Urban Forest Living Lab - 'Urban Symbiosis'

Vital Soil as Foundation for Future Proof Urban Forestscapes - Experimenting in Real Time Locations with Different Actors in The Hague

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Abstract

This essay reports on a 'living lab' approach to develop a new understanding of below- and above-ground ecological processes as the foundation for robust urban forest habitats. This experimental approach includes a series of design and implementation projects in the city of The Hague, the Netherlands. In contrast to mainstream greening projects led by local governments, these experiments enable urban trees to form more robust forest-like systems by creating a symbiosis between soil (organisms), trees, plant communities, and species. As implemented reference projects are limited, a learning-by-doing methodology was adopted. A transdisciplinary team, consisting of landscape architects/designers, arborists, botanists, municipal and private green space maintenance organizations, has initiated, implemented, and monitored a series of pilot projects. Analysis of ten natural reference locations in the surrounding countryside has helped to define natural and forest-like soil conditions and plant communities for the three living lab locations in the city. Local residents have been engaged in the design, implementation and maintenance process. Sharing insights so far contributes to the transition of reconnecting soil, nature, and people in cities.

Keywords

Biodiversity, co-creation, landscape architecture, residents, soil health, transdisciplinary research, urban forest, urban green space, urban transformation.

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Introduction

We present an ongoing experimental design and implementation project in the city of The Hague, Netherlands—a 'living lab' aiming to develop a new understanding of below- and above-ground ecological processes as a foundation for robust urban forest habitats. Contrary to mainstream greening projects in local governments, this project allows urban trees to form more robust forest-like systems, providing a wide range of ecosystem services. As implemented reference projects are limited, we adopted an experimental, learning-by-doing approach. In a series of pilot projects, our transdisciplinary team has initiated, implemented, and analyzed/monitored symbiosis between soil (organisms), trees, and plant communities. Analysis of ten natural reference locations in the countryside helped define natural and forest-like soil conditions [fig. 1] and plant communities for three urban locations. The projects were established in close collaboration with landscape architects, arborists, botanists, municipal and private green space maintenance organizations, and local residents. By sharing our insights so far, we hope to contribute to the slow transition of reconnecting soil, nature, and people in cities [fig. 2].

In academia, there is increasing awareness of the importance of urban forestscapes and associated vegetation in providing essential ecosystem services (Livesley et al., 2016). Strengthening the network of local green spaces will result in biodiversity, public health, and climate adaptation benefits, as reflected in the 3-30-300 rule for urban forestry (Konijnendijk, 2022). Urban trees should not be isolated but given the opportunity to form forest-like systems with vital soils and natural planting communities. Such forestscapes are more resilient than isolated trees and create more sustainable living environments by enhancing public health, climate change adaptation, and biodiversity (Livesley et al., 2016). However, in the professional practice of local governments, city trees are often planted in isolation, as 'urban furniture', with little consideration of the actual and natural soil habitat [fig. 3] or planting communities (Smith et al., 2019).

The Dutch government recently introduced a new policy on strong soil and water systems (*Kamerbrief Water en Bodem sturend*, 2022). Local governments have also adjusted their long-term ambitions for urban green spaces. For example, the municipality of The Hague has embraced Konijnendijk's (2021) 3-30-300 rule (*Haags Akkoord*, 2023–2026). Furthermore, The Hague's tree policy document (*Gemeente Den Haag*, 2021) aims to develop a strong and resilient network of healthy forests and urban trees with large canopies and good growing conditions.

However, developing, designing, and maintaining robust urban forest habitats has not progressed as far in practice as in theory. How can these ambitions be realized in specific projects where, contrary to the mainstream approach, natural soil and environmental conditions form the basis for the design, establishment and maintenance of forest-like habitats? At the moment, well-described reference projects are lacking. Therefore, this project aims to answer the following research question: What is a new approach to designing, implementing, and maintaining novel, functional public green spaces that align with ecological conditions and processes above and below ground?

This essay describes methods and discusses lessons learned (on co-creation, maintenance, etc.), related to both successful and unsuccessful results. Identifying, analyzing, and piloting good examples on an accessible scale (a park, a square, or a street [fig. 1]) and starting a dialogue 'on-site' is a starting point for opening up to new ideas. Three pilot projects with different types of public space were developed in The Hague since 2020: a park (implemented in 2021, monitoring ongoing [fig. 12-16]), a square (implemented in 2022, monitoring ongoing [fig. 17-20]), and a street (ongoing preliminary test on the TU Delft campus [fig. 22]).

In these pilots, a flexible collective of participants was brought together to jointly tailor solutions for each project. Participants included designers, arborists, botanists, municipal and private green space maintenance organizations, and local residents. To provide inspiration for the three pilots, ten existing woodland areas in South Holland were studied [fig. 4]. These reference locations vary in form and environment: from old to young woodlands, wet to dry landscapes, and natural to anthropogenic soils. They provide ecological insights into the diverse regional plant communities and their successional patterns, both above and below ground [fig. 5].

So far, the first tangible projects have been implemented in The Hague, with an emphasis on valuing the knowledge of all parties and implementing a design methodology in the steps: (a) soil detemineration, (b) viatal soil development, (c) co-creation with locals [fig. 6-10]. This is a soft and gradual way of achieving an inclusive and ecological transformation towards better greening practices in the city. This encompasses a process of discovery for new nature types that could develop in urban settings, reflecting the local landscape. The pilots are tools to organize and start this process, serving as a bridge between the municipality's parks, landscape, technical, mobility, and maintenance units, and the people living, working, and learning in the district. The nature-based methodology has received positive feedback from different perspectives and seems logical to stakeholders and residents. However, working with urban space from the perspective of a new aesthetic and with less conventional maintenance to cater for more ecological and recreational value remains challenging. Quick results are often expected, but natural development takes time, which calls for managing expectations [fig. 16]. Continuous monitoring provides insight into the pilot projects' development and important information to stakeholders and site managers.

We hope that, in the longer term, this project will inspire evidence-based and bottom-up greening initiatives in The Hague, Delft and other cities, helping to create ecological networks of green and brown infrastructure benefiting inhabitants [fig. 22]. Scaling up within the broader context of climate action, the project provides practical knowledge for more intra-municipality dialogue and collaboration. We aim to contribute to urban forestscapes that grow over time, encouraging ecological succession and resulting in green spaces that promote health and well-being in dense urban environments. Projects like these can help citizens reconnect with the slow growth of trees, enhancing nature contact and reinforcing a sense of place and social inclusion centred around sound green space stewardship.

Acknowledgments

Residents who participated in the co-creation process. Biology B.Sc. students from Leiden University have been joining monitoring campaigns since 2020. René Hoonhout, Head of Green Maintenance at the TU Delft Campus.

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FIGURE 1 *Urban symbiosis*. An ongoing experimental design study and 'living lab' understanding below- and above-ground ecological processes as a foundation for urban forest habitats. Using an ecological focus as a starting point for designing public spaces, the project team aims to reconnect soil, trees, and people in urban environments and regain a sense of identity with site-specific nature types for a specific place.

FIGURE 2 *Crossover discipline research by design*. We propose a research-by-design collaboration between practice and science, exploring soil as a support for urban forestscapes, experimenting on soil life, and testing more diverse 'forest-like' plantations for contrasted cityscape typologies, setting up comparative studies.

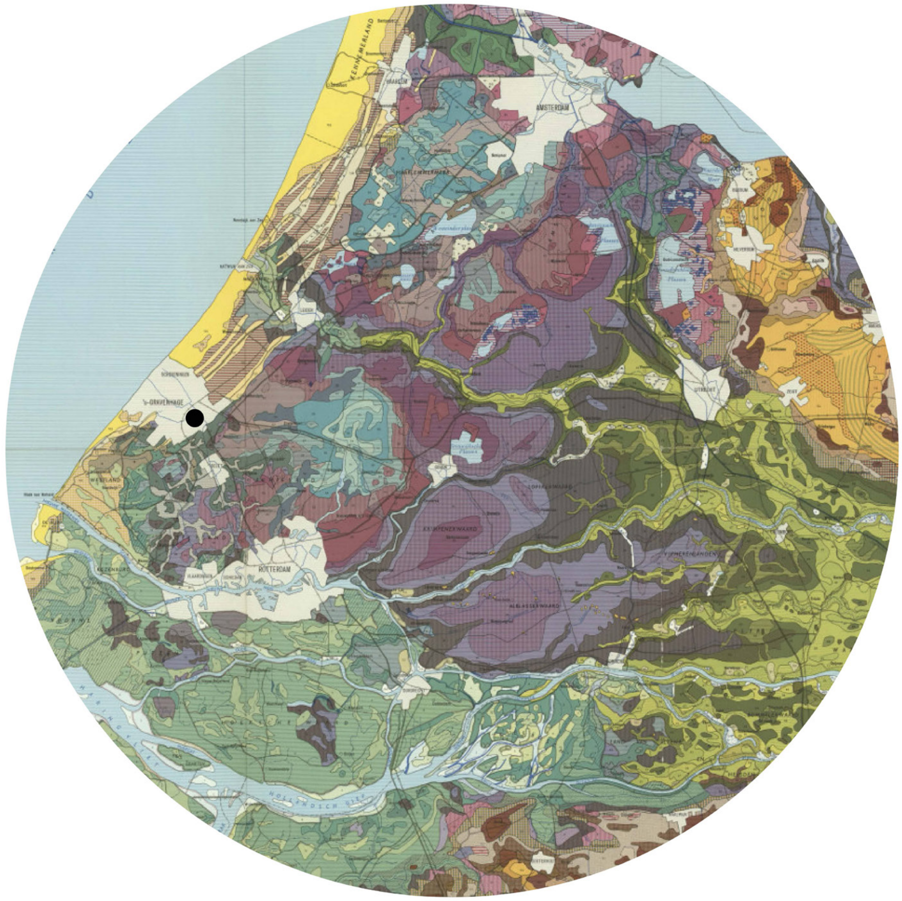


FIGURE 3 *Soil map of South Holland*. Soil maps are fascinating as they often leave blank spaces in urban settings. By having pilots in the city and reference locations outside the city, we hope to colour this type of map again: with very specific colours of soil for very specific nature for the people.

FIGURE 4 *Three living labs in The Hague and ten comparative locations in South Holland*. Together with the Municipality of The Hague, we are now working on three pilot projects, which represent three contrasted types of public space: a park, a square, and a street. The aim is to improve the living environment in the Laak district in The Hague and gaining knowledge for other cities. As a basis for the pilots, we first studied several forest sites in South Holland. These provide ecological insight into regional plant communities and their succession patterns.

FIGURE 5 *Example of monitoring at one of the ten reference sites: "Rotterdam Kikkerpad"*. The flora and fauna were monitored above and below ground. From these data, a specific plant community was determined, including the main target species for plants and underground insects, which was later used as a basis for the urban pilot projects.

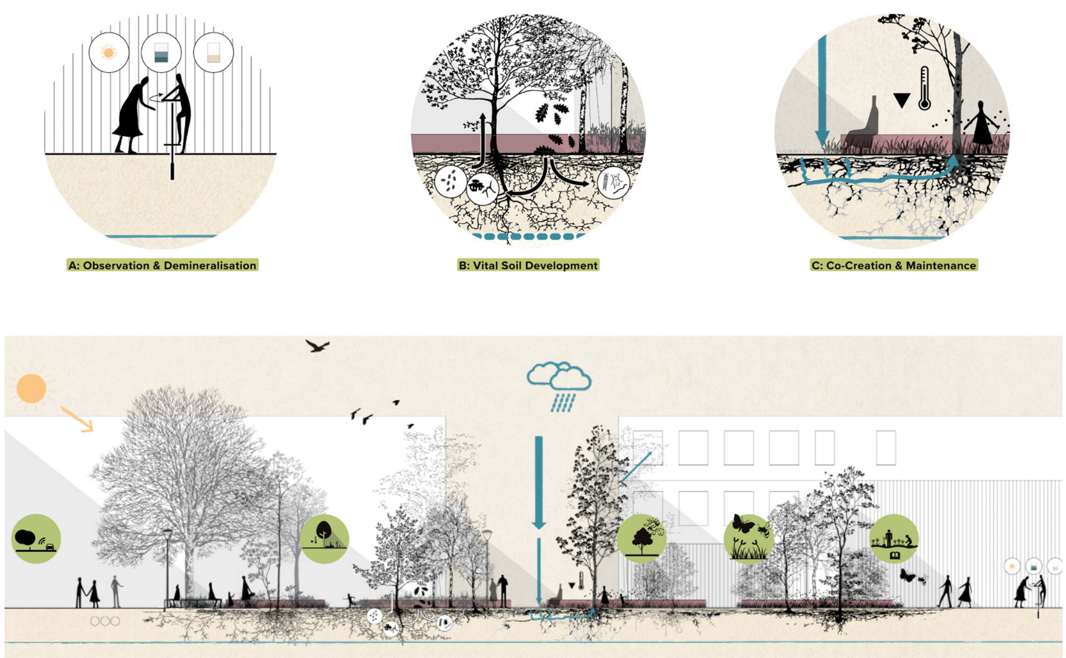


FIGURE 6 *A design methodology based on observation*. The degree of sunlight, shade, soil moisture characteristics, and soil type determine which natural habitat, its reference in South Holland, and its corresponding planting type are applicable for a specific urban location. Climate adaptation of the urban environment is therefore designed from the habitat of trees. Based on this initial analysis, three design principles were used in the pilots: A: soil demineralization, B: vital soil, and C: co-creation.

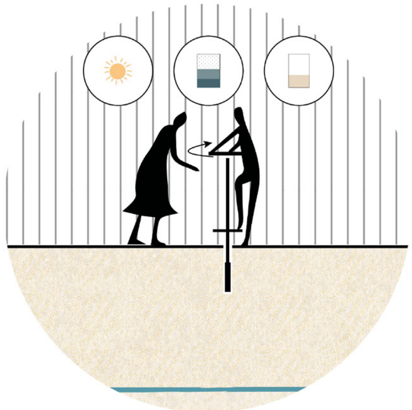


FIGURE 7 *Design principle A: observation and soil demineralization*. Soil demineralization is crucial when providing open spaces where generous, multi-stage planting can develop, and when allowing for biodiversity to flourish and proper rainwater drainage.

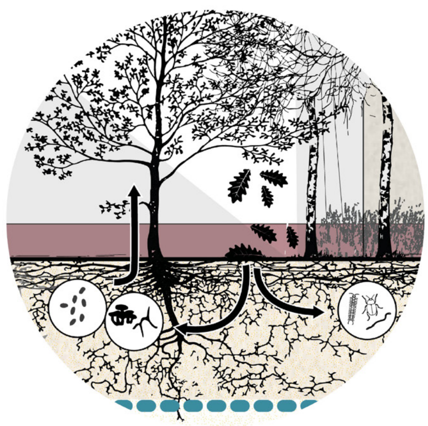


FIGURE 8 *Design principle B: vital soil development*. At the same time, we apply methods to develop a soil structure that is favourable to soil life. We install successive layers of soil materials (input or soil from the site) and plant materials of various kinds (woody debris, green waste, straw, leaf compost, etc.). This bedding reproduces the structure of forest soils, mimicking the natural process of humus production. Maintaining plant cover and/or mulching at all times of the year is then a next step to limit evaporation in favour of evapotranspiration.

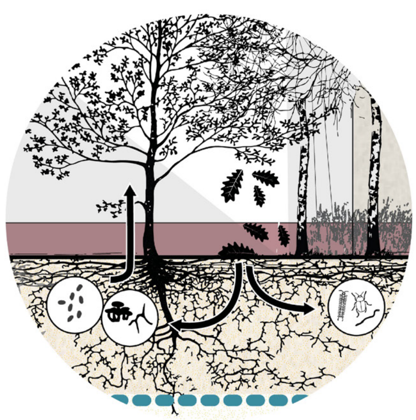


FIGURE 9 *Design principle B: vital soil in constrained areas*. Close attention is paid to all technical solutions that will make it possible to link the various open soil spaces. To improve the soil in more challenging sites, for example, due to paving conditions and/or car traffic, techniques known as 'second soil levels' can be used; these retain water under the paving and allow more oxygen to penetrate the soil.

FIGURE 10 *Design principle C: co-creation and maintenance*. We aim to co-design and develop scenarios with inhabitants for the joint and locally appropriate development of nature in the city. In this way, we want to propose a realistic vision of what is feasible and can be expected under local constraints and the impacts of, for example, climate change. The aim is to enhance and protect these new green spaces but also to create gradients or transitions towards more cultivated areas that residents can make their own, creating an attractive nature-culture gradient in dense urban environments. Gradients and variation can be created through different types and intensities of management and for different recreational uses. To provide robust public spaces, more attention to detail is needed. For example, between wooded areas and pavements, rest areas can be created to ensure the transition between the mineral ground and the planted ground, with grass-covered joints.

FIGURE 11 *Three living labs in the Laak district of The Hague, including a pre-test on the TU Delft Campus: three types of public space*. The pilot examples demonstrate nature-based and realistic solutions to create good conditions for nature development on challenging typologies such as narrow linear streets, densely used parks, and car-dominated squares.

FIGURE 12 *Pilot project 1: Park Slachthuisplein – implementation 2021*. The project area is an existing park with existing trees adjacent to a planted street. The goal was to diversify the tree canopy and implement a 1,200 square metres forest strip at the edge of the park, as well as an ecological gradient from tall trees to smaller trees, shrubs, and herb vegetation. Human activities have deeply transformed the initial peat landscape. The water level is low, and the soil is sandy. The environmental conditions are extreme, with the heat island effect and wind. The planting palette is inspired by reference locations in the back-dune forest habitat, where similar environmental conditions can be found. Space is given to allow planted species and spontaneous ones to grow together to form an urban plant community. A succession strategy was set up, inspired by the dune forest community. Clumps of pioneer species such as *Betula pendula* and *Sorbus aucuparia* were planted in a protective, nourishing bed of shrubs and dune grasses. They will improve the soil and prepare it for slow-growing successors such as *Quercus robur* and *Acer pseudoplatanus*.

FIGURE 13 *Pilot project 1: Park Slachthuisplein – soil development*. A site-specific method to sustainably enrich the soil was defined. Instead of being replaced, the first 40 centimetres of the soil was mixed with specific compost, biochar, and worms. Soil profile rebuilding (Day & Bassuk, 1995; Heyman et al., 2019; Percival et al., 2023; Sax et al., 2017) was used to make the soil more fertile. A specific mix of compost, biochar, and earthworms was mixed through the first 40 centimetres of the soil (Darwin, 1882; Müller-Inkmann, 2020). The amount of compost was calculated to increase the percentage of organic matter from 1–2% to 4–5%. At locations with grass, the existing soil was somewhat more fertile than locations under pavement. These variations will result in slightly different microhabitats, microbiology, and plant species. A mulch layer did not fit into the budget, so we used litter and dead plant residues in the first autumn as a starter for a mulch/litter layer.

FIGURE 14 *Pilot project 1: Park Slachthuisplein – participation*. The local community was involved, with the participation of the Vadercentrum Adam for the construction of bird and bat houses that were placed on-site. After implementation, the site was closed for three months to allow soil and plants to develop before it was opened to the public. In the meantime, a banner was placed on the site explaining the design principles to residents.

2. Methodology

2.1 Study site

On the location of the Slachthuisplein (N 52° 03' 50.5" and E 4° 19' 20.9"), three different locations were determined: an area within the ganivelle fences with artificially composed soil (see Figure 1, location 1), an area within the ganivelle fences with soil enriched with biochar (see Figure 1, location 2), an area outside the ganivelle fences which contains soil composed of the soil that was present before the Slachthuisplein was redesigned (see Figure 1, location 3). The steel fences are temporary, they help in the early stage of growth of the seed mixture, grasses, shrubs and trees. Besides these fences, wooden fences are present to keep out humans and garbage. The soil composition in each area and the vegetation used is elaborated in section 2.2. Apart from the Slachthuisplein, another location outside the Hague is selected to function as a reference location: The Blink in Noordwijkerhout (N 52° 16' 41.9" and E 4° 28' 39.4"). This natural location consists of a dune-forest like landscape, after which the project is designed.

Figure 1. Overview of the locations at Slachthuisplein in the Hague. Locations 1, 2 and 3, where the samples were taken, can be seen here.

2.2 Experimental design

At these four locations, five randomly distributed samples were taken every two weeks over a period of 10 weeks. Thus, data of six visits to the Slachthuisplein and The Blink were collected. The random sampling is done, according to the *Sampling for Biostatistics* procedure, see section 2.5. (Mícic, 2016a, pp. 15-24). The samples were taken, using Tullgren Funnels, or a so-called Berlese Apparatus (see Figure 2).

The samples were taken with the use of a small shovel (by hand), shoveling 20 cm into the ground. The soil was stored in the top jar of the Tullgren Funnel. The bottom jar was filled with 200 mL water, in which 20 grams of salt was dissolved. After sample collection, the samples were stored in a shed, creating a small home experimental design, due to Covid-19. Two heat lamps with 150W white light were placed above the twenty Tullgren Funnels. The distance between the heat lamps and the Tullgren Funnels was 60 cm. The warmth of these lamps desiccated the soil and the present soil animals were driven out, through the filter, to the bottom part of the Tullgren Funnel, where they would end up in the salty water. All materials used are described in section 2.4.

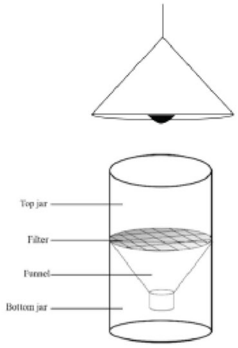
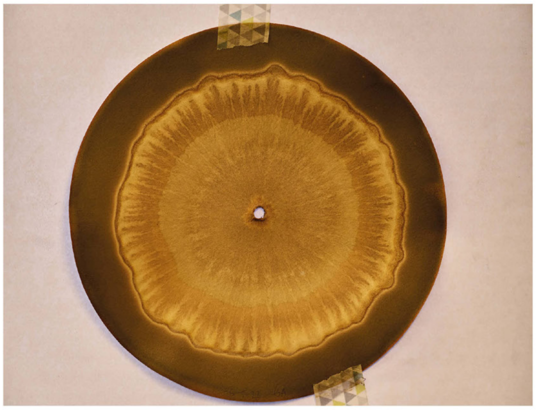
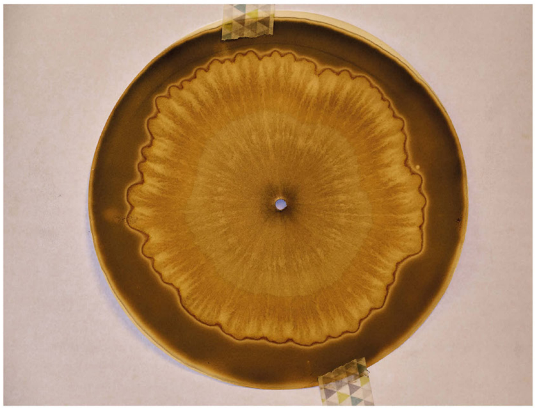
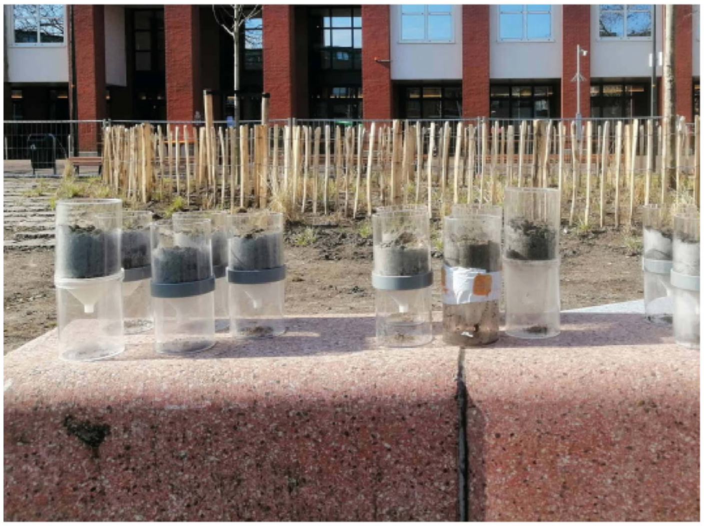


Figure 2. ***Schematic drawing of the used Tullgren Funnel.*** The image shows that the Tullgren Funnel consists of 2 compartments with a filter and a funnel in between. In the







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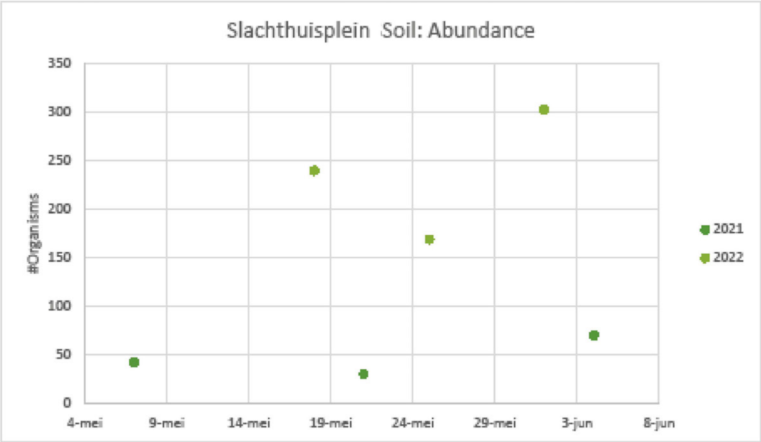
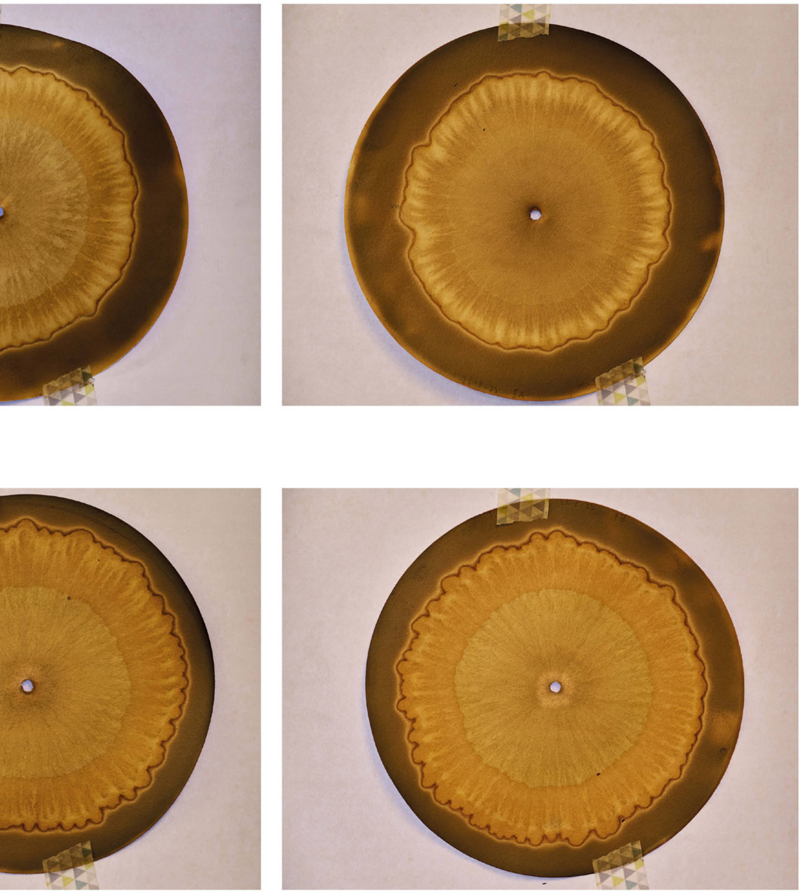


Figure 1a: Year two vs year one. The datapoints indicate three weeks of sampling at Slachthuisplein. For every dot, the number of organisms of three locations is taken together and presented as a datapoint.

FIGURE 15 *Pilot project 1: Park Slachthuisplein – ongoing monitoring*. In collaboration with Leiden University and Naturalis Biodiversity Center, forest growth is being monitored. At this stage of the project, soil life development is the most important factor for the future development of biodiversity above ground. Looking at the planting palette defined in the design stage, insects attracted by the selected trees, shrubs, and herb vegetation are being researched. What is the common soil fauna associated with the selected forest habitat (i.e., the back-dune forest)? In this study, Tullgren funnels are used to extract soil fauna from the soil (Akoijam et al., 2013; Smith et al., 2008). These fauna crawl down through the heat of a lamp and fall into a liquid that preserves them. The third season of monitoring is ongoing to enrich the database, which will also serve the development of a maintenance plan.



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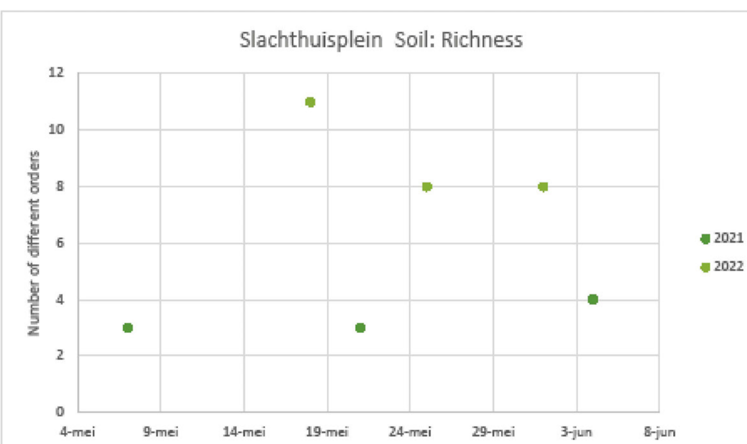

Figure 1b: Year two vs year one. The datapoints indicate three weeks of sampling at Slachthuisplein. For every dot, the number of species of three locations is taken together and presented as a datapoint.

FIGURE 16 *Pilot project 1: Park Slachthuisplein – constraints*. Some constraints occur during the maintenance phase. Parts of the dune grasses were mowed at the end of the first autumn, as well as parts of the herb vegetation, and removed from the site. Fortunately, nature is forgiving in a way; in the following spring, some dune grasses regrew, and many seeds were able to germinate. Thus, with an altered plant composition, the forest managed to develop. Another issue was people biking through planting beds to take the shortest route or parking their cars in planting beds. After planting some extra trees and shrubs and more mature herbaceous vegetation, these problems diminished over time and resulted in differences in herbaceous composition and height of vegetation.

FIGURE 17 *Pilot project 2: Square Van Musschenbroekstraat – implementation 2022*. Older trees in the city bring people together and contribute to the identity of a place. They are precious shelters for urban biodiversity as well as key actors in creating good living urban conditions by capturing large amounts of CO_2. The project area is a square acting as a stepping stone within the larger green corridor of the Van Musschenbroekstraat, a central street in the Laak District, The Hague. This project focuses on the 'Mother Trees' of the defined area, which includes five *Robinia pseudoacacia* (40 years old) and four *Aesculus hippocastanum* 'Baumannii' (60 years old). It is an exemplary pilot for tree care, focusing on soil improvement, understory development, and place-making under the canopy. Neighbours have asked for more greenery in the Van Musschenbroekstraat through a petition.

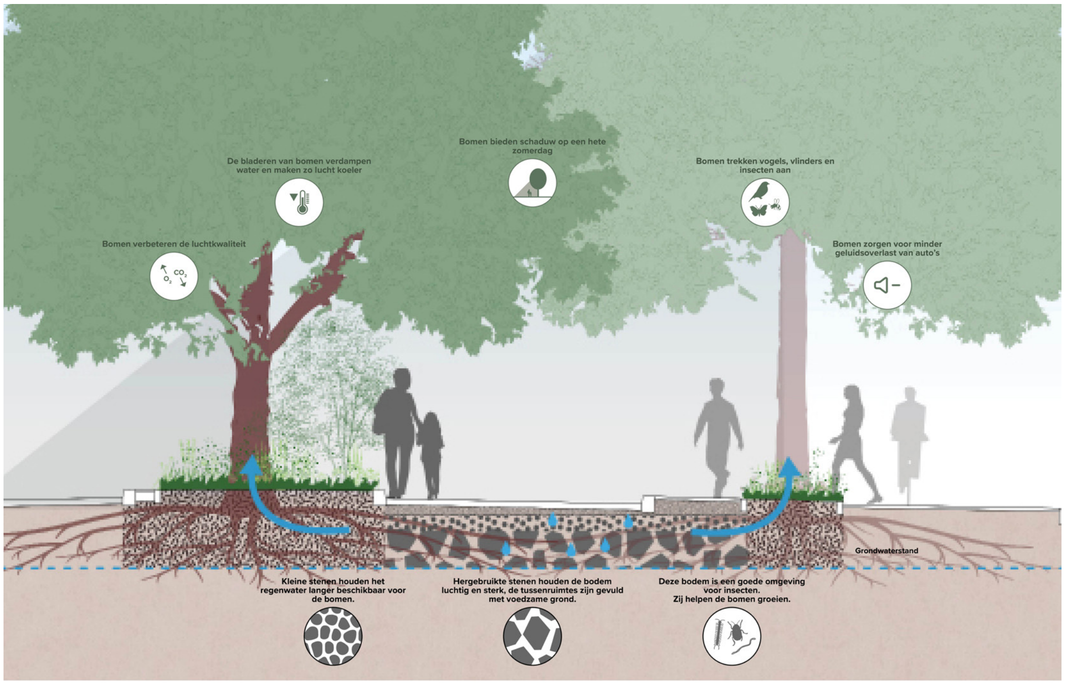

FIGURE 18 *Pilot project 2: Square Van Musschenbroekstraat – soil development*. The square consisted of an almost completely paved area with a parallel roadway with parking lots. In this situation, the trees grow on nutrient-poor sandy soil, and the roots 'eat' digested blossoms and leaves that end up in the soil through joints in tiles. This has resulted in many superficial roots up to four centimetres in diameter and heaving of pavement. We solved these problems by improving the soil and creating more space for roots. We applied soil profile rebuilding to a depth of 60 centimetres by using a special compost, earthworms, and a layer of five centimetres mulch (fraction 5–15 millimetres) for all trees and plantations. The percentage of organic matter increased from 1.5% to 4.5%. For the chestnut trees, we used a special technique that retains rainwater longer and improves soil aeration. The soil improvement consists of using the so-called Stockholm method (Embrén, 2009, 2015, 2016). Instead of using graded granite blocks of 100–150 millimetres, we used tiles and bricks partially released by converting pavement into planting beds. This 80 centimetres layer was made in three working passes. After each pass, the voids between these stones were filled with nutrient-rich soil. Elongation of roots and the thickness growth of roots are much less limited than in more standard structural soils. On top of this 80 centimetres layer, a clean 20 centimetres layer of 32–62 millimetres granite was used for rainwater storage and soil aeration. A geotextile, cunet, and brick were added to restore the parking lots and driveway.

FIGURE 19 *Pilot project 2: Square Van Musschenbroekstraat – co-creation*. As it is crucial that the urban forest is embedded in the community of a neighbourhood, the square design was tested on a scale of 1:1, presenting the project to the inhabitants and adjusting the design according to their ideas. The environmental conditions consist of low water levels, compacted soils from intense car parking, and micro-climate effects from the *Aesculus* (shadow).

FIGURE 20 *Pilot project 2: Square Van Musschenbroekstraat – ongoing monitoring*. The project is currently monitored in collaboration with Leiden University. In addition to soil organisms, we are researching which insects and in what quantity visit the site. Adhesive strips were used to trap insects. These strips were placed 1.0 metre below the lowest branch on the stem, out of reach of passers-by.

FIGURE 21 *Pilot Project 3 – Urban Bocage / Linear Forest – Implementation 2023: A pre-test in the TU-DELFT campus for possible applications in The Hague.* This project takes inspiration from a Dutch cultural landscape: the 'houtwallen' hedgerows/ wooded hedges (Müller, 2013a, 2013b), as a possible green solution for streets or boulevards. Today, these infrastructures work as barriers crossing cities. There are opportunities to turn these borders into public spaces when rethinking the road profiles and introducing linear forests as a missing link to connect parks and squares. The first urban bocage is tested on the Campus of the Delft Technical University. Two different types of plant communities were used. The first one is typical for the surrounding landscape, the second one can be found in France, about 400-500 km to the south with similar environmental conditions, but better adapted to climate change.

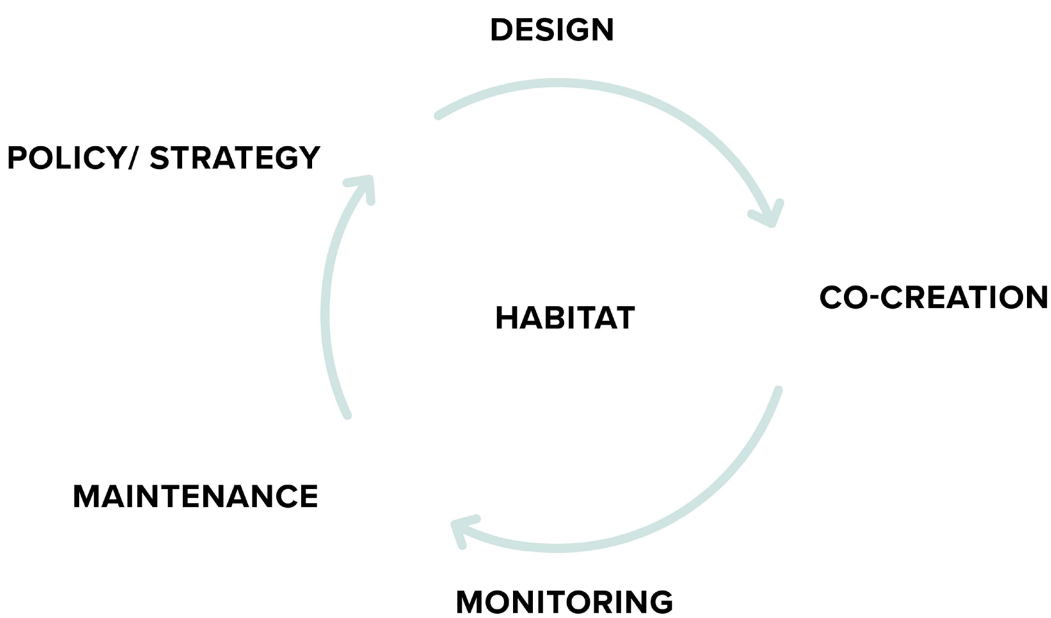

FIGURE 22 *Design process*. More than a toolbox for forestscape habitats, we intend to develop a methodology for a design process based on the relationship between the core concepts: habitat, design, co-creation, monitoring, and maintenance. In other words: how to design with natural processes in mind rather than defining a final picture.

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