas. Currently, there is still a lack of information on how plant communities respond to intermediate, persistent, and widespread disturbances attributable anthropogenic pressures. The latter can affect biotic communities (i.e., plants, animals, and humans) and their interactions, resulting in a reshaping of originally constructed green areas.

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