Network Nature

Design Brief 1

Biodiversity-positive Design in Urban Areas with NBS: **Approaches**

A Series of Design Briefs

This NetworkNature design brief series, the first of its kind, comprises three design briefs on biodiversity-positive design recommendations for urban and peri-urban areas with nature-based solutions. The series, developed with support of IFLA Europe, presents simple design suggestions for renaturing in built environments to restore or provide habitat for nature.

It is not meant to replace professional ecological or landscape guidance, but rather to encourage designers to intentionally consider how they can adopt an interdisciplinary approach to make projects more biodiverse. Specifically, it encourages professionals to adapt to and achieve biodiversity positive design in urban areas via nature-based solutions (NBS).

Design Brief 1

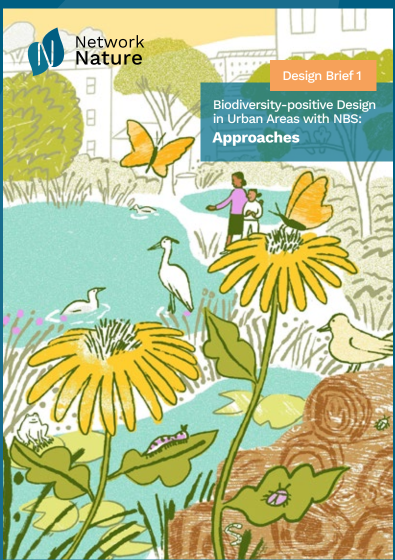
Learn more about Renaturing and biodiversity-positive approaches

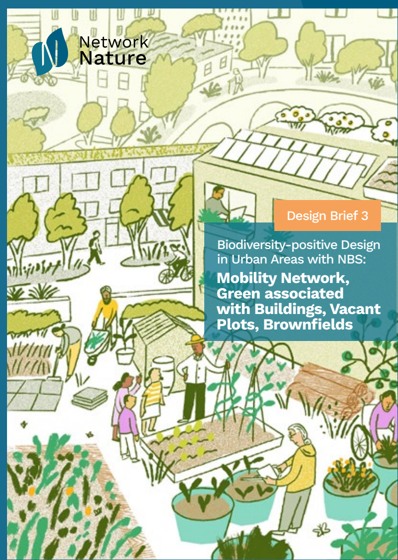
Design Brief 2

Learn more about Biodiversity-Positive Design Recommendations for Wildlife-friendly Areas, Conservation Sites and the Public Realm

Design Brief 3

Learn more about Biodiversity-Positive Design Recommendations for the Mobility Network, Green associated with Buildings, Vacant Plots and Brownfields





Why this Design Brief Series? Why now?

The European Green Deal, which strives to achieve carbon neutrality in Europe by 2050, seeks to protect and restore ecosystems and biodiversity, and to promote the widespread adoption of nature-based solutions (NBS) in policy and implementation. The EU Biodiversity Strategy for 2030 highlights a pressing need to incorporate biodiversity considerations into all policy areas considering the numerous human activities that are threatening it. More specifically, the EU Nature Restoration Law, which was recently proposed and is under review, marks the first legal requirement to mandate large-scale nature restoration to prevent further deterioration of protected habitats and species. This law aims to implement restoration measures in at least 20% of the EU's land and sea area by 2030, with the goal of restoring all ecosystems in need by 2050. Furthermore, this document can be seen as a complementary contribution to the Urban Greening Platform of the European Commission alongside the Urban Greening Plan Guidance Draft and the pending

At a global level, the United Nations has declared the decade from 2021 to 2030 as the Decade on Ecosystem Restoration, which sets a course to repair and restore ecosystems around the world. In addition, the Kunming-Montréal Global Biodiversity Framework (GBF), a key outcome of COP15 from December 2022, builds a strong foundation for global action on biodiversity. It complements the Paris Agreement on climate change by outlining a roadmap for protecting and restoring nature and using it sustainably for current and future generations. The agreement includes specific targets for protecting 30% of global terrestrial and marine areas and restoring 30% of degraded ecosystems, as well as a mechanism for financing these efforts through the Global Biodiversity Fund. It also includes a financial package of international solidarity, particularly for the most vulnerable countries and those with the most biodiversity. There is a growing recognition of the need to prioritise nature protection globally, and those delegates that have painstakingly negotiated the Kunming-Montréal's text, should be applauded. However, the ultimate impact of this agreement will depend on how governments and practitioners implement nature protection policies and design interventions at the local level.

Earth's ecosystems are in decline globally at rates unprecedented in human history – similarly, the rate of species extinction is accelerating, anticipated to have massive adverse impacts for people and nature around the world. The crisis, which has resulted in one million species being at risk of extinction, is a particularly significant topic for designers working in areas planned for urban and peri-urban development and particularly greenfield development. How can new developments incorporate biodiversity into their design? What design strategies can help create healthy and resilient spaces for both people and nature?

Who should read this?

The series is intended for anyone working with nature-based solutions (NBS), for example:

- practitioners directly involved in the design, development and implementation of NBS and across urban ecosystems,
- policymakers, and
- landscape managers,

who are active at the local and regional levels, tasked with implementing legislation issued by the European Commission or by national authorities themselves.

The United Nations Fifth Environment Assembly in March 2022 defined NBS as "**actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits.**"

Introduction

Biodiversity matters

The term "biodiversity" refers to the diverse range of life on Earth, including the variation among species and all forms of life, including rare, threatened, endangered, and even poorly understood species such as microbes, fungi, and invertebrates. According to the online glossary of the European Environment Agency (EEA), it is "*an umbrella term to describe collectively the variety and variability of nature. It encompasses three basic levels of organisation in living systems: the genetic, species, and ecosystem levels.*" Plant and animal species are the most recognised units of biological diversity, thus public concern has been mainly devoted to conserving species diversity. Biodiversity has value in many aspects of our lives, both for the benefits it provides to humans and for its own inherent worth. Utilitarian values of biodiversity include meeting the basic human needs such as food, energy, shelter, and medicine. Ecosystems also provide important services like pollination, seed dispersal, climate regulation, water purification, soil purification, nutrient cycling, and pest control. In addition to these practical values, biodiversity also has a cultural value by offering opportunities for recreation, relaxation, and inspiration. However, the intrinsic value of biodiversity refers to its inherent right to exist, independent of its value to humans or anything else. Finally, biodiversity can also be valued for the relationships it helps us form and maintain with each other and the environment. These relational values contribute to our sense of well-being, responsibility, and connection with nature. Understanding the different values of biodiversity is important to inform urban and peri-urban planning choices practitioners make every day. Biodiversity-positive design is about taking design decisions that reinforce the positive impacts on biodiversity and ecosystems and reduce the negative ones.

However, in the past century human actions have caused rapid ecosystem changes and significant loss of biodiversity worldwide, leading some to call our current era the "Anthropocene." While the Earth has always experienced changes and extinctions, they are now occurring at an alarming rate. Major threats to biodiversity include habitat loss and fragmentation, unsustainable use of natural resources, invasive species, pollution, and climate change. The root causes of biodiversity loss, such as environmental degradation, inequalities and overconsumption, are often complex and interconnected.

The Kunming-Montréal Global Biodiversity Framework

The Fifteenth meeting of the Conference of the Parties (COP 15) has been a significant moment for the planet, when the Kunming-Montréal Global Biodiversity Framework (GBF) was published to establish a shared commitment to protecting 30% of land and seas by 2030. This has been unanimously welcomed as the 'Paris moment' for biodiversity. Governments must follow through with their commitments on policies, action plans, and financial resources. This includes prioritising critical biodiversity hotspots, investing in urban green infrastructure, addressing over extraction, and transitioning towards a nature-positive economic model.

NBS and Biodiversity-Positive Design

Fortunately, humans have the opportunity and means to change actions and protect species and ecological systems. By understanding the threats to biodiversity and how they operate in specific contexts, designers can better prepare for conservation challenges. Conservation efforts in the past have made a significant difference in the state of biodiversity. On the one hand, protected areas such as national parks, wildlife refuges, game reserves, and marine protected areas, managed by governments and local communities, can provide habitat for wildlife and help prevent deforestation. On the other hand, when protecting habitat is not enough, other actions such as restoration, reintroduction, restrictions to land use conversion and controlling invasive species, have also had positive impacts. These efforts have been supported by measures to improve environmental policies at all levels. Additionally, individual and community lifestyles can greatly impact biodiversity and the environment.

Many years before the latest NBS definition by UNEA's Resolution, Eggermont (Eggermont et al, 2015) proposed a framework of three types of NBS to address environmental and social challenges:

- Type 1 - Minimal or zero intervention in ecosystems: Aims to maintain or enhance the provision of a variety of ecosystem services both within and beyond preserved ecosystems, with little to no intervention in the natural systems. Examples of this approach include safeguarding mangroves in coastal regions to reduce risks from extreme weather events and provide benefits for local communities, and establishing marine protected areas to conserve biodiversity within these areas while supporting the fishing industry through the export of biomass. This type of NBS is closely linked to the concept of biosphere reserves, which feature protected core areas for nature conservation such as those belonging to the Natura 2000 network, and buffer and transition zones where sustainable human activities take place.

- Type 2 - Sustainable and multifunctional management of ecosystems: Involves adopting sustainable and multifunctional management strategies for ecosystems and landscapes that are either extensively or intensively managed, with the aim of improving the delivery of specific ecosystem services beyond what conventional approaches could achieve. Examples of this approach include innovative planning of sustainable agricultural landscapes to increase their multifunctionality, or the use of approaches to enhance tree species and genetic diversity in forests to improve their resilience to extreme events. This type of NBS is closely associated with concepts such as natural systems agriculture (Jackson 2002), agroecology (Altieri 1989), and evolutionary-oriented forestry (Lefèvre et al. 2014).

- Type 3: Design and management of new ecosystems: Involves managing ecosystems in highly "invasive" ways or even creating entirely new ecosystems. This type can only be considered NBS if it contributes to the preservation of biodiversity and the sustainable management or restoration of ecosystems while delivering a range of ecosystem services. For agro-ecosystems and green spaces in urban areas, for instance, it is important to consider ecological complexity and connections with surrounding ecosystems to provide biodiversity benefits. Under this category there are actions aimed at increasing green space in squares and streets, restoring degraded areas within the city such as slopes or even quarries, provision of sustainable water management, etc.

The past few years of global pandemic have highlighted the importance of having access to natural spaces and nature in our communities. Protecting and enhancing nature is important not only in nature reserves and other protected areas (NBS Type 1), but also across urban and peri-urban landscapes, where one can find NBS Types 1, 2 and 3. New developments should be designed to support nature recovery networks and allow wildlife to thrive and move through the landscape, improving biodiversity. In this sense, local and regional authorities, through the planning and development consent processes, can positively affect the way in which developments are planned from concept to realisation. Landscape architects, designers and planners, along with staff working in local government planning agencies, have a key role for conserving biodiversity in human-modified landscapes or, where possible, enhancing it. Net-gain principles have been carried out in many countries such as the UK, Germany, France, Spain and Australia. Professionals can reconcile the needs of communities and healthy ecosystems to benefit both, connecting people with nature – e.g., creating new opportunities for children and young people to become immersed in nature and learn about the benefits through education. The more people understand and care for nature, the more they will contribute to protect biodiversity.

However, landscape designers and local government planning agencies often lack knowledge of wildlife ecology (e. positive and negative effects of cinegenic species on biodiversity) and biodiversity net gain, and the required skills for planning. Thus, there is an urgent need for recommendations guiding the design, planning, construction and 'stewardship' of urban ecologies. The approach is, by nature, a multidisciplinary one in tandem with the needs and aspirations of the human community inhabiting the urban realm.

Let's Shift towards Renaturing and Promote Biodiversity-positive Design

To address the ongoing challenges related to the twin biodiversity and climate emergencies, there is the need to significantly change how (re) development impacts the urban and the peri-urban landscape. It is key that designers commit to a systemic approach rather than to conserving isolated items that might be beneficial for biodiversity. The design concept must be to aim at safeguarding (or establishing) ecosystem networks and to promote the restoration of ecosystems processes at scale, considering conditions such as weather regimes, hydrodynamics, nutrients cycles, wind, water, geophysical configuration, light, soil, the interconnectedness of habitats, and more. Therefore, it is recommended to bring together professionals from various disciplines such as ecologists, hydrologists, geologists, biologists, engineers, architects, planners, and landscape architects, for the incorporation of ecological principles from the conceptual phase and throughout all projects phases of design, construction, maintenance and stewardship. This will assist in ensuring that the aspirations are carried out long term. Marketing and sales personnel should also understand the value of a nature-rich development for health and wellbeing.

The term 'renaturing' refers to the idea of restoring degraded or damaged ecosystems to their natural or semi-natural state, and it has gained popularity in urban environments due to the Net Zero Land Take goal, mentioned in the EU Soil Strategy for 2030. The concept is open to different interpretations depending on the stakeholders involved, so it is important to understand its goals and approaches in order to facilitate dialogue between urban stakeholders and propose frameworks for implementing renaturing projects (Grandin et al, 2022).

"Renaturing" projects can provide numerous opportunities for new nature-based enterprises to arise in the field of ecology, hydrodynamics, geology, etc. They can also bring communities together, giving rise to new entrepreneurial initiatives in the field of co-creation and NBS. Designers are called to carefully consider the renaturing possibilities in urban and peri-urban areas and the functioning of ecological processes since the beginning of the design process, exchanging with ecologists and other environmental scientists to contribute with landscapes that are resilient to environmental changes and climatic events. Initial steps involve professionals dedicating time to analyse the existing landscape and the underlying ecological process at play to set out a landscape baseline as a reference point to assess the quality of ecological processes: are these impeded by human-induced disturbances? What are the design measures to be taken to enhance biodiversity at the genetic, species, community, and ecosystem levels? How can planting design be informed by natural systems, including ecological expertise in the design team from the start? What is the status of the soil biodiversity, i.e. does it host a variety of living organisms including bacteria, fungi, protozoa, nematodes, insects, worms, and small mammals, which contribute to nutrient cycling, soil structure, water regulation, and plant growth? While many practitioners recognise the importance of increasing species richness and habitat diversity, there is still a lack of emphasis on the benefits of incorporating diversity at different levels, including above and below the species level, into planting designs.

Specifically, practitioners and designers need guidance on how biodiversity targets can be achieved, including, for example, measures to protect specific biodiversity sites and to reduce the pressure on freshwater ecosystems, in line with relevant policies and regulations (e.g. EU Biodiversity Strategy for 2030, EU Birds and Habitats Directives, Water Framework Directive, European Landscape Convention). Professionals require straightforward and feasible recommendations for biodiversity-friendly design, as the absence of such measures in current designs suggests. Although some urban designers may already be incorporating biodiversity-friendly measures into their work, it is not yet a widely accepted practice. Many urban areas still lack significant green spaces or wildlife corridors, which could be detrimental to local ecosystems and contribute to the ongoing loss of biodiversity. Therefore, it is important to emphasise the principles of biophilic design and provide practical recommendations for biodiversity conservation to ensure that these practices become more mainstream in urban design. It is crucial to raise awareness and provide guidance on these topics to promote more sustainable and ecologically friendly urban development.

Biodiversity needs to be at the forefront of local authority development plans and urban spatial planning. New developments should leave the natural environment in a better state than the encountered one, which can be fostered by ensuring that biodiversity protection policies are contained in development plans. In addition to protecting valuable green and wild spaces, new developments must enhance and restore ecological functions. By recognising the value of nature, designers can convince developers to view it as an asset rather than a cost or limitation. Introducing landscape infrastructure considerations in the preliminary stages of the design process can lead developers to see it as an opportunity to achieve various policy objectives. The enhancement of ecosystem processes within the landscape scale is not only crucial for biodiversity enhancement, but also to help with flood protection, shading networks and improvement of air quality. It is key that designers interact with social and economic scientists to prioritise the well-being of all members of the community, avoiding environmental gentrification.

This design brief series aims at demonstrating how bringing nature back into cities can be achieved through good design, while also creating attractive, healthy, and resilient places that reduce exposure to air pollution and help the city adapt to climate change. It offers simple design considerations for various types of urban greening features that allow for the incorporation of nature in built environments. It proposes a landscape design framework for the purpose of biodiversity enhancement that is based on current landscape ecological science and can be implemented in any landscape, also considering constraints on land use planning.

Different Approaches towards “Renaturing”

Ecological restoration involves re-establishing an ecosystem’s specific composition, ecological functions, and connectivity with the surrounding landscape. It has been primarily used to restore natural, especially aquatic environments and sites and soils contaminated by former industrial activity. The Society for Ecological Restoration (SER) has been developing ecological restoration for over 30 years, with over 4,000 members globally who exchange knowledge and expertise on tools, technologies, and scientific findings, promoting best practices, and effective restoration policy worldwide. Ecological restoration initiatives vary in form and degree of human intervention, ranging from minimal intervention to heavy equipment. Restoration ecology aims to establish the condition a site was in before it was damaged, but this is difficult to achieve in urban environments. In the context of urban planning and design, the concept of “patch size” refers to the size and arrangement of green spaces in urban areas, which can impact biodiversity and ecological functioning. The biogeographic approach aims to create linkages between patches of green space to create a connected network of green infrastructure. Larger patches and arranging patches in corridors can increase species diversity and provide more ecosystem services. Designing urban areas with patch size and biogeographic principles involves considering factors such as the size and shape of green spaces, types of vegetation used, and arrangement of patches. The goal is to create more sustainable and resilient cities that support biodiversity and the natural environment. Renaturing in urban settings typically involves rehabilitation, reclamation, or natural regeneration without aiming to return to an original state. However, historical research can be useful in restoring certain functions of the target ecosystem. Therefore, renaturing might lead to novel ecosystems with different functions and a different structure, so historical references are not necessary in cases of reassignment and natural regeneration (Grandin et al, 2022).

The more “laissez-faire” renaturing approach involves a rather passive framework, which takes place when human interference is halted, leaving nature to spontaneously develop and resulting in a state of “ferality”, in which ecosystems return to their wild state, similarly to the concept of rewilding (ibid). This “passive approach” that allows nature to take its course relies on existing natural elements near or in the area and involves no financial or environmental cost. This process is especially useful when it can occur over a long period and when ecological connectivity is present to allow animal and plant species to recolonise the site. Urban brownfield sites, for example, have real potential for urban biodiversity to develop by itself with low human interference, as these areas can represent refuges for “urban avoiders” struggling to adapt to urban conditions. These environments also contribute to the ecological continuity of local areas.

Another approach relates to the field of ecological design, whose premise is to use living organisms and the understanding of ecosystem mechanisms to design sustainable and adaptable developments to rehabilitate damaged ecosystems, restore functional communities, reintroduce species, and treat pollution. Ecological engineers use techniques inspired by the living world and aim to limit the use of non-renewable resources and inputs. They often rely on ecosystem engineers, such as mycorrhizae and earthworms, to modify the environment. Ecological design has a small ecological footprint and takes its cue from the context in which it is applied, but restoration initiatives often combine civil and ecological engineering.

The approaches to renaturing in natural and urban environments can complement each other, and the goal is to restore ecological functionality through natural processes, with varying degrees of human intervention. Objectives can range from restoring biodiversity to making ecosystems more functional and wilder, all with the aim of mimicking natural systems and ensuring proper carbon, water, and nitrogen cycles. Continuous adaptive management and monitoring are necessary until the ecosystems have recovered (ibid.).

The EU Biodiversity Strategy for 2030 recognises the importance of monitoring and assessing the status and trends of biodiversity and ecosystems to track progress towards the 2030 targets and inform policy decisions. However, today the European biodiversity data landscape is still fragmented. The most intensively monitored taxonomic groups are birds, mammals, and plants, with habitats and ecosystems covered to a lesser extent, and genetic diversity even more rarely monitored. Several countries struggle to fulfil monitoring obligations for EU Directives due to limited resources and differing taxonomies and habitat classifications. EuropaBON is an initiative that aims to design an EU-wide monitoring framework for biodiversity and ecosystem services. To build this framework, stakeholders should be engaged at all stages of the design process, from identifying user and policy needs for biodiversity monitoring to co-designing a new monitoring system.

Renaturing means more than "Urban Greening" and asks for Collaboration

Renaturing in urban settings is often mistaken for greening, which might be focused on creating a decorative green environment without considering ecological functionality. Greening often uses ill-adapted horticultural species and requires numerous inputs, while renaturing considers the climatic and geographical context, uses minimum resources, and targets relevant flora and fauna to maintain ecological functionality. Renaturing via ecological engineering aims to maintain ecological functionalities by taking each level of biodiversity into account, using minimum resources, and minimising future management needs. Creating substitute habitats for species and multiplying beehives can be ineffective for biodiversity recovery if they do not consider the needs of the targeted species. Ecological engineering using plant-based techniques, for example, has been applied to urban environments. This technique uses plants as living construction materials to restore ecological functionalities and degraded environments. Biodiversity is central to these operations, which involve the management of existing or creation of new ecosystems, and the principles can be applied to a multitude of urban projects. New techniques combining ecological and civil engineering have also emerged.

To transition from greening to ecological design, ecologists and landscape professionals must collaborate. Landscape ecology, which considers the composition and configuration of ecosystems as key elements, is used to study past, present, and

future forms of the landscape. It has contributed to ecological knowledge and the implementation of ecological connectivity in cities. Urban ecology and landscape ecology are complementary in the framework of urban renaturing projects. Ecological restoration projects are being developed on the scale of the landscape rather than on individual habitats alone. Landscape architects use “dynamic vegetation design” to create and work with systems over time. It is important to connect isolated environments in landscape matrices to allow for species movement. The restoration of green and blue grids can facilitate this and help restore biodiversity.

Furthermore, it is beneficial that landscape architects and designers work closely with local community groups, schools, and NGOs to promote awareness of renaturing and conservation needs. The most effective way to do this is by making recommendations for the engagement of the wider public in renaturing activities and education and training programmes.

Renaturing requires Genetic Diversity

Genetic diversity refers to the range of genetic variation within a species. It is a crucial aspect of biodiversity, which refers to the wide variety of life on Earth and the ways in which it interacts. Genetic diversity forms the foundation of the biodiversity hierarchy, which consists of genetic diversity, individual species, communities, and ecosystems. Within a species, there can be a wide range of variation among individuals in terms of traits such as size, age, and tolerance to different environmental conditions. This variation, known as intraspecific or within-species diversity, is often caused by both genetic and environmental factors. Genetic diversity is important because it makes populations less vulnerable to climate stresses, pests and diseases. It allows a species or population to adapt and respond to environmental degradation and climate change, helping to ensure its resilience. It can also influence the way that a species interacts with other species and functions within an ecosystem.

Using native material of local and wild provenance can bring numerous benefits for ecological restoration in urban and peri-urban environments. Efforts for the restoration of ecological processes often use a variety of woody and herbaceous plants, both terrestrial and aquatic. In fact, there is growing evidence that native species should be prioritised in ecological restoration programmes. Plant species that have evolved locally have developed specific adaptations to the local environment. In contrast, introduced species from other areas may not be well-adapted to the local environment. However, in some cases, native species used in urban restoration projects may be sourced from distant locations, potentially leading to the use of non-local genetic material. Wild native species that have been selected over generations for ornamental purposes and are widely used in commercial seed mixes may have undergone such significant genetic modification that they can no longer be considered "wild," and may have limited ecological value. These modified species are often selected for horticultural or aesthetic traits in urban and peri-urban areas but may not contribute significantly to ecosystem functioning while leading to biodiversity loss.

Global trade has led to competition among plant and seed suppliers, resulting in the easy availability and low cost of species from all origins. However, sourcing plant material from distant supply chains often ignores the potential impacts on local biodiversity and the plant's ability to adapt to local environmental conditions. This market globalisation also applies to seeds and plant cuttings, disregarding the fact that locally sourced plants and their genetic material have evolved to be adapted to specific local environmental conditions as have the local fauna. Genetic diversity can be lost through horticultural propagation practices such as seed collection, seed handling, and nursery growing conditions (Nagel, Durka, Bossdorf & Bucharova, 2019). These processes often involve sampling and selection of plants with certain traits, which can result in a genetic bottleneck (ibid). For example, seed collectors might only harvest seed from a small portion of a population or from plants that flower at a specific time. Seed cleaning, storage, and stratification can also impact genetic diversity. Nursery conditions, which are often more controlled than natural environments, can impose artificial selection on plants and reduce genetic diversity over a few generations. In some cases, growers may intentionally select plants with certain traits and discard others, while plant breeders may develop cultivars with uniform traits through breeding. In these cases, further offspring are often produced asexually, resulting in plants that are genetically identical to the original parent plant (Allen et al, 2021).

Regional sourcing of plants and herbs can help to achieve a balance between providing genetically diverse restored populations and maintaining large-scale patterns of genetic differentiation. The material available from nurseries, for example, is becoming increasingly genetically uniform and less resilient to stresses, at a time when threats are increasing. However, nurseries could have an important role in providing wild herbs and woody vegetation by having improved seed collection and plant propagation practices. Landscape architects can help raise awareness and shift industry practices by considering the origin and propagation methods of plants in addition to their physical characteristics. By applying native plant material of wild and local provenance in landscape projects, designers may influence project managers to incorporate this type of plant material to achieve environmental and societal goals outlined in the NBS concept while also delivering desired project outcomes. SER advises using native species that are sourced locally, if possible, for ecological restoration projects. In Europe, most native plant species used in cities are not subject to legislation regarding their origins and traceability. However, there is a growing trend towards considering the concepts of local provenance and high genotypic diversity in ecological engineering and restoration programs. These programs may rely on traceability systems to ensure the origin of the used plant material (Rivière et al, 2022).

The impact of native vs. non-native species on pollinators is a topic of ongoing debate. The precautionary principle suggests that using native, locally sourced plant resources whenever possible is advisable, as these species have evolved in line with local pollinators through coevolution. It is important to evaluate the effect of plant material on pollinators, particularly wild pollinators, as long-standing native vegetation may be more beneficial for them. Non-native plant species and native plant material from non-local sources may not be adapted to local pollinators and may provide poor nutritional value, potentially leading to starvation of pollinators. Additionally, introducing non-native plant material may harm native insects.

Invasive alien species (IAS) can also have a significant negative impact on biodiversity and ecosystem function. IAS are defined as non-native species that have been introduced, either intentionally or unintentionally, to a new area where they are not native and where they are able to establish and spread. These species can outcompete native species for resources and habitat, leading to declines in native species populations and potentially causing them to go extinct. IAS can also alter ecosystem processes and functions, leading to changes in the structure and function of ecosystems. The impact of IAS can be particularly significant in areas that are already under stress due to other factors, such as habitat destruction or climate change. There are many different pathways through which IAS can be introduced to new areas, including the intentional or accidental release of pets or other animals, the importation of plants for horticulture or agriculture, and the movement of species via ships or planes. Efforts to prevent the introduction and spread of IAS include stricter regulations on the import and trade of non-native species, as well as efforts to control and eradicate established IAS populations.

Invasive episodes, in which non-native strains of a species displace native types and expand their range, can also occur. The use of non-local provenance species, such as cultivars, may also lead to hybridisation with local congener species, potentially threatening their genetic variability and causing outbreeding depression (ibid). Therefore, to maintain a high level of genetic diversity, the collection and production of wild and local plant material should follow specific guidelines, including sampling thresholds and specific production methods with a limited number of generations. These technical specifications help to minimise the risk of selection bias for certain traits and maximise genetic variability.

There is increasing evidence that genetic diversity within plant populations is necessary for long-term evolutionary change and ecosystem functioning (Kettenring et al, 2014). To ensure the long-term viability of urban and landscape designs, with resistance and resilience to climatic challenges, it is essential to incorporate a multi-layered or nested hierarchy of levels of diversity in plant assemblages. This is true in both natural and constructed environments. Research has shown that genetic diversity can help plant populations establish quickly, resist invasion, recover from herbivory and extreme weather events, and adapt to climate change (Reusch et al, 2005; Crutsinger, Souza & Sanders, 2008). Genetic diversity can have positive impacts on the population, community, and ecosystem levels, sometimes similar in magnitude to the impact of species diversity.

Landscape architecture offices seeking to foster genetic diversity strive to create and restore multiple habitats. Some offices engage in gathering several varieties, cultivar, and breeding information on different species by consulting internet databases, peer-reviewed articles, and wholesale nursery catalogues for projects. This was the case of the office Mathews Nielsen Landscape Architects, who based on the raised information has developed two main strategies to increase the intraspecific diversity of species in their projects (Allen et al, 2021). One way was using a mix of local ecotypes, or genetically distinct populations within a single species that have adapted to a particular climate or microclimate over time. The study conducted by Allen et al (2021) found that it was possible to use the local ecotype approach for any species that have natural populations growing in proximity to the project site, such as within 50-150 miles. However, local sources of plant material may not always be available or accessible, and it may not be feasible to collect seed and arrange for contract growing due to time and budget constraints. In their project, it would have been feasible to follow a local ecotype approach for several species, but it would be challenging, for example, for the New York City Department of Parks & Recreation to require contractors to source plant material from specific locations. Therefore, the landscape architecture office suggested that planting material for one threatened species should be sourced within a certain distance from the project site and justified this recommendation with the species' threatened status.

INTRASPECIES PLANT DIVERSITY

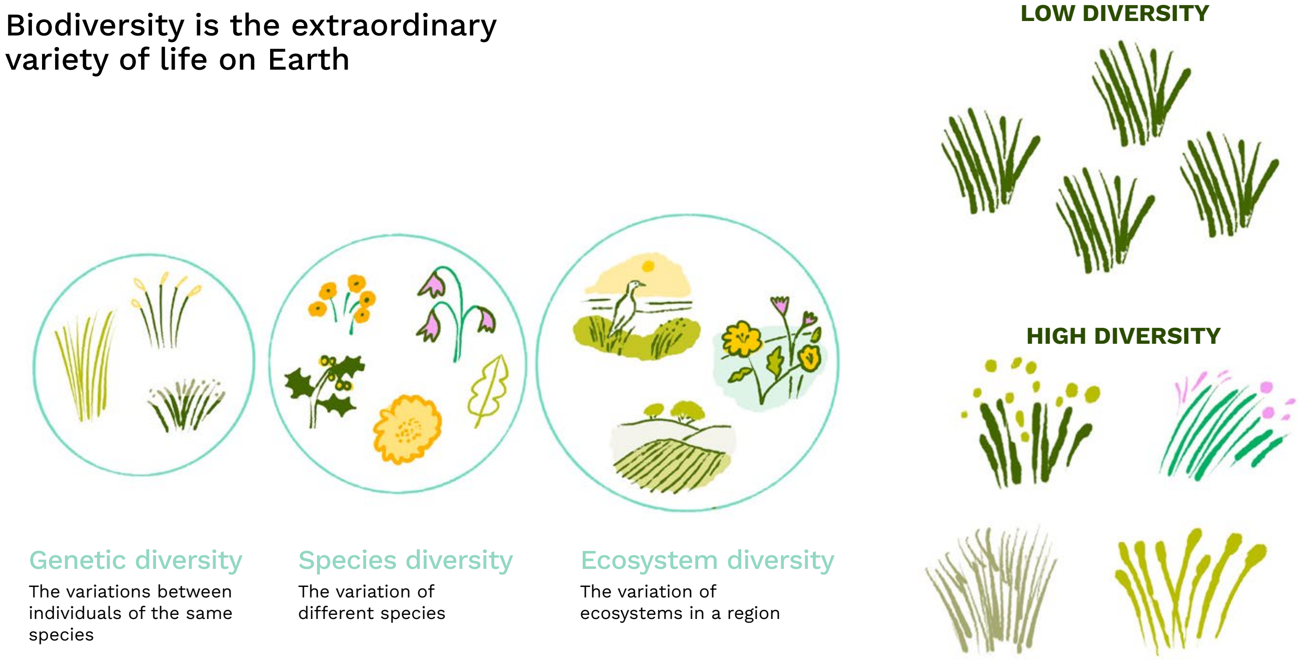


Figure: The left side of this diagram, which was redesigned from Allen et al (2021), shows the three based levels of organisation in living systems: the genetic, species, and ecosystem levels. The right side of the image shows the concept of low and high intraspecific or within-species diversity.

Another way to incorporate within-species diversity into the planting design was to use multiple varieties or cultivars of a single species (Allen et al, 2021). This approach was inspired by the cropping technique of planting fields with a mixture of varieties or cultivars, which has shown to increase resilience to biotic and abiotic perturbations and enhance a plant population's ability to resist invasion by other species (Tooker et al, 2012; Wolfe, M. S., 1985). Using multiple varieties or cultivars can also increase pollinator abundance and diversity and improve pollination services Genung et al (2010). In their study, Allen et al (2021) found that it was not feasible to follow the local ecotype approach for every species, so they decided to use between two to four different varieties or cultivars of each proposed species. When selecting multiple varieties or cultivars, they found that it is important to choose ones that are well-suited to the ecoregion or hardiness zone and that can flower at different times of the season. Planting them closely together can also help maintain distinct varieties or cultivars by making it harder for any seeds produced by the plants to establish in the limited open space (ibid).

Renaturing projects at various scales rely on the provision of a range of ecosystem services that benefit human communities. Diversity of seeds and plant propagules, which form the foundation of natural and constructed landscapes, is key. When selecting plant species for ecological restoration projects, for example, it is important to consider abiotic factors such as climate, soil, and topography, as well as the origin and physiological characteristics of the plant material (Rivière et al, 2022). Studies have shown that using a diverse native plant mixture can result in higher species richness and quality compared to using a low-diversity cultivar seed mixture. Native plant species that are sourced locally can provide resources such as pollen and nectar in sync with the needs of their associated fauna, such as pollinators, while the use of non-native species may cause ecological disruption and "genetic pollution." Non-native plant material may also introduce plant pathogens, fungi, or insect predators that could harm native species. The impact of non-native and exotic plants on rhizosphere microbiota needs further investigation.

Although information on the effects of increasing within-species diversity in urban landscape design projects is becoming more widely available through research networks and tools like biodiversity audits, there are still clear practical challenges for landscape architects to incorporate higher levels of biodiversity into their designs due to various constraints. It is important to continue researching and exploring practical solutions to these challenges to promote sustainable and biodiverse urban environments. For example, to address the negative impacts of invasive alien species (IAS) on biodiversity and ecosystem function, it is important to investigate and promote the use of alternative plants, including both native and non-invasive non-native species. These alternative plants should ideally have similar characteristics, uses, and requirements as the IAS they are replacing. There are currently codes of conduct at the European and national levels that recommend the use of such alternative plants. One solution for finding suitable replacements is to use assemblages of plant material of wild and local provenance. Increasing public awareness and shifting consumption patterns towards these alternative plants can help to reduce the negative impacts of IAS on the environment (Rivière et al, 2022). Furthermore, given the phenomenon of urban heat islands, where cities and towns tend to become hotter due to human activities such as transportation, industrialisation, and building construction, the distribution of plant and animal species may shift, with some species being pushed further north or south towards cooler areas. This can have significant impacts on local ecosystems and biodiversity, as well as the services they provide to humans, such as pollination and pest control. Therefore, plant choices must be made with consideration for predicted temperature increases, as certain species may no longer be able to survive in hotter conditions. This may require the selection of more heat-tolerant plant species or even the use of non-invasive non-native species that are better adapted to warmer temperatures. Urban planners, landscape architects and landscape designers can use climate modelling and other tools to predict how temperatures in their area may change over time and make informed decisions about species selection.

Renaturing includes Promoting Pollinators

The first and most important step to protect pollinators is to protect and restore a variety of habitats that are friendly to them, such as urban meadows, hedgerows, and agricultural environments. However, in densely populated urban areas, simply increasing the number of beehives can lead to an overabundance of honeybees that compete with wild pollinators for access to flowers. Additionally, creating substitute habitats like insect hotels or wildlife shelters may not necessarily fulfil the needs of the targeted species. While these initiatives can be useful for educating the public about nature, they may not always be effective in promoting biodiversity recovery. To help pollinators thrive, it is important to preserve and create new habitats for them, increasing the abundance of food resources and extending the availability of flower-rich resources throughout their life cycle. This can be done by mapping out existing and potential pollinator habitats and networks, both in public and private spaces. These habitats can then be protected and connected through land-use planning and management.

To create and restore habitats, it is important to improve ground conditions and provide nesting and hibernating habitats for wild bees. There is ample evidence to support the use of low-risk biological control measures and non-chemical pest control techniques to promote pollinator-friendly habitats in urban and peri-urban areas. For example, a study conducted in the United Kingdom found that using low-risk biological control measures like parasitic wasps and lacewings was effective in reducing pest populations and increasing crop yields in apple orchards (Lavandero et al., 2003). Invasive species should be controlled, and native plant mixes that are attractive to pollinators should be grown. Mowing practices should also be adjusted to be more ecologically friendly and support pollinators. Promoting grazing herbivores for mowing can help seed diversification and the soil compaction is reduced when compared to that of mowing machines. It is important to provide a continuous supply of nectar-rich flowers and trees, as well as herb-rich areas for pollinators to feed on (Wilk et al, 2019).

As a pollinator-friendly practice, it is important to choose local native plants. There is increasing evidence that native plants provide the greatest biodiversity value compared to exotic species and should therefore be the first choice. Native species receive more visits from pollinators, even generalist species (those that feed on many types of plants). They are more resilient, as they have adapted to local climate and soil conditions and provide food for both adult and larval pollinators. Choosing flowers that are high in pollen and nectar is recommended. While native plants are always the best choice, it is important to focus on flowers that are particularly rich in pollen and nectar. This is especially true for generalist pollinators (those that feed on many types of plants) and specialist pollinators (those that feed on specific types of plants, such as most butterflies). Considering Europe, habitats should provide a steady supply of pollen and nectar from March to September, which are the main periods of activity for pollinators. Early spring-flowering species should also be given special consideration as a vital food source after the winter. To support a diverse range of pollinators, it is important to offer a variety of flower resources throughout this period. As already mentioned, native plants are preferred, and alien species should be avoided.

Additionally, the prevention and the control of the spread of invasive alien species, both plants and animals, is a key factor. Measures for eliminating invasive alien plant species include limiting their growth through methods such as physicochemical or organic treatment, cutting aquatic weeds and grasses, grazing, manual removal, covering the plants with a tight cover to smother them without scattering debris, and encouraging competition with taller plants, trees, and shrubs. Invasive animal species may be more difficult to address due to their mobility and behaviour. Measures can include removal, relocation, or population control, such as extermination or controlled reproduction. In the case of vertebrates, waste management and sanitary measures are key.

Pollinators are “border-crossers”, so working across local authority areas can improve the pollinator resource and enhance pollinator habitat connectivity and populations throughout the landscape. Collaboration, such as sharing machinery and expertise, can also help make the most of existing resources. While local authorities play a crucial role in managing their land for pollinators, organisations such as wildlife trusts, community groups, and others can help implement actions and monitor pollinator populations. Private land can also be managed for pollinators.

Finally, monitoring pollinators is crucial for understanding their status and trends, and for implementing effective conservation measures such as protection and conservation zones. It is also useful for creating maps of pollinator habitats and identifying potential threats to pollinators, which can support pollinator-friendly land use planning and management. Additionally, monitoring is necessary for evaluating the effectiveness of pollinator-friendly measures and determining whether the targets set in pollinator strategies and action plans have been met (Wilk et al, 2019).

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