NATURE-BASED SOLUTIONS AND CLIMATE ACTION IN LANDSCAPE ARCHITECTURE












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1. INTRODUCTION

What is this chapter about:
The chapter introduces into the basic problematic of climate problems, Nature-based Solutions (NbS) and the role of landscape architecture. It provides with introductory information what the handbook is about and why it is worth further reading.

What you will learn:
- Which are the most important current climate problems.
- Basics about how NbS can be tools to solve these problems.
- The basic idea of the role of landscape architecture in implementing NbS.

To get started on the handbook topic, we need basic knowledge of current climate problems, the importance of Nature-based Solutions in addressing them, and the role of landscape architecture in this context.

1.1. CURRENT CLIMATE PROBLEMS (IN GENERAL)

In a synthesis report, published by the Intergovernmental Panel on Climate Change (IPCC, 2023), the following observed changes and impacts because of climate change are summarized:

- Due to human influence, the temperature of the atmosphere, ocean, and land has risen. The global mean sea level increased.
- As a result, the living conditions of between 3.3 billion and 3.6 billion people are highly vulnerable to climate change.
- Climate change has led to substantial damage and irreversible losses regarding numerous types of ecosystems.
- Climate change has negatively affected food security and water security.
- Health conditions and mortality of humans increase in regions with increasing extreme heat events.
- The negative impacts and related losses caused by climate change are unequally distributed across climate-exposed sectors and regions.
- The observed climate change has caused negative impacts, for example, on human health conditions, also in urban areas.

From this list, it is visible that the negative impact is a complex matter involving many interwoven aspects. As a key aspect, a strong negative impact on biological diversity can be named. The Millennium Ecosystem Assessment (MEA, 2005)

identified climate change as one of the main drivers directly affecting biodiversity and as one of two drivers (together with excessive nutrient loading) that will become more severe in the first half of the 21st century. Biological diversity "includes diversity within species, between species and of ecosystems" (Secretariat of the Convention on Biological Diversity, 2005, p. 8). Thus, biological diversity is more than species and their genetic features; ecosystems, which they are part of, must also be considered an important element of overall biological diversity. Ecosystems, the services they provide, and human well-being are linked in many ways (MEA, 2005). Therefore, the massive impact of climate change on ecosystems may have drastic consequences for the quality of human life. On the other hand, as we will see later in the text, ecosystems and ecosystem services may serve as opportunities and models for counteracting the negative consequences of climate change.

1.2. NATURE-BASED SOLUTIONS AS TOOLS TO SOLVE CLIMATE PROBLEMS

There is an urgent need to find solutions to counteract the problems described in the last subchapter. A society facing these types of challenges has different options available. According to Eggermont et al. (2015), there are two approaches: the first is directed towards technological strategies, whereas the second takes into account the dynamic nature of complex socio-ecological systems. In the latter context, Nature-based Solutions have been proposed, considering both the environment and society. This approach can be summarized as, "building on and complementing traditional biodiversity conservation and management strategies, NbS integrate science, policy, and practice and create biodiversity benefits in terms of diverse, well-managed ecosystems" (Eggermont et al., 2015, p. 243).

As a solution, ecosystem services can be applied because they are targeted towards this idea: to use the potential of natural resources, such as ecosystems, in order to improve the situation for humans. Ecosystem services can be divided into the following four categories (MEA, 2005):

1. Supporting services – those that are necessary to produce all other ecosystem services,
2. Provisioning services – products obtained from ecosystems,
3. Regulating services – benefits obtained from the regulation of ecosystem processes,
4. Cultural services – nonmaterial benefits people obtain from ecosystems.

As shown in Figure 1.1, among the regulating services is climate regulation. Ecosystems influence climate both locally and globally. Options are, for example, to use ecosystems for temperature reduction or carbon sequestration.

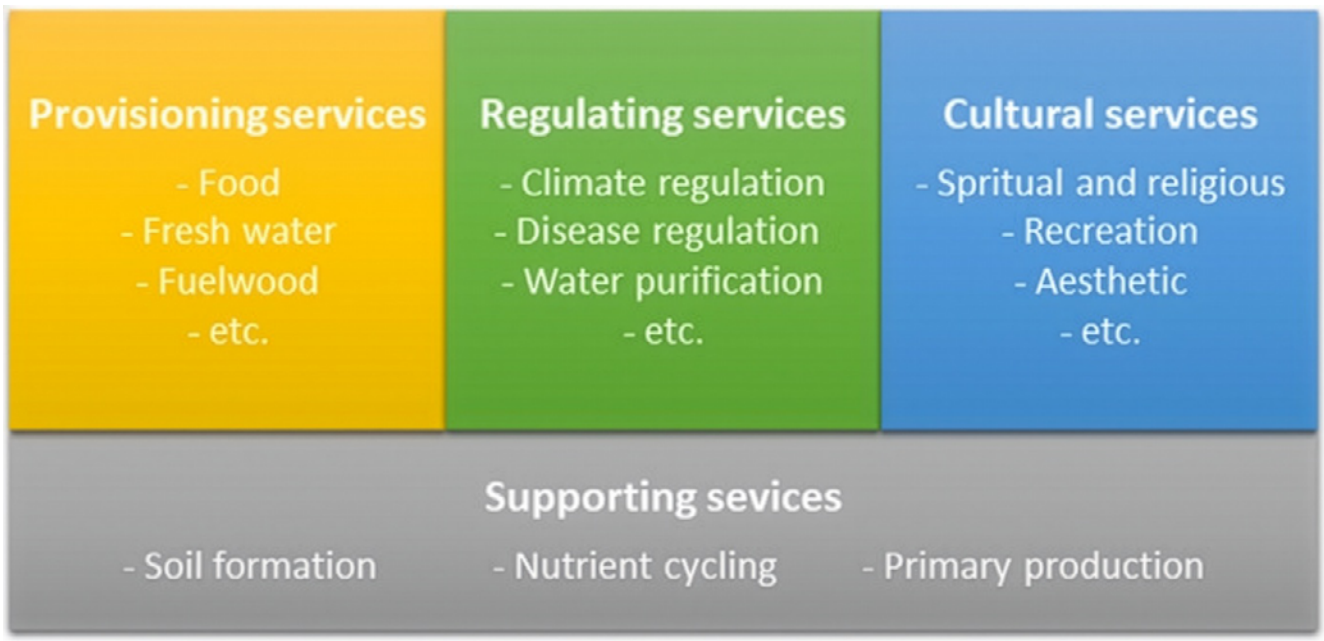


Figure 1.1. The different categories of ecosystem services with examples (after MEA, 2005)

1.3. THE ROLE OF LANDSCAPE ARCHITECTURE

Because of its impact on ecosystems and landscapes, landscape architecture is directly linked to Nature-based Solutions. Among other things, landscape architects may help design and plan Nature-based Solutions and promote them, as well as an integrated nature-culture approach (Gkoltsiou, 2022). Particularly when it comes to climate problems, landscape architecture plays an important role, for example, by mitigating urban heat islands and contributing to air purification through projects designed to achieve these targets (Seok et al., 2025). Basically, well-designed landscape architecture projects can fulfill the role of Nature-based Solutions. Accordingly, landscape architecture is also an important tool for realizing the goals of sustainable development, i.e., benefiting environmental, economic, and social development in the targeted area or region, and contributing to fulfilling the 17 United Nations Sustainable Development Goals (see the chapter “Nature-based Solutions and sustainable development”).

We can summarize that the current climate problems are severe and manifold, and Nature-based Solutions offer possibilities to tackle these problems. Landscape architecture projects can use the potential of ecosystems in the landscape to design Nature-based Solutions and support sustainable development. The present handbook examines this complex of topics in detail by providing a broad theoretical background as well as a practical part containing practical aspects of implementing Nature-based Solutions via landscape architecture projects, as well as case examples from Europe and Southeast Asia.

> Landscape architecture projects can use the potential of ecosystems in the landscape to design NbS and support sustainable development.

Review questions:

1. Which are the most important current climate problems?
2. Which categories of ecosystem services exist?
3. Why can landscape architecture projects fulfil the role of NbS?

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PART A
THEORETICAL PART

2. DEFINITION OF NATURE-BASED SOLUTIONS

What is this chapter about:
The chapter introduces common definitions of Nature-based Solutions (NbS) and their criteria. It introduces the basic types of these solutions and provides short examples.

What you will learn:
- The definition of NbS.
- Criteria for NbS.
- Differentiation from the term ecological engineering.
- Which types of NbS exist, including some selected examples.

2.1. DEFINITION(S) OF NATURE-BASED SOLUTIONS

Nature-based Solutions have been defined in different ways. The two most commonly mentioned definitions are those by the International Union for Conservation of Nature (IUCN), i.e.: “Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016, p. 2), and the definition by the European Commission: “Solutions that are inspired and supported by nature, which 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, n.d.). The IUCN definition was taken with slight modifications and delivered as a multilaterally agreed definition by the United Nations Environment Assembly (UNEA) as “nature-based solutions are 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, resilience and biodiversity benefits” (UNEP, 2022, p. 5).

The definition by the European Commission clearly underlines the fact that these solutions are based on ecological principles. However, the IUCN accentuates that “Nature-based Solutions (NbS) use ecosystems and the services they provide”

(Cohen-Shacham et al., 2016, p. 2). Since ecosystem services can be understood as ecosystem functions that benefit humans (Kremen, 2005), we can also see here a link to natural processes ongoing in ecosystems. Eggermont et al. (2015, p. 243) emphasize that "building on and complementing traditional biodiversity conservation and management strategies, NbS integrates science, policy, and practice and creates biodiversity benefits in terms of diverse, well-managed ecosystems."

Bringing all this together, we might attribute the following features to Nature-based Solutions:

- They benefit both humans and nature,
- Because of the environmental, economic, and social aspects, they support sustainable development,
- They are based on ecological processes and principles.

> NbS benefit both humans and nature, support sustainable development, and are based on ecological processes and principles.

The IUCN Global Standard for Nature-based Solutions provides greater clarity on the concept of Nature-based Solutions, offering a framework for designing and verifying them (IUCN, 2020). The IUCN launched the Global Standard for Nature-based Solutions in 2020. Developed through public consultation with over 800 practitioners and experts from more than 100 countries, the Global Standard serves as a practical, multi-dimensional, and versatile framework for designing, implementing, and evaluating Nature-based Solutions at local, national, and global levels. This standard consists of eight criteria and 28 associated indicators, each supported by guiding questions to help practitioners assess and improve their interventions (IUCN, 2020). These criteria (Table 2.1) address aspects ranging from tackling societal challenges and ensuring biodiversity gains to economic viability, inclusive governance, and long-term sustainability.

Table 2.1. The eight criteria for Nature-based Solutions are defined in the IUCN Global Standard for Nature-based Solutions (IUCN, 2020)

Criterion	Description
1	Nature-based Solutions effectively address societal challenges
2	Design of Nature-based Solutions is informed by scale
3	Nature-based Solutions result in a net gain to biodiversity and ecosystem integrity
4	Nature-based Solutions are economically viable

Table 2.1. The eight criteria for Nature-based Solutions are defined in the IUCN Global Standard for Nature-based Solutions (IUCN, 2020)(cont.)

Criterion	Description
5	Nature-based Solutions are based on inclusive, transparent, and empowering governance processes
6	Nature-based Solutions equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits
7	Nature-based Solutions are managed adaptively, based on evidence
8	Nature-based Solutions are sustainable and mainstreamed within an appropriate jurisdictional context

For individual implementations of Nature-based Solutions, application of the standard can give credibility when speaking with all kinds of involved stakeholders, can help to identify solutions for improvement, and can be useful when it comes to communication across sectors by providing a common framework and language. The standard is accompanied by a guidance and user manual. Also, a self-assessment tool has been developed to enable users to check how well their measures fit the eight criteria.

2.2. NATURE-BASED SOLUTIONS AND ECOLOGICAL ENGINEERING

Taking the aspects mentioned above into account, the term Nature-based Solutions comes close to the term ecological engineering, which is defined as “the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both” (Mitsch & Jørgensen, 2003, p. 363). However, despite a high degree of similarity, these two terms should be distinguished. Ecological engineering emphasizes the application of engineering techniques, with a special focus on the restoration of ecosystems; Nature-based Solutions is a much newer term, which is still evolving, but shows increasing popularity in recent years (de Oliveira Demarco et al., 2024). According to Wang et al. (2022), ecological engineering is a key means to promote ecological restoration, and some differences in the paradigms of ecological restoration and Nature-based Solutions exist, with Nature-based Solutions having a stronger focus on social aspects and a more complex implementation process taking into account relevant parties (stakeholders).

Cohen-Shacham et al. (2016, p. xi) define the range of Nature-based Solutions as “an umbrella concept embracing a number of different ecosystem based approaches” (Figure 2.1), among them ecological engineering. This term is here understood as a Nature-based Solutions concept with an ecosystem restoration

approach. Nature-based Solutions, as a newer term, have their foundations in such established practices and are nowadays considered “an essential mechanism for achieving sustainable development” (IUCN, 2020, p. 2).

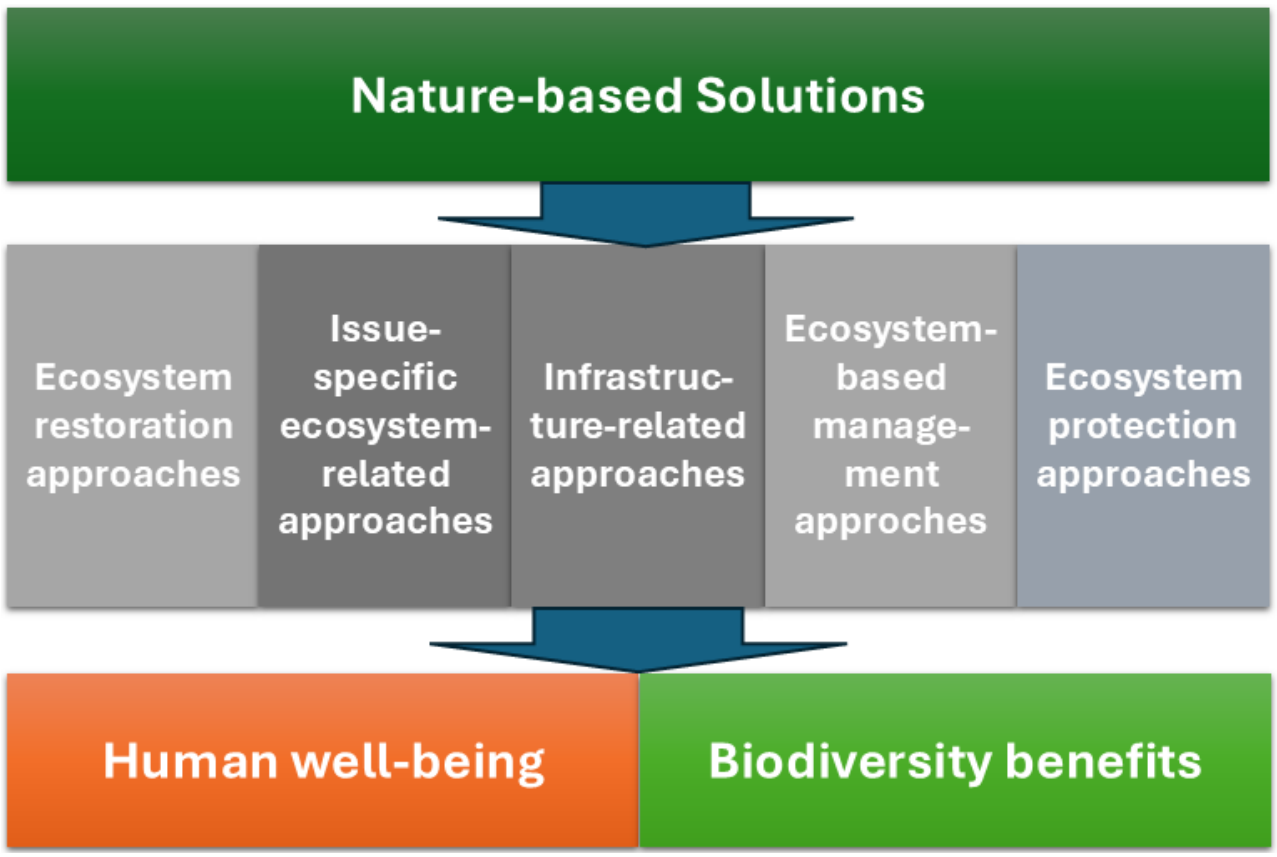


Figure 2.1. Nature-based Solutions as an overarching concept embracing ecosystem-based approaches (after Cohen-Shacham et al., 2016)

2.3. TYPES OF NATURE-BASED SOLUTIONS

Pereira et al. (2023) describe three types of Nature-based Solutions: those based on utilization of existing natural areas with very low or no intervention (Type 1), those focusing on the restoration or management of traditional ecosystems and may require management of varying intensity (Type 2), and those aimed to set up new ecosystems (Type 3).

Type 1 refers to Nature-based Solutions implemented in existing natural areas with minimal or no intervention, where the primary objective is to safeguard intact ecosystems, so they continue to provide essential ecosystem services such as carbon sequestration, hydrological regulation, and biodiversity conservation (Chausson et al., 2020; Seddon et al., 2020). Such approaches are particularly relevant in biodiversity-rich contexts, for example, the protection of primary lowland rainforests in Borneo or the establishment of marine protected areas in the Raja Ampat archipelago to conserve coral reef ecosystems and associated livelihoods (Hs et al., 2020).

Type 2 comprises Nature-based Solutions focused on restoring or managing traditional or modified ecosystems, where active intervention is required to recover ecological functions while ensuring the continued provision of socio-economic benefits (Cohen-Shacham et al., 2016; Nesshöver et al., 2017). As an example, agroforestry systems in Java, combine perennial crops with native shade trees to improve soil fertility and biodiversity while diversifying rural incomes (Mulyoutami et al., 2009). In Central Kalimantan, large-scale peatland rewetting has been introduced to curb peat oxidation and reduce wildfire frequency. These measures are also critical for maintaining long-term carbon storage in the region (Harrison et al., 2020).

Type 3 Nature-based Solutions involve the creation of entirely new ecosystems, often within highly modified environments, to deliver ecological and social benefits (Pereira et al., 2023). At the Indonesian House of Representatives complex in Jakarta, a section of the main roof was converted into a planted surface a few years ago. The idea was simple: see if a layer of vegetation could make the building cooler and reduce the puddles that often form after heavy rain. Similar interventions in Jakarta have demonstrated measurable impacts: green roofs were found to lower indoor mean radiant temperatures by more than 13°C and reduce heat flux by over 90%, leading to significant savings in cooling energy demand (Budhiyanto & Tampubolon, 2025). At Soekarno–Hatta International Airport, elements of the eco-green airport concept, such as vertical planting systems that have been piloted to enhance indoor air quality and mitigate heat within terminal spaces (Anggoman et al., 2024). Another case is constructed wetlands in Indonesia have demonstrated strong potential for wastewater treatment. For example, a pilot horizontal subsurface system planted with *Vetiveria zizanioides* achieved over 60% removal of ammonium, rising to 80% in optimized sand substrates (Purwaningrum et al., 2023). In a second case, combining *Moringa oleifera* seed powder pre-treatment with constructed wetlands effectively treated batik industry wastewater which achieving 89.3% reduction in chemical oxygen demand (COD), 98.1% in total suspended solids (TSS), and 92.1% in fats, oils, and grease (FOG) (Rahmadyanti, 2020).

NbS can be classified into three main types: conserving intact ecosystems (Type 1), restoring or managing modified ecosystems (Type 2), and creating new ecosystems in highly transformed landscapes (Type 3).

Review questions:

1. What are the main attributes of NbS?
2. Which eight criteria for NbS are defined in the IUCN Global Standard for NbS?
3. What distinguishes NbS from the term ecological engineering?
4. What are the three main types of NbS?

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3. CURRENT CLIMATE PROBLEMS

What is this chapter about:
Nowadays, we observe several severe climate changes. These changes are summarized in the chapter. Next, the chapter describes the impact of these changes on ecosystems and species, but also on humans, when causing socio-economic problems.

What you will learn:
- The most important observed climate changes.
- The impact of climate changes on ecosystems and species.
- The socio-economic problems caused by climate changes.

As already described in the introduction to this handbook, nowadays we observe numerous climate changes with severe consequences. These consequences concern ecosystems and species, but evidently also humans, by causing socio-economic problems.

3.1. SUMMARY OF OBSERVED CLIMATE CHANGES AND THEIR CONSEQUENCES

The synthesis report published by the Intergovernmental Panel on Climate Change (IPCC, 2023) identifies several parameters of global warming and its causes, for example:

- The global surface temperature increased by 1.09°C from 1850–1900 till 2011–2020.
- Total human-caused global surface temperature increase is best estimated with 1.07°C from 1850–1900 to 2010–2019.
- The observed increases in well-mixed greenhouse gases (GHG) concentrations since around 1750 are clearly caused by GHG emissions from human activities. For example, in 2019, the concentrations of atmospheric carbon dioxide (CO_2) were higher than at any time in at least 2 million years, and the concentrations of methane (CH_4) and nitrous oxide (N_2O) were higher than at any time in at least 0.8 million years.
- Global net anthropogenic GHG emissions in 2019 were about 12% higher than in 2010 and 54% higher than in 1990. The largest share and growth in gross GHG emissions occurred in CO_2 from the combustion of fossil fuels and industrial processes.

The consequences are appearances of heatwaves, floods, droughts, sea-level rise, and more, having sometimes drastic consequences on ecosystems, species, and human well-being (Figure 3.1), as outlined later. As an additional problem, these negative impacts and related losses caused by climate change are unequally distributed across climate-exposed sectors and regions (IPCC, 2023).

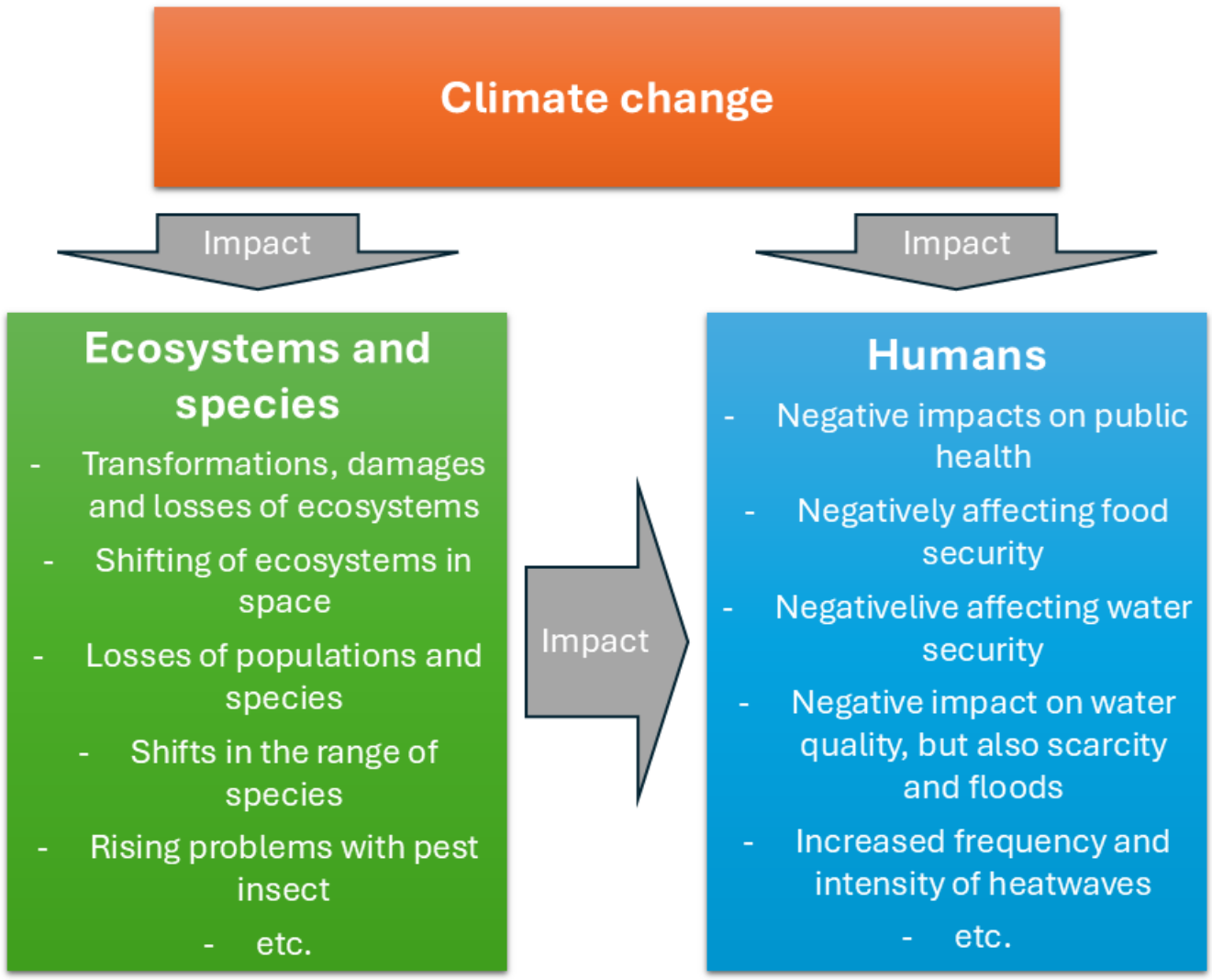


Figure 3.1. Schematic presentation of the impact of climate change on ecosystems, species, and human well-being (own work)

3.2. IMPACT ON ECOSYSTEMS AND SPECIES

Changes in climate have a direct impact on ecosystems and their species. On the other hand, changes in ecosystems (for example caused by land-use changes) can contribute to greenhouse gas emissions and thus contribute to climate change (MEA, 2005). When it comes to the impact on ecosystems caused by climate changes, we have to consider the following main problems.

Climate changes may cause transformations, damages, and losses of ecosystems. For example, the global mean sea level increased by 0.20 m between 1901 and 2018 (IPCC, 2023). Roy et al. (2023) discussed that sea level rise may cause changes in shoreline and damage to coastal habitats in India. Changes in climate are also one of the drivers of desertification processes (e.g., Rodrigues do Nascimento, 2023), leading to the expansion of deserts at the cost of other ecosystems.

Climate changes may also lead to the shifting of ecosystems in space, which is directly related to the impact on species, because it will cause a shift in the geographic range of species. The climate changes related impacts on ecosystems may also result in habitat losses and, in the worst case, lead to loss of species.

With respect to the nun moth (*Lymantria monacha*), a pest insect in coniferous forests, Fält-Nardmann et al. (2018) demonstrated a northward expansion of this species, which corresponds with changes in weather in Finland. Jaskuła et al. (2021) predicted habitat loss and shifting of the range of subspecies of the American red flat bark beetle (*Cucujus clavipes*) due to climate warming (shown for *Cucujus clavipes clavipes* in Figure 3.2). Shifts in the range of species may be even related to health-related impact on humans (see next subchapter), for example, due to the shifting of vectors of diseases, as shown for *Anopheles* (vector of malaria), based on models using climate variables and land cover classes to predict vector occurrences (Hertig, 2019).

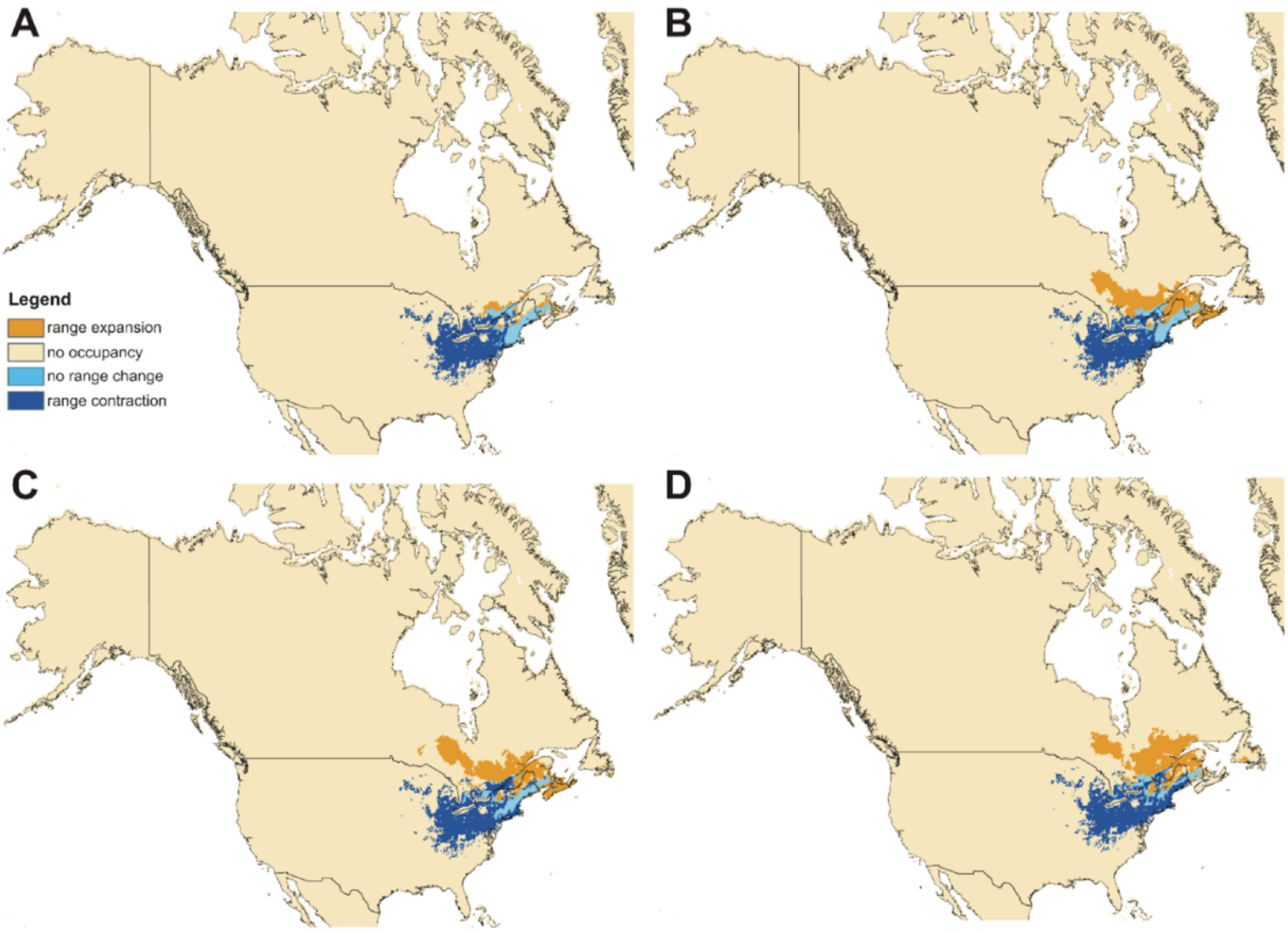


Figure 3.2. Future changes in the distribution of suitable niches of *Cucujus clavipes clavipes* according to four different climate change scenarios (A–D) (Jaskuła et al., 2021)

Because of the climate changes induced loss of ecosystems and heat extremes, it has also led to losses of populations and species. It is predicted that without additional adaptation to climate changes the dimension of these losses will increase (IPCC, 2023).

Climate changes are also assessed as a reason for rising problems with pest insects. As an example, for the US Southwest, Canada, and Alaska, unusually hot and dry weather patterns have been reported to cause increased outbreaks of pests (Logan et al., 2003). Accordingly, McNichol et al. (2022), studying *Ips* – genus of engraver beetles – argue that there is a need to study both changes in beetles and host trees and adaptive management strategies in those forests, which are endangered by droughts worldwide.

3.3. IMPACT ON HUMANS (SOCIO-ECONOMIC PROBLEMS)

Directly and indirectly due to the impact on ecosystems and species, climate change has serious consequences for humans. It is estimated that the living conditions of between 3.3 billion and 3.6 billion people are highly vulnerable to climate change (IPCC, 2023).

Climate change has an impact on public health, both in rural and urban areas. As already mentioned above, it may cause the shift of vectors of diseases into regions where the respective disease is not currently present. Observed or predicted effects on arthropod-borne diseases due to climate change concern, for example, malaria, Dengue and Zika virus infections, Lyme disease, West Nile virus infections, onchocerciasis (river blindness), plague, and human African trypanosomiasis (sleeping sickness) (Thomson & Stanberry, 2022). According to IPCC (2023), climate changes can also cause mental health challenges associated with increasing temperatures and trauma from extreme events, which also result in human mortality and morbidity. Chen et al. (2025) showed that heatwaves (see further) accelerate ageing.

Because many plant and animal species are basic food resources for humans, the effects on species and ecosystems also affect food security. For example, negative climate impact on fisheries occurs (IPCC, 2023). As an interesting example, Möllmann et al. (2021) reported that, for the Western Baltic cod, which already suffered from unsustainable exploitation levels, increased water temperature caused a stabilization of a novel and likely irreversible low-productivity state. Effects like those mentioned before also cause problems in achieving the targets of United Nations Sustainability Goal 2 (United Nations, 2015; see the chapter “International initiatives and conventions”).

As well as food security, climate change also affects water security and impacts the realization of the United Nations Sustainable Development Goal on safe water (Goal 6, see the chapter “International initiatives and conventions”). Reviewing water security challenges across 43 countries (Amparo-Salcedo et al., 2025) showed that each country faced at least one critical water-related effect. This concerns water quality, but also scarcity and floods. Pizzorni et al. (2024)

mention floods and droughts as primary hazards caused by climate change. They emphasize that solid scientific knowledge about interactions between floods and droughts is of high importance, for example, with respect to urban planning.

It is also evident that climate changes increase the frequency and intensity of heatwaves (e.g., NCAS, 2025). This not only negatively impacts human health aspects but may also cause disruption to travel and infrastructure or increased air pollution.

> Climate change causes severe problems with an impact on ecosystems and species, as well as living conditions for humans.

Review questions:

1. Which are the most important observed climate changes?
2. What impact do climate changes have on species and ecosystems?
3. In which way can climate change impact public health?

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4. INTERNATIONAL INITIATIVES AND CONVENTIONS

What is this chapter about:
This chapter provides information about important international initiatives and conventions, how Nature-based Solutions (NbS) fit into their context, and how they can contribute to realizing their goals and targets.

What you will learn:
- Basics about important international initiatives such as the European Green Deal and the United Nations Sustainable Development Goals.
- Basics about important conventions such as the Convention on Biological Diversity and the Climate Change Convention.
- How NbS are related to these initiatives and conventions.

Nature-based solutions are related to several important initiatives. Particularly important are the European Green Deal, the United Nations Sustainable Development Goals, and several international conventions, such as the Convention on Biological Diversity and the Climate Change Convention. As already outlined in the chapter “Definition of Nature-based Solutions”, the IUCN provides, with the IUCN Global Standard for Nature-based Solutions (IUCN, 2020), a framework for designing and verifying these kinds of solutions. This framework considers relevant aspects of the initiatives and conventions mentioned above.

4.1. EUROPEAN GREEN DEAL

The overarching aims of the European Green Deal are to reduce emissions to at least 50% by 2030 and to achieve a climate-neutral European Union by 2050. This process must be economically sound and socially fair (European Commission, n.d.-a). To do so, the European Green Deal focuses on nine policy areas that cover environmental, social, and economic aspects (Figure 4.1), thereby addressing the pillars of sustainable development (see the chapter “Nature-based Solutions and sustainable development”).

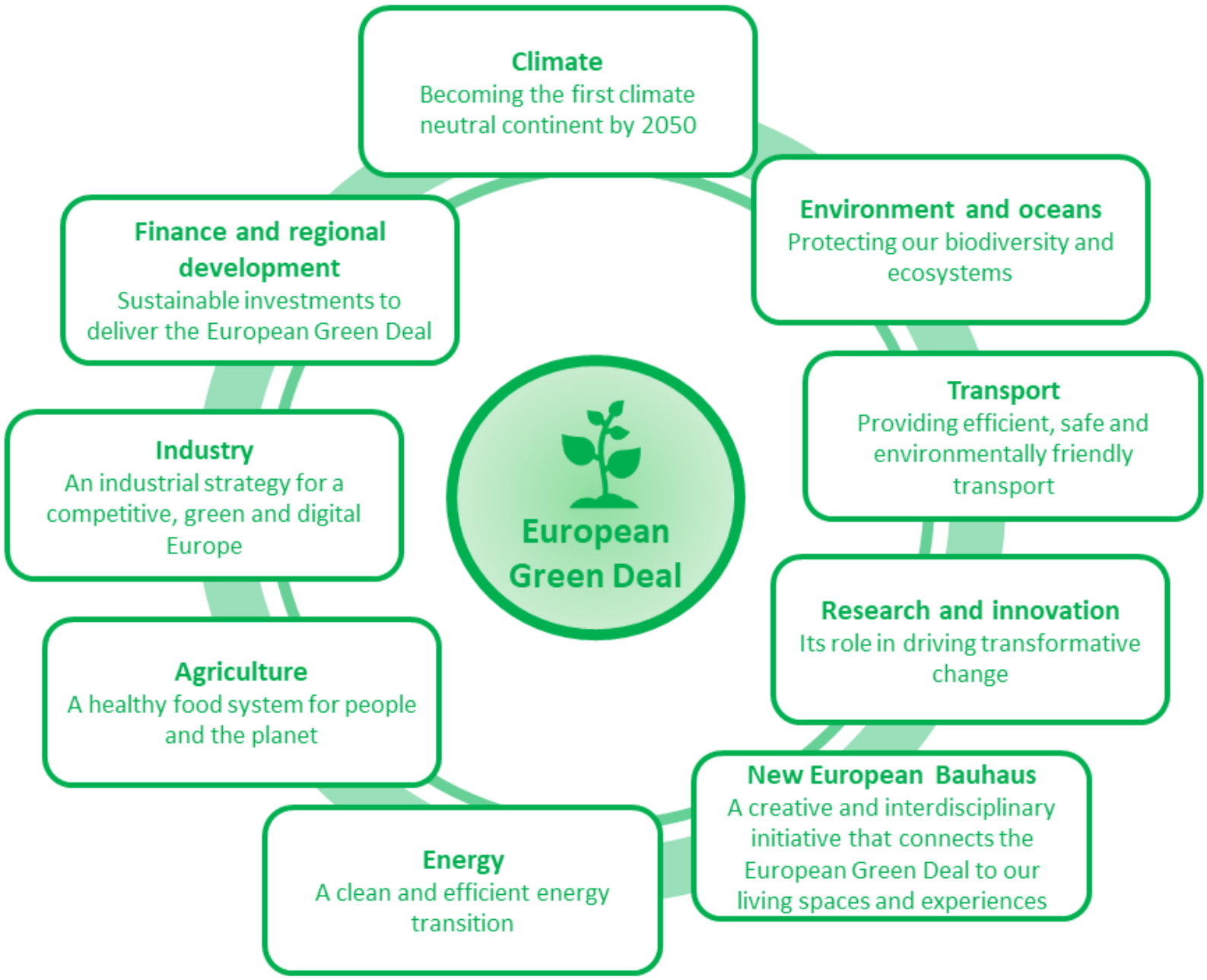


Figure 4.1. The policy areas of the European Green Deal (after European Commission, n.d.-a)

Nature-based Solutions can be a very suitable tool to help reach the targets of the European Green Deal (e.g., Calliari et al., 2022). Accordingly, in the research policy the European Commission Nature-based solutions are assessed to be a credible means to address key issues of the European Green Deal (European Commission, n.d.-b).

4.2. UNITED NATIONS SUSTAINABILITY GOALS

In its 2015 resolution, the United Nations defined 17 Sustainable Development Goals (SDGs), each with several targets (altogether 169 targets) (United Nations, 2015a; Table 4.1). Nature-based Solutions have a very high potential to help achieve these goals. According to Okolie et al. (2025), when paired with developed infrastructure, Nature-based Solutions can impact above 90% of the SDGs. For example, as formulated by Goodman (2023, p. vii), “when designed with ambition and for longevity, Nature-based Solutions (NbS) can have immediate and cost-effective benefits for both mitigation, adaptation, and disaster risk reduction.” Goodman (2023) also emphasizes the value of the IUCN Global Standard (IUCN, 2020) with respect to promising designing of Nature-based Solutions.

Table 4.1. The 17 United Nations Sustainable Development Goals (SDGs) (United Nations, 2015a)

SDG	Description
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

NbS can impact above 90% of the United Nations SDGs.

4.3. CONVENTION ON BIOLOGICAL DIVERSITY

The policy area “Environment and oceans” of the European Green Deal (European Commission, 2025a) and Goal 15 of the United Nations Sustainable Development Goals (United Nations, 2015a) directly concerns the conservation of biological diversity. A core part of the European Green Deal is the Biodiversity Strategy for 2030. A key element of the Biodiversity Strategy, in turn, is the Nature Restoration Regulation (European Union, 2024), which sets targets for restoration of ecosystems; not only for recovery of biodiversity but also other objectives as climate mitigation. The international convention, which addresses the issue of biodiversity conservation is the Convention on Biological Diversity (United Nations, 1992). In the convention, biological diversity is defined as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (United Nations, 1992, p. 3). Thus, it concerns not only the diversity with regard to species but also genetic diversity and diversity of ecosystems (Figure 4.2).

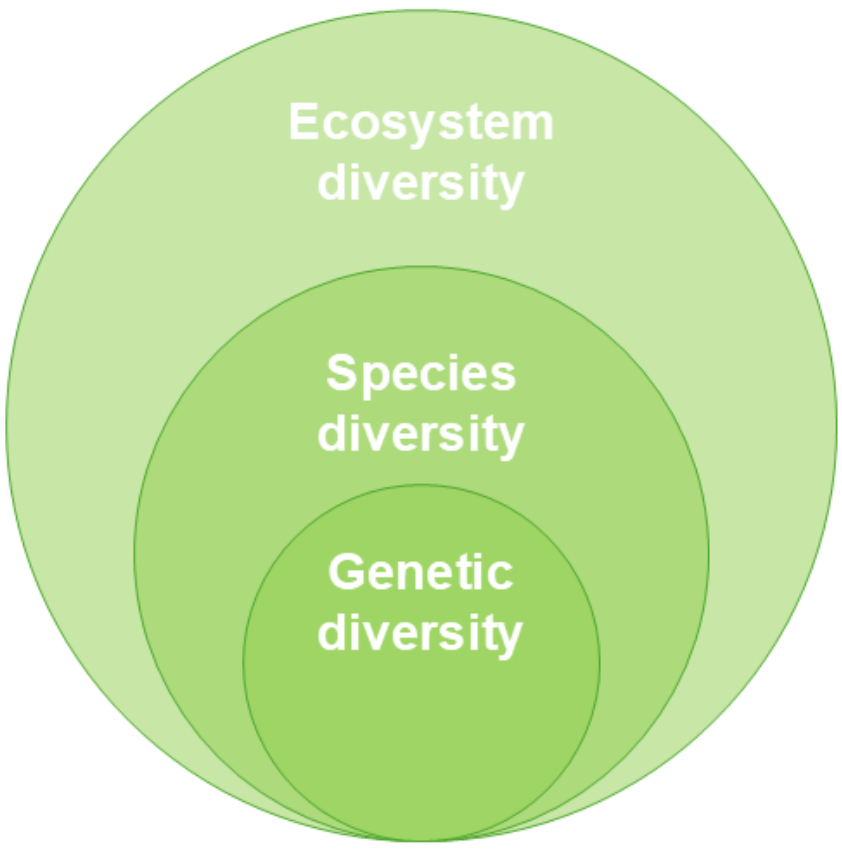


Figure 4.2. The three levels of biological diversity (after National Biodiversity Center, n.d.)

During the 15th Conference of the Parties (COP 15), the Kunming-Montreal Global Biodiversity Framework (GBF) was adopted under the Convention on Biological Diversity. In this framework, four global goals for 2050 and 23 targets for 2030 are defined (Secretariat of the Convention on Biological Diversity, 2024).

In the definitions of Nature-based Solutions, the benefits for biodiversity are explicitly mentioned, and Criterion 3 of the IUCN Global Standard for Nature-based Solutions (IUCN, 2020) emphasizes this aspect (see the chapter “Definition of Nature-based Solutions”). Nature-based Solutions are therefore predestined to help achieve biodiversity goals. Accordingly, WWF (2021, p. 5) states that “Nature-based Solutions can complement the Ecosystem Approach (EA) and the Ecosystem-Based Approach (EbA) in the context of the Convention on Biological Diversity and the Post-2020 Global Biodiversity Framework.”

4.4. CLIMATE CHANGE CONVENTION

Nature-based Solutions and climate action are the key issues of this handbook, and both the European Green Deal (policy area “climate”, see Figure 4.1) and the United Nations Sustainable Development Goals (Goal 13, see Table 4.1) emphasize the importance of this topic. The IUCN states that Nature-based Solutions can provide key solutions regarding carbon storage, and when it comes to climate resilience, and that according to the IPCC, they “are among the top five most effective strategies for mitigating carbon emissions by 2030” (IUCN, n.d.). The relevant international convention on climate change is the United Nations Framework Convention on Climate Change (United Nations, 1994), together with the Kyoto Protocol (United Nations, 1997) and its commitment periods. The recognition of Nature-based Solutions in the Paris Agreement (United Nations, 2015b), being adopted in 2015 at the United Nations Climate Change Conference in Paris (COP 21), is an important step to achieve the established climate goals (da Silva Bezerra, 2025).

> According to the IPCC, NbS will reduce carbon emissions by 2030, ranking among the top five most effective actions to mitigate negative climate changes.

4.5. EUROPEAN LANDSCAPE CONVENTION

The European Landscape Convention is an international legal instrument adopted in Florence on October 20, 2000 (Council of Europe, 2000). It obliges the signatory states to legally recognize landscape as an essential element of the human environment, an important component of quality of life, and a significant cultural, ecological, social, and economic resource. The convention defines landscape as a common good that requires conscious protection, management, and planning.

The definition of landscape adopted in the convention emphasizes its social dimension. Landscape is "an area perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000, p. 2). This approach emphasizes the importance of social perception and the shared responsibility of citizens for the quality of space. Consequently, public participation in landscape protection, management, and planning processes is mandatory.

The European Landscape Convention aims to protect all landscapes – not only those of outstanding natural or cultural value (e.g., within national parks), but also everyday common landscapes and even degraded landscapes that need to be restored and rehabilitated. This protection should be achieved through the establishment and implementation of a coherent landscape policy, integrated with other sectoral policies such as spatial, urban, social, economic, and agricultural policies.

The basis of landscape policy should be the identification, inventory, analysis, and assessment of landscapes within a given country, as well as the definition of so-called landscape-quality objectives for them. A quality objective means the desired state of the landscape that the state party undertakes to maintain or achieve.

The innovative approach proposed in the European Landscape Convention is to shift away from a purely conservationist model of protection towards an active landscape shaping approach in accordance with the principles of sustainable development. The document distinguishes three complementary types of activities: landscape conservation – preserving and maintaining its essential features; landscape management – taking regular measures to adapt the landscape to changing socio-economic needs while preserving its fundamental values; and landscape planning – activities aimed at creating new landscapes or restoring degraded ones.

An essential element of landscape policy implementation is public education and the formal guarantee of citizen participation in decision-making processes. This is intended to strengthen social responsibility and enable citizens to help shape the quality of their living space.

Although the European Landscape Convention does not refer directly to the concept of Nature-based Solutions, its assumptions remain consistent with it. Recognizing landscape as a common good, shaped by both natural and anthropogenic processes, aligns with the ecosystem approach and the concept of ecosystem services. The implementation of Nature-based Solutions can be a tool for achieving the objectives of the convention – by supporting natural processes, solving environmental problems, and co-creating space. Thus, landscape protection gains not only an aesthetic dimension but also ecological, climatic, and socio-economic ones.

In 2016, a Protocol amending the European Landscape Convention (Council of Europe, 2016) was adopted, which enabled countries outside Europe to accede to it. This opened the possibility of giving the document a broader, potentially global significance in the future.

Review questions:

1. Which are the nine core policy areas of the European Green Deal?
2. Which are the 17 United Nations Sustainable Development Goals?
3. Which convention deals with the conservation of biological diversity?

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5. MITIGATING CLIMATE PROBLEMS BY NATURE-BASED SOLUTIONS

What is this chapter about:
Climate change is no longer a distant threat; its impacts are already being felt in our daily lives. This chapter introduces how Nature-based Solutions (NbS) offer practical, sustainable, and inclusive strategies to help reduce greenhouse gas emissions and enhance resilience. Instead of relying only on technology, we can work with nature to restore balance and protect our future.

What you will learn:
- The connection between ecosystem health and climate change.
- How NbS contribute to climate mitigation efforts globally and locally.
- Key principles of responsible and inclusive NbS implementation.
- Everyday actions students and communities can take to support NbS.

5.1. NATURE'S ROLE IN CLIMATE MITIGATION

Nature works as a partner in climate action: healthy ecosystems take in carbon and lock it away, which helps slow warming such as forests, peatlands, mangroves, seagrass meadows, and inland wetlands absorb carbon dioxide (CO_2) through photosynthesis and store it in plants and soils or sediments, so together they act as large, natural carbon sinks (IPCC, 2022). Along coasts, much of this "blue carbon" sits in waterlogged, low-oxygen soils that keep carbon stable for long periods, which is why protecting sediments matters as much as protecting trees (Donato et al., 2011; Kauffman et al., 2020). Peatlands add another layer of strength: they slowly build up partially decomposed plant material over thousands of years, creating one of the most carbon-dense land stocks on Earth (Page et al., 2011). That balance flips when ecosystems are damaged, because stored carbon is released and the natural sink weakens. Land-use change, such as clearing or degradation, turns sinks into sources, and the loss can be large and long-lasting (IPCC, 2023). Draining peatlands is a clear example: once water levels drop, the peat is exposed to air, oxidation speeds up, and chronic CO_2 emissions and land subsidence follow (Hooijer et al., 2010). Coastal impacts tell a similar story: disturbing or converting mangroves can mobilize large soil carbon

stores and, in some places, also affect methane (CH_4) and nitrous oxide (N_2O) fluxes, which together amplify climate risks (Donato et al., 2011; Adame et al., 2021).

Because of this, the most effective first step is to keep intact ecosystems intact, avoiding emissions and safeguarding the carbon already stored there (IPCC, 2022). Where damage has occurred, restoration can turn the trend around; for instance, rewetting drained peatlands generally lowers net CO_2 emissions and helps restore their sink function, though CH_4 responses vary by site and must be managed (Mander et al., 2023). Scaled up, Nature-based Solutions can deliver roughly 5–11.7 $GtCO_2e$ per year by 2030, while cost-effective land-based "natural climate solutions" have been estimated at about 11.3 $GtCO_2e$ per year; critically, these actions must complement, never replace, and rapid cuts in fossil-fuel emissions from energy and industry (Griscom et al., 2017; UNEP/IUCN, 2021; IPCC, 2022). Well-designed Nature-based Solutions also help people right away by reducing flood risk, cooling cities, supporting biodiversity, and strengthening livelihoods, thereby advancing mitigation and adaptation together (IPCC, 2022).

Nature-based Solutions only work as well as the ecosystems behind them. If those ecosystems struggle under increasing climate stress, their ability to keep absorbing and storing carbon will also weaken. The role of ecosystems as carbon sinks depends on the interplay between their vulnerability, adaptive capacity, and the scale of climatic pressures they experience (Seddon et al., 2020; IPCC, 2023).

The ecosystems expected to absorb carbon are themselves under growing stress. More frequent fires, prolonged droughts, and pest infestations can all interfere with how carbon is stored. Under sustained pressure, the carbon locked in soils and vegetation does not always stay there. The likelihood of such carbon losses is projected to grow throughout the 21st century (Seidl et al., 2017; Anderegg et al., 2020). When ecosystems are managed carefully, they are better able to hold onto the carbon they store and cope with climate stress (Pörtner et al., 2021). Their buffering role is not infinite. As long as fossil fuels remain central to the global economy, nature-based approaches cannot carry the burden of mitigation by themselves. Moreover, many assessments estimating the mitigation potential of Nature-based Solutions do not explicitly account for the impacts of climate change on ecosystem stability, nor for the role of management interventions in strengthening ecosystem resilience (Fuss et al., 2018; Carton et al., 2020).

5.2. IMPLEMENTATION OF NATURE-BASED SOLUTIONS TO CLIMATE MITIGATION

Nature-based Solutions do not automatically generate positive outcomes simply because they are labeled as "green" (UNEP, 2021). In Indonesia and many other tropical countries, monoculture plantations such as eucalyptus and acacia for

the pulp and paper industry are often presented as forms of land rehabilitation or forest cover enhancement. In practice, however, these schemes can replace natural forests or peatlands that hold high biodiversity value (Brockerhoff et al., 2013). Although these species are capable of sequestering carbon rapidly, monoculture systems tend to be species-poor and more vulnerable to disturbances. Eucalyptus plantations are often discussed for their fast growth and carbon uptake. In practice, plantations like this often face pest and disease problems, both in their native regions and in countries where they are grown for industrial purposes (Brockerhoff et al., 2013; Widyati, 2022). If we only look at how much carbon can be absorbed, real issues like these can easily be overlooked. Soil degradation, ecosystem imbalance, and even land-use conflicts with local communities are real risks that often receive far less attention (Carton et al., 2020). These limitations show that NbS cannot be treated as a technical fix discussed only at the policy level. Addressing climate change still requires serious reductions in the use of fossil fuels. However, the success of Nature-based Solutions is determined not only by major policies but also by concrete actions at the local level. Simple activities such as planting trees, maintaining and increasing green spaces around your home, turning organic waste into compost, or encouraging others to understand the connection between climate and the environment can help ensure that these efforts truly make an impact and are not merely symbolic. Just as important is staying critical and questioning whether a project truly reflects nature-based principles or simply adopts the language of sustainability.

> We’re not just saving nature, we’re saving ourselves. Working with nature is one of the most powerful, accessible, and hopeful responses to the climate crisis.

Review questions:

1. Why is it important to protect natural ecosystems in the fight against climate change?
2. How much could NbS contribute to reducing global carbon emissions by 2030?
3. Why is social inclusion important in the design of NbS?
4. What simple actions can you take to support NbS in your community?

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6. NATURE-BASED SOLUTIONS AND SUSTAINABLE DEVELOPMENT

What is this chapter about:
The chapter introduces the idea of sustainable development and that Nature-based Solutions (NbS), by definition, can contribute to all of its pillars. This with be exemplified by examples. However, it must be acknowledged that, in some cases, trade-offs between the pillars may also occur.

What you will learn:
- The basic idea of sustainable development.
- How NbS can benefit the pillars of sustainable development.
- NbS may lead to trade-offs.

6.1. IDEA AND THEORY OF SUSTAINABLE DEVELOPMENT

The idea of sustainability dates back even to the end of the 1960s (Adams, 2006). Over time, the definition of sustainable development has evolved. The mainstream thinking about sustainable development is based on the idea of three pillars – the environmental, social, and economic pillars (Figure 6.1).

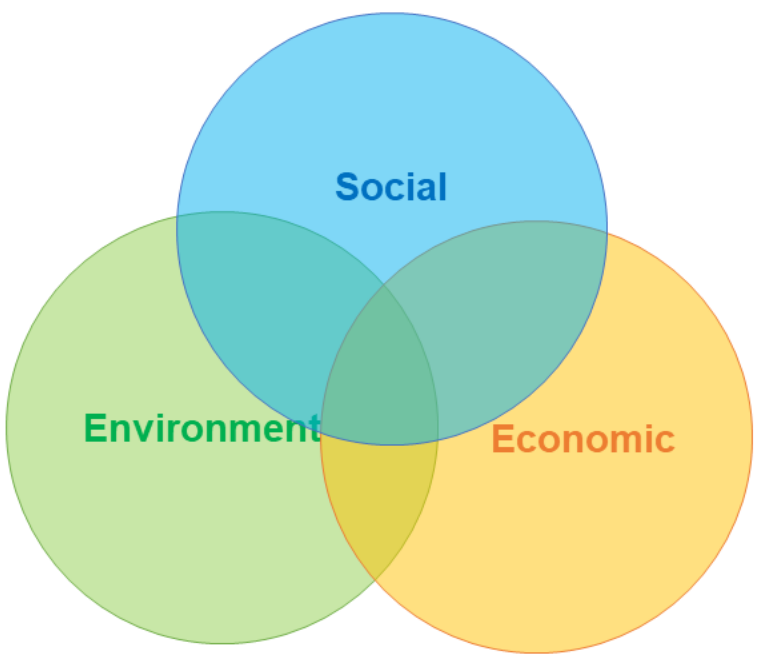


Figure 6.1. The three pillars of sustainable development (after Adams, 2006)

However, nowadays, a fourth pillar can often be found in literature – the institutional pillar – because of the awareness that sustainable development cannot be reasonably implemented without an appropriate development of the responsible institutions.

As an important step, the United Nations adopted 17 Sustainable Development Goals in its Agenda for Sustainable Development (United Nations, 2015) as a very ambitious vision for transforming our planet. As outlined in more detail in the chapter “International initiatives and conventions”, Nature-based Solutions are considered to help with addressing these challenges (UNEP, 2022). There is an urgent need to intensify our actions; because “we are deeply off-track to reach the Sustainable Development Goals” Goodman (2023, p. v).

6.2. HOW CAN NATURE-BASED SOLUTIONS CONTRIBUTE TO SUSTAINABLE DEVELOPMENT?

Nature-based Solutions, by definition, should “benefit both humans and nature” and are therefore predestined to have the potential to support sustainable development (see the chapter “Definition of Nature-based Solutions”). Nature-based Solutions can benefit all three pillars, as exemplified by the examples described in the latter subchapter.

6.2.1. Benefiting environmental development

One of the most important goals of Nature-based Solutions, and also included in Criterion 3 of the IUCN Global Standard for Nature-based Solutions (IUCN, 2020) (see the chapter “Definition of Nature-based Solutions”), is that they result in a net gain to biodiversity. Nature-based Solutions, however, may also benefit other environmental targets, such as combating pollution or carbon sequestration.

As a good example of benefiting environmental development, the restoration of the channel and riparian habitats at the Allan Water in Scotland may serve as a case study in the context of the Horizon 2020 project MERLIN (https://project-merlin.eu/). The aims are to restore the upper reaches of the river, which were strongly modified in the 19th century, and to mitigate flood risk in downstream towns and cities. Different measures were applied, including installation of woody structures in the channel, riparian tree planting and removing of a section of a part of the flood embankment to reconnect the river with its floodplain, As benefits, amongst others, the recreation of natural river sides and their vegetation as well as adjacent wetlands and floodplains and also the reduction of downstream flooding by holding water back in the upper catchment were expected. A special target, however, was to reach a positive impact on native biodiversity by providing habitats and refuges for fish, wading birds, and other species (Figure 6.2).



Figure 6.2. A remeandered channel in the Allan Water with large woody debris used to reinforce banking and riparian tree planting to slow flow in floods and provide shade to river channel (photo by Axel Schwerk, 2023)

6.2.2. Benefiting economic development

Criterion 4 of the IUCN Global Standard for Nature-based Solutions (IUCN, 2020) states that they should be economically viable, expressing the importance of the economic pillar of sustainable development. However, Nature-based Solutions can even contribute to economic development. For example, Chausson et al. (2024, p. 28) state "that NbS can significantly contribute to economic recovery by stimulating economic output and creating employment."

González-García et al. (2025) analyzed 83 Nature-based Solutions in the Alps, with the aim of also finding out about the co-benefits. Overall, with respect to the analyzed solutions, every euro invested resulted in a return on investment of 2.8 EUR. When it comes to value per hectare, according to this study, the most valuable ecosystem service delivered by Nature-based Solutions was flood mitigation, followed by climate regulation, heatwave mitigation, and landslide protection.

6.2.3. Benefiting social development

Often, Nature-based Solutions contribute to social development, whether as a major goal or as a co-benefit of implementation. For example, measures for improving ecological conditions and leading to net gain in biodiversity very often lead to the creation of areas with high value for education and recreation.

Several projects that improved recreational values were described by Golfieri et al. (2017), who present the benefits of river restorations across Europe. For example, the removal/setback of artificial levees for floodplain reconnection, benefiting macroinvertebrates and fish, also benefited recreational values, deculverting of a river improved landscape values and recreational values, and a multi-targeted restoration project aimed to mitigate channel incision, to improve the ecological conditions, and also to improve access to the river for recreational activities.

Among the Nature-based Solutions monitored in the case studies of the Horizon 2020 project MERLIN, several projects resulted in additional active travel routes, and several case studies reported improved well-being, access to the restored natural environment, or increased aesthetic attractiveness of the environment (Schwerk et al., 2025). For example, restoring the Hutovo Blato wetlands in Bosnia and Herzegovina (Figure 6.3) resulted in demonstrably better conditions for well-being and perceptions of nature.



Figure 6.3. Scenic landscape of the Hutovo Blata wetlands (photo by Axel Schwerk, 2022)

6.3. THE PROBLEM OF TRADE-OFFS

Nature-based Solutions have a high potential to deliver multiple benefits. However, there is a need to accept that in some specific situations, trade-offs between different goals of sustainable development have to be accepted. This problem is already addressed by Criterion 6 in the IUCN Global Standard for Nature-based

Solutions (IUCN, 2020) (see the chapter “Definition of Nature-based Solutions”), which mentions that these kinds of actions “equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits.”

As an example, within a project studying the impact of Nature-based Solutions implemented in 18 case studies (Horizon 2020 project MERLIN), trade-offs between criteria were apparent for sustainable farming systems (Farm2Fork), because land available for agricultural production declined, and for zero pollution indicators for peatland and wetland restoration projects. However, the latter may be a short-term response to the implementation of the restoration measures (Schwerk et al., 2025). In their review, Chausson et al. (2024) detected the most frequent trade-offs between biodiversity and income or profitability. They described several mechanisms for this result, which are restriction of the use of natural resources in areas designated for protection, lower profitability of nature-based production methods, high implementation or labor costs, and poor intervention design or management focused on short-term profits – which can lead to negative impact on biodiversity (e.g., due to excessive ecotourism). Moreover, ecosystem protection can increase human-wildlife conflicts, which may cause reduced crop yield.

Being aware of possible trade-offs is important when it comes to the practical implementation of Nature-based Solutions projects, as such projects very often involve many stakeholders. Stakeholders, who are negatively affected, are more likely to have a negative attitude towards the project. Accordingly, reviewing Nature-based Solutions targeted to mitigate climate change, Mariani et al. (2024) concluded that there is a need to identify trade-offs and to consider them during decision-making processes. Because such trade-offs are often unavoidable, it is very important to clearly define the desired goals before implementing a Nature-based Solutions (see the chapter “The process of implementation of Nature-based Solutions”).

NbS have high potential to deliver multiple benefits, but trade-offs may arise between different goals of sustainable development.

Review questions:

1. What are the pillars of sustainable development?
2. How can NbS benefit social development?
3. Why is it important to be aware of trade-offs when implementing NbS?

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7. NATURE-BASED SOLUTIONS AND LANDSCAPE ARCHITECTURE

What is this chapter about:
This chapter characterizes various perspectives and conceptualizations of the landscape. It defines the role of the modern landscape architect to illustrate the inherent links between landscape design practice and the concept of Nature-based Solutions (NbS). Furthermore, it describes NbS applications commonly used by landscape architects to address environmental chal-
lenges within the framework of sustainable development.

What you will learn:
- Various perspectives on landscape.
- The role of the landscape architect in the design process.
- Key environmental and climate challenges.
- Goals and tasks of a landscape architect.
- Popular NbS implemented in landscape architecture projects.

7.1. DEFINITION OF LANDSCAPE

Landscape is a multifaceted concept, a fact that stems from its inherent complexity. Consequently, it is a subject of interest across numerous scientific and practical disciplines. Since each discipline operates within its own system of axioms/assumptions to support its scientific discourse and utilizes specific research and analytical tools, each defines the concept of landscape differently. A comprehensive review of the literature would reveal hundreds of diverse definitions. However, we shall focus on the practical and legal definitions that relate to professional practice and the scientific foundations of landscape research.

In European law, the landscape is defined by the European Landscape Convention (Council of Europe, 2000). The convention defines the landscape as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors.” (Council of Europe, 2000, p. 2). In this view,

landscape is a somewhat subjective concept, as it refers to how space is felt and perceived by its users. The subject here is the human being, whose process of perception constitutes the landscape.

This definition addresses the relationship between the human/observer and their surroundings, a focus prevalent in the humanities. This traditional approach served as the basis for the definition adopted by UNESCO in the 1972 Convention Concerning the Protection of the World Cultural and Natural Heritage. This convention used the term cultural landscape to refer to the combined works of nature and man (UNESCO, 1972). Here, landscape is an expression of the development of civilization and settlement patterns, shaped by the potential of a specific natural environment that either fosters or limits such development. In this line of reasoning, landscape appears as a record of human history. A further subjectivization of the concept is introduced by psychology within the phenomenological framework. Here, landscape is presented as a "tamed" space, filled with meanings and emotional values. It is no longer merely a material structure visible to the human eye, but also a collection of human meanings and emotions assigned to a given place (Norberg-Schulz, 1980).

At the opposite end of the spectrum are the considerations introduced by physical geography and systems theory. This field seeks to objectify the landscape concept. Landscape is defined here as a three-dimensional slice of the Earth's surface with its interdependent components: landform, water, vegetation, and climate. Interacting with one another, these components form units called geosystems, which are organized into a superior unit known as the natural landscape. Human activity is superimposed upon this. The interaction between geosystems and humans shapes the cultural landscape. Such an approach was proposed as early as Passarge (1922), followed by other landscape researchers in geography, including Kondracki (2002).

Landscape is also a subject of interest in ecology, which studies structures and the flow of matter (including organisms) and energy in space. Therefore, an ecological landscape is a heterogeneous land area composed of a mosaic of interacting ecosystems (e.g., forests, meadows, villages), characterized by specific structures and processes (Forman & Godron, 1986). Consequently, it is accepted that an arrangement or mosaic of interconnected ecosystems forms an ecological landscape (e.g., Richling & Solon, 1996). The latter two approaches, in particular, form the basis for the application of Nature-based Solutions.

7.2. DEFINITIONS AND GOALS OF LANDSCAPE ARCHITECTURE

Landscape architecture is both a scientific and practical discipline that integrates all the aforementioned perspectives on landscape. Its current interdisciplinary nature is the result of centuries of development and the evolution of garden art.

The term landscape architecture was first used in the 19th century by Frederick Law Olmsted, who viewed the profession as a form of “sanitary urbanism” aimed at ensuring the well-being of city dwellers (Olmsted, 1900).

In the second half of the 20th century, discipline evolved toward the comprehensive shaping of the human environment. The landscape architect’s focus shifted to the natural environment and its key components, including topography, water resources, soil, and climate. Ian McHarg (1969), in his fundamental work entitled “Design with Nature”, formulated the principles of an ecological approach to design, supported by in-depth analyses of environmental components. Through this evolution, landscape architecture transformed from traditional gardening into an interdisciplinary engineering profession with broad competencies.

The International Federation of Landscape Architects (IFLA) states that modern landscape architecture involves the planning, design, and management of space across various scales – from urban to rural. This scope of activity requires a synthesis of knowledge from the humanities, social sciences, natural sciences, engineering, and the fine arts. This allows for the creation of harmonious spaces that ensure a high quality of life while adhering to the principles of sustainable development and the preservation of natural and cultural heritage (IFLA, 2017). A modern designer must therefore combine multidisciplinary scientific knowledge with technical skills and artistic sensitivity to create healthy, functional, and aesthetically pleasing environments for present and future generations (IFLA, 2017).

Currently, landscape architects, guided by the principles of sustainable development, pursue multi-dimensional professional goals:

- Social: Building environments conducive to health and well-being, while ensuring social inclusivity and accessibility for people with special needs.
- Cultural: Protecting heritage and restoring the identity of a place (*genius loci*).
- Economic: Increasing property values through high-quality landscapes, supporting tourism development, and rational resource management (energy efficiency, water retention).
- Environmental: Solving urgent global environmental problems, such as climate change adaptation, countering biodiversity loss, and restoring the quality of water, air, and soil (Zeunert, 2017; ASLA, 2022).
- By adopting these goals as the foundation for action in a dynamically changing environment, the landscape architect is obligated to employ integrated design. This approach assigns a leading role to the landscape architect within interdisciplinary design teams shaping modern space.

The multi-dimensional professional goals of landscape architects are guided by the principles of sustainable development.

7.3. INTERSECTION AND COMPLEMENTARITY BETWEEN LANDSCAPE ARCHITECTURE AND NATURE-BASED SOLUTIONS

Traditionally, the role of the landscape architect focused on the aesthetic quality of spaces used by society. Today, given the significantly expanded professional objectives, it is necessary to adopt a sustainable design approach. While human well-being remains central, modern projects must balance social, economic, and – to a very large extent – environmental goals. For this reason, environmental engineering tools have become an essential foundation for shaping space.

In the last decade, the concept of Nature-based Solutions has emerged as a particularly useful approach in modern design. This concept complements the landscape architect's toolkit in achieving ecological goals, specifically those related to climate change adaptation (European Commission, 2015). In the design process, particular attention is paid to mitigating the urban heat island effect and achieving energy savings, especially in highly urbanized environments. At the planning scale, emphasis is placed on creating ventilation corridors and maintaining the continuity of natural areas (green infrastructure) (Benedict & McMahon, 2006). At the local scale, solutions such as green roofs, vertical gardens, and pocket parks are utilized to reclaim every available fragment of abandoned urban space.

Another key challenge is finding engineering solutions that support sustainable water management to mitigate anthropogenic disruptions to the hydrological cycle. The goal is to increase local stormwater retention and infiltration at the source (Fletcher et al., 2015). Water consumption in artificial irrigation systems is reduced by employing closed-loop water systems in artificial reservoirs. Furthermore, solutions aim to use harvested rainwater rather than groundwater. Popular measures include permeable pavements made of natural materials, retention basins, and rain gardens.

A crucial element of design is protecting biological diversity, including native flora and fauna. The restoration of habitats for wild flora and fauna is a priority, as land-use change has been a leading factor threatening biodiversity (United Nations, 1992). This is effectively served by the concept of blue-green infrastructure developed at the city scale. Ensuring the connectivity of system elements and restoring local habitats for living, breeding, or wintering – optimized for the requirements of specific animal, plant, and fungal species – are tasks now linked to the traditional role of landscape architecture specialists.

In vegetation design, the use of native species adapted to the site's potential is promoted to support natural ecosystem processes. Equally important is the elimination of undesirable invasive species that are harmful to the local natural environment (e.g., disrupting food chains and ecosystem balance), the local economy (losses in crops and plantings), or society (IUCN, 2020).

Due to the ongoing search for new ideas, solutions, and technologies, a vital pillar of landscape architecture integrated with the Nature-based Solutions concept is scientific research. This research enables verifying the effectiveness of implemented solutions and discovering new ones.

7.4. HOW LANDSCAPE ARCHITECTURE CONTRIBUTES TO THE DEVELOPMENT AND IMPLEMENTATION OF NATURE-BASED SOLUTIONS

Since the breakthrough in thinking about the landscape architecture profession, with the concept of “design with nature” becoming established and the introduction of an ecosystem approach to urban planning (McHarg, 1969), the role of the landscape architect in the implementation and development of Nature-based Solutions has continued to grow. Working at the interface between art, social science, engineering, and ecology, landscape architecture bridges the gap between theoretical ecological concepts and their practical implementation in the urban fabric. Working in open spaces, otherwise known as ecosystems, and using largely natural materials such as vegetation, waters, soils, and relief, landscape architects influence the modification of ecological processes.

Today, landscape architects can play a key role in the implementation of Nature-based Solutions. They influence rainwater management, e.g., by designing rain gardens and retention systems that minimize the risk of urban flooding (Zhu et al., 2019; Pramit et al., 2021). They can have an impact on mitigating the urban heat island as they plan the shape of the green space system, design green roofs and vertical gardens on facades, which allows the use of evapotranspiration to reduce urban temperatures (Seddon et al., 2020). Finally, landscape architects take care of biodiversity by giving ecological solutions a functional form, transforming open areas devoid of recreational/social functions into attractive parks, thus increasing the acceptance of “wild” nature in the city. By modernizing urban spaces, they influence the restoration and expansion of biodiversity habitats. Chapter 10 of this handbook presents project examples, showing theoretical design solutions and implemented projects using nature-based solutions.

Review questions:

1. How is landscape defined by the European Landscape Convention?
2. Towards which four dimensions professional goals of landscape architects are directed?
3. Regarding which key challenges intersection and complementarity between landscape architecture and Nature-based Solutions exists?

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PART B

PRACTICAL PART

8. THE PROCESS OF IMPLEMENTATION OF NATURE-BASED SOLUTIONS

What is this chapter about:
The basic phases of planning and implementation of Nature-based Solutions (NbS) are described in this chapter, including the most important problems and pitfalls that might occur. The information is supplemented by case study examples.

What you will learn:
- The basic phases in the implementation of NbS.
- Most important problems and pitfalls.
- Case studies of NbS.

8.1. PHASES OF IMPLEMENTATION

When implementing a Nature-based Solution, some basic phases must be completed (Figure 8.1). Albert et al. (2021) mention six steps when planning a Nature-based Solution: Co-define setting, understand challenges, create visions and scenarios, assess potential impacts, develop solution strategies, and realize and monitor; the first five fall into the time before implementation.

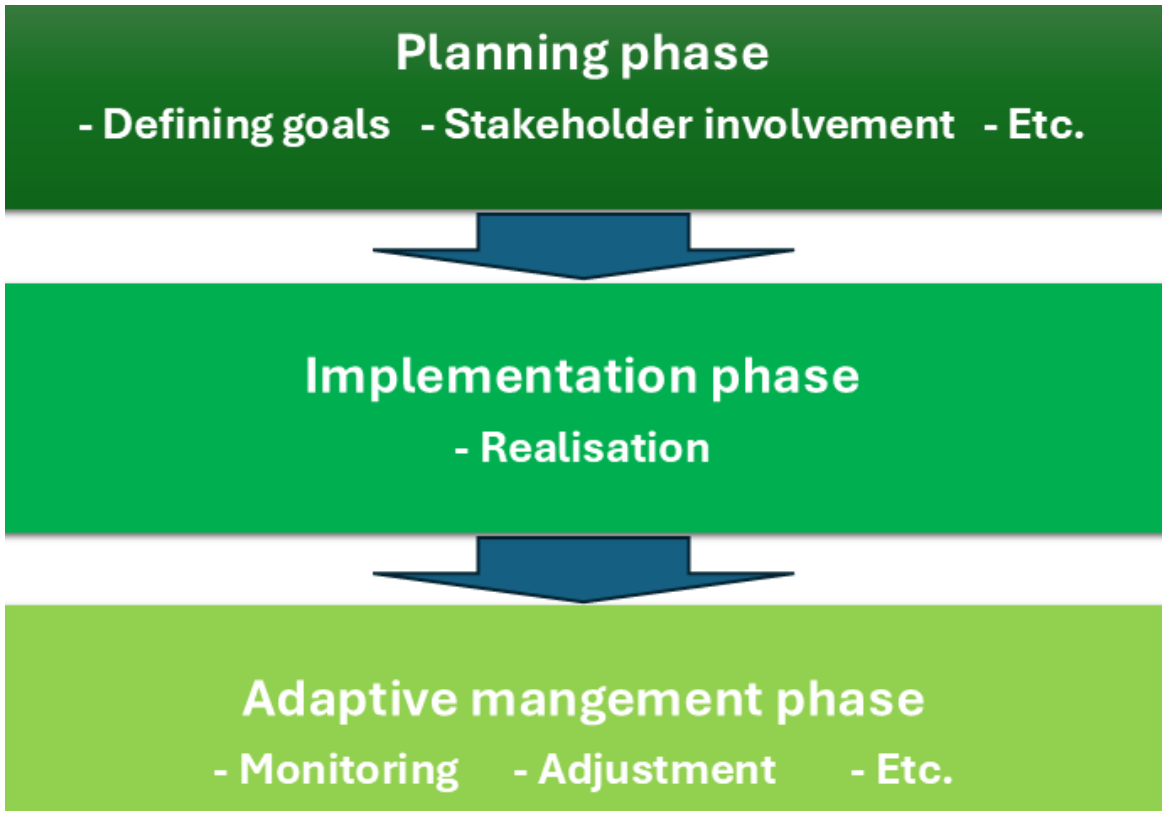


Figure 8.1. Basic phases of implementing Nature-based Solutions (own work)

According to Cohen-Shacham et al. (2016, p. 5), the overarching goal of Nature-based Solutions is “NbS are intended to support the achievement of society’s development goals and safeguard human well-being in ways that reflect cultural and societal values and enhance the resilience of ecosystems, their capacity for renewal and the provision of services. NbS are designed to address major societal challenges, such as food security, climate change, water security, human health, disaster risk, social, and economic development.” However, each Nature-based Solution is different and has its own characteristics. Therefore, during the planning phase, it is very important to define the specific goals and targets to be reached by the measure. As demonstrated during the MERLIN Horizon 2020 project (https://project-merlin.eu/), applying a Theory of Change approach can be very helpful when defining primary as well as secondary goals of the respective project (Pott et al., 2025). The Theory of Change (Weiss & Connell, 1995) is a structured approach indicating the relationships between project interventions and long-term goals. It is also very important to involve the relevant stakeholder from the beginning. According to Albert et al. (2021), the first step – co-define setting – is already carried out in collaboration with stakeholders.

After planning the Nature-based solution and fulfilling all necessary preconditions, it must be implemented accordingly.

An important phase of Nature-based Solutions is adaptive management (“a structured, iterative process of robust decision making”, Wikipedia, 2026), i.e., to adjust the measure in order to reach the desired targets, which have been, for example, defined with the help of a Theory of Change, if necessary. Thus, the Theory of Chance can be helpful when it comes to adaptive management (Pott et al., 2025). To be able to do so, adequate monitoring is necessary (see the chapter “Monitoring the success of Nature-based Solutions”). The monitoring results will indicate if the goals of the implemented measure have been reached (or will be reached in the future). In the case of ineffectiveness with respect to one or more goals, the measure should be adopted respectively (Figure 8.2).

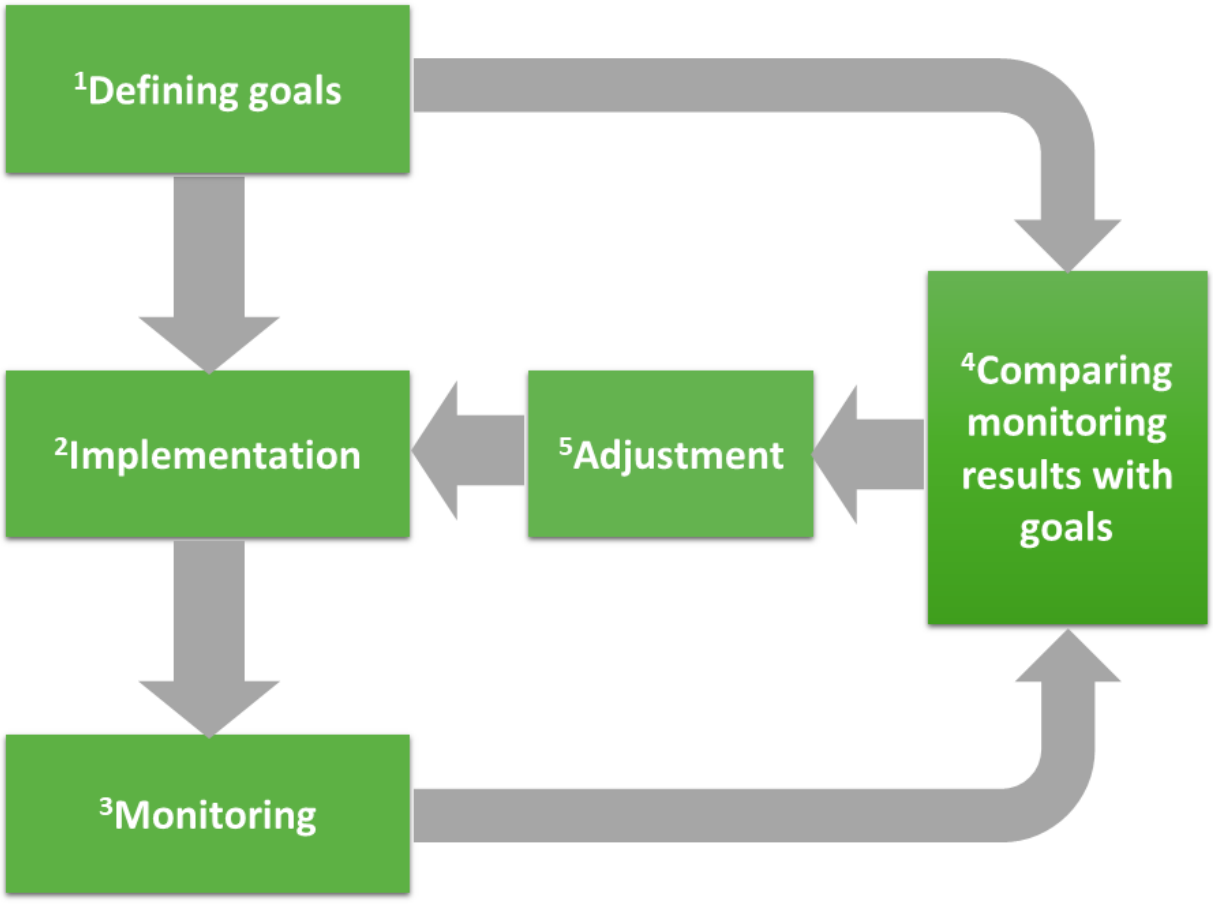


Figure 8.2. Adaptive management: After defining the goals (1), the Nature-based Solution will be implemented (2); data from subsequent monitoring (3) will be compared with the defined goals (4) and, if necessary, an adjustment will be carried out (5) (own work)

8.2. PITFALLS AND PROBLEMS

The implementation of Nature-based Solutions faces several challenges. Very often, individual stakeholders who are related to the respective measure are critical of the project. This can be, for example, farmers who fear that they will suffer economic losses due to the implementation of the project. Regarding a floodplain rewetting project at the Tisza – river in Hungary (Schwerk et al., 2025), some stakeholders were initially reluctant to support restoration measures associated with the risk of loss of agricultural land. Such problems might be overcome by engaging the stakeholders through information forums, seminars, and conferences, attended by both local people and professionals, and being organized already during the planning and implementation of the project. As mentioned above, all relevant stakeholders should be involved from the beginning.

Another challenge is to realize sufficient monitoring, in order to be able to check whether the goals of the measure were reached and to be able to adapt the project, if necessary. However, monitoring approaches of Nature-based Solutions are often imbalanced with respect to measuring the impact on the targets of the measure. Indicators with a focus on social and economic aspects are often underrepresented compared to environmental indicators (e.g., Waylen et al., 2019;

Cupertino et al., 2024). We have to remember that by definition, Nature-based Solutions should benefit both humans and nature (see the chapter “Definition of Nature-based Solutions”); therefore, the socio-economic indicators also have to be covered to a sufficient degree by the monitoring program. Moreover, monitoring data elaborated on Nature-based Solutions are often very diverse and heterogeneous, and one fails to evaluate them further in a meaningful comparative way. It is therefore of high importance to adopt systemic monitoring approaches that capture the multifaceted impacts of NbS. The challenges related to monitoring will be discussed in more detail in the chapter “Monitoring the success of Nature-based Solutions”.

When implementing NbS, all relevant stakeholders should be involved from the beginning.

8.3. CASE STUDIES

Contemporary cities are faced with the need to reduce greenhouse gas emissions, increase energy efficiency, and create environmentally friendly spaces. In this context, Nature-based Solutions that integrate technical, ecological, and social functions within a single urban system are of particular importance.

One of the most recognizable examples of such integration is the CopenHill (Amager Bakke) project in Copenhagen – a modern waste-to-energy plant that combines infrastructure, recreational, and ecological functions.

The idea of building a new waste-to-energy plant in Copenhagen was conceived at the beginning of the second decade of the 21st century. Amager Resource Center (ARC), the operator of the local waste management system, was looking for a modern solution that would enable the city to achieve its goal of climate neutrality by 2025. In 2011, an international architectural competition was announced, which was won by the Danish firm Bjarke Ingels Group (BIG). The project involved transforming the power plant into an icon of sustainable development – a place that not only processes waste but also brings residents closer to the idea of a circular economy (Ingels, 2019).

CopenHill (Figure 8.3) is not only a waste-to-energy (WtE) plant but also a model example of the integration of technical infrastructure with urban greenery. The facility takes the form of an artificial mountain, whose roof has been designed as a public park with a ski slope, cable car, toboggan run, walking paths, and a viewing point. The highest wall of the building, 85 meters high, functions as a climbing wall. The roof houses a bar, a civic center, and an environmental education hub. The landscape design was created by SLA, which developed a unique vegetation system resistant to extreme urban conditions such as strong winds and sun exposure.



Figure 8.3. General view of the CopenHill complex – a combination of industrial infrastructure and a green roof (© SLA; SLA, 2016)

When designing the incineration plant, the designers used a number of Nature-based Solutions. These include a green roof (10,000 m²), covered with diverse vegetation that supports water retention processes, improves air quality, and reduces the urban heat island effect (the local temperature is estimated to be reduced by 1–3°C). In 2020, biologists working with the SLA design studio conducted an inventory of plant species found on the site. The results of the study showed that of the 119 species recorded, as many as 56 were new taxa compared to the previous year, indicating a clear increase in biodiversity in the analyzed area. The substrate system was designed to allow excess water to drain away while ensuring adequate moisture for the plants. The planted species are dominated by native grasses and perennials, which attract pollinating insects and urban birdlife (ZinCo, n.d.). The green roof and vegetation act as a biological filter, reducing dust and CO_2 in the immediate environment (Figure 8.4). In addition, the building's facade is made of aluminum panels with a brick structure, which allows climbing plants to grow. The drainage and rainwater reuse system supports the natural cycle of matter, reducing the need to use drinking water for irrigation. As a result, the facility has become an example of urban ecology, where energy infrastructure coexists with nature (BIG, 2020). CopenHill processes approximately 440,000 tons of waste annually, and thanks to the technologies used, emissions have been minimized by 95%. Although the project is costly and technologically complex, it serves as an inspiration for global initiatives combining energy, architecture, and ecology.



Figure 8.4. CopenHill green roof – retention and vegetation layers (© SLA; SLA, 2019a, SLA, 2019b)

There are several other similar facilities around the world. This group includes the Spittelau waste incineration plant in Vienna, Austria, Maishima in Osaka, Japan, and Sysav in Malmö, Sweden.

In the face of the climate crisis and progressive environmental degradation, the use of existing architectural resources is also becoming increasingly important. Adapting old buildings to new functions related to nature conservation, environmental education, or sustainable food production is not only a pro-environmental measure, but also a cultural and social one. The revitalization of former factories, warehouses, and public buildings reduces the consumption of raw materials and CO_2 emissions resulting from new investments, while giving these spaces a new, ecological identity. A particularly important direction in this process is the implementation of Nature-based Solutions, which combine functionalities with ecosystem regeneration.

The introduction of green roofs, rain gardens, vertical walls, and rainwater retention systems in adapted buildings helps to improve the microclimate, increase biodiversity, and enhance the quality of life for residents. In this way, old architecture becomes not only a testament to history but also an active element of sustainable environmental transformation. This process is particularly important in large cities with limited free space for development.

An example of such an initiative is the history of the Zhongshan Stadium in Taipei, Taiwan, which has been transformed into a community garden (Figure 8.5). Like other large agglomerations in Asia, this city faces the problem of high population density and limited land availability, which is why informal green spaces (IGS) play an important role in its sustainable development.



Figure 8.5. Zhongshan Stadium (Agata Jojczyk, Michał Banaszek)

Modular containers with vegetables and herbs were used, and management was based partly on a participatory model. This is also an example of temporary urbanism (tactical urbanism), i.e., low-cost, short-term changes that have evolved over time into permanent infrastructure in Taipei. The transformation of the stadium into a community garden shows that old sports infrastructure, often seen as problematic after losing its original function, can be incorporated into the green transformation of a city without radically interfering with its structure. Between 2018 and 2021, the project was institutionalized as the “Expo Green Roof Farm” and combines the ideas of urban agriculture with the concept of a smart city, integrating residents into the action and increasing their resilience to the effects of climate change (Meerow et al., 2016). Community gardens help reduce urban heat islands and increase rainwater retention.

Furthermore, the described combination of technology and green infrastructure is in line with the trend of “ecological modernization” (Mol & Sonnenfeld, 2000), where technical modernization supports environmental goals without incurring high financial costs. There are many examples of similar solutions around the world, as shown in Table 8.1.

Table 8.1. Examples of adaptations of urban objects and spaces using Nature-based Solutions

Location	Object/Project	Type of adaptation/ Function	NbS implemented	Environmental and social benefits	Source
London, UK	Highbury Stadium	stadium → residential complex	green courtyards, internal park, integration of greenery with buildings	reduction of the urban heat island effect, recreation, and improvement of residents’ quality of life	dll (2008)
Detroit, USA	urban farms	post-industrial areas → urban farms	green roofs, flower meadows, vegetable gardens, and educational spaces	local production – shortening the supply chain, enriching biodiversity, water retention, supporting pollinators, socio-economic revitalization: activating local communities and the unemployed	Keep Growing Detroit (n.d.)
Freiburg, Germany	Vauban – district	revitalization of post-military areas	green infiltration ditches, permeable surfaces, green roofs, allotment gardens, green areas and parks, eco-friendly transport	water retention, CO_2 reduction, improved quality of life, and sustainable urbanization	Coates (2013) Green City Times (n.d.)

Table 8.1. Examples of adaptations of urban objects and spaces using Nature-based Solutions (cont.)

Location	Object/Project	Type of adaptation/ Function	NbS implemented	Environmental and social benefits	Source
Seattle, USA	urban agriculture spaces	abandoned urban plots → community gardens, urban farms	community vegetable garden, green spaces, and environmental education spaces	environmental education, local production, microclimate, and social integration	McLain et al. (2012) City of Seattle – Office of Planning and Community Development (n.d.)
Duisburg, Germany	Duisburg--Nord Landschaftspark	post-industrial area (former steelworks site) → landscape park	renaturalization, water retention zones (e.g., artificial urban wetlands, use of post-industrial reservoirs, planting of trees and shrubs, meadows, etc.)	environmental education, enrichment of local biodiversity, recreation, water, and air purification	Landschaftspark Duisburg-Nord (n.d.)
Turin, Italy	Parco Dora	post-industrial site → urban park	urban plantings, retention reservoirs, restoration of the original course of the Dora Riparia, and green recreational spaces	enrichment of local biodiversity, improvement of the microclimate, environmental education, and recreation	Latz + Partner (n.d.) Architonic (n.d.)
New York, USA	Park High Line	former railway viaduct → urban park	renaturalization, water retention zones, planting of trees and shrubs	water retention, CO_2 reduction, improved quality of life, enriched biodiversity, including support for pollinators – 33 species of wild bees inventoried, reduction of the urban heat island effect	Friends of the High Line (n.d.)

The case studies presented prove that Nature-based Solutions are not only an aesthetic element in the urban landscape but also function as a systemic environmental infrastructure. Their effectiveness results from the combination of environmental restoration with social innovation and spatial transformation. Nature-based Solutions can be considered an important component of climate change adaptation strategies and building urban resilience.

> **Review questions**:
> 1. What is the Theory of Change approach about?
> 2. What does adaptive management mean?
> 3. What are the major challenges when implementing NbS?
> 4. Which NbS were applied when designing the CopenHill project?

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9. MONITORING THE SUCCESS OF NATURE-BASED SOLUTIONS

What is this chapter about:
This chapter introduces important aspects of monitoring Nature-based Solutions (NbS), such as monitoring approaches, obstacles, and spatial and temporal aspects that have to be considered.

What you will learn:
- Basic approaches for monitoring NbS.
- The BACI monitoring design.
- Relevant spatial and temporal considerations.

As mentioned in the chapter “Nature-based Solutions and sustainable development”, Nature-based Solutions produce numerous benefits but may also lead to trade-offs between different important aspects. As indicated in the chapter “The process of implementation of Nature-based Solutions”, it is of high importance to define primary and secondary targets of the respective implementations. To be informed if these targets are reached and with which kind of trade-offs we have to deal, solid monitoring of the outcomes of the implementations of Nature-based Solutions is necessary. Based on a well-established monitoring program, it is also possible to adapt the implanted measures to counteract negative outcomes or even multiply their benefits.

9.1. APPROACHES TO MONITORING

A few approaches have been published for comprehensive monitoring of Nature-based Solutions. For example, the European Commission published a handbook for practitioners (Dumitru & Wendling, 2021). However, this handbook focuses to a high degree on urban areas. In the context of the Horizon 2020 project MERLIN (https://project-merlin.eu/), a monitoring framework was elaborated with a focus on monitoring systemic impacts of freshwater and wetland restoration actions (Carvalho et al., 2022).

A good monitoring approach of a Nature-based Solution should consider at least the following aspects: the matching of indicators with the goals of the measure, a holistic monitoring approach focusing on environmental, economic, and social aspects, which is a balance between these pillars, and an adequate lifetime

that covers an adequate space. However, these aspects are often not met, with monitoring showing mismatches between goals and indicators or an imbalance across different pillars (e.g., Waylen et al., 2019; Cupertino et al., 2024).

To acquire monitoring data, different techniques can be applied:

- Acquisition of data by measurements or surveys: Data acquisition directly in the field.
- Acquisition of data from information sources, such as Corine Land Cover, Eurostat, etc.: Data acquisition using already existing data via data providing services, databases, etc.
- Modelling approaches: For example, when indicators are expected to show a lag in response or are difficult to measure, modelling approaches might be useful.
- Narratives as information source: Nature-based Solutions are often directed towards multi-disciplinary, interwoven goals and targets. Interpreting the monitoring data for such measures is quite complex. Information provided by narratives from people directly involved on site can provide valuable information about the entire complicated complex of the respective measures, especially when the impact cannot be quantified.

9.2. MONITORING OBSTACLES

The major problems with respect to monitoring of Nature-based Solutions are related to insufficient monitoring on the one hand and heterogeneous datasets, which are difficult to interpret, on the other hand.

Insufficient monitoring data may be characterized by missing necessary monitoring data and/or an imbalance of monitoring data with respect to the goals (socio-economic indicators are often underrepresented). Ideally, a combined Before-After-Control-Impact (BACI) monitoring design (Figure 9.1) should be realized, in order to be able to provide robust evidence and attribute changes to the restoration measures. A BACI monitoring design helps determine if observed changes are indeed a result of the intervention and not due to other environmental or societal factors (Carvalho et al., 2022). Monitoring also has to be appropriate with respect to its spatial and temporal scales, which is often not adequately realized.

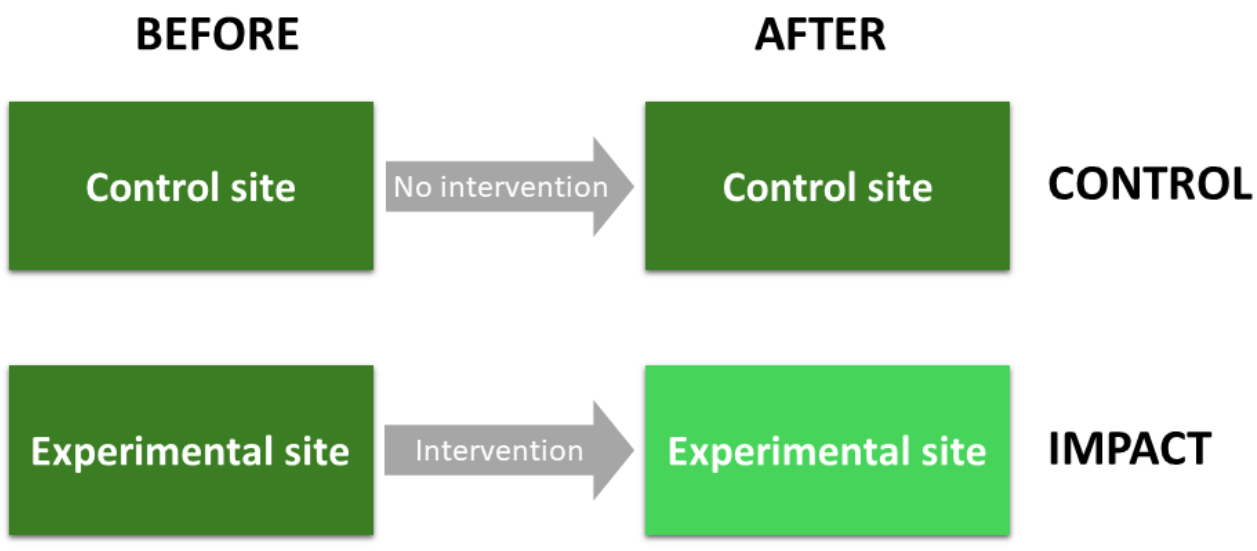


Figure 9.1. Before-After-Control-Impact monitoring design (own work)

Particularly when received from different sources, the monitoring data might be quite heterogeneous. However, it is necessary to objectively assess the outcomes of Nature-based Solutions, ideally indicating the direction of the measure's impact and providing data confidence.

To overcome these obstacles, it will be very helpful to establish clear guidance and standardized indicators. In the Horizon 2020 project MERLIN (https://project-merlin.eu/), for example, standardized monitoring templates were developed for facilitating consistent monitoring (Schwerk et al., 2025).

When monitoring NbS, a combined BACI monitoring design is the ideal approach.

9.3. SPATIAL AND TEMPORAL CONSIDERATIONS

The relevant scale for monitoring is indicator-specific and context-specific. Accordingly, both spatial and temporal scales must be considered (Carvalho et al., 2022).

Spatial scale refers to the size of the area under monitoring, which may range from small patches to large areas, depending on the context and indicator. For example, the impact of a project on pollinator species may concern a small habitat in the project area, whereas the impact on improving conditions for recreation may concern an entire city district.

When considering the temporal scale, it is necessary to know that indicators may respond in very different time frames: some may react immediately, while others may react with a delay. Many insect species, for example, settle rather quickly on the newly created habitats, whereas a measurable impact of these habitats

with respect to carbon may need a longer timeframe. As mentioned above, for indicators with expected lags in responses, modelling approaches might be useful.

> **Review questions**:
> 1. Why can using narratives be an important monitoring method?
> 2. What does BACI stand for?
> 3. Why is it important to consider the spatial scale of monitoring?
> 4. Why is it important to consider the temporal scale of monitoring?

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10. NATURE-BASED SOLUTIONS – CASE STUDIES FROM POLAND AND ICELAND

What is this chapter about:
The chapter presents examples of projects using Nature-based Solutions from Poland and Iceland. The examples focus on different ecosystems and landscapes – forests, riverbanks, and urban landscapes.

What you will learn:
- Possibilities to apply NbS in European countries.
- Possibilities to apply NbS in different ecosystems and landscapes.

10.1. RESTITUTION OF DECIDUOUS FOREST – TUCZNO FOREST DISTRICT

10.1.1. History and problems

Designing forest landscapes, integrating ecological values, human needs, and aesthetics, belongs to the tasks of landscape architecture. This may include improving or even restoring the ecological status of forests. Forest landscape restoration (FLR) is understood as a Nature-based Solutions approach (Cohen-Shacham et al., 2016) aimed at regaining "ecological functionality and enhancing human well-being across deforested or degraded forest landscapes" (Maginnis et al., 2014, p. 15).

When discussing larger forest areas, we have to consider that they are composed of forest fragments of different ages and often also different species compositions. As a result, we have a mosaic of different types of forest parcels, which rather constitute an ecological landscape than a homogenous forest ecosystem. As an ecological landscape, we understand a set of interdependent ecosystems (Andrzejewski, 1992). The survival of many species depends on heterogeneity in ecosystems across the landscape, as illustrated by bird species (Figure 10.1.1).

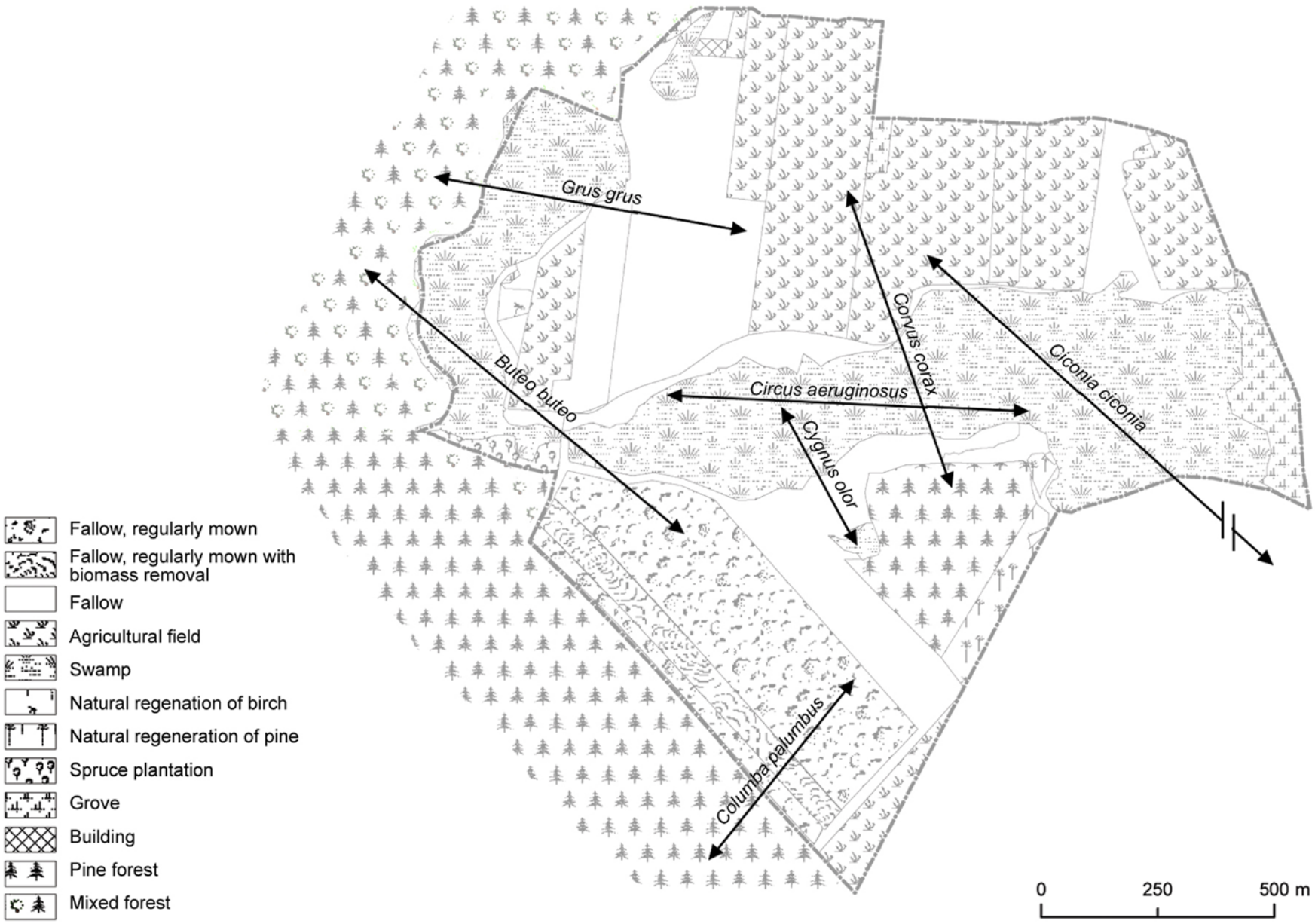


Figure 10.1.1. Scheme of an ecological landscape composed of different ecosystems with characteristic bird species drawn in. Arrows indicate the spatial activity pattern of the species between the nesting and feeding sites (Schwerk, 2016)

An example of FLR was carried out in the Tuczno Forest District in North-western Poland. For centuries, in large areas of this area, the natural deciduous beech and oak forests were cut, and Scots pine (*Pinus sylvestris*) was planted to produce a high volume of timber. However, with ongoing commercial use, different problems emerged: as the number of forest rotations increased, the amount of timber that could be harvested decreased, species diversity declined, and the number of pest outbreaks increased. These incidents prompted the implementation of countermeasures.

10.1.2. Goals

To counteract the problems mentioned above, measures were implemented, beginning of the 1970s. One might question to what extent the measures would stand up to in comparison with nowadays criteria of the IUCN Global Standard for Nature-based Solutions (IUCN, 2020), but they were based on ecological processes and principles and targeted towards the needs of both nature and humans. Therefore, the project can be interpreted as an early precursor of what is now understood as Nature-based Solutions.

The major goals of the project were to halt the observed degradation of forest habitats and the loss of species diversity, to restore beech and oak forests, and to counteract outbreaks of pest insects.

10.1.3. Nature-based Solutions project

From the 1970s, selected Scots pine stands in the Tuczno Forest District have been underplanted with beech and oak (Dymitryszyn et al., 2013) to regenerate the degraded forest ecosystems or even to restore a deciduous forest.

In order to exemplify the regeneration measures, two selected forest parcels will be presented. The first parcel is a pine forest stand of 46 years in 1993 (Plot 91 of the Laboratory of Assessment and Evaluation of Natural Resources in Tuczno). This plot was underplanted with beech around this year (Figure 10.1.2). The second example is a 63-year-old pine stand in 1970 (Plot 92 of the Laboratory of Assessment and Evaluation of Natural Resources in Tuczno), where beech was introduced as undergrowth this year.



Figure 10.1.2. A young beech as undergrowth in a pine forest (photo by Axel Schwerk, 1995)

The project was accompanied by a long-term monitoring. The monitoring concerned soil parameters, such as carbon content in the soil, different forest pest insects (*Panolis flammea*, *Lymantria monacha*, *Tomicus* spp.), and ground beetles (Carabidae) as indicators for biological diversity.

It is worth mentioning that the stands serve as educational plots in order to teach sustainable forestry-related topics.

10.1.4. Selected outcomes

The forest parcels treated by the measures changed their ecological characteristics, for example, dominating ground beetle species (Table 10.1.1 and Table 10.1.2). On both study plots, the five dominating species changed, with very clear changes on Plot 91 and less pronounced changes on Plot 92. It is interesting to notice that in earlier years (1997–1999), both plots were quite similar, with the first four species being the same ones, even in the same order. However, 20 years later (2017–2019), only three species were the same. An additional interesting aspect is that on both plots in later years, the species *Carabus coriaceus* appeared – the largest ground beetle species in Poland and characteristic of old forests (Figure 10.1.3).

Table 10.1.1. Changes in dominating ground beetle species at Plot 91 (own work)

Early (1997–1999)	→	Late (2017–2019)
1. *Pterostichus niger*		1. *Pterostichus oblongopunctatus*
2. *Carabus violaceus*		2. *Carabus hortensis*
3. *Pterostichus oblongopunctatus*	→	3. *Carabus coriaceus*
4. *Carabus nemoralis*		4. *Carabus violaceus*
5. *Carabus problematicus*		*Leistus rufomarginatus*
		Notiophilus palustris

Table 10.1.2. Changes in dominating ground beetle species at Plot 92 (own work)

Early (1997–1999)	→	Late (2017–2019)
1. *Pterostichus niger*		1. *Carabus violaceus*
2. *Carabus violaceus*		2. *Pterostichus oblongopunctatus*
3. *Pterostichus oblongopunctatus*	→	3. *Pterostichus niger*
4. *Carabus nemoralis*		4. *Carabus coriaceus*
5. *Calathus micropterus*		*Harpalus rufipes*



Figure 10.1.3. *Carabus coriaceus* – a ground beetle characteristic of old forests (photo by Axel Schwerk, 2008)

Together with the changes in ecological characteristics, the visual aspect also changed. In both forest parcels, a successive change from dominating pine trees to beech trees was observed (Figure 10.1.4, Figure 10.1.5). However, this change in the visual appearance of the forest fragments occurred more rapidly in Plot 91. Figure 10.1.4 and Figure 10.1.5 suggest that the study plots have increased aesthetic value over time, thereby improving the value to visitors to the forest for recreation.

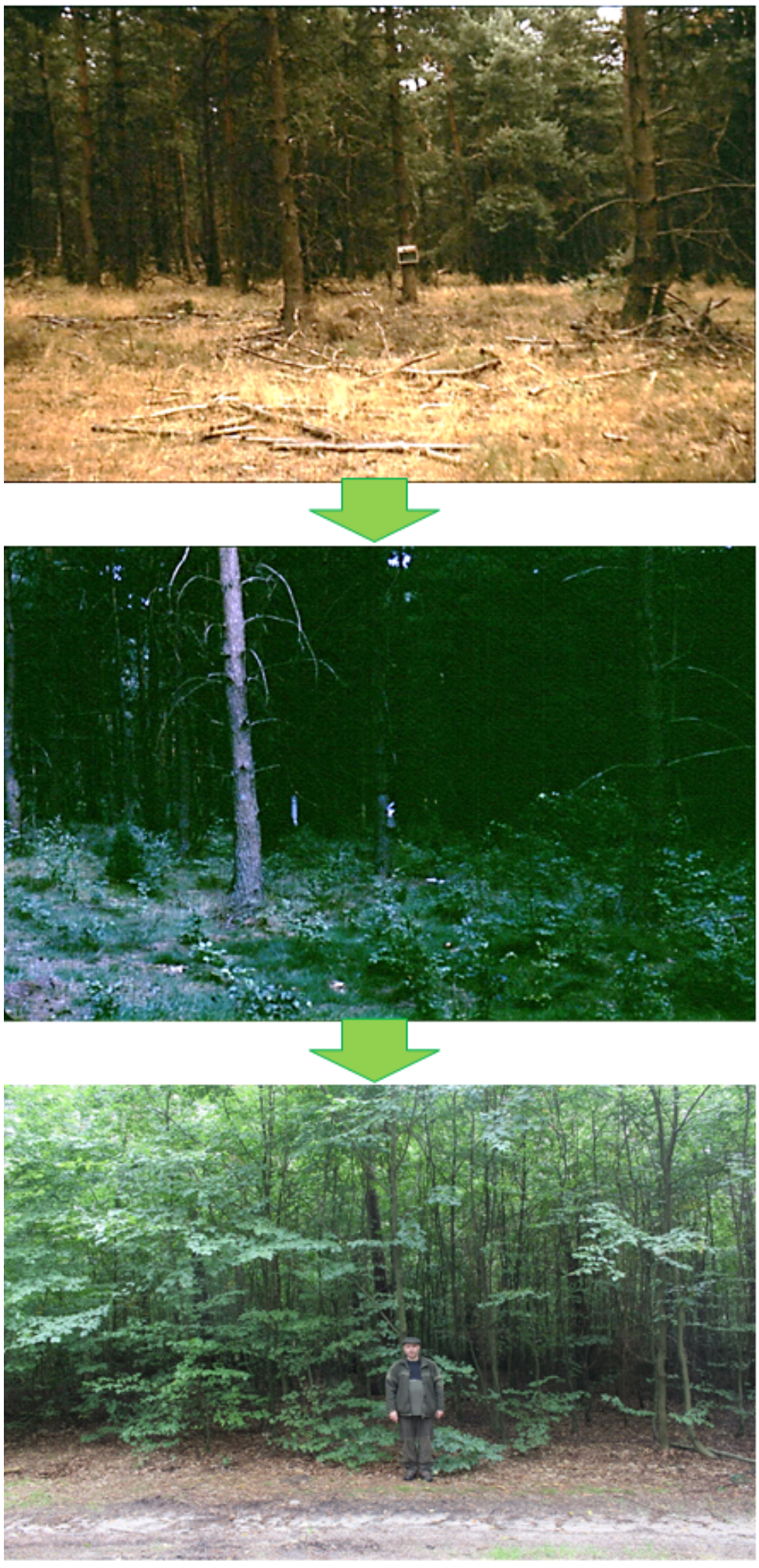


Figure 10.1.4. Changes in the visual aspect in Plot 91: top – visual aspect in 1992, middle – visual aspect in 1996, bottom – visual aspect in 2017 (Szyszko et al., 2019 – modified)

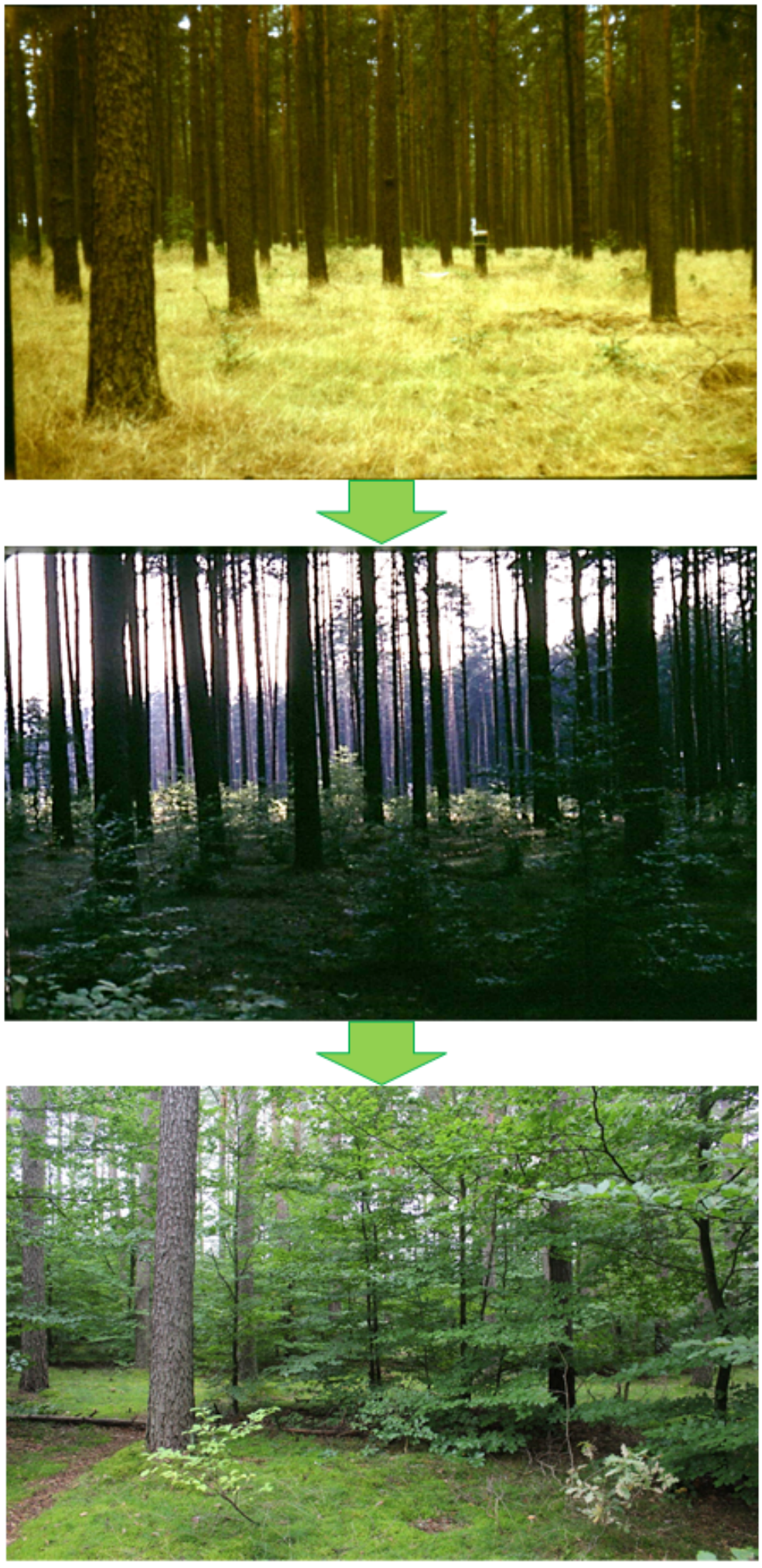


Figure 10.1.5. Changes in the visual aspect in Plot 92: top – visual aspect in 1992, middle – visual aspect in 2000, bottom – visual aspect in 2017 (Szyszko et al., 2019 – modified)

Regarding the ecological landscape, these transformations of the forest parcels contributed to the heterogeneity of the Tuczno forest landscape by increasing the number of forest fragments dominated by beech, which are generally rather poorly represented.

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10.2. RESTORATION OF THE RIVERBANK – ANDAKILSÁ RIVER

Riverbank restoration is a Nature-Based Solution that works using sustainable bank protection around the river, constructed with materials coming from the surrounding countryside to control erosion of the riverbanks and implement biodiversity in rivers, wetlands, and waterways. The approach is to replicate natural physical processes to achieve greater sustainability, thereby providing resilience for climate change. Since the Nature-based Solutions rely on using wood structures rather than stones or concrete to stabilize the riverbank, it is a less invasive approach, preserving both the visual and natural integrity of the river. Restoration of riverbanks using this measure can enhance coastal and marine ecosystems, as rivers are reproductive habitats for fishes, like salmons, which then migrate to the ocean when they reach a specific size. Protection from degradation and erosion of riverbanks also allows replanting the riverbank with native species, restoring the river vegetation.

Andakilsá (Figure 10.2.1), Western Iceland river, suffered from strong erosion. Recently, large wood structures were used to stabilize the bank, where the root plate of the tree breaks has been positioned off the flow. The whole trees are used, or 5–6 m of trunk. After that, soil is set to stabilize further, consequently allowing the vegetation to grow. The only negative aspects of that Nature-based Solutions are related to the material and instruments needed for the measure and the related cost. In fact, there may be constraints related to access to the area with the necessary machinery or the availability of natural materials in a nearby area. This could affect the funding required to implement the measure. Anyway, erosion and landslides can be controlled sustainably, thereby increasing biodiversity. Also, reproductive habitats for fish in the rivers could improve. Knowledge of ecosystem characteristics is needed to understand the local soil's response to the intervention, as well as the time required for the local vegetation to reshape the riverbank. In that case, local stakeholder involvement has been encouraged to minimize societal barriers, also in planting the riverbank with native species.



Figure 10.2.1. Visual impressions of the Andakilsá river (photo by Daniele Stefàno, 2025)

10.3. CONTEMPORARY ECOLOGICAL HOUSING ESTATE – BEAUFORT ESTATE

10.3.1. Context

Beaufort Estate in Pogórze near Gdynia, developed by Euro Styl, part of the Dom Development Group, is one of the most representative examples of contemporary ecological residential architecture in Poland. The project repeatedly awarded – including in the Adapterra Awards 2019 and Green Building Awards 2023 – demonstrates how Nature-based Solutions can effectively support sustainable urban development and improve residents' quality of life (Sołomiewicz, 2023).

The estate comprises twenty-four intimate three- and four-story residential buildings, complemented by ground-floor commercial units, a kindergarten, and extensive recreational facilities. The low-rise structure allowed for the creation of green, thematic urban quarters connected by pedestrian and cycling paths. Each interior courtyard was carefully designed to balance public and private zones, ensuring comfort and a sense of privacy for residents. Vehicular traffic is excluded from the inner courtyards, while the architecture – through the use of natural materials, soft façade colors, and abundant greenery – forms a harmonious and coherent urban composition.

10.3.2. Green infrastructure and surface water retention

Beaufort Estate represents a model investment implementing an integrated system of stormwater management based on nature-based processes. The concept was developed by an interdisciplinary design team in collaboration with an investor open to innovative approaches. The result is multifunctional green infrastructure forming an integral part of the public space, performing retention, filtration, and ecological functions.

Across the estate, various forms of surface retention were introduced – infiltration basins, rain gardens, and small constructed wetlands (Figure 10.3.1). These systems enable the retention of rainfall corresponding to an event with a 1% probability (90 mm) – a standard usually reserved for large hydrotechnical facilities. At Beaufort Estate, this was achieved through decentralized, ecosystem-based processes rather than traditional drainage and rapid runoff systems.



Figure 10.3.1. Interior rain garden – Beaufort Estate (photo by Kasper Jakubowski, 2023)

Such solutions help mitigate flood risks, reduce the effects of droughts, and improve the local microclimate, all while representing a cost-effective and efficient development model (Figure 10.3.2 and Figure 10.3.3).

Over time, the rain gardens have become a distinctive element of the estate's landscape, thriving with lush and diverse vegetation – including cattails, irises, miscanthus, willows, and ornamental grasses. These natural habitats have evolved into small aquatic ecosystems, home to birds, pollinators, and small mammals.

a



b



Figure 10.3.2. Vegetated bioswale (a) and chained infiltration ponds (b) – Beaufort Estate (photo by Kasper Jakubowski, 2023)



Figure 10.3.3. Examples of various runoff channels – Beaufort Estate (photo by Kasper Jakubowski, 2023)

The integrated water management system delivers multiple benefits:

- retains all stormwater within the estate boundaries, supporting the natural water cycle,
- reduces flood risks even during extreme rainfall,
- lowers operational costs by eliminating the need for stormwater discharge to the municipal system,
- improves the microclimate – during hot periods, air temperatures within the estate are significantly lower than in surrounding areas.

10.3.3. Biodiversity and aesthetics inspired by nature

The green infrastructure of Beaufort Estate functions as a living ecosystem. Plant species were selected based on an analysis of local habitats such as the Pomeranian beech forest and currant alder carr, following phytosociological principles. As a result, the vegetation is resilient, low-maintenance, and adapted to local climatic conditions.

The rain gardens feature wetland and riparian species – including cattails, irises, miscanthus, grasses, and willows – creating layered, dynamic plant communities that foster local biodiversity. Over time, these green spaces have become habitats for waterfowl, pollinators, and small mammals, transforming the estate into a micro-nature enclave within the urban fabric.

10.3.4. Shared spaces and social integration

Beaufort Estate is designed as an open and welcoming residential environment. Its central hub, Beaufort's Harbour, serves as a community center offering areas for recreation, play, and neighborhood gatherings.

In partnership with the Kosakowo Municipality, the developer also created an extensive public recreational zone, featuring a skatepark, sports fields, cycling paths, a crossfit area, playgrounds, and an open retention basin integrated with the green infrastructure system. These spaces promote social cohesion, physical activity, and community well-being.

Beaufort Estate exemplifies a form of green urbanism, where nature, architecture, and social functions coexist harmoniously to create a high-quality living environment.

10.3.5. Energy efficiency and circular economy

The project also supports the circular economy concept. The estate is connected to a district heating network utilizing waste heat from electricity production, while green areas are maintained using compost derived from organic waste. This approach ensures a closed loop of matter and energy within the local ecosystem.

Such measures help reduce emissions, minimize waste, and embody the principles of sustainable development on the neighborhood scale.

10.3.6. Estate of the future

Five years after completion of the first phase, the retention system continues to perform flawlessly – no flooding incidents have been recorded, and the vegetation maintains a stable, self-regulating ecosystem.

Beaufort Estate has become a model of sustainable urban design, proving that residential developments can successfully integrate economic, environmental, and social goals. It stands as an example of modern, eco-friendly urban housing and a benchmark for climate-resilient city development.

FACT SHEET

Beaufort Estate, Pogórze (Kosakowo Municipality) – Nature-based Stormwater Management

Location:	Pogórze, Kosakowo Municipality, Pomeranian Voivodeship
Investor:	Euro Styl, Dom Development Group
Design:	Rayss Group
Implementation:	2017–2021
Awards:	Adapterra Awards 2019, Green Building Awards 2023 – Best Ecological Multifamily Residential Development

Beaufort Estate is a pioneering Polish example of **Nature-based Solutions** applied in stormwater management. Instead of conventional drainage, the estate uses a **surface retention system** incorporating r**ain gardens, retention beds, and constructed wetlands**. These elements retain all stormwater on site, preventing flooding and enhancing the local microclimate.

The rain gardens, planted with native species such as **cattails, irises, and willows**, serve **retention, phytoremediation, and aesthetic functions**, while promoting **biodiversity** and creating a **healthy, human- and nature-friendly environment**. The project demonstrates that **green infrastructure** can successfully replace traditional technical systems, delivering tangible **ecological, economic, and social benefits**.

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10.4. STEPPING STONES ECOLOGICAL CORRIDOR BETWEEN URBAN PARKS – POLE MOKOTOWSKIE AND ŁAZIENKI KRÓLEWSKIE

10.4.1. Project's background

Progressive urbanization changes the structure and functioning of ecosystems, leading to habitat fragmentation, simplification of species composition, and weakening of key ecosystem services. In urban environments, the conscious design of spaces that promote biodiversity is particularly important.
An ecosystem, as a dynamic system of interdependence between living organisms (biocenosis) and the inanimate environment, functions properly only when its elements remain in balance. Plants play a fundamental role in this system – they form the basis of food chains and determine human food security. Their generative reproduction largely depends on pollinators, including bumblebees, which enable the continuity of angiosperm generations.

In cities, anthropogenic pressures – development, surface sealing, and the isolation of green areas – limit the availability of habitats for pollinating insects. At the same time, research shows that with appropriate urban green space design, it is possible to maintain and even increase the diversity of pollinators in urban areas. Flower strips, street greenery, parks, and other elements of green infrastructure can serve as so-called ecological corridors and play a special role here. These corridors provide structural and functional connectivity between isolated habitat patches (green areas with flowering plants), enabling the migration of organisms and genetic exchange between populations.

In densely built-up areas, an effective design strategy is the so-called stepping stones model, i.e., a system of discontinuous but functionally connected environmental islands distributed throughout the urban space. This solution allows pollinators to move gradually between larger green areas, minimizing the negative effects of landscape fragmentation.

10.4.2. Project's objectives

The aim of the project entitled "Design of a stepping stones ecological corridor for selected bee species, connecting Pole Mokotowskie and Łazienki Królewskie parks in Warsaw", elaborated by landscape architect Paulina Kaczmarczyk (2026), is to highlight the importance of planning urban ecological corridors as a tool for pollinator conservation and support for ecosystem services in the city, and thus to demonstrate the role of landscape architects in the active protection of biodiversity. This issue has not only a natural dimension, but

also a social and functional one – well-designed green infrastructure improves the quality of life of residents, strengthens the environmental resilience of cities, and promotes the implementation of sustainable development principles.
In the face of climate change, a responsible approach to land use to protect native biodiversity seems particularly important.

10.4.3. Project's methodology

Work on the project began with an analysis of the selected study area (Figure 10.4.1) located in two districts of Warsaw – Śródmieście and Mokotów.



Figure 10.4.1. Area covered by surface analysis against the background of the immediate surroundings. Prepared by Paulina Kaczmarczyk based on 2023 data from the National Geoportal (Main Office of Geodesy and Cartography)

After analyzing the layout (Figure 10.4.2) and the availability of green areas (Figure 10.4.3) to identify potential components of the planned ecological corridor, a detailed vegetation inventory was conducted.



Figure 10.4.2. Identification of potential components of the migration corridor for *Apis mellifera* and/or *Bombus* spp. (bumblebees) (Kaczmarczyk, 2026)



Figure 10.4.3. Analysis of potential components of the migration corridor in terms of availability for further analysis (Kaczmarczyk, 2026)

Among the plantings, total of 130 plant species were identified, including 48 trees, 41 shrubs, 41 herbaceous plants introduced in individual plantings, and 55 species of spontaneous plants. In addition, pollinating insects were observed in the selected area. Representatives of the Apidae, Pieridae, Vespidae, and Syrphidae families were inventoried. The Apidae family was the most numerous, and it was decided to dedicate the planned ecological corridor to its representatives. The observation (Figure 10.4.4) enables the identification of locations where no insects were found, indicating poorly designed greenery (a lack of useful plants) or its absence, which constitutes a barrier to migration.



Figure 10.4.4. Map showing the distribution of pollinating insect observation points (Kaczmarczyk, 2026)

To assess the potential risk of excessive food competition from *Apis mellifera* (honey bee) and to verify whether the dispersal capacity of the analyzed pollinator species is sufficient for the planned area to function as an ecological corridor, the location of urban apiaries was analyzed. It was assumed that 1,500 m is the economic flight distance of a honeybee, i.e., the distance at which the energy balance of resource acquisition remains positive. This species has one of the highest dispersal abilities among the pollinators considered, so the adopted radius was treated as a reference value in the spatial analysis (Beekman & Ratnieks, 2000; Zurbuchen et al., 2010).

The identified plant species were grouped into 156 functional groups, which were analyzed for pollen and nectar yield, i.e., their ability to provide basic food resources for pollinating insects. The assessment showed that most of the distinguished plant groups (150) have high or moderate nutritional value, which indicates the significant potential of the studied area to serve as a forage source for pollinators during the growing season. The results of the analysis are presented in Figure 10.4.5.

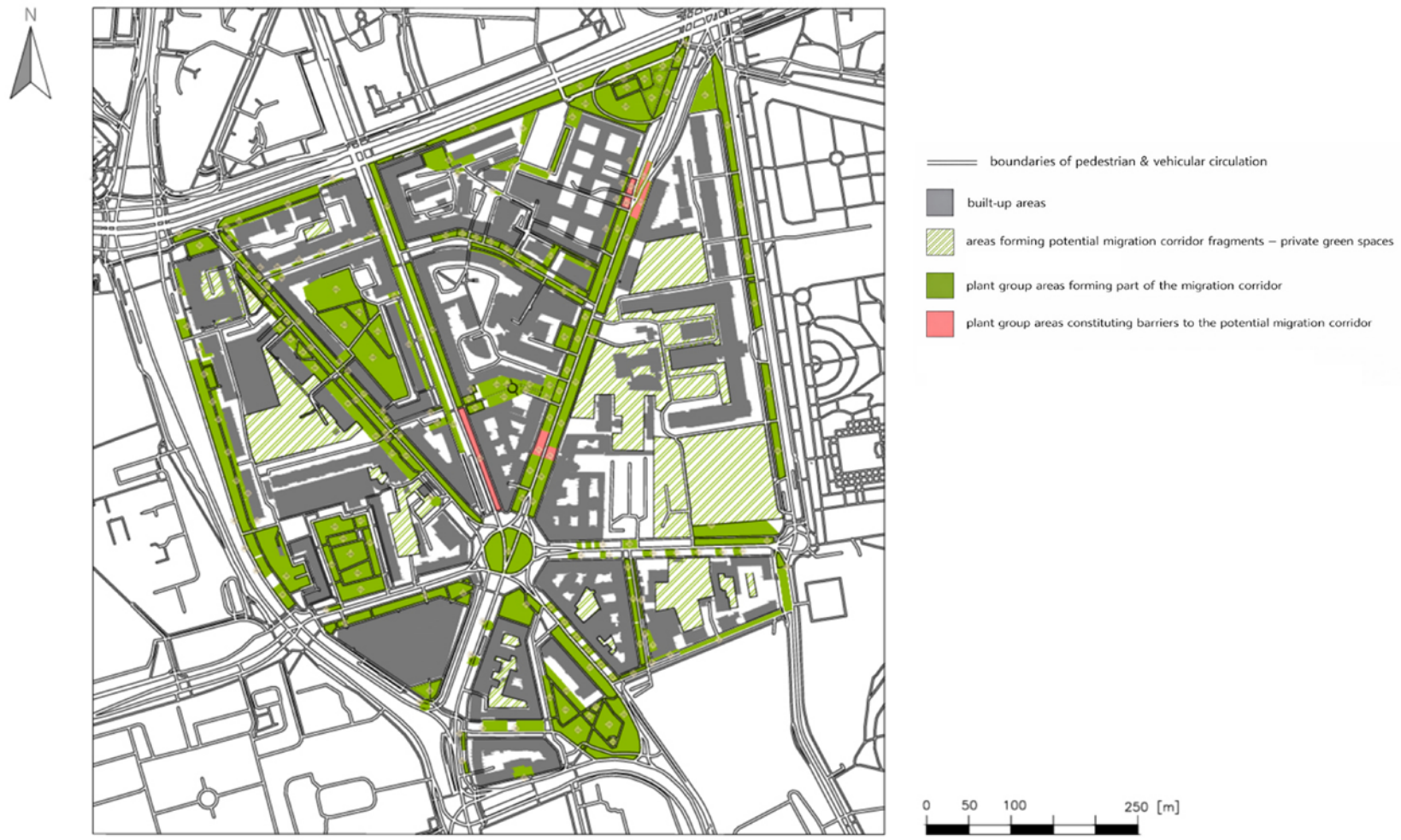


Figure 10.4.5. Analysis of the species composition of plant groups in terms of their usefulness in the form of nectar and/or pollen for *Apis mellifera* and/or *Bombus* spp. (Kaczmarczyk, 2026)

The diversity of plant species and the extension of their flowering periods help ensure the continuity of food resources, which is crucial for maintaining stable pollinator populations. For this reason, the selected plant groups were further analyzed, with the criterion of flowering continuity within each group, defined as the maintenance of an uninterrupted supply of pollen and nectar throughout the entire period of pollinator activity. The results of this analysis are presented in Figure 10.4.6, which shows that most pollinating insects observed occurred in areas with host plants available throughout their seasonal activity. This means that the phenological continuity of vegetation is one of the key factors determining the functionality of a space as an ecological corridor, and therefore, the lack of such continuity – resulting from interruptions in flowering or low

species diversity – can create migration barriers. As a result, even formally existing green areas may not fulfill their connecting function and thus contribute to the disruption of the ecological corridor.

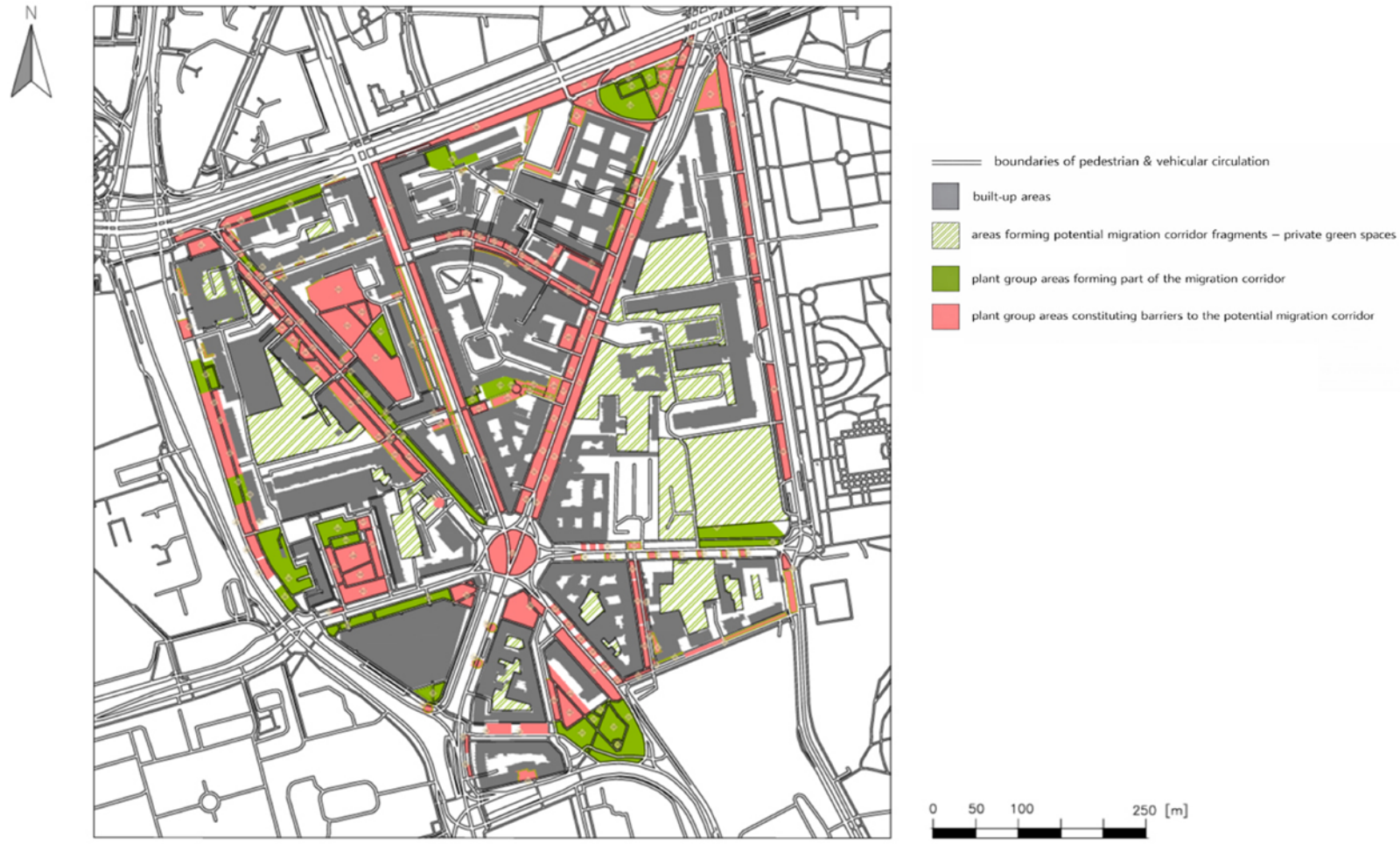


Figure 10.4.6. Analysis of continuity in the provision of nectar and/or pollen for *Apis mellifera* and/or *Bombus* spp. (Kaczmarczyk, 2026)

10.4.4. Project's results

Based on all the analyses carried out to develop a design concept for a section of the migration corridor for the indicated bee species, a section of land was selected according to the following guidelines:

a) it is part of urban greenery,
b) the vegetation present on it does not ensure a continuous supply of nectar and/or pollen throughout the entire period of bee activity,
c) it is in a strategic part of the research area in the center, among other elements that do not meet the previous sub-points (pink groups in Figure 10.4.7),
d) its location allows, even at the level of changing a single fragment, for the clearing of a larger section of the migration corridor for insects; it is a fragment of street greenery, with linear planting, repeated along the entire street, which allows for the design of a single but repeatable module. In this way, by repeating such sections of plantings, it is possible to seal the migration corridor along the streets located in the studied area.

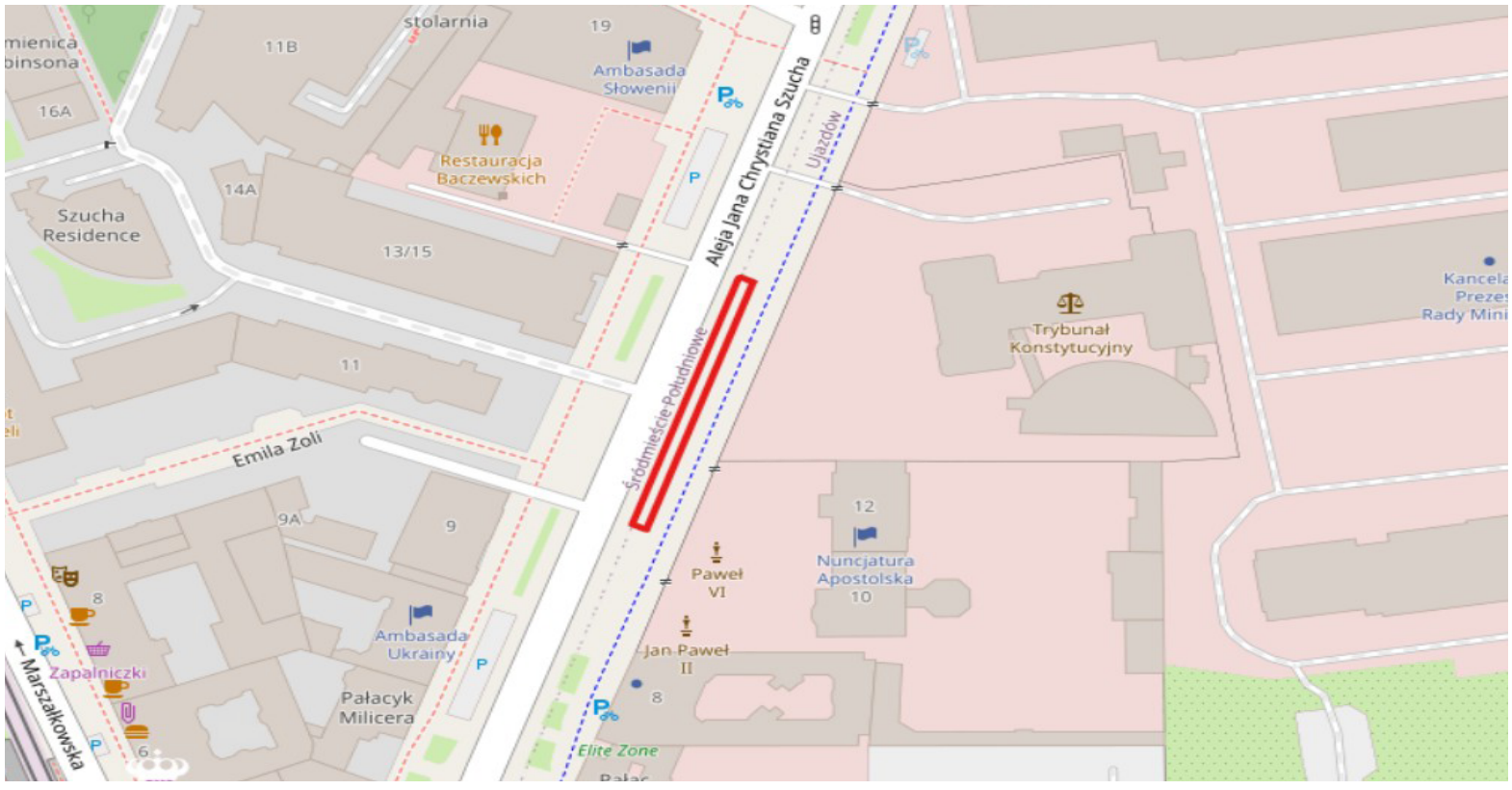


Figure 10.4.7. Boundaries and location of the selected fragment against the background of its immediate surroundings (Kaczmarczyk, 2026 based on 2025 map from database OpenStreetMap)

The analyses carried out have shown that the planned area, which is part of a historic Baroque urban complex under conservation protection, requires the preservation of the historic oak avenue (*Quercus robur*) and the emphasis of the linear, representative character of the spatial layout. Due to its central location and dominant residential, service, transport, and representative functions, the design should ensure high aesthetic quality throughout the year, clarity of composition, and unambiguous guidance of users along pedestrian and vehicular routes, without creating visual barriers. Restrictions resulting from dense underground infrastructure determine the selection of plants with shallow root systems and the need to maintain access to technical equipment. Natural analyses have shown insufficient species diversity, a shortened flowering period (May–July), and limited utility value of the existing greenery, which justify expanding the species composition and ensuring the continuity of the food base for pollinators from April to September. At the same time, due to bumblebees' limited dispersal capabilities, the planned section may serve as an intermediate link in the ecological corridor structure, provided that the spatial and temporal continuity of the foraging habitat is ensured and adapted to the semi-shaded conditions prevailing in the analyzed area.

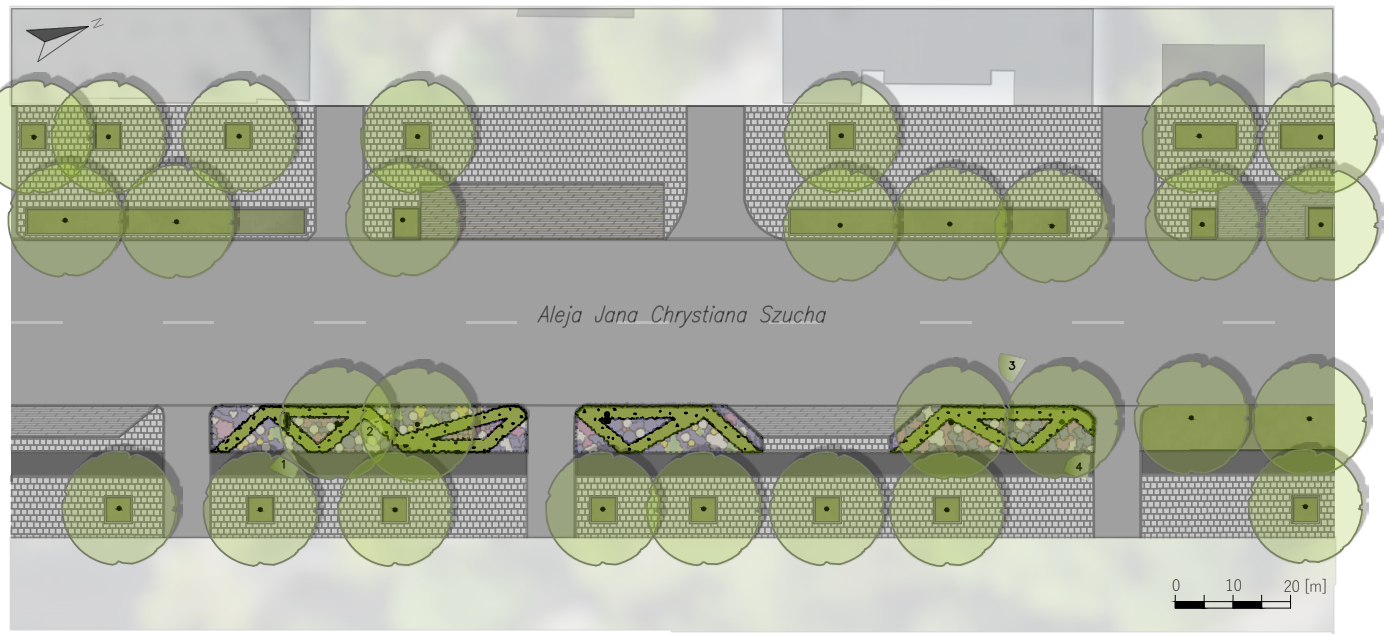
The concept (Figure 10.4.8) involves redesigning the green belt along the avenue to strengthen its function as a migration corridor for bees and selected bumblebee species between two urban parks – Pole Mokotowskie and Łazienki Królewskie. The design is based on the principles of linearity and modularity,

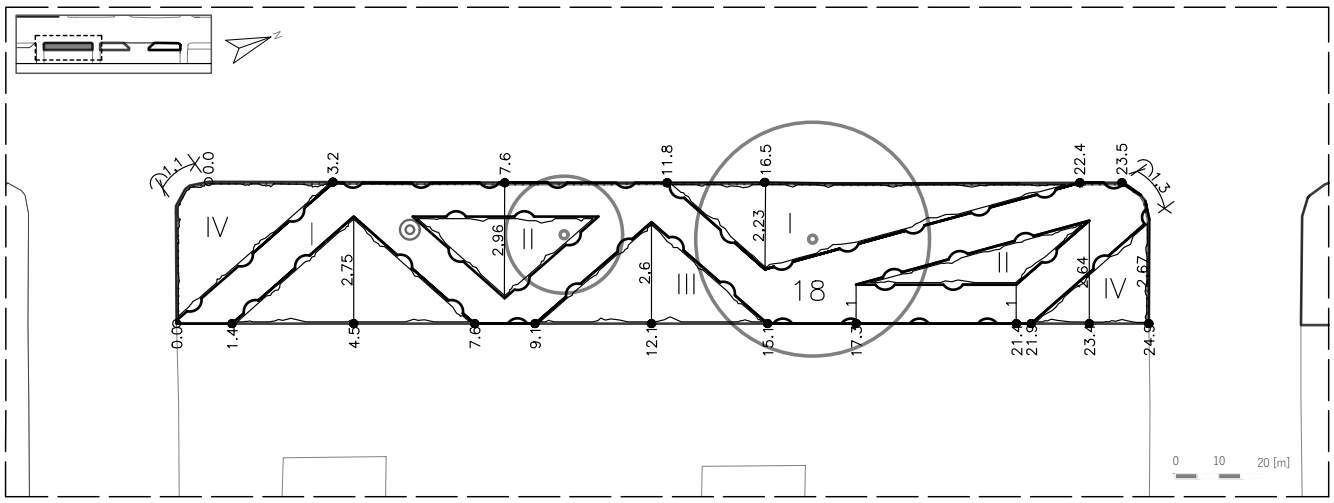
respecting the historical Baroque urban layout and preserving the historic oak avenue, while excluding new tall greenery due to conservation regulations and underground infrastructure. The composition is a contemporary interpretation of an ornamental parterre – the framework is formed by a hedge of shrubby cinquefoil (*Potentilla fruticosa*), and the filling consists of 17 species of native perennials and ornamental grasses, selected for their habitat resistance, phenological continuity (April–September), the adaptation of flower morphology to the mouthparts of pollinators, and the color preferences of insects (dominance of purple with accents of yellow, white, and pink). Due to heavy shading and intense anthropogenic pressure, the introduction of nesting sites was abandoned, focusing instead on ensuring a continuous, efficient food base and maintaining the representative character of the space while guaranteeing access to technical infrastructure.

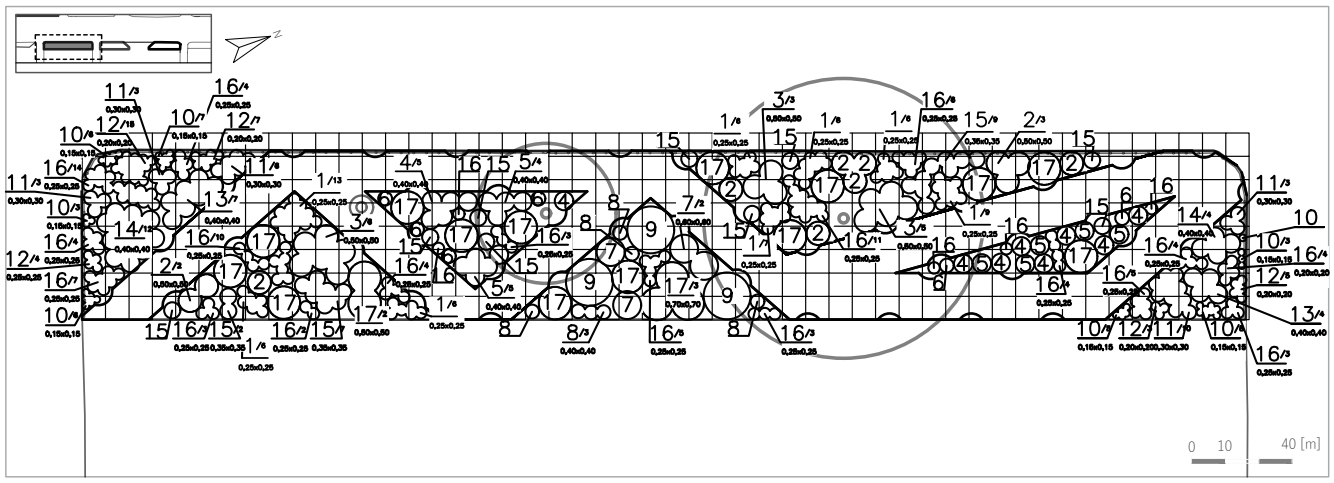
The analyses and the developed design concept demonstrate that even small, precisely planned interventions in the urban greenery structure can significantly improve habitat conditions for wild animal species, especially pollinating insects. The key factor here is not the spatial scale of the action, but its quality – based on a reliable diagnosis of historical, functional, habitat, and technical conditions, and on a conscious selection of plant solutions that ensure the continuity of the food base and the functionality of the space as part of an ecological corridor.

The example of the analyzed area shows that small patches of greenery in a highly urbanized context can act as “intermediate links” in the city’s natural connection system. However, this requires maintaining the spatial and phenological continuity of plantings, increasing species diversity, and integrating biocenotic functions with the aesthetic and representative requirements of public space. Thus, green space design ceases to be solely a compositional issue and becomes a tool for shaping the city’s ecological resilience.

The systematic implementation of similar measures – even in the smallest green niches, such as street verges, squares, pocket parks, or infrastructure-accompanying flower beds – can yield measurable results in biodiversity protection on a city-wide scale. Scattered but conceptually coherent interventions create a network of microhabitats that, together, build a functional ecological structure, increasing organisms’ ability to migrate, feed, and survive under anthropogenic pressure. As a result, small-scale design measures, consistently implemented and grounded in ecological knowledge, can serve as a foundation for sustainable development in modern cities.







Nr.	Nazwa łacińska
	ROŚLINY ZIELNE
	I – 0,60 m
1	*Aquilegia vulgaris*
2	*Hypericum perforatum*
3	*Teucrium scorodonia*
	II – 0,60 m
4	*Betonica officinalis*
5	*Geranium phaeum* 'Raven'

6	*Veronica spicata*
	III – 0,60 m
7	*Ballota nigra*
8	*Origanum vulgare*
9	*Symphytum officinale*
	IV – 0,10–0,40 m
10	*Crocus vernus*
11	*Lamium maculatum* 'Album'
12	*Lathyrus vernus*

13	*Prunella grandiflora*
14	*Prunella vulgaris*
	I–IV
15	*Anchusa officinalis*
16	*Festuca ovina*
17	*Lamium album*
	KRZEWY
18	*Potentilla fruticosa* 'Chilo'

Figure 10.4.8. Conceptual design for a section of the bee migration corridor: green strip along Aleja Szucha in Warsaw (Poland). The study presents the design of a flower bed layout intended to restore the structural and functional continuity of the pollinator migration corridor, supported by a scientifically grounded selection of host plant species (elaborated by Paulina Kaczmarczyk, based on Kaczmarczyk, 2026)

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10.5. PROTECTION OF ENDANGERED SPECIES ASSOCIATED WITH AQUATIC HABITATS IN WARSAW

10.5.1. Project's background

The project entitled "Protection of endangered species associated with aquatic habitats in Warsaw" was implemented by the Capital City of Warsaw, and the unit directly responsible for performing the tasks was the Warsaw Greenery Board (Zarząd Zieleni m.st. Warszawy – ZZW), which manages the city's green area system. The undertaking was co-financed by the European Union under the Cohesion Fund, as part of the Operational Programme Infrastructure and Environment for 2014–2020 (Priority Axis II: Environmental protection, including adaptation to climate change). The actions were classified under project Type 2.4.1 regarding in-situ or ex-situ protection of endangered species and natural habitats, under call for proposals No. 2.4.1/1/2016.

The formal basis for the implementation was contract No. POIS.02.04.00-00-0033/18-00 signed on January 27, 2020, with subsequent annexes. According to the final financial statements, the total project value was estimated at 8,599,220.70 PLN (with eligible expenditure of 6,887,350.00 PLN). The actual cost of implementation was 8,541,438.19 PLN, with a grant of 4,855,427.29 PLN, which constitutes 85% of the eligible costs (5,712,267.90 PLN).

10.5.2. Project's objectives

The main goal of the initiative was to improve the state of preservation and active protection of endangered animal species and habitats inherently associated with Warsaw's water bodies and streams. This goal was achieved through multifaceted activities: improved water retention [construction of small dykes in Las Kabacki (forest park and woods nature reserve) and the Kanał Sobieskiego (canal)], renaturation of bank zones, active species protection, and extensive environmental education.

10.5.3. Project's execution

The investment process began with the preparation of comprehensive design documentation (Task 1) for key locations, including Stawy Brustmana (ponds), Jeziorko Czerniakowskie (lake), and Pole Mokotowskie (urban park). The extensive renaturation of the bank zones (Task 2) was carried out as part of the field work. A total of 1,223 m^2 of concrete reinforcement was removed and replaced with biological solutions, including fascines and wooden palisades. This work was carried out at Stawy Brustmana (2 ponds with a connected canal) at Tołwińskiego Street, Kanał Piaseczyński (canal), and the water reservoirs at the Trasa Siekierkowska (thoroughfare) and in Ursynów (2 reservoirs – Moczydło 1 and Moczydło 2), where a wooden footbridge and floating islands were additionally built.

Parallel to this, biological invasion control was carried out (Task 3), eliminating knotweed (*Reynoutria* spp.) and Manitoba maples (*Acer negundo*) in the floodplains of the Vistula and removing alien fish species (through electrofishing) from the Moczydło 2, which was crucial for protecting local amphibians. Task 4 focused on protecting the breeding sites of the little ringed plover (*Charadrius dubius*) in Wilanów by clearing the brush from the sandy banks of the Vistula.

As part of the construction and technical tasks (Task 5), a number of local actions were carried out: the installation of platforms for the black tern (*Chlidonias niger*) on Jezioro Powsinkowskie (lake) and platforms for the white-tailed eagle (*Haliaeetus albicilla*) in the central Vistula valley, the construction of three small dykes in Las Kabacki, and modernization of the water storage structure on the Kanał Sobieskiego (canal), which made it possible to maintain proper water levels in the woods nature reserve Morysin, the installation of a platform with reed bed vegetation on the Kanał Piaseczyński and fences to protect bird breeding grounds from anthropogenic pressure.

An important strategic element was the acquisition of land (Task 6) near the Moczydło 2, which enabled merging the area into a coherent protective area. The entire work was supported by coherent management planned under Task 7 and promotion (Task 8), which included educational workshops on amphibians and a film promoting nature in Warsaw.

10.5.4. Project's methodology and results

The project was fully successful with regard to the adopted indicators (Figures 10.5.1–10.5.8). It protected 5 types of habitats (including willow-poplar riparian forests (*Salicetum albae*), oxbow lakes, and oak-hornbeam forests (*Galio-Carpinetum*) and 13 key species (8 bird species and 5 amphibian species). These species include the black tern (*Chlidonias niger*), white-tailed eagle (*Haliaeetus albicilla*), common kingfisher (*Alcedo atthis*), and little ringed plover (*Charadrius dubius*). As for amphibians: European fire-bellied toad (*Bombina bombina*), great crested newt (*Triturus cristatus*), and green toad (*Bufotes viridis*).

The direct result indicator, which determines the area of habitats supported to achieve better protection status, exceeded expectations: instead of the planned 290 ha, 328.74 ha of nature conservation area received actual support. Thanks to these activities, Warsaw gained new blue-green infrastructure and fundamentally improved the living conditions of the most endangered inhabitants of its aquatic ecosystems (ZZW, 2023).



Figure 10.5.1. Canal by Stawy Brustmana before renaturalization (ZZW, 2023)



Figure 10.5.2. Stawy Brustmana before renaturalization (ZZW, 2023)



Figure 10.5.3. Canal by Stawy Brustmana after renaturalization (ZZW, 2023)



Figure 10.5.4. Stawy Brustmana after renaturalization (ZZW, 2023)



Figure 10.5.5. Moczydło 1 before renaturalization, (ZZW, 2023)



Figure 10.5.6. Moczydło 1 after renaturalization (ZZW, 2023)



Figure 10.5.7. Glinianki Włościańskie before renaturalization (photo by Łukasz Poławski, 2023)



Figure 10.5.8. Glinianki Włościańskie after renaturalization (ZZW, 2023)

One and two years after the completion of this project, a landscape architect from Warsaw University of Life Sciences (SGGW) monitored its effects on avifauna. This is presented in the engineering work of Agata Moniuszko entitled “Assessment of the effectiveness of renaturation activities towards avifauna species undertaken within the project ‘Protection of endangered species associated with aquatic habitats in Warsaw’ identified on three selected ponds in Warsaw parks” (Moniuszko, 2025).

The main goal was a detailed analysis of the impact of renaturation works carried out in 2020–2023 within the project on the populations of wetland birds. The study covered three water bodies in Warsaw within the project: Stawy

Brustmana and Glinianki Włościańskie (artificial ponds), and Moczydło 1, a natural standing water body. The effectiveness of the investment actions undertaken was assessed by comparing data collected before project implementation with the results of ornithological inventories conducted during the 2024–2025 research cycle. Data were obtained from the bird inventory conducted as part of the investment prior to construction (Rowiński, 2021).

The research used the cartographic method, based on 6 field inspections in 2024 and 12 in 2025. To precisely determine changes in the environmental structure after construction work under the project, orthophoto map analysis was used, allowing calculation of percentage changes in bank coverage with reed beds, concrete quays, and other forms of vegetation. In addition, sound baiting targeting the common moorhen (*Gallinula chloropus*) and the little grebe (*Tachybaptus ruficollis*) was used on selected ponds to verify the presence of specific species.

The analysis of environmental changes showed an increase in reed bed area on all the studied water bodies (by about 4–6%) at the expense of concrete reinforcement and open water surfaces. The most spectacular change was recorded at Stawy Brustmana, where the area covered by concrete was reduced by a factor of 4 (Table 10.5.1, Figures 10.5.9–10.5.11). These transformations directly translated into the avifauna situation – an increase in the number of breeding pairs of species closely associated with reed vegetation was observed, including mallard (*Anas platyrhynchos*), common coot (*Fulica atra*), and common moorhen (*Gallinula chloropus*).

Particular success was recorded at Glinianki Włościańskie. This water body, which was devoid of breeding species before the project began, became a nesting site for the common coot (*Fulica atra*) after the work was completed. At Moczydło 1, no statistically significant changes in the number of breeding pairs were observed, suggesting a different response dynamic of the local population to the introduced modifications. The difference results from the origin of the reservoirs and their ecological status. Moczydło 1 is a naturally formed body and its ecosystem, despite anthropogenic influences, maintains a relatively higher ecological balance. Therefore, renaturation work produced less dramatic effects on birds.

Table 10.5.1. Changes in land cover types resulting from the implementation of the project "Protection of endangered species associated with aquatic habitats in Warsaw" (ZZW, 2023; elaborated by Agata Moniuszko based on Moniuszko, 2025)

Parameter	Stawy Brustmana					
	2021		2024		Difference [m²]	Difference [%]
	Area [m²]	Area [%]	Area [m²]	Area [%]		
Total area	15,593.0	100.00	15,593.0	100.00	–	–
Open water surface	10,233.0	65.63	9,499.0	60.92	−734.0	−4.71
Open terrain	4,300.7	27.58	3,526.1	22.61	−774.6	−4.97
Concrete elements	45.3	0.29	10.9	0.07	−34.4	−0.22
Reed beds	538.0	3.45	1,419.0	9.10	881.0	5.65
Shrubs	476.0	3.05	1,138.0	7.30	662.0	4.25
Trees	2,464.0	15.80	2,464.0	15.80	0	0
Parameter	Glinianki Włościańskie					
	2021		2024		Difference [m²]	Difference [%]
	Area [m²]	Area [%]	Area [m²]	Area [%]		
Total area	12,677.0	100.00	12,677.0	100.00	–	–
Open water surface	2,356.0	18.58	1,797.0	14.18	−559.0	−4.41
Open terrain	9,958.0	78.55	10,052.0	79.29	94.0	0.74
Concrete elements	152.0	1.20	22.0	0.17	−130.0	−1.03
Reed beds	211.0	1.66	721.0	5.69	510.0	4.02
Shrubs	0	0	85.0	0.67	85.0	0.67
Trees	4,383.0	34.57	4,383.0	34.57	0	0
Parameter	Moczydło 1					
	2021		2024		Difference [m²]	Difference [%]
	Area [m²]	Area [%]	Area [m²]	Area [%]		
Total area	10,641.0	100.00	10,641.0	100.00	–	–
Open water surface	2,870.0	26.97	2,587.0	24.31	−283.0	−2.66
Open terrain	6,370.0	59.86	6,000.0	56.39	−370.0	−3.48
Concrete elements	92.0	0.86	92	0.86	0	0
Reed beds	1,309.0	12.30	1,962.0	18.44	653.0	6.14
Shrubs	0	0	0	0	0	0
Trees	4,694.0	44.11	4,694.0	44.11	0	0

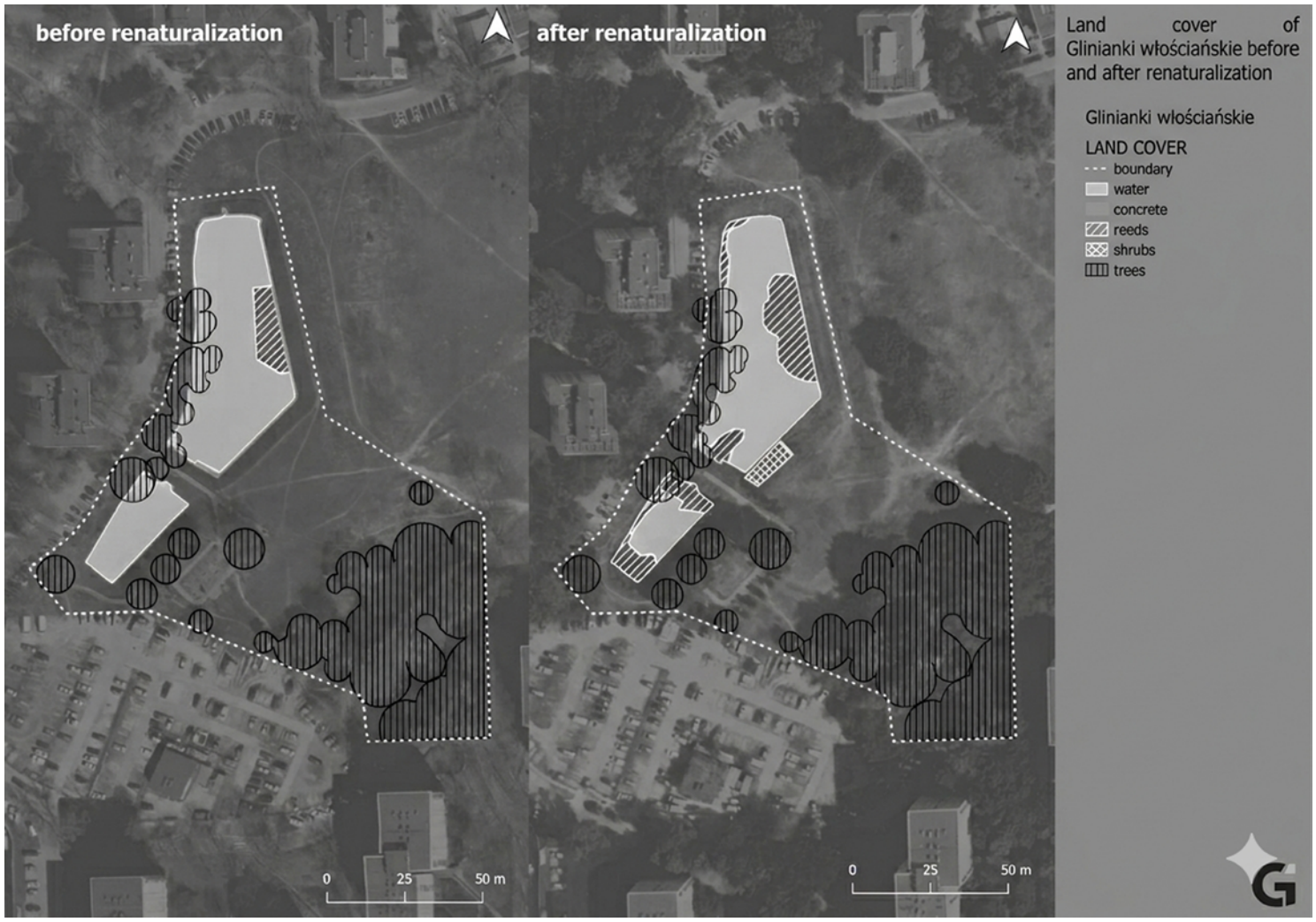


Figure 10.5.9. Changes in land cover at Glinianki Włościańskie as a result of the implementation of the project “Protection of endangered species associated with aquatic habitats in Warsaw” (ZZW, 2023; elaborated by Agata Moniuszko based on Moniuszko, 2025)



Figure 10.5.10. Changes in land cover at Staw Moczydło 1 as a result of the implementation of the project “Protection of endangered species associated with aquatic habitats in Warsaw” (ZZW, 2023; elaborated by Agata Moniuszko based on Moniuszko, 2025)

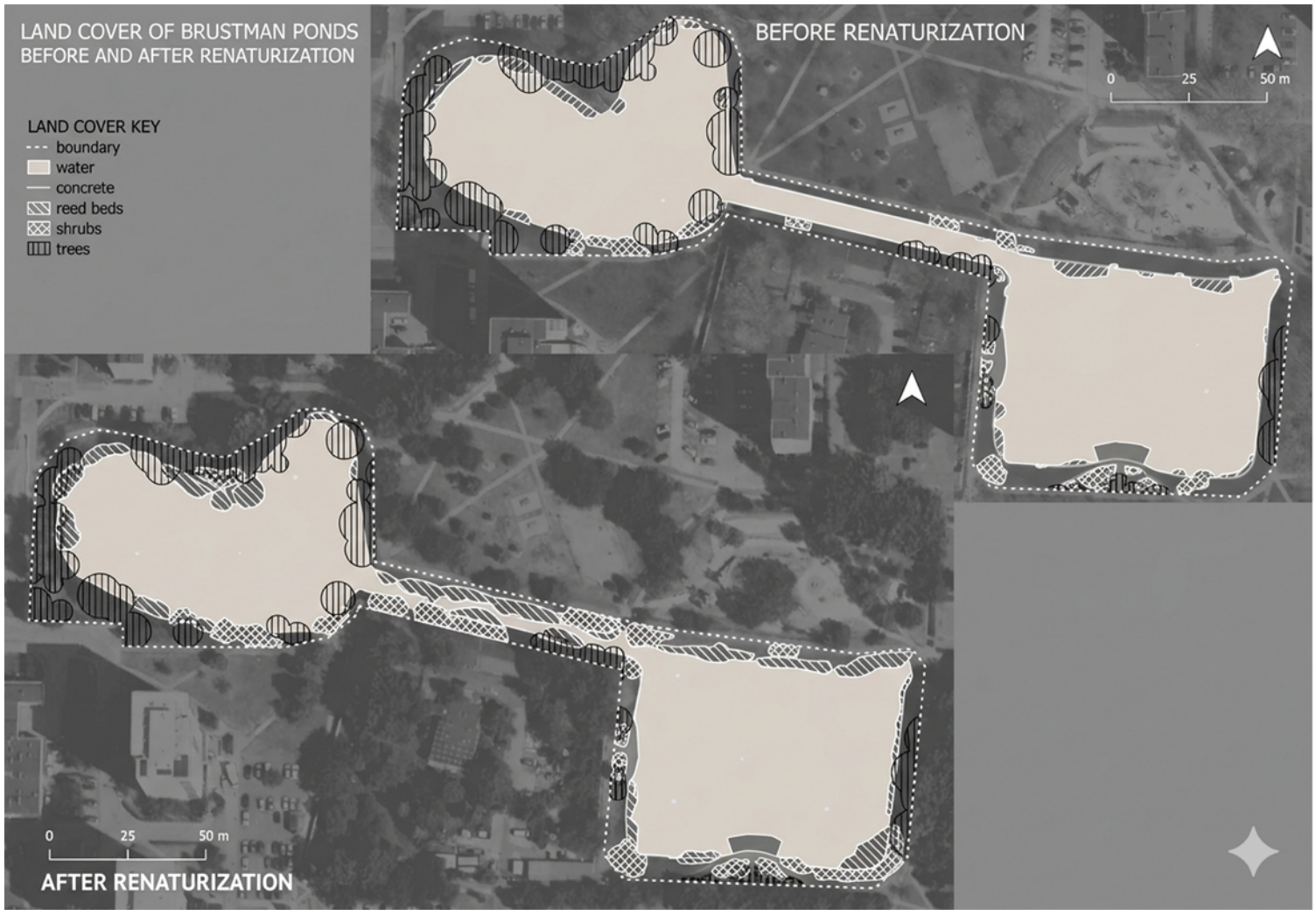


Figure 10.5.11. Changes in land cover at Stawy Brustmana as a result of the implementation of the project "Protection of endangered species associated with aquatic habitats in Warsaw" (ZZW, 2023; elaborated by Agata Moniuszko based on Moniuszko, 2025)

In light of the obtained results, the author indicates the need to strengthen cooperation between landscape architecture and hydraulic engineering designers and ornithologists already at the planning stage in similar projects. Apart from designing aesthetics and functional layout, precise knowledge of the habitat requirements of the species to be beneficiaries of the changes is crucial.

Review questions:

1. Which main targets does forest landscape restoration have?
2. How can riverbank restoration be realized by NbS?
3. Which benefits were achieved by implementing NbS in Beaufort Estate?
4. How can pollinators be protected by NbS?
5. How can endangered species be protected by NbS?

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11. NATURE-BASED SOLUTIONS – CASE STUDIES FROM INDONESIA AND THAILAND

What is this chapter about:
The chapter presents examples of projects using Nature-based Solutions (NbS) from Indonesia and Thailand. It shows how NbS are implemented and how social, cultural, and economic benefits are achieved.
The chapter presents the examples that focus on different ecosystems and landscapes – forests, riverbanks, and urban landscapes.

What you will learn:
- Possibilities to apply NbS in Southeast Asian countries.
- How social, cultural, and economic benefits are achieved by the projects.

11.1. INCREASING THE RESILIENCE OF CITIES – TEBET ECO PARK

11.1.1. Context

Tebet Eco Park (ArchDaily, 2025) is one of the urban parks in Jakarta, located in the South Jakarta Municipality. This 7.3-hectare park is crossed by an open drain with a length of 714 m and a road corridor that divides the area into north and south. The park is surrounded by several land uses, including dense residential areas, commercial and services, and education, with a fairly high density of land use (Figure 11.1.1). The park is accessible via a collector road served by public transport, making it easy to reach. The park was built in 1960 and first revitalized in 2010 as a public green open space in southern Jakarta. The park was revitalized again in 2022, when the Jakarta government commissioned SIURA studio to redesign the park.



Figure 11.1.1. Tebet Eco Park is surrounded by high-density land use (courtesy of SIURA studio)

11.1.2. Problem

Tebet Subdistrict is one of the areas in South Jakarta that has long been prone to flooding (Triuri & Marwasta, 2012; Aryanti et al., 2024). Tebet Subdistrict is crossed by several rivers, one of which is the Ciliwung – a large river with its headwaters in Mount Pangrango, West Java. Land use changes around the river and sedimentation caused by waste have reduced the capacity of the Ciliwung, causing it to flood during heavy rainfall. Meanwhile, prior to the second revitalization, Tebet Eco Park was described as a degraded public park. Not only was it used as a waste-dumping site with a polluted waterway, but the condition of the park's elements, both plants and hardscape, were also degraded because the park was frequently flooded.

Thus, the park was not functioning as a popular recreational park and had low or limited public use before its transformation.

11.1.3. Main goals

The revitalization of Tebet Eco Park focuses on regenerating the site's ecological functions through tree conservation and improvements to blue-green infrastructure, enabling the park to play a key role in flood mitigation in the area. River naturalization as an ecological approach has been implemented to reduce flooding. The landscape development concept is based on the main concepts of ecological function, social space, education, and recreation.

11.1.4. Implementation of Nature-based Solutions

Tebet Eco Park is redesigned as a public open space with an ecological approach. The facilities developed on the site broadly consist of a thematic garden, community and event lawn, children's playground, amphitheater, wetland boardwalk, forest buffer, and nursery (Figure 11.1.2). Referring to Pereira's et al. (2023) statement on the three types of Nature-based Solutions (see the chapter "Definition of Nature-based Solutions"), with these various facilities, we can consider that Tebet Eco Park falls into the Nature-based Solution category based on the establishment of new ecosystems. The implementation of Nature-based Solutions on the site is as follows:

1. **River re-naturalization of a 714-meter canal** into a wider, meandering waterway with **riparian planting** using native species; and a **floodplain** to boost hydraulic capacity, infiltration, and water cleansing.
2. **Green-blue infrastructure** across the site (wetland/retention areas, vegetated swales, permeable landscapes) integrated with paths and boardwalks.
3. **Tree conservation and circular construction**: above 1,500 existing trees surveyed and retained where possible; felled logs and canal stones **reused/upcycled** for furniture and play elements.
4. **Inclusive green connectivity with** the **Infinity Link Bridge** threads between mature trees to stitch the north-south parks without cutting vegetation, prioritizing universal access.

The first and second forms of implementation are key interventions in restoring the natural hydrological system to reduce the impact of flooding, the main objective of revitalization. By creating floodplains, riparian areas, retention ponds, vegetated swales, and rain gardens, the park helps mitigate urban flooding by absorbing and slowing stormwater runoff. These interventions are supported using native plant species, which contribute to improved water infiltration, enhanced biodiversity, and reduced maintenance requirements.



Figure 11.1.2. The landscape plan of Tebet Eco Park proposed by SIURA landscape architect consultant; the infinite bridge in the middle connects the north and south areas of the park, which are separated by a road (courtesy of SIURA studio)

11.1.5. Success story

Although it has only recently been revitalized, Tebet Eco Park has proven its success as an urban green open space that contributes significantly to addressing urban environmental issues. In relation to Nature-based Solutions, this park's success lies in its ecological services, particularly in regulating flood control and micro-climate comfort, supporting urban biodiversity enrichment, in addition to cultural services, since the park provides recreational opportunities for people. Through river naturalization, the hydraulic capacity of the waterway that crosses the park has increased significantly, helping to manage stormwater and reduce flood risk in the park and nearby areas (www.archdaily.com). The planting of various types of shrubs, including at least 80 native species, which has led to the creation of wildlife habitats, is an important effort in increasing urban biodiversity. Other than that, Tebet Eco Park has become one of the prominent green open spaces in Jakarta, which is able to accommodate the need for open space for the people of South Jakarta in particular.

11.1.6. Ecological impacts

Developed as a multifunctional green infrastructure, the park serves not only as a recreational space but also as an ecological buffer that enhances urban resilience. The tangible ecological impact of the park's development is flood reduction (Figure 11.1.3), where the application of Nature-based Solutions helps increase soil infiltration. Additionally, green corridors and tree canopies help regulate local microclimates, reduce the urban heat island effect, and provide habitat for birds and pollinators. Research by Mulyani et al. (2023) shows that the number of bird species in this park is quite high compared to other parks in Jakarta.

From these various impacts, it is evident that, in addition to hydrological management, the park's design promotes ecological connectivity and supports urban biodiversity. The ecological impacts that have emerged indicate that the Nature-based Solutions approach generates ecosystem services related to provisioning and regulating. This study shows that the implementation of Nature-based Solutions at Tebet Eco Park in Jakarta demonstrates how ecological principles can be integrated into urban public space design to address multiple environmental and social challenges simultaneously.



Figure 11.1.3. The revitalization of the canal to improve hydrological management to reduce the impact of flooding (courtesy of SIURA studio)

11.1.7. Economy, social, and cultural benefits

Tebet Eco Park (Figure 11.1.4) is now considered to have become an important public park for the people of Jakarta. In addition to its ecological impact, the revitalized Tebet Eco Park has been able to provide benefits in social, economic, and cultural contexts. It is no surprise that this park has a large number of visitors, reaching at least 4,000–5,000 people per day, which is far more than before the revitalization (Ryadi et al., 2024).

This park's contribution in the social dimension is mainly in its role as a recreational area that is accessible to all age groups, whether they are from Tebet, Jakarta, or outside Jakarta. This indicates the inclusiveness of Tebet Eco Park as an urban public green space. The park offers various facilities such as walking and jogging paths, lawns for exercise areas, and playgrounds with exploratory, motor-skill-developing equipment for children, promoting health and physical activities, as well as social interactions. Through the availability of interpretation signage, plant labels, thematic planting, wetland boardwalks, and the presence of flora and fauna, visitors are exposed to environmental education. Furthermore, playground areas designed with exploratory zones provoke children's curiosity about nature. Thus, this park provides its visitors with opportunities to gain insight and knowledge.

One of the unique elements in this park is the Infinity Link Bridge, which connects the northern and southern areas of the park. This bridge has become an iconic feature and symbol of the park. In addition, the development of themed gardens and art installations has enhanced the park's aesthetic appeal and provided visitors with distinctive experiences. Furthermore, this park offers several areas, including plazas and lawns, for gatherings and community programs. Either regular or one-off events, including festivals, concerts, and shows, take place in Tebet Eco Park. This evidence demonstrates that this park has provided considerable cultural benefits to people.

a



b



c



d



Figure 11.1.4. Tebet Eco Park today: the naturalized channel and floodplain which also serves as lawn for visitors (a); the Infinite Bridge has become icon of the park (b; courtesy of SIURA studio); Children playground is one of important facilities for visitors. The pathway enables connections and visitors' movement (c); Outdoor gym supports visitors' health (d)

Tebet Eco Park contributes to the local economy. A previous study that perceived the park as a sustainable tourism destination found that visits to the park increased street vendor turnover by up to 30% (Ryadi et al., 2024). The park itself was designed to accommodate MSMEs (micro, small, and medium enterprises), which have created business opportunities in food, drinks, and souvenirs. Moreover, as park visitation drives demand for transportation, Tebet Eco Park has driven 30% of indirect contributions via transportation (Ryadi et al., 2024). Furthermore, since the surrounding area of the park has become a strategic location, several small cafes and restaurants have emerged; thus, Tebet Eco Park has potentially increased property values.

From the Tebet Eco Park case study, we can learn two important things. It is clear that an ecological approach can be integrated into public use to deliver co-benefits for climate adaptation, biodiversity enhancement, and human well-being.

Thus, we see that a well-designed Nature-based Solution can provide multiple benefits for the environment and people. This aligns with the IPCC (2023) statement that Nature-based Solutions also help people immediately by reducing flood risk, cooling cities, supporting biodiversity, and strengthening livelihoods, thereby advancing mitigation and adaptation together. In conclusion, Tebet Eco Park serves as a model of urban landscape planning that aligns environmental goals with community needs.

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11.2. INCREASING THE RESILIENCE OF CITIES – BENJAKITTI FOREST PARK

11.2.1. Context

Benjakitti Forest Park is in Bangkok, Khlong Toei District, Thailand, and serves as a model of ecological restoration. The park sits amid high-rise office towers, luxury condominiums, hotels, and major commercial districts (Asoke–Ratchadaphisek area). It is directly connected to Queen Sirikit National Convention Center and near BTS (skytrain) and MRT (subway) stations, making it highly accessible to both locals and tourists. Benjakitti Forest Park is defined by its transformation from a former industrial tobacco factory in the heart of Bangkok into a multifunctional ecological forest park that restores natural systems, mitigates flooding, and provides urgently needed green space for residents in a dense urban core.

11.2.2. Problem

Located on the Chao Phraya river delta, Bangkok is a densely populated city with more than 10.5 million residents. The urban area is flat and low-lying, with an average elevation of just 1.5 m (4 ft. 11 in.) or less. Most of the area was originally swampland, which was gradually drained with canals and extensive groundwater pumping and irrigated for agriculture. The region experiences a monsoon climate with an average precipitation of about 1,500 mm (59 in.) per year. Extensive groundwater pumping has caused severe subsidence; coupled with the effects of global warming, this has increased flood risk due to Bangkok’s low elevation and inadequate drainage infrastructure. Heavy downpours cause urban runoff to overwhelm drainage systems, leading to severe flooding that affects much of the city.

The project is in central Bangkok’s Khonti District, covering about 41.3 ha (102 acres). The site was formerly a tobacco factory, densely occupied by single-story warehouses, with a number of canopy trees scattered between them. The site is surrounded by Phaisingto Canal to the north, which was contaminated with urban runoff and sewage; Duang Phithak Urban Expressway to the west, which cuts the site off from the adjacent community; an artificial lake to the east; and a hospital, hotel, and the Queen Sirikit National Convention Center to the south. In addition to the challenges of the site itself, the budget for this project was limited (ultimately capped at 20 USD per 1 m2), and the project was expected to be completed in just 18 months. An additional challenge was that the project was overseen by the army, which lacked extensive experience managing landscape projects.

In addition to a high potential for flooding, the canal on the northern edge of the site is heavily contaminated. Except for the creation of a small museum for the tobacco factory and a sports center, there were no programmatic requirements for the site. Our team's design was selected through an international competition.

11.2.3. Main goals

To tackle the various challenges posed by the site and its densely populated urban environment, the project was conceived as a central park designed to offer comprehensive ecosystem services to the city. This includes managing stormwater to adapt to the evolving monsoon climate, serving as a model for nature-based solutions that filter polluted urban runoff, supporting native species, and providing essential public spaces for recreational and cultural activities. The design approach was guided by four key strategies: 1) reuse and recycle, 2) creating porosity and wetlands, 3) low maintenance by fostering a "messy" nature, and 4) creating immersive places for people.

Reuse and recycle. All existing trees on the site were preserved and incorporated into the park's design. To keep costs manageable, all major roads were retained. Existing factory structures were repurposed to accommodate the sports center and museum, seamlessly integrated into the landscape. Materials from demolished concrete were recycled for use in earthworks and paving.

Creating porosity and wetlands. First, cut-and-fill techniques were employed to establish wetlands featuring islets, created without the need to import or export soil. This process transformed the previously impermeable concrete ground into a spongy, porous landscape capable of retaining up to 200,000 m^3 (23 million gallons) of stormwater during the monsoon season. The modified landscape also turned hard clay soils into wet, spongy habitats, encouraging a rich native plant community to thrive with minimal irrigation during dry spells. The design can be executed with a single excavator, reducing reliance on skilled labor. Each islet's foundation was reinforced using recycled concrete materials. While existing trees were preserved at the center of the islets, young canopy tree seedlings were planted on newly constructed mounds at low cost. The three main wetlands feature two depths: a shallow, terraced edge and a deeper central area. The terraced edges connect to a linear wetland that remediates water quality by filtering polluted canal water, capable of improving 8,152 m^3 (2 million gallons) of water daily from Grade V to Grade III. This filtered water sustains the wetlands during the dry season, transforming the shores into a vibrant ecotone that supports a lush plant community. Second, while the major roads were preserved and reused, a cut was made in the middle of each roadway to create a permeable bioswale and flower bed that separates a bicycle lane and pedestrian path, helping to bring a more human scale to what were originally wide roads designed for heavy truck traffic.

Third, for the sports center and museum that make use of existing buildings, the principle of porosity was also applied to transform the factory buildings by daylighting portions of the roofs and allowing the living landscape to penetrate through the buildings' concrete shells.

Low maintenance by fostering a "messy" nature. Altered landform, with its variety of micro-environments, was seeded and planted with tree seedlings, laying the groundwork for a self-sustaining semi-natural plant community. The result is a low-maintenance mosaic of vegetation that naturally flourishes with native species. An ecological partnership is forming between the flora and fauna, and the "messy" nature of the constructed wetland is creating a dynamic, diverse aesthetic that contrasts sharply with the urban surroundings (Figure 11.2.1).

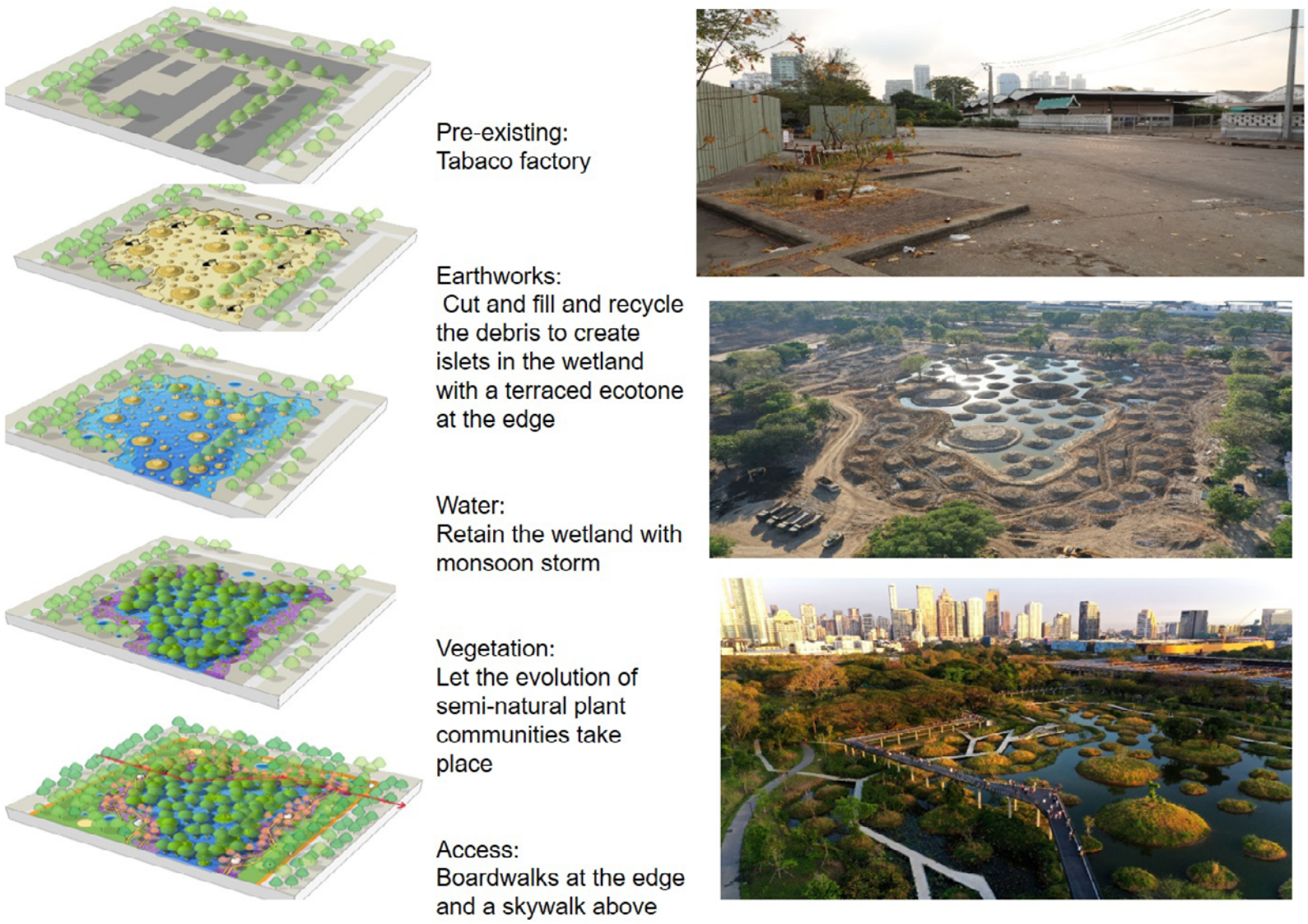


Figure 11.2.1. Benjakitti Forest Park pre- and post-construction (© Turenscape and Arsomsilp Community and Environmental Architect; Turenscape, 2023)

Creating immersive places for people. Numerous boardwalks were designed along the edges of the shallow wetlands, allowing visitors to connect with urban nature. A skywalk suspended through the tree canopies, linking the entire park, which was historically divided by major roads, and providing a unique immersive experience amidst the tropical greenery (Figure 11.2.2).

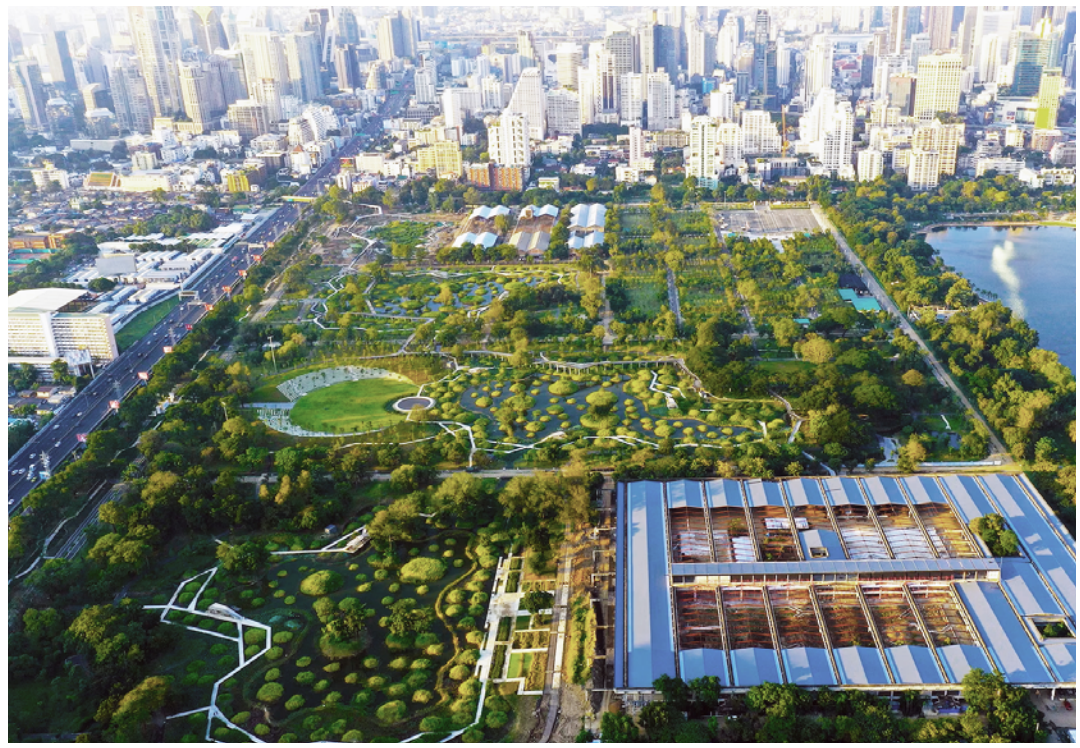






Figure 11.2.2. An elevated skywalk crosses the forest canopy in the Benjakitti Forest Park (© Turenscape and Arsomsilp Community and Environmental Architect; Turenscape, 2023)

11.2.4. Implementation of Nature-based Solutions

As categorized by Eggermont et al. (2015), the landscape architectural design of Benjakitti Forest Park exemplifies an effective approach to developing new ecosystems. The park repurposes the former tobacco factory site, transforming a previously industrial landscape into an urban forest and artificial wetland. This section will delineate the design process of Benjakitti Forest Park, encompassing design concepts and strategies, construction methodologies, and ongoing landscape maintenance (Sung, 2023).

The design concept and strategy were influenced by Queen Sirikit's speech: "If His Majesty is regarded as 'Water', I will be the 'Forest', and the 'Forest' will always be supportive and loyal to 'Water'." The park's design aims to integrate both forest and water elements, reflecting the ecological balance found in nature. Four sub-concepts were introduced for the forest park: Water + Forest Ecological Park, Living Learning Center, Urban Ecological Infrastructure, and Urban Forest Model (Likitswat & Sung, 2025; Table 11.2.1).

Table 11.2.1. Design concepts related to Nature-based Solutions for Benjakitti Forest Park (Likitswat & Sung, 2025)

Sub-concept	Project's aim, goal, and highlight
Water + Forest Ecological Park	Restore the native habitat, and create a large water storage area in the city center of Bangkok
Living Learning Center	Provide an outdoor learning space emphasizing the value of the forest and environment
Urban Ecological Infrastructure	Recreate a new "urban lifestyle" embracing urban-nature activities
Urban Forest Model	Design an ecological park to maximize the city's benefit, promote sustainable management, and urban forest to other urbanized areas

The following sub-concepts are connected to eight design strategies that draw inspiration from nature to effectively address urban challenges and improve the functionality of public parks. These strategies are designed to tackle a range of urban issues, including habitat preservation, stormwater management during both flood and drought conditions, urban wastewater management, and the constraints posed by limited natural resources and energy. Furthermore, they address challenges related to human resources and budget constraints, as well as connectivity, accessibility, and the scarcity of open green spaces. The primary objective is to promote Nature-based Solutions within the urban area of Bangkok (Table 11.2.2).

Table 11.2.2. Urban challenges and design strategies and Nature-based Solutions for Benjakitti Forest Park (Likitswat & Sung, 2025)

Challenge	Design strategy
Stormwater management; flood and drought	1. Managing the monsoon climate. The park is envisioned as a “sponge”, capable of retaining and discharging water during both rainy and dry seasons. The wetland area has a storage capacity of 128,000 m^3, designed to respond to floods and droughts throughout the years.
Urban wastewater	2. Using natural systems for wastewater treatment. This strategy involves the use of a constructed wetland and an artificial pond system to treat wastewater from Khlong Phai Singto (canal), located north of the park. Approximately 1,600 m^3 of wastewater can be effectively treated, particularly during the dry season.
Habitat preservation	3. Preserving existing trees in the project area. Existing trees within the project area were deliberately preserved to maximize the utilization of natural resources. Simultaneously, this approach helps reduce costs associated with transplanting new trees into the park.
Limited natural resources and energies	4. Reusing and recycling material onsite. A balanced approach to cutting and filling the soil onsite was calculated and designed to minimize energy consumption during transportation. Demolished concrete waste from previous buildings was repurposed onsite. Serving as a concrete stone in the eco-canal. Additionally, some buildings and warehouses were retrofitted into museum and sports facility spaces with a focus on sustainability and energy efficiency.
Limited human resources and budget	5. Reducing long-term maintenance. The design of the wetland park incorporates local knowledge from traditional raised bed gardens. This technique facilitates the tree roots in absorbing both air and water efficiently, consequently reducing the need for long-term landscape maintenance on the trees.
Poor connectivity and accessibility	6. Opening access to the public. The park is designed to establish connections with other public parks and surrounding communities through pedestrian pathways and skywalks, enhancing accessibility for the public.
Habitat preservation	7. Creating an ecological forest park. Developed from a former industrial site, the design of the forest park establishes a new habitat with over 400 species of the local plant community. Approximately 5,600 new saplings of rare native species have been introduced, transforming the park into an outdoor learning space for local plant species and the community.
Lack of open green space	8. Providing recreational space for all. The park serves as a space for the community and urban residents to engage in recreational activities. Simultaneously, it serves as a home for urban wildlife and other creatures, creating an ecological space that seamlessly integrates urban activity and nature within the city.

11.2.5. Success story

Despite having been built on an extremely compressed timeframe, Benjakitti Forest Park has proven a great success (Figure 11.2.3). While much of Bangkok was flooded summer of 2025, the park and its immediate vicinity were not. The water-quality remediating wetland is performing well and produces enough water to keep the wetland alive through the dry season. A wide variety of birds and other wildlife have taken up residence in the park. The most striking achievement is that this naturally regenerative system is now the largest park in densely populated central Bangkok and attracts tens of thousands of visitors daily, who use it for a wide variety of activities, including jogging and cycling, family gatherings, school commencements, picnics, dates, and wedding photographs. It has been celebrated extensively on social media as a new symbol of Thailand's capital city.



Figure 11.2.3. Tree islets that are centered with the preserved trees were constructed through modular design (© Pierrick; Yu & Wang, 2024)

11.2.6. Ecological impacts

After the construction of Benjakitti Forest Park, the ecological impacts are significant because the project transforms a brownfield industrial site into a resilient urban ecosystem, improving biodiversity, water management, air quality, and climate regulation, while providing ecological education for the city (Figure 11.2.4).



Figure 11.2.4. All existing trees on the site are preserved and integrated into the design (© Turenscape and Arsomsilp Community and Environmental Architect; Yu & Wang, 2024)

These are the six main ecological impacts of Benjakitti Forest Park:

1. Urban biodiversity restoration

The park introduced native forest species, wetlands, and meadows into central Bangkok. It provides habitat for birds, insects, amphibians, and aquatic species that previously had little to no refuge on the industrial site. This supports urban ecological corridors, connecting with nearby green areas.

2. Improved water management and flood mitigation

The park integrates constructed wetlands and retention ponds. It absorbs and stores stormwater, reducing urban flooding in adjacent neighborhoods. Polluted runoff from surrounding streets is filtered naturally through wetland plants, improving water quality.

3. Carbon sequestration and climate regulation

Thousands of trees planted across the site capture carbon dioxide, mitigating climate change impacts. Shaded forest canopy reduces the urban heat island effect, lowering local air and surface temperatures. The microclimate becomes cooler, more humid, and more comfortable.

4. Soil and air quality improvement

Vegetation stabilizes soil and reduces erosion compared to the previous paved/ industrial condition. Plants filter dust and air pollutants, improving urban air quality.

5. Ecological education and awareness

The park functions as a living ecological classroom, showcasing forest succession, wetland ecology, and biodiversity. Visitors learn about Nature-based Solutions and sustainability through direct experience.

6. Long-term ecosystem services
This park's existence supports urban pollinators (bees, butterflies, birds). It enhances groundwater recharge. Furthermore, it creates an ecological buffer that helps Bangkok adapt to climate resilience challenges (heat waves, intense rainfall).

11.2.7. Economic, social, and cultural benefits

Benjakitti Forest Park is not just an environmental project; it generates economic savings and local economic growth, social well-being and inclusivity, as well as cultural identity and education, making it a model of multifunctional urban green space. Benjakitti Forest Park has become an important symbol of Bangkok's transition toward green urbanism and sustainable city development, reinforcing the city's cultural identity while promoting environmental awareness (Table 11.2.3).

Table 11.2.3. Benefits generated by the Benjakitti Forest Park

Aspect	Benefit
Economic	• Provides the largest public recreational space in central Bangkok, attracting tens of thousands of visitors daily, which supports local businesses and generates economic activity. • Built with a relatively low cost ("limited budget") in a compressed timeframe (18 months) demonstrates cost-efficiency in urban park development. • Reuse/recycling of materials (demolished concrete, existing trees/ buildings) reduces construction and material costs (Turenscape, 2023; ASLA, 2024; Yu & Wang, 2024).
Social	• Offers new public amenities (running, cycling paths, boardwalks, skywalk, amphitheater) that support the health, recreation, and well-being of city dwellers. • Inclusive and accessible design: paths and skywalks that allow people from around Bangkok to access nature, including diverse ages and abilities. • Community gathering: park accommodates events (cultural and recreational), places for family gathering, picnics, and leisure (Arifwidodo & Chandrasiri, 2021; ArchDaily, 2023).
Cultural	• Adaptive reuse of old tobacco factory buildings into an indoor sports center & museum preserves historical/industrial heritage. • Incorporation of art and culture: art installations ("Greeting Benjakitti") that connect nature, public art, pollination themes (stingless bees), etc. • The park acts as a living "botanical classroom" where people can learn about native plant species, ecology, and hydrology. • Symbolic value: becoming a "new cultural symbol" for Bangkok, representing green urbanism, sustainability (Bangkok Post, 2023; Yu & Wang, 2024).

Review questions:

1. How are NbS implemented in Tebet Eco Park?
2. What are the social, cultural, and economic benefits of NbS implementation in Tebet Eco Park?
3. What potential challenges exist in maintaining long-term funding for green infrastructure, such as the Benjakitti Forest Park?
4. How does Benjakitti Forest Park demonstrate the social benefits of NbS?

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12. CONCLUDING REMARKS

Climate hazards are increasing worldwide. The consequences of climate change are appearances of heatwaves, floods, droughts, sea-level rise, and more, which sometimes have drastic consequences on ecosystems, species, and human well-being. Promising approaches to counteract these problems consider the dynamic nature of complex socio-ecological systems. Accordingly, Nature-based Solutions, which, by definition, should benefit both humansand nature, seem to be a useful tool to deal with the climate problems. They have their fundamentals in established practices such as ecological engineering and can be considered as an essential mechanism for achieving sustainable development.

There are three types of Nature-based Solutions: characterized by minimal or no interventions (Type 1), the restoration or management of traditional ecosystems (Type 2), or the establishment of new ecosystems (Type 3). Nature-based Solutions are highly valuable for meeting the demands of many important international initiatives and conventions. For example, they can impact more than 90% of the 17 United Nations Sustainable Development Goals and can be a very suitable tool to help achieve the targets of the European Green Deal.

The role of landscape architecture is important in implementing Nature-based Solutions. Modern projects of landscape architecture should, among others, be directed towards sustainable development. Thus, a clear intersection between landscape architecture and Nature-based Solutions can be identified. Landscape architecture can contribute to the development and implementation of Nature-based Solutions and secure the sustainable development of regions on different spatial and temporal levels.

An important aspect of implementing Nature-based Solutions is defining their goals. It is also very important to integrate all relevant stakeholders from the beginning (i.e., already during the planning phase). Realization of Nature-based Solutions should be accompanied by monitoring, which allows for the objective assessment of their outcomes (for example, co-benefits and trade-offs) and enables adaptive management of the respective implementations. Accordingly, monitoring approaches need to be holistic, focusing on environmental, economic, and social aspects, to be balanced between these pillars, and to have an adequate lifetime and to cover an adequate space.

As shown by the presented examples, the regional context plays an important role. Environmental conditions and cultural background are decisive regarding challenges and design strategies for Nature-based Solutions. However,

as the examples demonstrate, basic principles seem to be consistent, which is also based on the eight criteria for Nature-based Solutions defined by the IUCN Global Standard for Nature-based Solutions. Common features of such implementations seem to include goals aimed at sustainable development, with ecological aspects having a strong focus on conservation of biological diversity, support of aesthetic features, and the longevity of the implemented measures.

13. RECOMMENDED READING

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