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Roggema, Rob; Tillie, Nico

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# Realizing Emergent Ecologies: Nature-Based Solutions from Design to Implementation

**Rob Roggema [1,2,*] and Nico Tillie [3]**

1 Technologico de Monterrey, School of Architecture, Arts and Design, Monterrey Campus, Monterrey 64849, Mexico
2 Cittaideale, 6706LC Wageningen, The Netherlands
3 Faculty of Architecture, Delft University of Technology, 2628BL Delft, The Netherlands
* Correspondence: rob@cittaideale.eu

**Abstract:** The current state of nature is concerning. The levels of biodiversity are rapidly decreasing; existing policies sketch ambitious objectives, but their effectiveness is relatively low. This is caused by a combination of three main elements: physical elements, planning processes, and psychological reasons. In dealing with these deeply rooted problems, following qualities are missing: attention to planning and design in nature-based solution policies, the gap between plan and execution of plans, and the transformation to eco-leadership of young people. In four consecutive years, research design studios have been executed, in which students collaboratively design eco-solutions for complex and urgent problems. The core subjects of each of these studios were four interlinked aspects of eco-design: (1) designing in parallel at master plan and concrete project level, (2) planning, designing and building within a short period, (3) the emergence and succession of ecosystems on site, and (4) ecological leadership practice. By investigating these aspects year after year, designing integrated and coherent solutions, and realizing these solutions in built form, an ecological spatial framework emerged within which smaller projects were and will be embedded. This way, the ecosystem on campus grows, matures, and develops as a self-regulating system. Moreover, new leadership emerged amongst the young participants in the research design studios.

**Keywords:** biodiversity; nature-based solutions; research by design; eco-leadership; landscape-driven design; eco-campus

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## 1. Introduction

An increasing number of scholars emphasize the importance of nature, the need to stop biodiversity loss [1], and the need to change our collective view towards nature, from viewing nature as a resource that can be utilized and exploited to seeing nature as a holistic system of which mankind is a part, cherishing its resilience, and respecting its features and parts as sacred [2].

The problem of biodiversity loss is strongly related to climate change [3]. Biodiversity is under severe pressure due to climate change, with 3 to 14% of terrestrial species likely to become extinct at global warming levels of 1.5 °C, a number that only increases should temperatures rise further. Similar findings are reported for ocean and coastal ecosystems and endemic species in biodiversity hotspots [4]. Across the world, populations of mammals, birds, amphibians, reptiles, and fish decreased by an average of 68% between 1970 and 2016. In tropical central and South America, animal populations fell by 94% [1]. While the most significant driver of this loss to date is land-use change from pristine ecological landscapes into agricultural productive lands, climate change is projected to become the most important driver of biodiversity loss. Simultaneously, loss of biodiversity accelerates climate change, which is a toxic mutuality [1]. In addition, the loss of coastal habitats has put 100–300 million people under an increased threat of floods and hurricanes, because the natural buffer against extreme weather events will be lost when these habitats are gone [3,5].

The aim to stay within 1.5 °C warming compared to pre-industrial levels, as the Paris Agreement states, is under constant debate and uncertainty. Failing to stay within these limits could accelerate biodiversity loss and put human lives under increased pressure due to the tipping points that are triggered [6].

In many cases, planning decisions that were once taken for granted have a long-term effect and are often path dependent [7]. Many planning decisions are economically driven, changing land use from nature into agriculture or urban uses. Undoubtedly, this reduces the space for natural landscapes, and implicitly decreases biodiversity. As an example, the analysis of regional spatial planning in the province of Groningen, the Netherlands, shows that over a period of 15 years (three consecutive plans) land use was only allowed to change on 2% of the area, even though proposals for a significant change of up to 30% was proposed to accommodate climatic impacts in the area [8]. Moreover, once a planning proposal is launched, it takes a long time before plans are implemented. The plan for increasing resilience in the river landscape of the Netherlands, the so-called Plan Ooievaar, was developed in 1986 [9], but before it came to realization in the Space for the River program [10], which ran between 2007 and 2019, it took more than 20 years. Similarly, the initial concept for the Sponge City [11,12] was conceived in 2000, but implementation took another 15 years [13,14]. As the emergence of ecosystems from pioneer to climax stage requires time, the long gap between plan and implementation increases the difficulty of creating the conditions for a rich, biodiverse natural environment. This is even more difficult because human decision-making often replicates decisions taken in the (recent) past. In times of a climate emergency, a fundamental break with current systems of decision-making is needed, but these find themselves bound by habits, implicitly agreed approaches, and agreements that are often underpinned by people who have been in the game for a longer period of time. Historic approaches, and decisions, will therefore be hard to change.

At the same time, a substantial number of the innovative plans that have been made are not realized, due to various reasons. Examples date back to early 20th century, such as Le Corbusier's La Ville Radieuse [15], but also more recent plans have not been implemented, such as the proposition to create new islands in front of the Dutch coastline to protect the coast from inundation [16], or to prepare the Netherlands for flooding by proposing a 'Plan B' [17]. The implementation of nature reserves in Europe also shows the lack of an efficient process. For instance, the realization of the Natura2000 network faces challenges resulting from different opinions and systems regarding legislation, stakeholder engagement processes, finance, and spatial planning approaches within the European Union [18]. Moreover, the implementation of rewilding projects and programs is often compromised because of differences in views on conservation [19], the acceptance of large carnivores in rewilded areas [20], or the wide range of challenges in realizing Nature-Based Solutions (NBS); these are related to participation and equity, governance, valuation, infrastructure integration, and scale and feedback [21]. Hence, a major gap can be distinguished between abstract policy, objectives, and ambitious plans and their implementation.

Firstly, the way humans use the land, live their lives, and utilize (natural) resources has a significant impact on nature. For instance, the pressure on biodiversity resulting from the way food is grown is great [22–24].

This reform is necessary to reverse the negative impacts of nitrogen deposition [25–27], generally seen as reducing plant species diversity [28]. It could also relieve the contamination of groundwater resulting from food growing practices [29,30], freshwater pollution [31], or surface water pollution [32]. The Netherlands can be taken as an illustration of this, as it is generally seen as an agricultural system that is managed in balance with the environment and, moreover, the second largest exporter of agricultural products in the world. However, the current agricultural practices in the Netherlands cause several problems for the environment; they release high levels of nitrogen [33], which are deposited in nature reserves, leading to biodiversity loss, and cause water contamination [34], with both surface and ground water abstraction becoming an increased problem, contributing to droughts in the country [35]. Moreover, the import of feedstock and the export of large amounts of meat leads to a manure surplus [36,37], contributing to the aforementioned harm to the environment. As agriculture in the Netherlands covers 66.4% of the land surface [38], substantial improvements could be achieved by adjusting agricultural intensity and practice.

Secondly, the impact of urbanization aspects such as housing, infrastructure, or mobility on ecosystems and biodiversity is profound [39]. "Direct impacts of urban growth on habitat and biodiversity are cumulatively substantial, with 290,000 km$^2$ of natural habitat forecast to be converted to urban land uses between 2000 and 2030. Studies of direct impact are disproportionately from high-income countries. Indirect urban impacts on biodiversity, such as food consumption, affect a greater area than direct impact" [40]. "Urban development results in loss, degradation, and fragmentation of natural habitats, increase in impervious surfaces as well as in environmental effects associated with the heat-island effect, water, air, noise and light pollution, and the introduction of non-native species" [41].

The space that is occupied by urban use is quite literally reducing the amount of space that is available for nature. For instance, in the Netherlands, only 14% of the land surface is currently classified as 'nature' [38]. "As a key aspect of the anthropization of natural areas, urbanization comes with a complex mix of changes" [42]. "Urbanisation has been a main cause of land use land cover (LULC) change worldwide, often with irreparable consequences to the provision of ecosystem services. LULC changes resulted in losses of 89% in the estimated value of eight ecosystem services, including climate regulation, water flow regulation, moderation of disturbance, nutrient cycling and biological control" [43]. Land-use modifications and environmental disturbances increase the pressure on local remnant species diversity [44] and induce the assembly of novel ecological communities [45].

Intensified urban use, higher densities, and disconnected green networks lead to an increase of habitat fragmentation, decreasing the resilience of ecosystems [46]. For most anthropogenic land-use types, increasing their intensity of use is associated with significant reductions in pollinator biodiversity, particularly in urban areas [47]. Moreover, disconnected green spaces, such as isolated gardens, reduce the overall biodiversity, while green corridors may enhance it [48]. The urban form also affects biodiversity potential and quality. For instance, (semi-)detached housing areas provide better opportunities to increase biodiversity quality [49]. Indirectly, reduced space for nature and the accessibility of green space negatively impact human health [50–53], which also reduces psychological and mental health [54,55].

Thirdly, in an industrialized world, enormous amounts of energy are used to produce, move, and live. The way this energy is generated depends mainly on fossil resources, such as coal, oil, and natural gas. The carbon emissions from this cause climate change, which puts pressure on nature [56,57]. When, at the same time, the amount of nature and forests is decreased, the take up of carbon is compromised and climate change further increases [58].

Globally, 2/3 of biodiversity has been lost since the 1970s [1]. To reverse the degradation of ecosystems, the start of restoration marks the pathway to a regenerative ecosystem. However, as an estimate to imagine the magnitude of the restoration challenge humanity faces, the lost 2/3 of biodiversity can be taken as the task at hand. In other words, if we wish to recreate the biodiversity that there once was, diversity, species richness, and/or the surface area for biodiverse ecosystems must be tripled. Future biodiversity will never be like the 1970's situation (which is taken as the reference year for the research carried out recently [1]); however, to return to the 1970's level of biodiversity, a task to triple the ecological quality can be estimated. Though nature-based solutions [59,60] and rewilding [61–63] practices have become well-established, a real ecological transformation requires additional efforts.

Nature-based Solutions (NBS) [64] focus on a range of topics and policy fields. Some are societal [65] or economical [66] in nature, while others focus on sustainability [67], aligning nature conservation and sustainability goals [68], and/or address climate change [69]. In the NBS-discourse there is currently a lack of focus on planning processes. Implicitly this means that, from a planning perspective, planning and designing with nature as a priority fails. This 'planning nature and landscape first', or nature-driven [70–72], landscape-driven urbanism [73,74] should transform the way regular planning approaches are conducted. Such a novel approach could start with identifying the existing ecological and landscape qualities, followed by designing the space required for an abundant and adaptive future natural system as a prerequisite for embedding other (urban) uses and functions.

The process of designing buildings, urban environments, and cities, till realization (the 'plan-to-build' process), the connections between identified emergencies, such as biodiversity loss and climate change, the objectives of how to respond/solve these, and the execution of projects that materialize these objectives are not always clear. The discourse here is limited to aim for climate adaptation [75,76] or biodiversity recovery [77,78], in or through spatial planning, withstanding the fact that these planning ambitions are not always turned into adjusted urban environments [8].

The (political) decision-making is not always in favor of counteracting biodiversity loss [79] or mitigating climate impacts [80]. It is estimated that this is caused by the current power balances, in combination with existing backgrounds of decision makers that stand in the way of transformational thinking and actioning. Often, responsible leaders have a background in public administration, law, finance, or economics [81], and less so in design, ecology, or climate change subjects. Therefore, there is a need to develop new leadership and encourage young people to become intrinsically motivated for establishing a fundamental transformation.

In this article Nature-based Solutions (NBS) are taken as the central objective for urban planning. The way these solutions are implemented in the context of the Delft University campus is the main focus.

## 2. Materials and Methods

A fundamental rethinking of the role ecosystems can play in adapting to (disruptive) change by regenerating their resilience is urgently needed. This asks for transformative approaches that can bridge the gap between ambitions and objectives laid down in policies and plans, and their implementation in realized projects and solutions on the ground. In this article, we propose to develop a strong connection between the way our environment is planned and designed, the implementation of change-eluding projects, and the human responsibility to increase biodiversity.

To stimulate thinking about this fundamental shift deemed necessary, two concepts derived from ecological scholarship are found useful: symbiosis and emergence.

- Symbiosis is a term in biology that has, for a long time, been the subject of confusion in terms of its definition [82]. In general, it may be defined as: "the way in which organisms live together for their mutual, and therefore, intrinsic benefit." [83]. In this paper the 'living together' of ecology, design of urban landscapes, and education of future leaders is seen as symbiotic, namely for their mutual benefit. Moreover, viewing these relationships as symbiotic improves the chances of achieving long-term regenerative change.
- Emergence refers to the existence or formation of collective behaviors—what parts of a system do together that they would not be able to do alone [84]. In this article, the term emergence is used both in an ecological and a social sense. The process of shaping a new collective 'behavior' from seeding to maturity is achieved both for the development of ecosystems (from pioneer to climax stage) as well as for individual participants in the research design studio (from learners to leaders). The interactive processes instigate emergence, as the behavior would not happen by individual parts of the system (species, students) alone, but originates due to their collective processes.

To halt biodiversity loss and regenerate ecological systems, and even increase the size and quality of natural systems, a range of actions could be taken. The following objectives for these actions have been identified:

- Create nature as an indistinguishable factor in the city.

- Close the gap between design and implementation in parallel processes.
- Realize continuous ecological implementations for a longer period working together towards a coherent ecosystem.
- Design and build at different spatial scales, connecting master planning and project designs.
- Develop a deep engagement for transformative ecological practice, supporting students to become self-directive and dedicated.

Restoring biodiversity in an urban context is not an objective that is easily integrated and realized in urban development processes. In terms of planning and designing cities, decision-making processes, and the necessity to increase resilience in times of disruptive transformations, there is a gap between aim and implementation. This is also a gap in knowledge as these fields of study are only marginally merged. In this article we emphasize the integrative character of the research, process, and outcomes. As problems related to biodiversity, climate change, and land use are intermingled, so are the solutions. Therefore, we have chosen to present the results as one outcome without entering one specific field of science only.

The objective of this paper is therefore to illustrate the connection between the improvement of biodiversity, the role landscape urbanism design can play, and the role of educating novel eco-leaders to take responsibility for the process of implementing projects and solutions that manifest the relationship between ecology and design in a semi-urban context.

*Methodology*

In four consecutive years (2019–2022), ways to fundamentally transform current planning and design into ecologically driven design and execution have been tested in a design-led research project with four groups of Master students, consisting of landscape architects, urban designers, and architects, together with civil engineers, mechanical engineers, and public policy students. Between 10 and 35 students participated on a yearly basis.

The campus of the University of Technology in Delft, the Netherlands, located at the southeastern side of the city, links the higher lying landscape of central Delft with the landscape (lower lying, wetland, and peat meadows) surrounding the city. The campus is urbanized; at the same time, there is ample open space between buildings and 'not-yet-used' areas, waiting for occupancy. The fact the University is, to a large extent, owner of the land, makes the area, from a landscape ecological point of view as well as regarding the potential to implement projects, an ideal experimentation site.

The TU Delft campus is therefore used as the testing ground for eco-innovations, with the ambition to start with small projects, building to a connected ecological system. The design, thus, aims to connect master planning, project design, and building of the project (Figure 1). Each year design research is carried out, using actual urban ecology knowledge in parallel with an immersive assignment. In this task, the students view the site from the perspective of a specific species. The category changes every year (birds, plants, trees, insects, etc.). This design research informs both the master plan as well as the project designs that will be built. Year by year, the master plan for the campus is refined and improved; additional, realized projects are embedded in the bigger picture. This way the campus eco-vision grows from individual interventions to an ecological connective structure.

During the process, the responsibility for the planning and design, organization, communication, and presentation of the results is placed with the students, to stimulate leadership and motivation.

After the fourth year, a solid foundation of ecological innovations has been realized; however, this process will be continued for the years to come, enriching the ecology on campus even further.

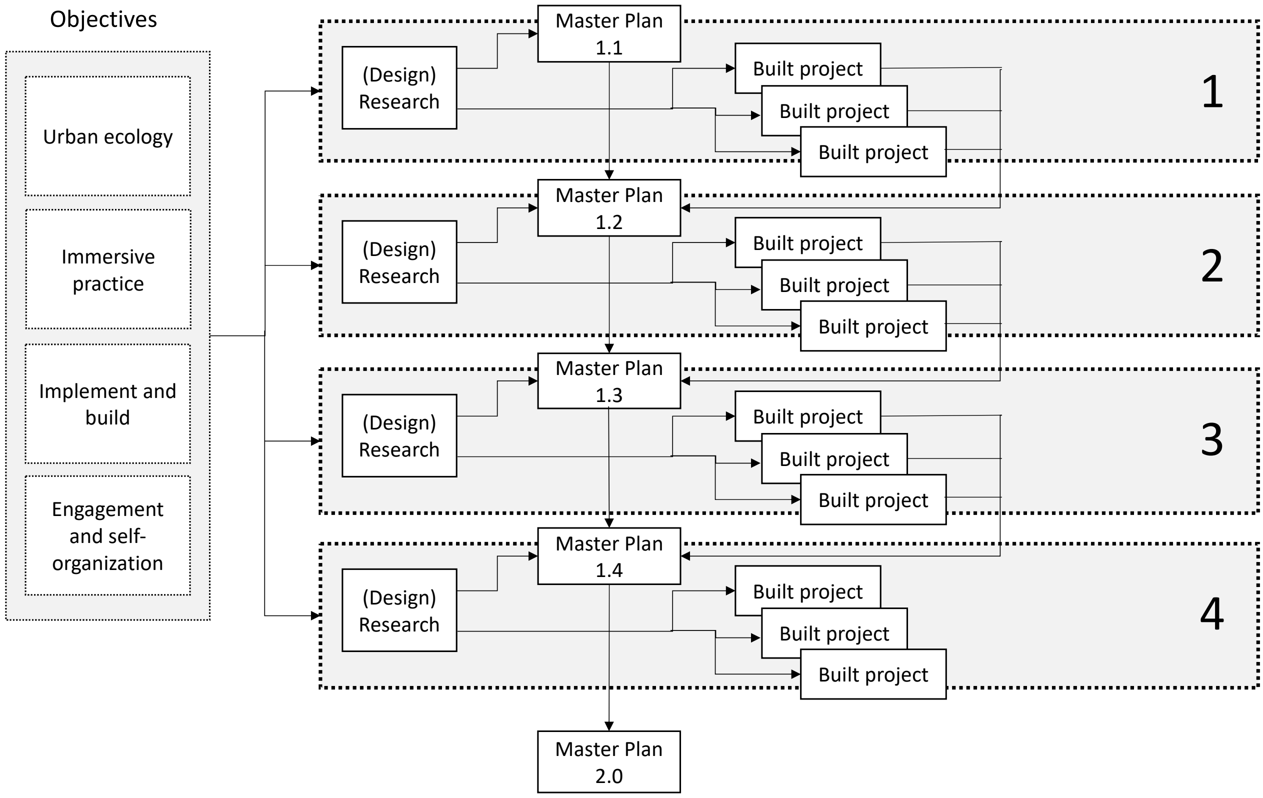


**Figure 1.** Methodology: integration of four general objectives in a yearly process of design research, master planning and building/implementing ecological projects.

## 3. Results

The multifaceted problem of biodiversity degradation is tackled at several parallel fronts. The research project aims to tackle the loss of biodiversity, improve the effectiveness of ecological transformation, and minimize the period between problem-policy-plan-implementation. Though each of these aspects are interlinked, specific actions and research parts are connected to the problems, which are defined as physical, planning, and psychological.

- The identified physical problems are responded to by creating space for ecology at master plan and specific project design levels. In this context the landscape is first, taken as the initial point of departure of the design process. This way an overall ecological and landscape-based structure is implemented (master planning), which literally creates the framework for embedding ecological qualities (through the design of smaller projects). This leads to a fundamentally different land use than would exist in a business-as-usual process.
- The approach to tackle the planning problems is to prioritize ecology over economy through acceleration in the process of design and build ecological interventions. This way, planning and design is directly connected with building concrete projects.
- The psychological state of being is dealt with by transforming the human mindset to accept nature as the overarching principle, in which man is part of nature. In this overall ecological vision, people thrive within the context of ecological functioning of the system, immersing themselves as if being a piece of nature, a species. Moreover, such a mental transformation requires putting emphasis on ecological leadership, especially among young people. Through making them self-responsible for the process, the outcomes, and the understanding of the essential role of ecology and biodiversity in spatial design, new leadership can be born.

### 3.1. Development of Master Planning

Every year, the student cohort works on master planning the Eco-Campus. Over the years, the conceptual master plan evolves into a sophisticated in-depth philosophy on the spatio-ecological framework for the campus. By revisiting the master plan level year by year, advanced responses to the identified physical problems are found.

Every year, new layers of analysis and planning have been added to enrich the depth of the plan (Figure 2). Starting with the landscape types and gradients, being on the edge of the peat-meadow landscape and sandy ridges along the old Schie-canal, underneath the current orthoganal urban pattern and heavily paved campus site the landscape is still active, represented in the water and ecological processes that take place and can be regenerated and brought back to the surface. A thorough analysis of the water and green systems on campus and the wider environment adds to the understanding of the highs and lows, the wet and dry soils, the nutrient-rich and nutrient-poor. On top of this, each year-group adds a specific category of species, be it trees, butterflies, bees, plants, or birds. This immersive practice is linked to the landscape conditions. Next, to the landscape, water- and green-systems, and the understood requirements of species categories, climatic impacts, such as heat, humidity, wind and shade are connected. Additionally, the human experience, routing and mobility, as well as beauty is added. After four years of design-redesign, the master plan reaches a sophisticated level of spatial quality and distinguishes major and minor ingredients to enhance ecological qualities. It forms the basis framework for implementing smaller designs.

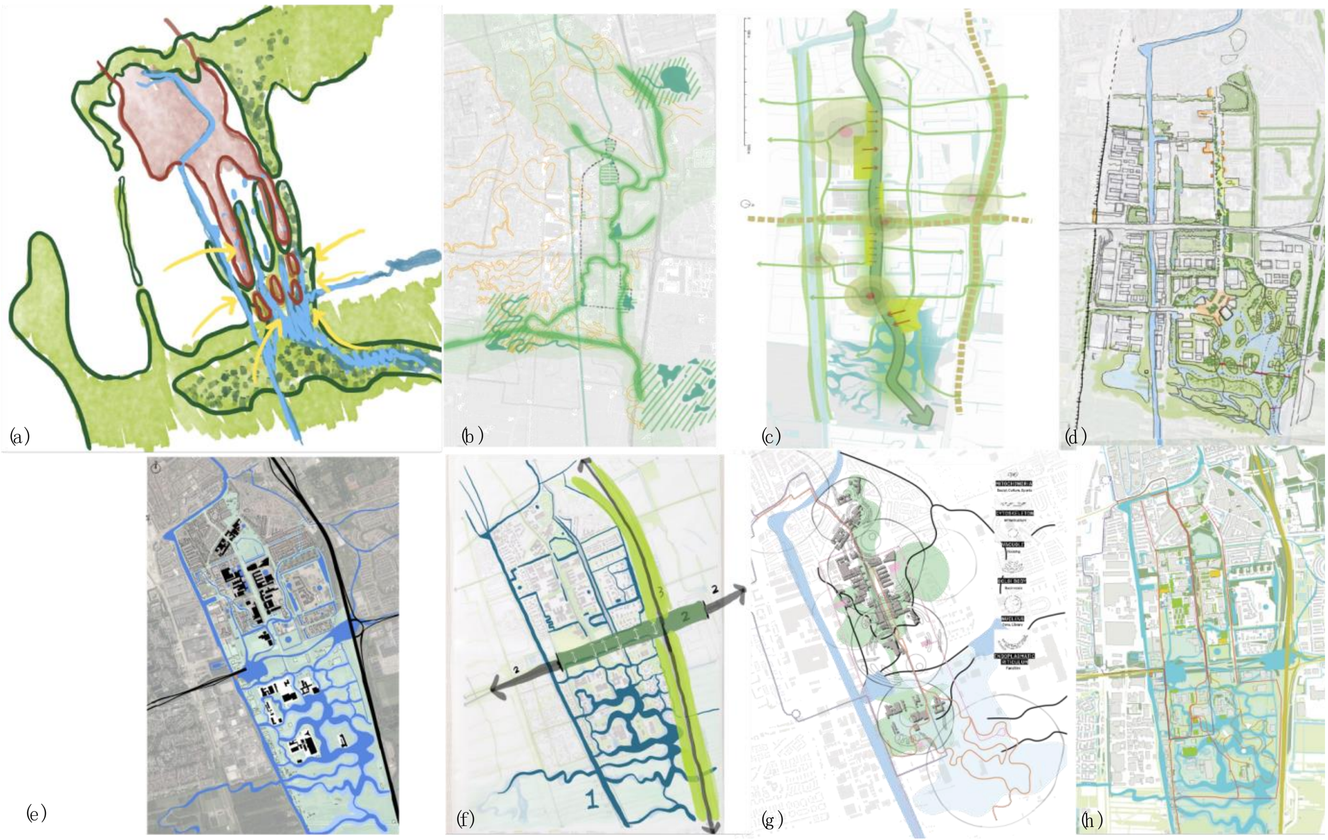


**Figure 2.** Emergence of the designed-redesigned master plan with (**a**) conceptual landscape, (**b**) preliminary green structure, (**c**) connected ecological spaces, (**d**) integrated green-urban landscape, (**e**) preliminary water system, (**f**) green-blue connectivity, (**g**) interconnected places, water, green and mobility, (**h**) integrated Master Plan.

### 3.2. Built Projects

In parallel with designing at master plan level, each year a series of small-scale projects are designed and built. The immediate execution of these project allows for acceleration of ecological implementations, shortening the process of transformation and linking ecological timeframe to the usual economic time horizons. This accelerates the planning process, hence tackling the 'planning-apathy' of slow change.

During the four years of this research studio, 16 projects are realized. Due to COVID in 2020 and 2021, a relatively small number of projects were realized, however, in combination with each other, an ecological emergence on campus has become visible. As an example, four of the projects are highlighted here (Table 1). Each of them has a specific angle to the ecological problem and enhances biodiversity in its own way. The 'trickling trail' emphasizes the capture and availability of water by providing the conditions for wet ecosystems. In the 'peat garden' project the perspective of regrowth of peat bog is taken by transforming an existing pond to form the basis for the slow process of peat developing. The 'bee burrows' take the perspective of regenerating the insect population, in particular the bees on the campus, by providing a place for nesting and foraging, attracting a range of bee species. The 'rain pavilion' focuses on the human experience and engagement to better understand the ecological value of the water cycle.

**Table 1.** Brief description of four realized eco-campus projects.

| **Trickling Trail** | **Peat Garden** |
|---|---|
| The trickling trail harvests and accompanies rainwater from the surrounding buildings of the site, flowing through the public space, before it reaches the pond. During this travel it provides cooler conditions, and the basis for growth of natural plantations. Part of the Trickling Trail are the floating gardens, which can be found in the artificial water basin in front of the faculty of Industrial Design Engineering. The floating gardens are covered with plants which purify the water and thus improve the living conditions of the flora and fauna. The gardens are made of PVC tubes, filled with empty reused plastic bottles. The 'Trickling Trail' provides a breeding ground for various birds. Soon after realization, the geese and coots started using the floating gardens to breed on. | The peat garden centers around a pond where inlets have been created by braiding willow twigs. These inlets are filled up with soil and covered with Sphagnum peat. This peat will grow over the course of a few years and if the area is suitable, it will spill over the surroundings. There are different types of peat. For this project Sphagnum is used as this type makes the most demands on its environment. If this Sphagnum experiment succeeds, other peat species will most likely be able to grow on the other locations on campus. Peat has the ability to store large amounts of carbon contributing to the goal to be carbon neutral by 2030. |
| **Bee burrows** | **Rain pavilion** |
| In the wild, solitary bees and bumblebees will search for suitable places for the building of their nests in for example open, sandy soil or in holes in dead wood [85]. In our over-designed and neat looking cities, it can be hard for wild bees to find such spaces. Therefore, artificial nesting places will be provided to mimic the conditions that wild bees will look for to build their nests. The nesting places will be spread over campus, functioning as different nesting types fitting the habitats and the desired interaction or non-interaction with human visitors of the campus. Bee burrows are large nesting facilities [86]. These will function as large hotspots in the so-called 'nectar necklace', providing underground nesting space in loamy sand and, in a smaller amount, nesting in holes in wood and stems. Two bee burrows have been realized on campus. The bee burrow provides nesting space for a large variety of wild bee species, for both species nesting underground and above ground. The base form of a bee burrow is a half-moon made of sand, oriented to the south. In there, the main elements are: (1) steep edges made of loamy sand, (2) flat humus-poor soil with no or little vegetation, (3) a variety of holes in wood and stems [86]. | To enable a new perspective on water, embracing water as a playful and interactive element adding joy to our everyday life, the objective of the design is to experience the water, and tackle the urban heat island effect by contributing to a more humid and cooler microclimate. Therefore, the design is inspired by natural examples like stalactites and willow trees, creating a private, cool and humid atmosphere through hanging branches, drops of water dripping down. This rain pavilion creates an atmosphere that is similar to a willow tree and adds the element of interaction and experiencing. The way the Dutch created dry land resulted in an unhealthy and not very resilient ecosystem. Therefore, the rain pavilion highlights the importance of the natural water cycle in contrast with usual water management aiming to discharge the water as quickly as possible. The pavilion involves visitors into natural processes of rainfall and evaporation and makes them aware of the need to restore our wetland ecosystems. As people operate the pump, water is filtered and irrigated into the cloud roof, to be dropped back into the pond, closing the cycle. Furthermore, natural infiltration ensures a healthy soil and greater biodiversity, to combat salinization and land subsidence. Through this pavilion, people will be part of the water system and embrace the rain they create. |

Each of these projects has been the result of a spatial analysis, a research-by-design approach, conceptual and detailed designs, and the materialization and execution of the propositions (Figure 3). This way, the run-through time of this process is only three months. After this short process of realizing the projects, each of these will mature over time and come to ecological fruition in the upcoming years.


**Figure 3.** Four examples of built projects from design to visualization to realization: (**a**) Trickling trail, (**b**) Peat garden, (**c**) Bee burrow and (**d**) Rain pavilion.

### *3.3. Ecological Emergence*

The combination of improving and elaborating the master plan, and in conjunction designing and realizing a growing number of eco-interventions, connects immediate realization with the emerging overarching vision. During the research period, a progressive and accelerated realization of ecological objectives becomes visible, that also show extensions into the entire campus (Figure 4).


**Figure 4.** Transformative ecology, from individual eco-interventions to an embedded ecological framework: (**a**) projects realized in 2019, (**b**) projects realized in 2020, (**c**) projects realized in 2021 and (**d**) projects realized in 2022.

### *3.4. Eco-Leadership*

The lacking psychological valuation of nature as the overarching condition for all life requires novel leadership. In current education and human resource development, not much attention is paid to this type of 'eco-leadership', putting man in the position of being a part of its natural environment. To genuinely have a deep impact on the ecological conditions of young people, the research studio is organized to give students the responsibility for the understanding (analysis), planning (design), and organization (process) of the outcomes. This gives them the motivation to realize eco-innovations, and moreover, they feel strong ownership of these projects. This is experienced as a mind-changing process, which establishes direct links with future leadership, including a more ecosophic vision on landscape design and planning. The evaluation and reflection after the research studio show clearly the impact of the self-organization that is demanded during the process.

## 4. Discussion

At a philosophical and psychological level, the way nature is viewed and valued determines human actions and behavior in the relation between people and their environment. The dominant global focus on short-term profits and economic growth, often excluding the consideration of multiple values of nature in policy decisions, is seen as a key driver of the global biodiversity crisis and a vital opportunity to address it. In this article the main problems of biodiversity degradation and the underlying causes have been identified. The ecological mismatch that can be witnessed in practice has three main reasons:

1. Physical use of land that is dominated by human, industrial functions, with ample space for ecology and natural systems.
2. The planning deficit of postponing realization of plans causing delays and plans disappearing, often not effectuating well-meant policies.
3. The conviction that man must shape order and maintain nature, subjecting ecology to his own demands.

To be able to cope with these causes three main aspects that are missing in action have been defined:

- A lack of focus on the role of planning and design in many NBS-programs.
- A gap between the urgency of climate change and biodiversity problems and the actual tools to change current spatial practices.
- The neglect of alternative leadership that is more focused on the quality of life on the long term than current leadership practice, focusing on short term economic goals.

The results of four consecutive years of eco-campus design and build reveal several success factors:

- The strong and direct link between design and realization of projects in a parallel planning and execution process.
- The self-organization of the studio by the students, hence creating ecological leadership.
- The good and short lines with the maintenance-real estate department, which through personal relationships causing fluid realization of projects.
- The availability of a small but strongly appreciated budget for materials.
- A slow but certain process of small projects in a step-by-step way, that leads to a consistent ecological development, adding constant new values to the campus.
- The integrated and parallel execution of the process leads to an interconnected ecosynthesis of developing plans and projects, building them and personal growth in leadership.

## 5. Conclusions

In the research design studio conducted over four consecutive years (so far), these aspects play a major role in achieving transformative ecologies. In a synchronized effort, solutions are conceived and implemented. As a result of consecutive ecological interventions, the growth and succession of ecosystems is effectuated across the campus area. This maturing ecosystem is achieved by working on two scales in an integrated manner. This way, smaller projects can be embedded in a bigger ecological framework, and thus add quality to the entire system. The effectiveness of the research studio is manifested by the direct implementation of designs. Not only does this realize ecological improvements, for the students involved it is also a fast-learning process on what simple lines on a drawing mean for the complexity of the realization. Moreover, the active self-organizing process gives students more responsibility and they are, therefore, more attached to the subject, which increases the chances of developing novel eco-leadership competences.

The approach of connecting designing, learning, and building within one scoped process, is replicable in other places and with a different group of participants. The principles to design and build in a brief, connected period can be undertaken by project teams within developing industries or government bodies. The interrelation of planners that do (build) and doers that plan (design) increases the impact of mutual learning and enriches the impact of ecological progression through mutual understanding of designers and executors alike. Finally, the way the process is organized as a self-reliant team increases the taking up of responsibilities and ownership by the team members. This implicitly will gauge new forms of ecological leadership, for which there is a pressing need.

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