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Knowledge and possible application of urban vegetation patches as a technique to create biodiversity in landscape architecture

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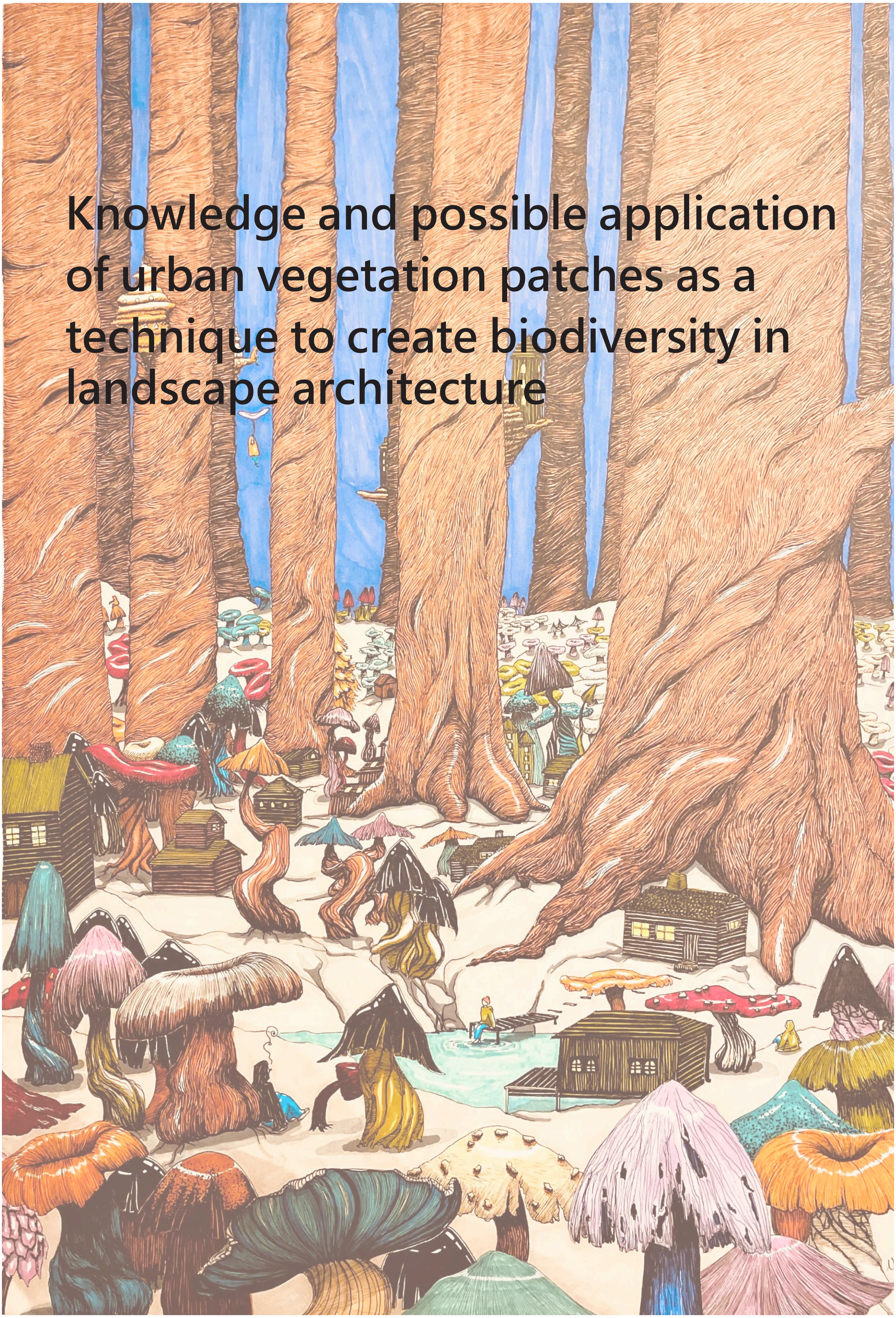


01. Preface

This master thesis is written at the Norwegian University of Life Sciences (NMBU) and is the finishing marker of a five-year course study in landscape architecture for global sustainability. Ecology have been a significant part of my course study and therefore, this thesis Is a result of an interest with increasing biodiversity through landscape architecture. This thesis hopes to create more focus on patches within landscape architecture. It also is a step in the direction of making theoretical information in this field more practical. A big thanks my supervisors Wenche Dramstad and Kerstin Potthoff.

The last semester at NMBU was a bit affected by isolation, being situated outside of the campus, in Bergen. Meetings with Wenche and Kerstin was through teams. Another challenge has been finding a suitable place to write this thesis.

Despite this, and writing the thesis alone, I've learnt to become a bit more secure in my own abilities and happy to find use of my artistic skills. The illustrations I've made are marked with my name. An example is the illustration behind the thesis title on page 3. This illustration depicts a society that is built after elements of nature, such as the large trees. The idea of designing after nature is a prevelant theme in the thesis.

0.2 Abstract

Biodiversity loss is a global issue that is due to land-use changes. A driver behind land use-changes is urbanization. To counter this development, cities create ways to support biodiversity through urban green spaces. Although urban spaces are fragmented, landscape architecture can assist the colonization of species. However, much of urban biodiversity supporting strategies focus on green corridors and connectivity. Even though corridors and patches both have significant positive effects on biodiversity, there is a lack of biodiversity supporting strategies for urban green/vegetation patches. This master thesis addresses the globally applicable factors that has the potential of creating biodiversity in and with urban vegetation patches. The thesis will also include a practical example of how these factors can be applicated in a design. The reason for including a practical example, is because there is lacking a conversion from theory to practise in this field. There can be many interpretations of how to create biodiversity in urban vegetation patches, and practical examples can improve the theoretical information by making it applicable for reality.

Table of Contents

01 Preface	6
02 Abstract	7
1 Introduction	9
2 Method	11
3 Inspirational design project	13
4 Landscape architecture in relation to nature	16
5 Urban ecosystem	17
6 Biodiversity	19
7 Patches	22
8 Species	26
9 Factors to include when designing urban biodiverse vegetation patches	30
10 Case design	32
11 Discussion	42

1. Introduction

1.1 the global issue of biodiversity loss

Biodiversity loss has become a global issue. According to the Living Planet Index, 20 000 populations of 4292 species have declined by 68% globally from 1970 till 2016 (NINA, 2020; Almond et al., 2020). There are many reasons for the decline in biodiversity, both indirect and direct drivers (A. Ipbes, w. y.). Examples of the direct drivers are land-use change, pollution, invasive species, and over-use of natural resources (A. Ipbes, w. y.). Land-use change has the most impact on biodiversity, and it can include all human influence of habitat (A. Ipbes, w. y.). The human influences can be deforestation, agricultural management, and changes in land cover, which are often found in urban areas (A. Ipbes, w. y.). In Norway, the status of biodiversity follows a similar trend.

Birds are valuable indicators for the state of the ecosystem (Pedersen & Krøgli, 2017) and thus biodiversity. Today, many of Norwegian bird species are endangered (Miljødirektoratet & NVE, 2022). This is also due to land-use changes, that remove habitats (Miljødirektoratet & NVE, 2022). However, the land-use changes impact the biodiversity of ecosystems, not just birds (A. Ipbes, w. y.). For example, changes in land affecting forestry are assumed to negatively affect 41% of all threatened Norwegian species (Artsdatabanken, 2021). Moreover, 9 of 10 species on the Norwegian red list of threatened species have habitat loss due to land-use change destroying their habitat as their greatest threat (NINA, 2020).

Biodiversity loss stems mainly from anthropogenic factors, which might increase the responsibility to act upon them. The age of the Anthropocene (Lewis et al., 2015) has affected the distinction between the term's nature and urban. As every inch of the planet has been affected by humans, directly or indirectly (Prominski, 2016). The term 'andscape' covers the linkages between everything biotic and abiotic (Prominski, 2016). 'Andscape' focuses on the dynamic relationships between humans, animals, stones, or everything from human culture, and nature (Prominski, 2016). This thesis will use the terms urban and rural to describe landscapes, for the sake of simplicity. Rural landscapes are characterized as a blend of natural and human landscapes, and urban landscapes have the characteristics of a city (Dewey & Troughton, 2016). They both have complex internal ecosystems (Dewey & Troughton, 2016).

A large portion of land changes are due to urbanization, which is a major threat to biodiversity. To counter this development cities, have increasingly created strategies to support biodiversity through urban green spaces (Lepczyk, et al., 2017; Aronson et al., 2017). As a result, many of these urban green spaces are habitats that support biodiversity in the city (Lepczyk et al., 2017; Nielsen et al., 2014).

1.2 Colonization of plant species in urban enviroments

Urban green areas are often fragmented, and they can have a large proportion of foreign species in comparison to native species. In some cities foreign species make up more than half of biodiversity (Schlaepfer, 2018). Whether this is a positive trend or not is not definite. Biodiversity by native species or foreign are both supported by urban green spaces (Lepczyk, et al., 2017). The assortment of species in urban landscapes can consist of red listed species, non-native species, and native species (Müller et al., 2013). The species that colonise in urban green spaces have traits which makes them able to adapt to the landscape. For example, plant species that transform to the conditions in the urban landscapes can be classified as a new species (Müller et al., 2013). These plant species are known as anecophytes (Müller et al., 2013). Anecophytes have traits that can help them colonize in urban areas (Müller et al., 2013). The conditions and fragmentation of urban landscapes can make colonizing difficult for native species.

Landscape architecture can be a tool that can assist colonization of species and contribute to increasing urban green space biodiversity. These urban green spaces have become important habitats for biodiversity (Lepczyk et al., 2017). This is because urban green spaces can support species of the surrounding area (Lepczyk et al., 2017). In addition, urban green spaces can support threatened species, and help conserve native species (Lepczyk et al., 2017; (Ives et al., 2016). Along with the ecological benefits of urban green spaces, there are benefits for people (Zhu et al., 2022). Humans are dependent on biodiversity and the ecosystem services it derives from (Zari, 2018). Ecosystem services provide benefits for people, both directly and indirectly (Zari, 2018). Examples of these benefits can be positive effects on physical health, psychological health, economic health, and cultural health (Zari, 2018).

1.3 Using nature's lead in design

The benefits of ecosystem services provide function for urban green spaces. Some landscape architects use ecological knowledge to create a design that contributes to biodiversity. This idea is Ian McHarg known for (Yang & Li, 2016). McHarg was an influential establisher of using nature's lead in design (Yang & Li, 2016). McHarg was a landscape architect that helped redefine design with his ideas for projects, use of maps and through his book, 'Design with nature' that he published in 1969 (Snl, 2020; Yang & Li, 2016). Ian McHarg believed that planning and design should be integrated after ecology and take into consideration the character of the landscape in a way that makes anthropogenic interventions into an integral part of the landscape (Yang & Li, 2016). The influence of his ideas can be seen today, such as in the Wulijie Eco-City.

Wulijie is a project of a town that accommodate 100,000 residents (Turenscape, 2011). This town design is based on ecological infrastructure, to integrate existing natural processes and provide ecosystem services for the residents (Turenscape, 2011). Turenscape, (2011) described the previous agricultural landscape as a landform with rolling hills, and many ponds. The difference in elevations created many ponds of different sizes to catch water. These ponds create a waterbody that supports ecological infrastructure, retains, and cleanses stormwater (Turenscape, 2011). According to Turenscape, (2011) the waterbody infrastructure organizes the town, and create habitat for native vegetation such as lotus, wild rice stem and water caltrop. Wulijie is a project following the ideas of Ian McHarg. This is because the project is preserving ecological processes and increase the existing biodiversity based on ecological and landscape characteristics.

The ideas of Ian McHarg can also be seen within a typical trend of today's landscape architecture. In this field of landscape architecture there is a focus on 'green corridors and 'connectivity' around biodiversity. Both vegetation corridors and connectivity use ecology as a basis for design. Yet, 'green' city planning is a lacking focus on vegetation patches within landscape architecture. The existing literature about patches is about rural landscapes even though the most fragmented landscapes; urban areas, (Dubois & Cheptou, 2017) might have a greater need for biodiverse patches. This is because patches function as habitat for populations of species and can have a great significance for biodiversity (Beninde et al., 2015).

1.4 Corridors and patches

The spatial distribution of urban green spaces can affect how much they contribute to biodiversity (Beninde et al., 2015). Beninde et al., (2015) found that corridors and patch sizes had the strongest positive effect on biodiversity. Thus, both urban vegetation spaces of large patches and corridors can benefit urban biodiversity. It's important to note that corridors may also have possible negative impacts (Haddad, et al., 2014). Among these are a higher risk for influence of species with a negative impact on the existing biodiversity, like predators, pathogens, or exotic species and fire, or population synchrony, reducing persistence (Haddad, et al., 2014). Beninde et al., (2015) describes the relationships between species and spatial attributes in urban landscapes as similar to rural landscapes. This establishes possibilities for applying ecological knowledge into urban landscapes.

Aside from spatial distribution, biotic factors within habitats seems to have a significant impact on biodiversity (Beninde et al., 2015). This implies that the structure and assortment of plants is important for creating biodiversity (Farwell et al., 2021). To contribute to development of knowledge in this field, this thesis will focus on urban vegetation patches. However, the field of biodiversity in urban vegetation patches lacks practical examples, leaving a gap between theory and practise. Practical knowledge can be significant for designing new ideas, and actually impacting landscapes.

1.5 The aim of this thesis

This thesis aims to create knowledge and possible application of urban vegetation patches as a techniqe to create biodiversity in landscape architecture. More spesifically this thesis uncover some of the existing knowledge of urban vegetation patches. From this knowledge, this thesis tries to figure out how to design urban vegetation patches that creates biodiversity with vegetation composition that also creates biodiversity with bird and insect interactions?

The idea of McHarg, that design should be integrated after ecology will be utilized in this thesis. Thus, ecological knowlegde about urban vegetation patches and biodiversity determine the design.

This thesis will access factors that should be considered when designing a vegetation patch for biodiversity in an urban landscape. The factors are analytical and design related. The factors should be globally applicable. Although possibly with modifications based e.g. on climate and site conditions. To bridge the gap between theory and practise, a case study provides a direct example using the the factors. Finally, the factors and their use in design is discussed.

1.6 Limitations and potential challenges

The definition of biodiversity includes variability within species (genetic pool), between species and between ecosystems (Feest, et al., 2010). Measuring the variability with scientific tools in a genetic pool and ecosystems proves difficult (Feest, et al., 2010). In addition, the arbitrary scale that will capture the variability is unclear (Feest, et al., 2010). A common measurement of biodiversity is species richness, and this is the common measurement in studies for this thesis. Still, due to the complexity of biodiversity, it is important to recognize that species richness is far from a flawless measuring method. Yet, imperfect measuring methods can still function as gauges (Scholes & Biggs, 2005). More accurate measurement methods, and more data on how to measure biodiversity is needed. Yet, the urgency of biodiversity loss makes action more valuable than attaining the perfect dataset. Moreover, every installation that creates habitats and supplements the biodiversity is useful in an era where increased biodiversity is urgent.

2. Method

As depicted in Gaaren and Solenes, (2020) and Eikaas and Rousse, (2013), a usual approach to create biodiversity design contains case studies. In Gaaren and Solenes, (2020), the structure of their work consists of a presentation of literature behind sustainability and define different terms within this field. Then they introduced three reference projects that they have used. They then form a list of actions based on previous findings. Finally, to exemplify the practice, a case study is introduced.

This thesis has applied a similar approach. Firstly, a literature study was conducted to confirm the existence of a knowledge gap. Then, to show how similar projects are realized, an inspirational project is presented. Then, the existing knowledge is presented together with the selected factors. These factors are applied to a case study, to test and demonstrate how the factors can be brought from theory to practise.

2.1 Literature study

Relevance and purpose

A literature study can be useful when a part of literature needs exploration. It can help create an indication of the literature that exists and what might be absent. A literature study is relevant for this thesis because I assumed there existed a knowledge gap within landscape architecture, which was the biodiversity in urban vegetation patches. The purpose of this thesis was to find out an whether this knowledge gap existed, within the frames of this literature study. This aims to give a well-founded understanding of the existing literature from the study.

Process and limitations

In this literature study I will create a selection of studies that I will proceed to analyse and evaluate. The literature study was conducted between the 12.07.2022 an the 18.08.2022. There is thus no coverage of studies published after this timespan.

The search used in Oria contained key words that is central to this field. “Patches, Landscape architecture, design, urban, case” was listed in the search field. The theme Landscape architecture, and English as language was also selected. These keywords were used in the search because they are well known terms within the field of landscape architecture. These terms had a chance of capturing literature that focused on vegetation patches within urban landscapes. Because this search could be narrow, I ruled out the term biodiversity.

The search produced a total of 345 search results. To investigate and filter the literature, I read the abstract and conclusion, sometimes the discussion if it was necessary. Based on this I disregarded the most irrelevant search results. Most of the irrelevant search result were at the end of the search. The relevant literature was then categorized by themes and visualized in a diagram below (figure 1).

The knowledge/technology theme in the diagram covered studies about knowledge and technology within the field. This included new approaches to measure and evaluate spatial characteristics of landscapes. The ecological services/biodiversity theme included studies measuring species richness and theories to achieve biodiversity without focusing on patches. The spatial investigating theme included the studies about general green spatial distribution. A significant number of studies about ecology and green spatial distribution were Chinese. Which is perhaps telling of the growing importance of urban green infrastructure, globally.

The literature that included some text about patches were included in the patch theme. No studies were about how to design patches in urban landscapes, however the studies about patches were about patch characteristics, patch coverage in landscapes or species richness in patches. A large number of studies identified through the search turned out to be about spatial functionality of patches in forests. These were not included in further work on this thesis.

A fair number of studies focused on green corridors, green belts, and connectivity. It is worth noting as none of those key words were used in the search. These studies are found under the theme “Focus on connectivity” in the diagram below. (Figure 1).

Selection criteria for this study

The search area

The literature in this study was based on literature from the database, NMBU Oria. This database is free and available and contains 27 databases in total. This database is international and includes a variety of types of literature.

Criteria 1: type of literature

To create a wide search and a good selection, I included all types of literature. This includes books, journal articles, book chapters and more.

Criteria 2: Literature that actively report on patches

For this I had to read through all abstracts and conclusions of search results, and I was left with four literature findings

Findings

My analysis of the findings was based on 1: the literature purpose/intention and 2: the thoroughness of the literature. See table 1. The intention of the literature can tell if patches is a main theme of the study or not. The thoroughness of the literature can say how much emphasis is has.

Number	Source	Type of literature	Purpose/intention	Relevance	thoroughness
1	Conservation of fragmented grasslands as part of the urban green infrastructure: how important are species diversity, functional diversity and landscape functionality? (van der Walt, 2015).	Journal article	Comparing plant species composition, diversity with the landscape functionalities of grassland fragments in urban and rural areas the Tlokwe Municipal area of South Africa.	Includes how patch characteristics, matrix and intra patch characteristics affect plant species richness.	No known departments behind
2	Park design between community and professionals: the Wollefoppenpark in Rotterdam (Brinkhuijsen & Steenhuis, 2015).	Journal article	An assessment of a the Wollefoppenpark and Noordelijk Wijkpark parks from the 80's that utilizes patches as way to create stability and versatility.	Assessing the development of the park patches in an urban landscape.	No known cost of project
3	Island biogeography theory outweighs habitat amount hypothesis in predicting plant species richness in small grassland remnants (Lindgren & Cousins, 2017).	Journal article	Assessing how patches size and distribution can predict plant species richness in semi natural grasslands.	Assessing characteristics of and plant species richness in rural landscapes.	Large portion of data consisting of 131 midfield islets in 27 landscapes in Sweden.
4	Parallel Calculation Method of Patch Area Landscape Art Index Based on Surface Coverage Data (Xu, 2021).	Research Article	Assessing a method of calculating patch area and spatial attributes.	Assessing calculating metric methods of patches and spatial attributes and land cover.	Original research

Observations from the analysis

From the abstracts and conclusions of these findings I found that very few search result had a purpose that included patches. Two of the four findings that includes patches within their main purpose/intention was about patches and dynamics within urban landscapes. The other two were about spatial metrics and patch dynamics in rural landscapes. Within this framework, I can conclude that there was little literature covering patches within urban areas. This literature study does not include all research, but it can be used as an indication of the literature that is lacking. The few results including patches as a main purpose, and the many about results about connectivity can also indicate where the focus within landscape architecture is.

2.2 Collecting data for the thesis

The approach for finding information and data was by using keywords in Google scholar and Oria. Each time I found litterature, I did so by a new search.

3. Inspirational design project

Due to all the Chinese studies discovered through the literature search, the landscape architecture projects in China sparked interest. The smart city of Daguan wetland was inspirational for this thesis because of the functionalities of the design. Ecology is implemented in the design in a way that contributes to native biodiversity. The project enchances the existing landscape charchteristics. The new wetland was a creative way of using natural structures in favour of ecological functions.

3.1 Guangzhou Tianhe Smart City Daguan Wetland

The inspiration for this project is by the smart city of Daguan wetland. This landscape architecture project has adopted the theory of a previous project called "sponge city" (Turenscape, 2011). (Turenscape, 2011). The Guangzhou Tianhe smart city used the same method as was first applied in the "sponge city" and restored a damaged ecosystem that could function as an urban wetland corridor (Turenscape, 2011). The Guangzhou Tianhe smart city used low-impact technology to design the sites (Turenscape, 2011).

Turenscape, (2011) describes the project site of 46.8 hectares that is inside the city of Guangzhou, on a landscape node in the Tianhe smart water corridor. The previous landscape consisted of farmland, fishponds and the Xingtang reservoir. The previous landscape was a wetland that this project wished to restore.

According to Turenscape, (2011) the design is an artificial wetland purification landscape. The water is cleansed through water sources on land that catch the high amount of rainwater. There are also multi-pond wetland systems that use aquatic plants with purification properties. In this way, ecological processes cause self-purification of water. The design of the site alleviates urban flood in addition to purifying the surface water, increasing the quality. These urban green spaces restore stormwater management, collects pollution, and provide a public recreational space where visitors can study, relax, or exercise (Turenscape, 2011). This creates benefits for people, in addition to the ecosystem services of the design (Turenscape, 2011).

The site has many challenges for vegetation, as the environmental conditions create frequent drought and flood. The changing climate is due to heavy rainfalls, and intense dry seasons. Therefore, the vegetation of the site needs to be both wet and drought tolerant. (Turenscape, 2011).

The landscape design enhances the existing terrain by digging into the existing pondscapes and creating an artificial wetland landscape. These spaces can together with vegetation, reduce the amount of stormwater on the site. The multi pond wetland system is designed with different zones to purify the water before it reaches the main pond within the Xingtang reservoir. (See Fig. 1). Sediments, pathogens, and other pollutants are filtered through a terraced field of water and vegetation. The filters of reeds, calamus, iris, cigu and lythrum slow down the pace of the water flow and absorbs pollutants. The native aquatic plants had in general well develop root systems, high oxygen uptake, and were tall. This creates a wetland landscape that is aesthetically appealing with its colours. The project is restoring a beautiful ecosystem of an ancient river for visitors to see (Turenscape, 2011).

The smart city of Daguan wetland uses native plants species and enhance the existing terrain to create an ecosystem (Turenscape, 2011), which is an example of a way to design with nature. This is another interpretation of Ian McHarg's idea. Although the project main purpose and framework is based upon the ecosystem, landscape and environment, people benefit from the "hidden" ecosystem services. This gives the landscape architectural project more significance than surface level visual benefits. Although a rich ecosystem may also be visually appealing for people, ecosystems provide for much more holistic benefits.

Figure 1. Illustration of the multi-pond wetland system in Daguan Wetland

4. Landscape architecture in relation to nature

4.1 Approaches to landscape architecutre

In landscape architecture, there are different approaches to planting vegetation, and different reasons to do so. According to Spirn, (1997) urban green space is shaped by natural processes and human hands. Spirn, (1997) further explains that it's impossible to make a garden without communicating ideas about nature. This can suggest that landscape architecture can reveal the relationship humans have with nature. Spirn, (1997) further explains that we often try to produce perfect gardens with aesthetical qualities with rich soils that can result in struggling plants. This is because some plants prefer less nutrients. We can often see straight lines and symmetry with vegetation in landscape architecture. These visual design choices can we see in the Chatsworth landscape park in Derbyshire, England. In this example it almost seems like aesthetics is the main intention of the park, and that nature surrenders to these harsh lines. However, what is visually appealing is different to for every person.

Landscape architecture has been regarded as a meeting point between science and art (Etteger et al., 2016). In later years, we have seen a larger shift away from aesthetics and towards functionality and sustainable design (Etteger et al., 2016). However, the terms aesthetics and art can differ from person to person. There are different interpretations on what accounts as 'art' (Etteger et al., 2016). Following Etteger et al., (2016) Nick Zangwill calls the newer shift of landscape architecture art. His definition differs, as he perceives art providing functions that are visually appealing and functional. These functions could be ecological or social inclusion. This does not mean that aesthetical qualities will appear in all functional design as weak functionalism can suggest (Etteger et al., 2016).

In urban landscapes, urban green spaces can provide ecosystem services. These ecosystem services can benefit people while tackling environmental problems in cities (Mexica et al., 2018). Urban green spaces can provide social benefits with access (Yang et al., 2016). This can be through a path, an area for recreational use, or other use.

4.2 Functionalities of urban green spaces

The functional aspect of urban green spaces can be linked to assisting nature in some way. This can be urban green spaces with vegetation that deal with pollution or provide ecological value and contribute to biodiversity (Mexica et al., 2018; Etteger et al., 2016; Huang, et al., 2015). Pollution or contamination levels can vary, therefore there isn't an obligation to manage pollution if it is at an acceptable level.

Sometimes, there are also a cultural or educational benefit as well, which is exemplified in Shenyang Architectural University Campus. The campus has a combination of cultural, educational, and sustainable functionalities (Turenscape, 2011). This project used native rice species with historical value into a university campus. This provides cultural value, and educational purposes that displays sustainability with a productive landscape (Turenscape, 2011). It is bringing the traditional agricultural landscape into the urban environment (Turenscape, 2011).

It is possible to conclude that landscape architecture can serve both nature and people. The functionalities of a design can serve biodiversity and humans as long as there is access (Yang et al., 2016). Other functionalities like contamination management can be used if there is a necessity. Ecosystem services come with a biodiversity design. The aspect of art and aesthetics in landscape architecture is important for the urban landscape (Etteger et al., 2016). However, it can occur automatically with the heterogeneity of biodiversity design. Moreover, the design can be planned after the plant's conditional needs (Spirn, 1997).

For vegetation to survive, it is important to know the sun exposure of the intended patch location. According to Beck, (2013) designers often place plants into wrong locations, with unfitting conditions. This includes putting shade tolerant species into areas with a lot of sun exposure.

5 Urban ecosystem

5.1 Urban ecosystems have complex conditions

Contrary to popular belief, most urban landscapes are not homogenous asphalt jungles. According to Kattel et al, (2013), there exist a spatial heterogeneity within an urban ecosystem, that consists of biophysical and human processes. The highly complex human-modified ecosystems interact with patch dynamics, from energy exchanges to nutrient cycles (Kattel et al., 2013). Humans contribute to heterogeneity through transporting species, modifying landforms, building infrastructure, and creating drainage systems, which can create effects of fragmentation (Kattel et al., 2013; Rybicki et al., 2020). Therefore, urban areas will have distinct disruptions for its internal ecosystems (Kattel et al., 2013). Examples of disturbances and stressors that exists in urban landscapes are related to stormwater runoff, contamination, or spatial attributes such as buildings (Kattel et al., 2013).

5.2 The urban to rural gradient

Ramalho and Hobbs (2012), discuss how the urban-to-rural gradient oversimplify the complexity of cities. Every conditional factor from history, geology, urbanization, environment, and urban land use will create distinct impacts, both long term and short term (Ramalho & Hobbs, 2012). However, every factor of figure 2 is not necessarily applicable to highly managed urban green spaces. The social sciences, and every aspect of historical change in a landscape might not be relevant to analyse the current status of a landscape (Ramalho & Hobbs, 2012). (Fig. 2) illustrates the different stages that generate our complex human-modified ecosystems.

5.3 Different scales

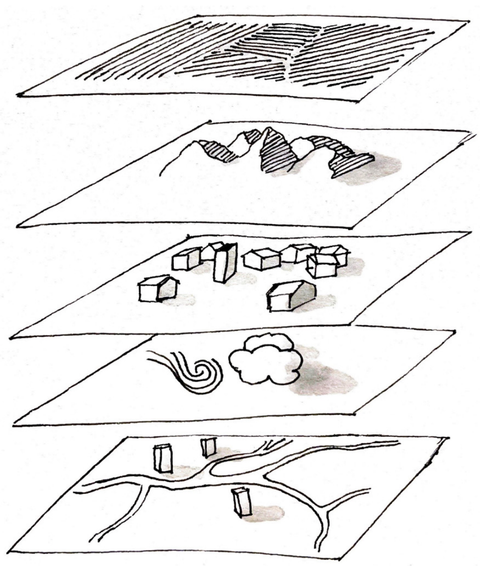
Every factor that generates an urban landscape will have different impacts at different scales. Thus, an analytical approach should have different scaling dependent on what best represent the landscape characteristic (Gazvoda, 2002). Therefore, to properly map a landscape to obtain all the relevant knowledge that affects biodiversity, an analysis can be divided into smaller and larger scales. For example, landscape characteristics like geology and can be important to include in an analysis of a landscape (Hu et al., 2020). Detailed geological maps can show more details at site scale.

5.4 Landscape characteristics

Urban landscapes are the product of many pre-existing landscape characteristics along with human modifications. And some of these characteristics can affect vegetation biodiversity. This is because ecosystems are shaped by drivers such as climate and parent rock and weathering (Hu et al., 2020).

The geology can have an effect on plant communities and can be directly linked to biodiversity (Hu et al., 2020). However, the effect that it can have in urban landscapes can differ, because some areas are fertilized or modified. This can make it difficult to categorize an urban soil, since it can vary widely (Pouyat et al., 2007). Still, the geology will probably affect the native plant species and communities (Hu et al., 2020).

Another landscape characteristic is climate, which is closely linked to ecosystems and consequently, biodiversity (Hu et al., 2020). There is a lot of literature related to the response of vegetation to climate, and climate change. Plant species have to find suitable climate in order to thrive (Jump & Peñuelas, 2005). The temperature is often linked to the sun exposure of the location. In urban areas, buildings might block the sunlight. A lack of sunlight might create different climatic conditions. Plants tend to migrate to the conditions they thrive in, and in response to climate changes, plants have for example been found to migrate to colder temperatures by climbing to higher altitudes (Jump & Peñuelas, 2005).



Land use legacies

Past remnant configurations

Urbanization age

Local enviroment

Socio-economics, urban land use

Figure 2 Factors that form urban landscapes illustrated from (Ramalho & Hobbs, 2012)

6 Biodiversity

6.1 Measuring biodiversity

Biodiversity can be a difficult concept to quantify. A mere number of species in an area, does not fully capture the amount of measurable diversity found in nature (Hillebrand et al., 2018). Species richness is an easy and widespread measurement of biodiversity, becoming the default method (Hillebrand et al., 2018). Other measures include the species diversity, biotic processes and the product or structural amount of each (Swingland, 2013). This thesis includes studies that use species richness to measure biodiversity. According to Swingland (2013), biodiversity refers to the variety within and between organisms, populations, communities. Also, there are different aspects of analysing and describing biodiversity when measuring species on a site.

Alpha diversity, beta diversity and gamma diversity, all describe different community diversities in landscapes (Andermann et al., 2022). Alpha diversity covers the diversity found in a patch, like a pond, or a park (Andermann et al., 2022). Beta diversity describes the differentiation of species between communities (Andermann et al., 2022). Gamma diversity describes the diversity of species on a large geographical area (Andermann et al., 2022).

6.2 Genetic diversity

According to Swingland, (2013) genetic diversity means the heritable variation within one or more populations. The genetic diversity can even include the amount of DNA and the different chromosome structures found in each cell in an individual (Swingland, 2013). It is important that the gene pool has variety within a population of species. This is because small gene pools can cause inbreeding effects (Swingland, 2013). The resilience and persistence of a species is dependent on genetic variety (Furlan et al., 2012). This variety can be accomplished by having enough individuals. Variety in plants can occur through dispersal and cross-fertilization.

For a population, a reduced gene pool can result in reduction of reproductive fitness and limited ability to adapt to environmental change, diseases, or other disturbances (Furlan et al., 2012). Isolated islands can be similar to patches, and Furlan et al., (2012), further describes that island populations are at a higher risk of inbreeding. Island populations exist in places where fragmentation in a matrix creates patches of habitat. This fragmentation can be found in landscapes diverting from dense forests to urban areas. Therefore, the island biography theory has a range of applicable landscapes. This means that urban landscapes with patches can be affected in the same way as island populations (Rybicki et al., 2020).

6.3 Biodiversity in urban habitats

There is a significant biodiversity also in the urban landscape although this does not include every taxonomic group or species. The number of animals decrease from rural to urban areas, whereas plant species increase, which gives vegetation a significant role with providing biodiversity in cities (Beninde et al., 2015). This is because vegetation is a major influence for fauna, providing food, habitat, and ecological services (Beninde et al., 2015).

Habitat fragments of vegetation can appear in different structures. In urban landscapes there are typical examples of matrixes, corridors, and patches. Demircioğlu Yıldız et al., (2021) classified these into typical elements of urban landscapes. They exemplified that urban vegetation patches could be parks, sports fields, wetlands, cemeteries, campuses, open green spaces. Typical corridors could be streams, canals, roads, power transmission lines and drainage paths. Urban matrixes can be urban settlements, industrial areas, and commercial areas. However, landscape structures are often more complex than these typical classifications, and habitat fragments can be scattered and small (Demircioğlu Yıldız et al., 2021).

Parks, sports fields, cemeteries, and campuses are frequently exposed to management techniques. When management techniques such as lawn mowing are too frequent, patches that should be highly biodiverse might not be so (Aronson et al., 2017). Aronson et al, (2017) also presents pervasive managements techniques as barriers to biodiversity. Therefore, many patches have less biodiversity, and many patches have potential to be more biodiverse.

Patches in urban landscapes consists also of privately owned lawns and gardens. Up to 70% of urban green space is privately owned, thus the vegetation on those properties is significantly important, and can influence biodiversity greatly (Müller et al., 2013). This can impact the response that species have to urbanization. According to Müller et al, (2013), there are six responses that species have to urbanization; (1) no response, (2) negative response, (3) punctuated response, (4) an intermediate response, (5) bimodal response, and (6) a positive response. A positive response was reported after species richness increased in Phoenix, Arizona, after urbanization (Müller et al., 2013). This suggests the possibility for increasing biodiversity along with urbanization. However, a positive response is not certain. To create a positive response, the use of biotic factors such as vegetation, has the most impact on biodiversity (Beninde et al., 2015). Plants can both be biodiverse themselves and create biodiversity with other species. Therefore, creating vegetation patches has the potential for being biodiverse and creating biodiversity through other species like birds or insects (Beninde et al., 2015; Huang, et al., 2015).

The varied responses species have to urbanization can be attributed to many factors. The complex urban landscape can affect biodiversity in many ways. Müller et al., (2013) presented these possible attributes of urban areas that can affect biodiversity.

Urban landscape attributes that can affect biodiversity directly or indirectly

Box 10.2 A Number of Attributes That Define an Urban Area and Can Subsequently Affect Biodiversity (From Müller and Werner (2010) After Sukopp and Wittig (1998) and Pickett et al. (2001)) (See Chap. 1 for a Definition of Urban)

1. Configuration of buildings, technical infrastructure and open spaces where the extent of hard surface (including buildings, paving and other structures) covers an average of 30–50 % of the land surface in the urban fringe and suburban areas, and well in excess of 60 % in the core areas.
2. Formation of an urban heat island effect in temperate and boreal zones with longer periods of plant growth, warmer summers and milder winters than the surrounding countryside.
3. Modification of the soil-moisture regimes, tending to become drier in temperate zones, but with opposite effects in desert areas due to irrigation.
4. High levels of nutrient input at both point source and broad-scale.
5. High biomass production in parks, private and community gardens, and similar intensively cultivated or managed areas.
6. Intentionally and unintentionally elevated food availability for animals both wild and domesticated.
7. Soil contamination, air pollution, and water pollution; with particular impacts on soil organisms, lichens, and aquatic species.
8. Disturbance such as trampling, construction (often with removal of all vegetation), mowing, radical soil change, light and sound pollution, and litter or illegal dumping.
9. Fragmentation of forests, grasslands and waterways as well as existing green spaces.
10. High proportion of introduced plant- and animal species.
11. High proportion of habitat generalists and common plant and animal species.

Figure 3 Urban attributes that can affect biodivesity (Müller et al, 2013)

7. Patches

7.1 Biodiversity within patches

According to Gillson, (2013) patches are spatial units that are differing from their surroundings. The internal patch structure can be both homogeneous and heterogeneous (Gillson, 2013). Patches can be grouped at different scales, from a singular tree in a forest to large forest areas (Gillson, 2013). In cities or urban landscapes, a typical example of patches for biodiversity exists in urban green spaces. However, cities can be dense environments where urban green spaces can exist as small patches of herbaceous vegetation or trees (Vega & Küffer, 2021). According to Vega and Küffer, (2021), small green spaces can also mitigate harmful effects that urbanization can have on biodiversity, reducing the risk of local extinctions.

Even though species richness is positively correlated with patch area, the different patch sizes contribute to different types of diversity (Vega & Küffer, 2021). Since species richness exclude does not take into consideration the abundance of each species, the size factor for species richness might overlook the positive biodiversity impact of smaller patches, and how they might contribute uniquely to an ecosystem. A study conducted in the city of Zurich, Switzerland, found that smaller patches contributed significantly more than expected to wildflower species richness in the city (Vega & Küffer, 2021). Moreover, when patches are taken together, small patches showed similar species richness and higher beta diversity that larger patches (Vega & Küffer, 2021). Additionally, these smaller patches can function as important stepping-stone habitats (Vega & Küffer, 2021). Also, the biodiversity found in habitat patches, can be classified as alpha diversity (Vega & Küffer, 2021).

7.2 Biodiversity and patch size

The amount of biodiversity is clearer through analyses of beta-diversity (Vega & Küffer, 2021). Beta-diversity analyses often finds that two small patches can be diverse compared to each other, and that multiple small patches have higher species diversity combined than several larger patches (Vega & Küffer, 2021). Vega and Küffer, (2021) defined large patches as >300 m2, medium as 30 – 20 m2, and small as <20 m2. Small patches have lower alpha diversity, but a higher beta diversity with a more equal proportions of species (Vega & Küffer, 2021). Several small habitat patches outperform singular large ones in species richness, even in matrixes found in cities, which can be hostile (Vega & Küffer, 2021).

There are some plausible explanations as to what gives the high biodiversity contribution of smaller patches, including that they often have a high turnover, or much immigration and extinction (Vega & Küffer, 2021). This can result in a random complexion of the local species (Vega & Küffer, 2021). This patch environment provides opportunity for colonization of new species (Vega & Küffer, 2021). Large habitat patches have more predictable communities of species, with a more competitive environment (Vega & Küffer, 2021). This is exemplified by a re-survey of a larger meadow patch in Zurich after 20 years, where little compositional change of species was found (Vega & Küffer, 2021). The survey indicates that connectivity has less of an effect with increased patch size, as they rely less on immigration and pollinators from other patches, however these large vegetation patches are less common in urban areas (Vega & Küffer, 2021). In summary, small patches functions as connectors with potential to carry diverse species, and larger vegetation patches in cities acts as population sources for smaller ones (Vega & Küffer, 2021). Hence, both smaller and larger patches have roles that are important for creating a biodiverse urban landscape.

7.3 Spatial separation of patches

The amount of biodiversity of urban green spaces will depend on factors such as size, connectivity, and inner structure (Vega & Küffer, 2021). Most studies analyse spatial configurations of green space at large scales that cover city ecosystems (Vega & Küffer, 2021). In Vega and Küffer, (2021), the vegetation patches varied from 1m2 – 30, 000 m2, where over 75% of these was defined as smaller (<20m2), and they were on average closer in proximity.

Vega & Küffer, (2021) found that on average smaller patches had 16 m separation, medium had 55 m, large patches had 106 m. If patches were separated by more than 100 m, they had a really low chance of being connected with species (Tulloch et al., 2016). This separation between patches supports the idea that the larger patches can need smaller patches for connectivity. Nevertheless, the connectivity between patches depends on more than spatial separation, it depends on species and the matrix.

Several factors can affect how these urban green spaces carry biodiversity. Ecology distinguishes between characteristics of patch habitat and the surrounding landscape/matrix (Beninde et al., 2015). Landscape factors determine the permeability of the matrix and thus influence the species dispersal (Beninde et al., 2015). Permeability is the extent that movements is impeded or assisted by the landscape characteristics (Beninde et al., 2015). The suitability for species or a group of species are determined by the local, or internal factors of a patch (Beninde et al., 2015; Scharf et al., 2018).

7.4 Patch factors that affect biodiversity

The local/internal characteristics of habitat patches can have positive effect on biodiversity (Vassiliki, et al., 2010). Beninde et al., (2015) created a list of traits with impact on species richness (see Fig. 4). The categories with a positive impact on species richness were area, habitat richness, management, herb density, herb cover, herb structure, shrub structure, shrub cover, tree structure, tree cover, vegetation structure and water cover (Beninde et al., 2015). The categories that had most significant impact were area, herb density, tree structure, tree cover, vegetation structure, and water cover (Beninde et al., 2015). This is an indication that internal heterogeneity with vegetation (Vassiliki, et al., 2010) and larger area is important for species richness. However, larger area was only significant for species richness in this study, and that does not include the beta-diversity of smaller patches.

Internal heterogeneity can be accomplished by a structural mosaic composition of plants, with different height and species (Hovick et al, 2014). Additionally, the local/internal patch factors that had the most impact on biodiversity were in general, biotic. The biotic factors are also prevalent, within the landscape/surrounding factors that surrounds patches.

7.5 Matrix factors that affect biodiversity

A matrix is defined as the dominant majority of land surface (Gökyer, 2013). The matrix can be many different types of land cover, from urban areas, agricultural land to forests (Gökyer, 2013). The matrix can be hostile or even function as a secondary habitat to species that live in habitat patches (Prevedello & Vieira, 2010). Urban landscapes can be hostile.

According to Beninde et al., (2015) urban green spaces are best connected through corridors and patches that can function as stepping-stones (Fig. 5). Patches functioning as stepping-stones habitats, increase the permeability of the matrix if distance between then is within the reach of the species. A long distance between stepping-stones impedes the spread of diseases (Beninde et al., 2015). However, long distances between habitat patches might affect seed dispersal (Traveset & Rodríguez, 2010). This effect on movements is very dependent on the content of the urban matrix, where wind dispersed plants can be aided by seeds sticking to vehicles, or by vehicle airflow and being transported (von der Lippe & Kowarik, 2008; von der Lippe et al., 2013; see Fisher et al., 2013). Even walking people could disperse seeds through them sticking to shoes, or clothes and falling off in other places (Wichmann et al., 2009; Auffret & Cousins, 2013). Walking could disperse seeds at least 10 km (Wichmann et al., 2009), making it likely that cyclists also will disperse seeds, along other means of transportation (von der Lippe & Kowarik, 2008).

Traffic has also been shown to further disperse seeds through tunnels and following the overall directions of traffic (von der Lippe & Kowarik, 2008). Though wind dispersal species might be affected by the urban landscape structures, that is also the case in dense forests (Traveset & Rodríguez, 2010).

Urban landscapes have fewer animal dispersers to rely on (Müller et al., 2013). Without vectors/animals there will be a dispersal failure (Traveset & Rodríguez, 2010). However, taxonomic groups such as birds and pollinators does succeed in urban environments (Beninde et al., 2015). In general, the urban matrix should not be viewed as a boundary since stepping-stone habitats and urban means of seed dispersal makes new establishment and recolonization of species possible (Lizée et al., 2012). Seed dispersal increases biodiversity in patches by increasing gene flow, population dynamics such as recolonization and revegetation and connectivity (Traveset & Rodríguez-Pérez, 2019; Cruz et al., 2013).

7.6 Urban patch biodiversity design factors

There are many internal and external factors of urban patches, which can affect biodiversity. These factors are important for biodiversity design. The internal factors are tied to the composition of vegetation, like herb density, tree structure, tree cover, vegetation structure, and water cover (Beninde et al., 2015).

The internal vegetation factors of a patch can determine which species can find use of it. For example, wild grasses and herbs can attract insects (Huang, et al., 2015). Furthermore, the richness of insect communities can increase the number of birds (Huang, et al., 2015). A possible explanation could be that insects are a food resource for birds in the urban landscape (Huang, et al., 2015).

Species richness of birds are also closely linked to plant structure (Huang, et al., 2015; Stirnemann et al., 2015). Diversity with vegetation structure is positively associated with species diversity (Guo, et al., 2017; Stirnemann et al., 2015). This might be because structural heterogeneity can create ecological niches for insects or birds (Guo, et al., 2017; (Vassiliki, et al., 2010). Wild grasses, herbs, and other plants dependent on insect or bird dispersal can be useful in a biodiverse design (Huang, et al., 2015; Guo, et al., 2017). A heterogenic patch is best suited for biodiversity (Beninde et al., 2015). The heterogenic patch can possibly be designed with a diversity of plant species of varied height, phenology etc. and assembled in a mosaic composition (Hovick et al, 2014) with a choice of species which provides resources for other species.

The idea of a mosaic landscape can also be applied on a larger scale. This is because diff ent sizes of patches can fulfil different functio as stepping-stones and as habitats in urban landscapes (Vega & Küffer, 2021). Therefore, it is also important that these patches are connected through dispersal routes, which may be wind patterns, but also directions of movement of traffic and people (von der Lippe & Kowarik, 2008). To sum up, the landscape factors indicates that surrounding patches and dispersal routes are important for species establishment.

Figure 4 Illustration of a mosaic landscape

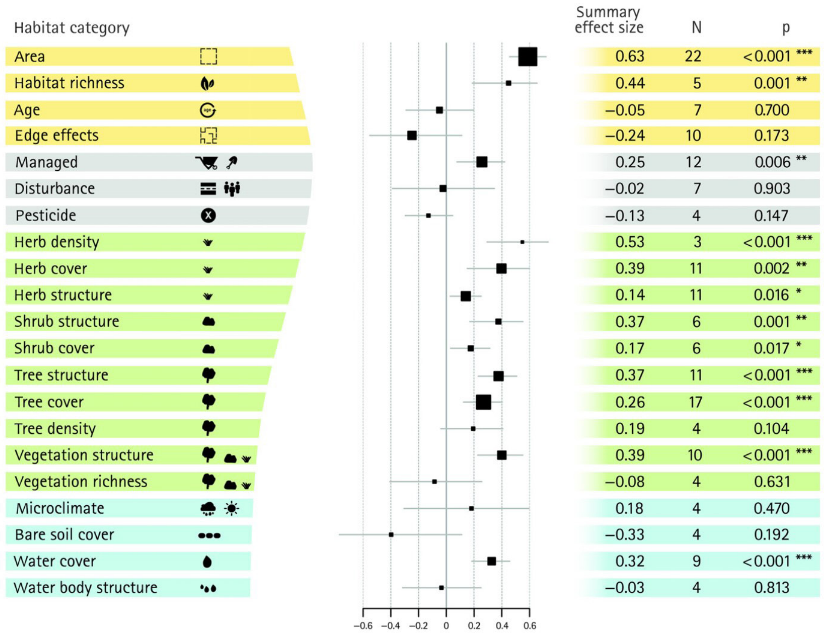


Figure 5 Factors that impact species richness in patches (Beninde et al., 2015).

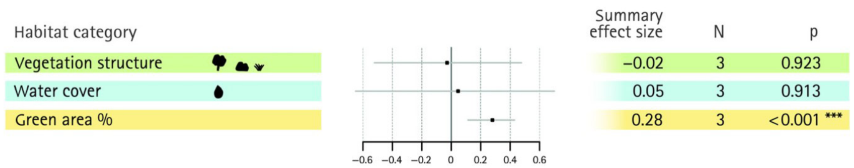


Figure 6 Landscape factors impact on species richness (Beninde et al, 2015).

8 Species

8.1 The effects of the urban matrix on species populations

Urban landscape structures and climate can influence plant seed dispersal (Buther et al., 2020). These dispersal differences will affect the gene flow in plant populations, which might create metapopulation persistence (Buther et al., 2020). Metapopulation persistence is created when populations will adapt differently to the environment, providing a larger gene pool (Buther et al., 2020).

Increased gene flow promotes a populations ability to utilize natural selection due to a large gene pool (Buther et al., 2020). Decreased gene flow may promote local adaptation (Buther et al., 2020), but may also cause inbreeding depression. There is always a negative risk with gene flow even though the patterns of pollen dispersal and gene flow in urban areas have been found to be similar to populations in rural areas (Buther et al., 2020).

8.2 What contributes to a high species richness in urban environments

The vegetation thriving in urban areas share traits (Knapp et al, 2008). Knapp et al., (2008) found that species richness of urban areas consists of plants with similar environment adaptations. For example, biennial or wind-pollinated plants are adapted to urban challenges like fragmentation, and they appear less frequently in rural areas (Knapp et al., 2008). Although the species are closely related, they cannot share the exact same niche (Knapp et al., 2008). If they are too similar, they cannot coexist (Knapp et al, 2008). Knapp et al, (2008), found the similar traits in different non-related plants, can be due to evolving in similar environments. It could also be due to species rapidly adapting to a habitat that changes quickly.

8.3 Native and non-native species for biodiversity

Humans have a long history of introducing non-native species into new geographical locations due to traveling, and since the Neolithic period about 12 000 species have been moved to central Europe, and 10 % of those became naturalized (Müller et al., 2013). Naturalized means that they have established themselves into a new location (B. Ipbes, w, y). There is a link between the density of humans and the proportion of non-native species, where a rise of naturalized species increased along with the populations of Berlin (see Fig. 6) (Müller et al., 2013).

Naturalized species in urban areas can be non-native, endangered species, native, and anecophytes (Müller et al., 2013). Anecophytes are species that evolved within agricultural urban or industrial spaces (Müller et al., 2013). Quine et al, (2010), found that non-native/exotic species are not better for biodiversity than native species, and that native species should be encouraged. Yet non-native species could have a positive role in conservation supporting existing ecosystem processes (Quine et al., 2010). This entails that native species can be supported by non-native species, but that native species and red listed species should be preferred.

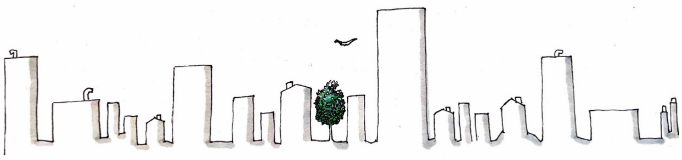
8.4 Urban environments for threatened species

Cities tends to provide unique habitats for threatened plant species (Ives et al., 2016). Urban environments have also been shown to harbour threatened species (Ives et al., 2016). The assemblages of species vary greatly in urban areas and can favour a wide variety of species (Duncan et al., 2011), increasing beta diversity (Ives et al., 2016). This high beta diversity is more likely where native ecosystems impede the urban landscape (Ives et al., 2016).

Ecological functions should also be considered when conserving threatened species, since these species can have important roles (Luna et al., 2018). Therefore, creating habitats that sustain ecological functions are as important as preserving threatened species (Luna et al., 2018).

8.5 Colonization in urban ecosystems

There are difficulties for species to naturalize in urban environments with disturbances and fragmentation that cause reproductive, dispersal and survival barriers (Kowarik & von der Lippe, 2018). Urban environments are categorized into hybrid and novel ecosystems, where hybrid ecosystems are modified from their natural state, but can be restored into previous conditions or be further developed into urban green space (Kowarik & von der Lippe, 2018). Novel ecosystems emerges from built structures, such as succession managed in vacant lots (Kowarik & von der Lippe, 2018). Hybrid ecosystems are typically perceived as urban green spaces.



Following Kowarik & von der Lippe, (2018) hybrid ecosystems seem to exceed expectations when it comes to establishing alien species, and there seems to be a lower number of endangered species in these compared to natural remnants, which are close to what is perceived as "natural landscapes" in the Anthropocene (see Fig. 7.). In order to prioritize endangered species and native species when designing hybrid ecosystems, it is important to ensure that they can survive in urban environment.

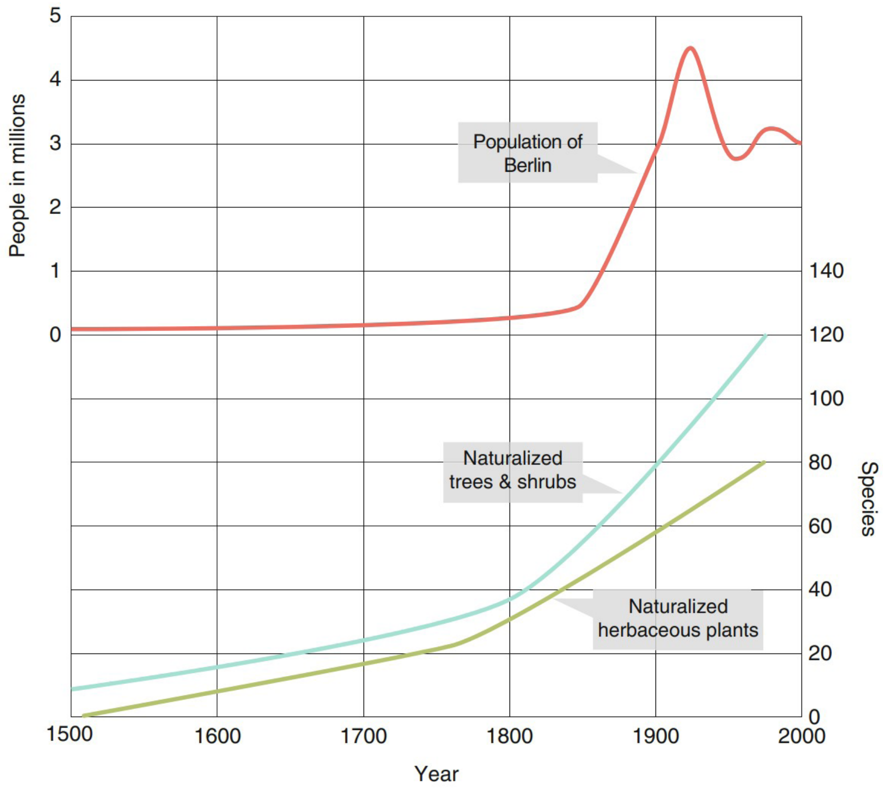


Figure 6 The relationship between humans and naturalized species in Berlin (Müller et al., 2013).

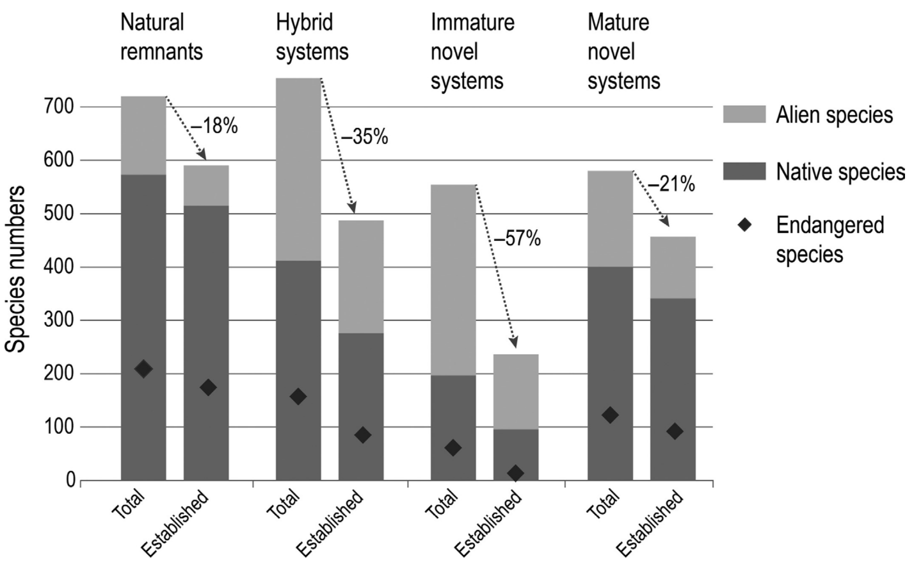


Figure 7 Number of established species in ecosystems (Kowarik & von der Lippe, 2018)

8.6 Species traits of urban plants

There are typical traits of established urban plants. As mentioned earlier, both native, non-native and may have traits that make them fit the urban environment vegetative (Duncan et al., 2011). Finding which species will succeed in the urban environment, can be based upon the traits of established plants. This is because these plants are thriving in urban environments, and their common attributes can help signify which plant traits are best suited for urban landscapes.

Urban landscapes favour plants that are generalists (Johnson et al., 2018) both native and non-native (Müller et al., 2013). The urban environment can elevate soil and air temperatures, have high concentrations of heavy metals in the soil, have increased air pollution, have more nitrogen and calcium deposition, and increased water stress (Müller et al., 2013). These conditions have favoured traits in plants that are biennial or annual, C-strategists (Fisher et al., 2013), and wind-pollinated plants that flowers in mid-summer, reproduce vegetatively (Williams et al., 2015) and with seeds that disperse through humans or wind, thriving with a lot of light and nutrients (Müller et al., 2013).

There are three strategy schemes which are functional traits that create a survival strategy (Negreiros et al., 2014). C-strategists are competitors to neighbouring plants, S-strategists survive losses of biomass, and R-strategists have short stature, short longevity, and high reproductive investment (Negreiros et al., 2014). The favouring of C- strategists in urban green areas might be due to irregular disturbances that creates a mosaic of various stages of successional development (Müller et al., 2013). The favouring of perennial and annual (Williams et al., 2015) species might be because of adaptations for sustaining in the droughty and anaerobic conditions found in urban areas (Müller et al., 2013).

Other vegetation traits typical in urban green spaces consists of wind-dispersed, fast growing and shade tolerant species (Müller et al., 2013). Thompson and McCarthy, (2008), found plant traits with high light requirements and lower moisture requirements tend to succeed in urban landscape. Furthermore, the urban environment has promoted and altered genotypes of species, previously stated as anecophytes, that have no origin habitat (Müller et al., 2013). Examples of commonly appearing anecophytes in urban areas species are mouse barley (Hordeum murinum), prostrate knotweed (Polygonum aviculare), and lambsquarters (Chenopodium album) (Müller et al., 2013).

Compared to native species, non-native species tend to have faster growth, grow into taller plants, have more lateral growth, vegetative reproduction and extended flowering periods (Müller et al., 2013). Other traits found to be more common were earlier germination, and germination that could occur under a wider range of conditions, in addition to higher use efficiencies for water, nitrogen, and phosphorus (Müller et al., 2013).

8.7 Plant traits of invasive species

Similar to non-native species in urban environments, invasive species can develop the traits that succeed in cities. Invasive species can adapt to urban environments, and have attributes specifically designed for its location such as rapid growth after disturbances, which can be seen in increased leaf area (Lake & Leishman, 2004). Urban landscapes might free plants from herbivores, which might result in less defence mechanisms in plants, such as less leaves with rough textures or hairy surfaces (Lake & Leishman, 2004). Lake and Leishman, (2004) predicted that leaves will develop to be glabrous and soft-textured, and that the seed production development will likely maximize its colonization through more, but smaller and lighter seeds (Williams et al., 2015) with hairs, wings and pappus (Schleicher et al., 2011). Vegetative propagation is also an advantage where disturbances frequently happen, and through maximalization of growth, and little investment in structural support, a lot of invasive species are climbers or vines, to take advantage of nutrient dense sites (Lake & Leishman, 2004). Another reproductive strategy might be an increased flowering period to combat disturbances and produce more seeds (Lake & Leishman, 2004).

8.8 Seed dispersers and pollinators in urban environments

Much of seed dispersal and pollination is dependent on interactions with pollinators and seed dispersers, and this is vital for biodiversity (Bascompte & Jordano, 2007). This network structure of interaction between species has implications for the continued existence of populations and the coevolutionary process (Bascompte & Jordano, 2007; Ridenhour, J, B, 2016). There are some species of birds and insects, or seed dispersers and pollinators, frequently found in urban green spaces (Beninde et al., 2015). Taxonomic groups of species react to various attributes of urban green spaces, as documented by Beninde et al. (2015), both birds and insects respond strongly to size of area, birds responded strongly to vegetation structure (Stirnemann et al., 2015; Hovick et al, 2014), and insects responded strongly herbaceous vegetation.

8.9 Species that can contribute to biodiversity

Even though native plants are in general considered the better choice, they often fail to settle in urban areas, whereas non-native plants, anecophytes and invasive species have seemingly evolved to better match these conditions. These evolved traits of established non-native invasive and anecophytes species have the possibility of indicating preferable traits in native species for urban green spaces. A strategy thus seems to be identifying which plant traits are successful in an urban landscape and looking for similar traits in native species. Possibly resulting in colonization of native species. Endangered native species should also be a priority, and where possible, should be implemented in hybrid ecosystems, since endangered, native, and non-native species have shown establishing capabilities (Kowarik & von der Lippe, 2018).

Additionally, urban dispersal of seed and pollen seems to be dependent on birds and insects (Beninde et al., 2015). These birds and insects are significantly impacted of different aspects of the vegetation, where birds respond positively to vegetation structure (Stirnemann et al., 2015), insects respond positively to herbaceous vegetation, and both respond significantly to size of area (Beninde et al., 2015). Therefore, urban biodiversity design should have vegetation that depends on insects, birds, and humans for dispersal.

9 Factors to include when designing urban biodiverse vegetation patches

To adhere to the idea of nature's lead when designing, the information about how urban patch biodiversity functions in urban green spaces is vital. Therefore, the following factors sum up the literature regarding the most effective influences on biodiversity in urban vegetation patches.

The information gathered is sectioned into main factors. Each factor has other factors influencing it. All factors are based on knowledge about nature. The analysis factors are presented according to main topics; these are climate and environmental, species, neighbouring urban green spaces, possible dispersal routes, contamination, and sun exposure. Along with these factors, there are factors for designing biodiverse urban patches. These design factors are vegetation heterogeneity, plant species that can benefit from dispersal routes, and possible adjustments for urban use The list of factors begins with an analysis to gain information about the patch location.

Information about a landscape can whether to apply small- or large-scale analysis are dependent on which measure that represent the data best. For example, in order to map large patches in an urban landscape, it is likely better to 'zoom out'.

The analysis factors

9.1 Climate and environmental

Climactic and environmental factors are important to examine to establish which plants will survive. For example, the length of seasons, and the severity of drought and flood can severely affect which species will survive. The humidity of costal climates can affect both temperatures and cause milder seasonal differences.

9.2 Plant species

The method of selecting species is going to differ depending on the data available. The most important aspect is that they are native, or even endangered species that fit the climate. The species selection is also dependent on the many traits which appear to be beneficial for plants survival in urban landscapes.

List of plant species traits favourable in the urban landscape

- Generalist species [1]
- Annual species[2]
- perennial species[3]
- C-strategist species[4]
- Wind-pollinated species[5]
- Vegetative reproduction[6]
- Small seeds that can disperse through humans or wind[7]
- Fast growth[8]
- Lateral growth[9]
- Germination under a wide range of conditions[10]

1 (Johnson et al., 2018; Müller et al., 2013)
2 (Williams et al., 2015; Müller et al., 2013)
3 (Müller et al., 2013)
4 (Fisher et al., 2013; Müller et al., 2013)
5 (Müller et al., 2013)
6 (Müller et al., 2013)
7 (Williams et al., 2015; Müller et al., 2013)
8 (Müller et al., 2013)
9 (Müller et al., 2013)
10 (Müller et al., 2013).

9.3 Neighbouring urban green spaces

The surrounding urban green spaces can indicate the potential gene flow, and which directions there are stepping-stones.

9.4 Possible dispersal routes

Likewise, possible dispersal routes are important to map, in order to see the direction and length of seed flows. This is important to consider species that may utilize the routes. For example, if there is a water body nearby, choosing species seeds known to spread along waterways might be an advantage. Another example can be infrastructure of any sort, such as roads, walking paths, which wind pollinating species might take advantage of.

9.5 Area use

For the smaller scale analysis, it is important to establish what the design area was previously used for, and what purpose it served. If for example children are using the area for play, this might be important information that will affect species selection. For example, it is a bad idea to have highly toxic plants next to a playground. This is also important to establish, because not every area in an urban landscape can become a biodiversity promoting vegetation patch.

9.6 Contamination

The levels of contamination can be vital knowledge to establish whether it's possible to plant selected species. This is probably more visible at a smaller scale.

9.7 Sun exposure

The sun exposure of a patch can vary in cities, due to buildings blocking the sun. This can change the climatic conditions, so it is important to check if buildings create a shade over the selected design area.

Design factors for urban vegetation patch biodiversity

9.8 Vegetation heterogeneity

To create internal heterogeneity within a patch, it is possible to use a mosaic pattern for planting species. This mosaic should consist of different shapes in different sizes. The structure of the plants should also have different heights, which creates structural variety.

9.9 Plant species that can benefit from dispersal routes

The species should be selected based of the possible dispersal routes. These traits can be chosen from the species that fit climatic factors and favourable traits. Additionally, plant species need to be selected based on traits that fit the potential dispersal routes. For example, wind dispersal plant species can use traffic as a dispersal route.

9.10 Possible adjustments for urban use

Since the vegetation patch design is in an urban environment, urban use and humans needs to be considered. The use of the area can indicate whether any possible adjustments for the use of the patch is needed.

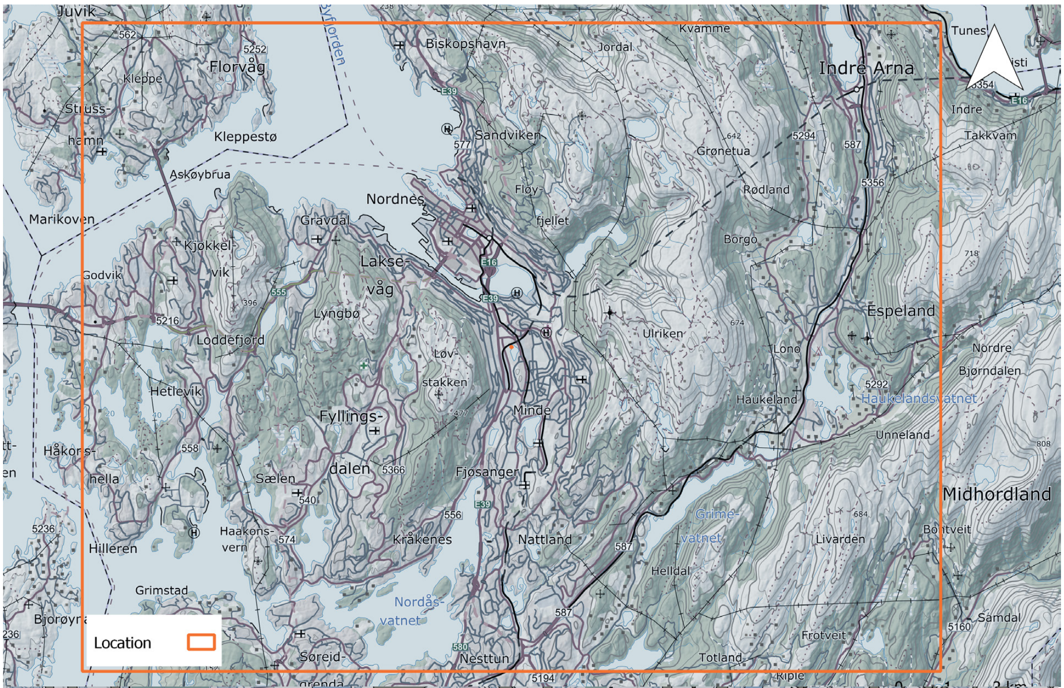
10 Case design

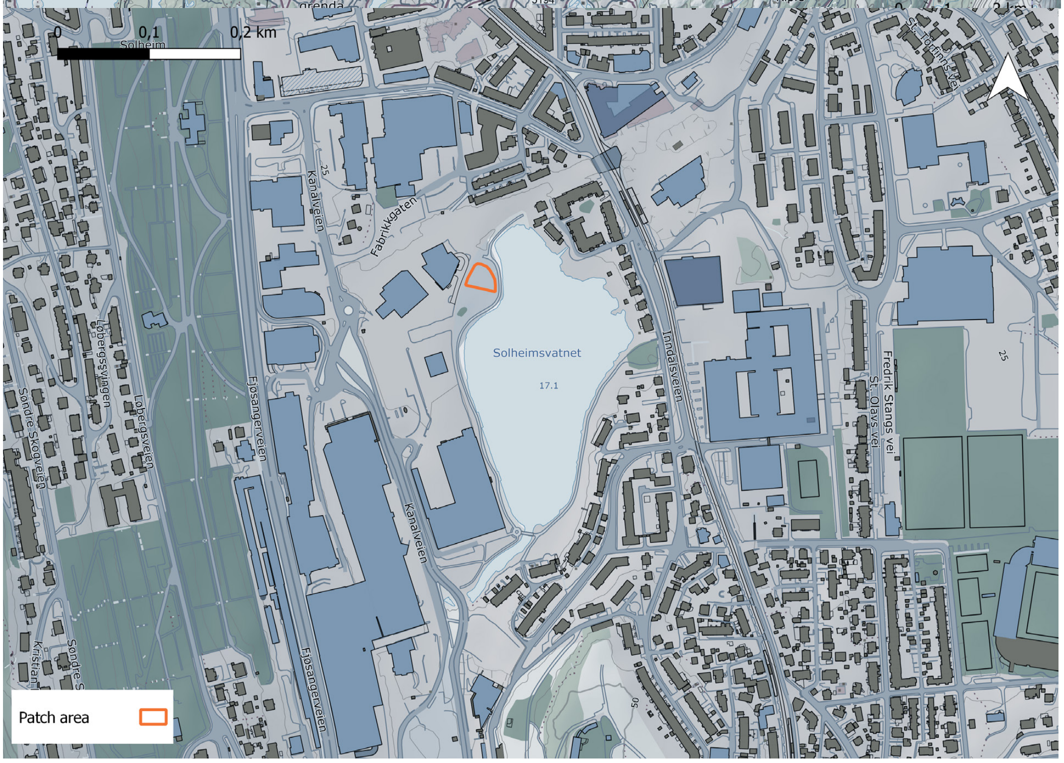
Presenting location site

The case location is an example of an urban green space that has lost its original purpose. All urban areas have parks and green areas that are more favoured than others, and abandoned areas are created. These areas are more or less maintained, nor have a clear current purpose. For this study, the example area chosen as a case is an area of 659,556 m² that upon closer inspection looks uninviting and forgotten. This area has potential for serving as an urban biodiversity patch. Today the area seems to have little to no disturbances, with a small path that is almost regrown. The area is located in Bergen, next to Solheimsvatnet.

Maps sources (Topografisk Norgeskart, 2021),

(QGIS, 2022).





10.1 Design factors for urban vegetation patch biodiversity

The analysis factors

Climate and environmental

In Bergen the altitude of the mountains and the oceanic climate, provides a range of different habitats (Moe, 2002). Therefore, species that tolerate harsh mountain conditions can live alongside delicate costal plant species (Moe, 2002). The costal climate in Bergen results in a long growth season, a lot of rainfall and unstable winters (Moe, 2002). The patch is also located right next to a large body of water, which makes for even more humid conditions.

From these climatic conditions, it is possible to assume that the soil of the patch has a high level of moisture. Due to the existence of both Angelica archangelica, which demands a somewhat richer soil, and Rhododendron which has lower nutritional demands, it’s possible to assume that the nutrient richness of the soil is probably in the middle of those two.

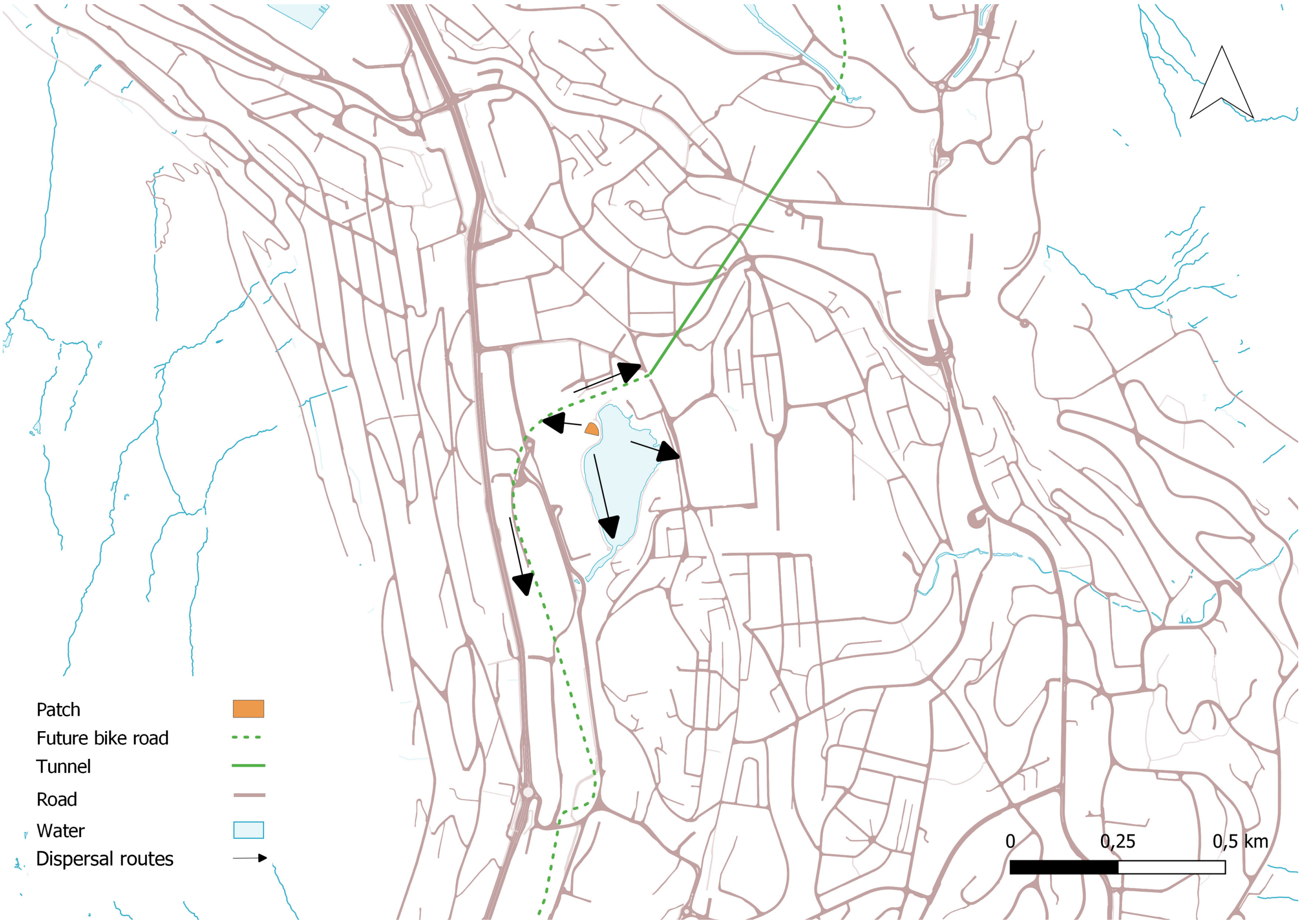
Plant species

The selection of plant species was filtered through different requirements. They are native to the region, and they fit the climatic conditions of the patch location. According to (Moe, 2002), most plant species in this area suit an oceanic climate with moist soil, and therefore a lot of species were costal species. Therefore, a species map (Artsdatabanken, 2017) could filter out from a selected region. A line surrounding the urban landscape, while avoiding the mountains. All species within this region were visible in a table. A could filter could display the costal species, and red listed species of the selected area. These plant species could also be filtered out, leaving the rest of the commonly occurring urban species. From this selection, the plant species could be further filtered through one or more traits that fit the surroundings of the patch.

Neighbouring urban green spaces

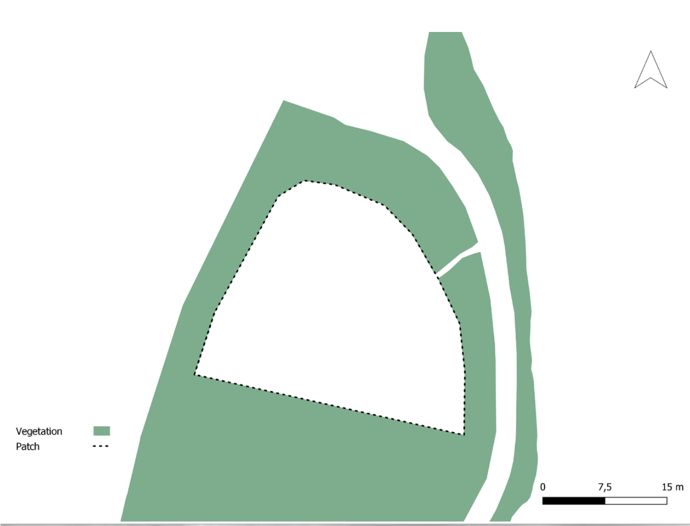
There are many surrounding green spaces. Additionally there is a large body of water. There are many large patches and stepping-stones in the area. The map is made with (QGIS, 2022; Topografisk Norgeskart, 2021)

Possible dispersal routes



There is a future dispersal route of the area, which is a bike lane that is very close to the patch. The bike lane goes through a tunnel and is a continuous long road that has the potential for long dispersal. The path inside of the patch can potentially create human-meditated dispersal. Here people can have direct access into the patch and catch seeds on clothing or shoes and transport seeds elsewhere. The map is made with (QGIS, 2022; Topografisk Norgeskart, 2021)

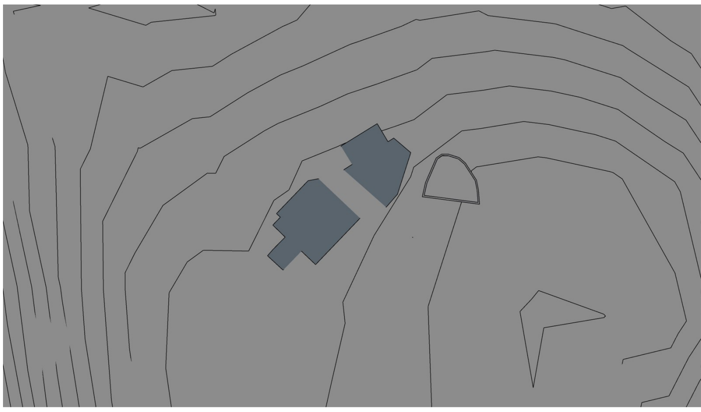
Area use



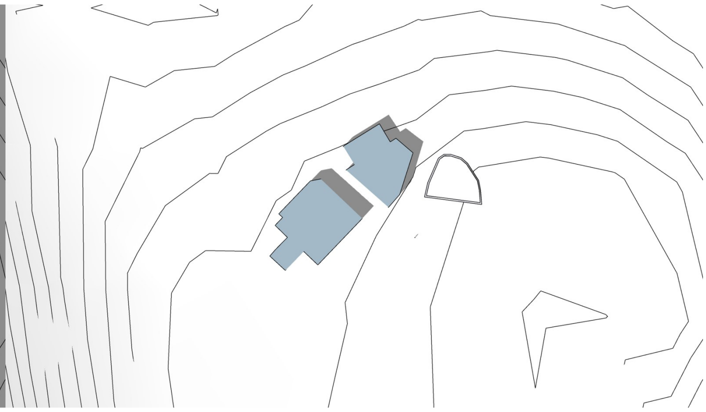
The patch area has several signals of being abandoned, or low maintenance. The bushes are covering the benches, to the point where it's hard to see them. Moreover, the path leading into the area is nearly invisible. Next to the patch area is a sitting group, made for a fireplace, which is a new instalment. Furthermore, the neighbourhoods are located on the opposite side of the lake, and the urban green spaces with the lake view seems more maintained and have more signs of use. The high bush of Rhododendron blocks the view of Solheimsvatnet and makes this space uninviting.

In the map of the patch, there is a line where there is no green space leading into the patch. This trail looks appear hidden for visitors from inside the patch. The map is made with (QGIS, 2022)

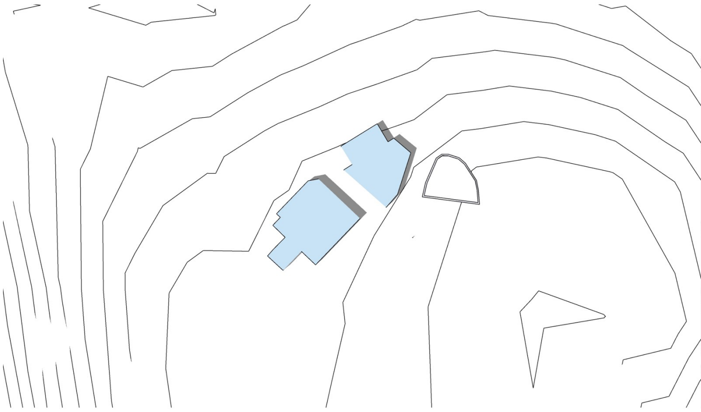
Sun exposure



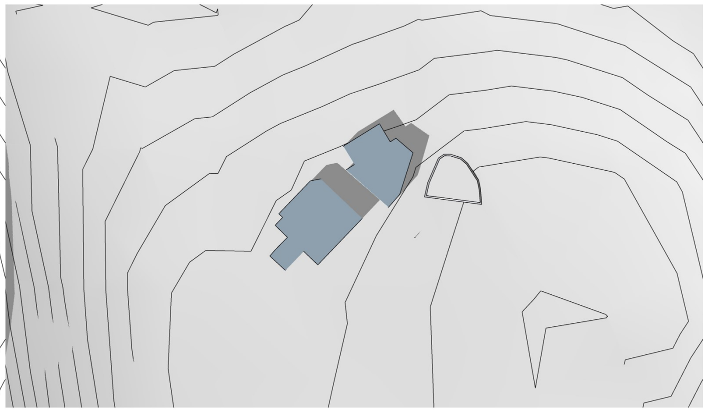
Janurary, 1. 2 pm.



April, 1. 2 pm.

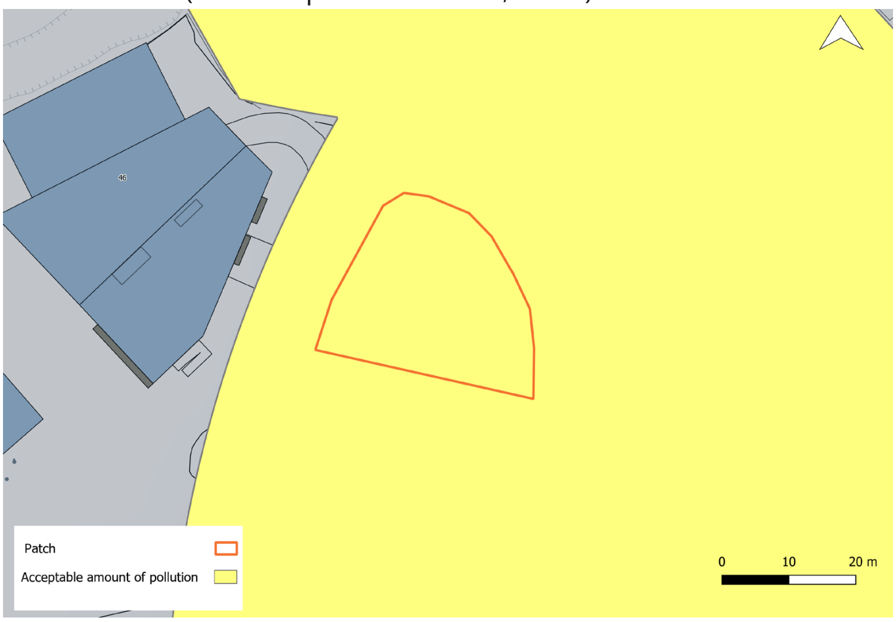


July, 1. 2 pm.



October, 1. 2 pm.

There is decent sun exposure in the patch. There are no buildings blocking the sun, and the mountains of the area cast some shadows, however this patch is not too affected by this. The sun analysis is made with (SketchUp Pro 2022.Ink, 2022).

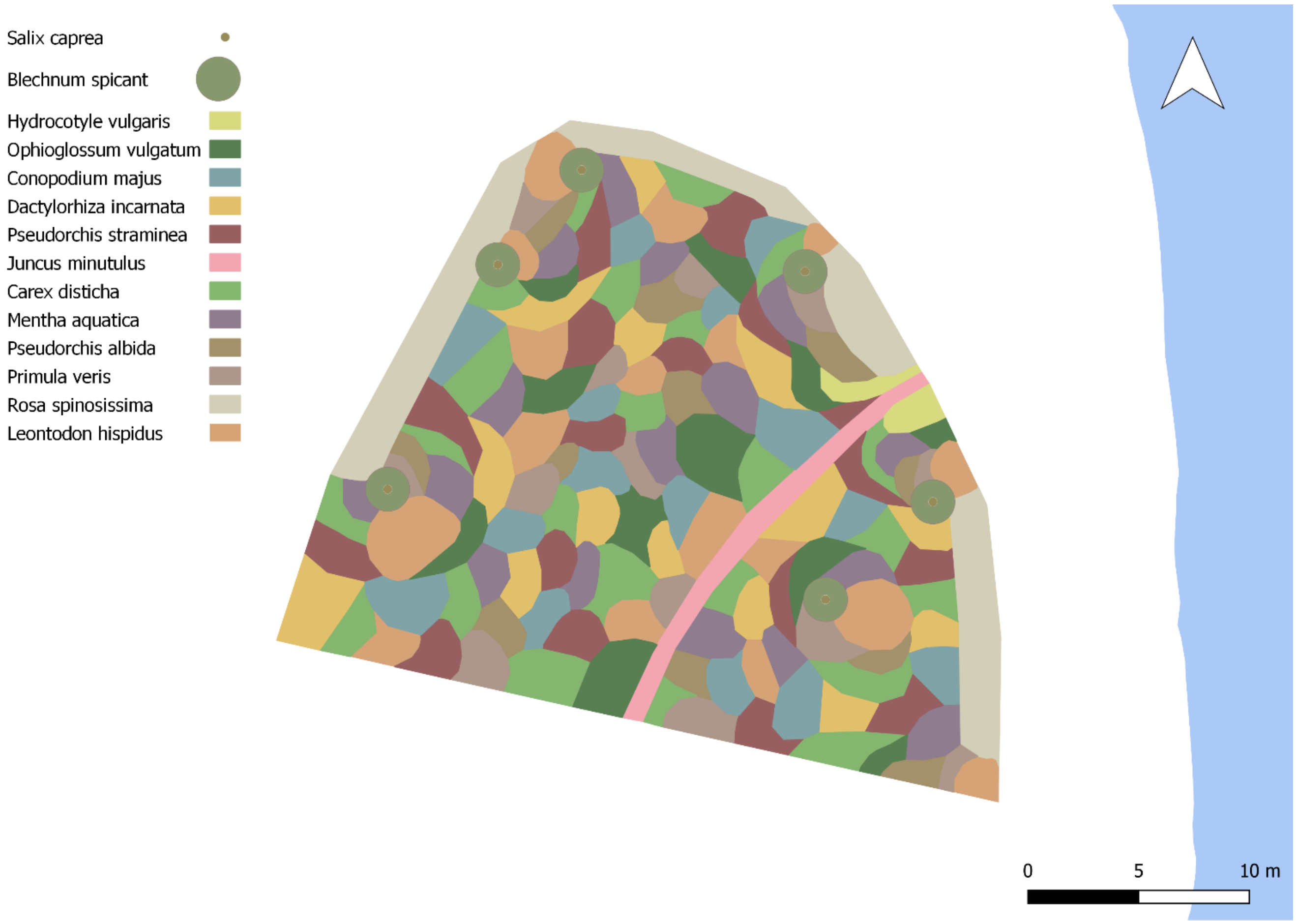


Contamination

The contamination levels around and within the patch are classified as acceptable levels and does not need to be accounted for. The map is from (Forurenset grunn, 2021; QGIS, 2022; Topografisk Norgeskart, 2021)

10.2 Design factors for urban vegetation patch biodiversity

Vegetation heterogeneity



The vegetation is assembled in a mosaic structure. The mosaic has different sizes and shapes in order to increase the heterogeneity. It also creates small spaces for selected plant species. These spaces for each plant species can give them room to have different heights, generating structural variety. Additionally, the shadow tolerant species are beneth the trees, to make use of the canopy shadow. The map is made with Qgis, (QGIS, 2022; Topografisk Norgeskart, 2021)

Plant species that can benefit from dispersal routes

The final selection of species was a combination of the available dispersal routes, the climatic conditions the plant species thrive in, and the favourable plant species traits. The climatic factor of species selection is evaluated by Ellenberg's Indicator Values (Hil et al., 1999). Finally, twelve plant species were included in the design.

A chart containing the selected species, and their value by Ellenberg's Indicator Values (Hil et al., 1999).

Plant species	Light	Soil moisture	Nutrient
Carex disticha	7	8	8
Salix caprea	7	8	7
Ophioglossum vulgatum	8	7	7
Hydrocotule vulgaris	8	7	6
Blechnum spicant	5	6	3
Conopodium majus	6	5	5
Dactylorhiza incarnata	8	8	6
Pseudorchis albida	8	5	6
Leontodon Hispidus	8	5	6
Primula veris	7	4	7
Rosa stylosa	7	4	8
Juncus inflexus	7	7	7

Rosa spinosissima and Juncus minutulus were not found on the list of species by Ellenberg's Indicator Values (Hil et al., 1999). They were replaced by closely related species of Rosa spinosissima and Juncus minutulus. This is because it is likely that they thrive in similar climatic conditions.

List of plant species traits

Species	Reproduction	Life cycle	Height	Other preferable traits	Category
Salix caprea[11]	Wind dispersal	Perennial	3-15 m	Small seeds with fine hair	Common urban
Ophioglossum vulgatum[12]	Vegetative and wind pollination	Perennial	5-30 cm	Long flowering period	Endangered, costal
Hydrocotyle vulgaris[13]	Vegetative and wind	Perennial	5-20 cm		Endangered, costal
Carex disticha[14]	Wind pollination	Perennial	30-90 cm	Herb	Costal
Blechnum spicant[15]	Water reproduction	Perennial	10-60 cm	Herb	Common urban
Conopodium majus[16]	Insect pollination	Perennial	20-50 cm	Herb	Common urban
Dactylorhiza incarnata [17]	Insect pollination	Perennial	25-50-cm	Very small seeds	Costal
Pseudorchis albida[18]	Insect pollination	Perennial	10-30 cm	Smell to attract insects	Endangered, costal
Leontodon Hispidus[19]	Insect pollination	Perennial	10-40 cm	Long flowering period	Endangered
Primula veris[20]	Insect pollination	Perennial	10-30 cm	Small seeds	Endangered, costal
Rosa spinosissima [21]	Vegetative and bird dispersal	Perennial	2-2.5 m	Strong vegetative reproduction	Endangered, costal
Juncus minutulus[22]	Wind pollinated	Annual	1-5 cm	Tolerates being stepped on	Costal

11 (Stedje, 2022), (Artskart, 2022), (Mossberg & Stenberg, 2021)
12 (Bonham, 2022), (Artskart, 2022), (Mossberg & Stenberg, 2021)
13 (Liu et al., 2014), (Artskart, 2022), (Mossberg & Stenberg, 2021)
14 (Stedje, 2022), (Artskart, 2022), (Mossberg & Stenberg, 2021)
15 (Artskart, 2022), (Mossberg & Stenberg, 2021)
16 (Stedje, 2022), (Artskart, 2022), (Mossberg & Stenberg, 2021)
17 (Stedje, 2022), (Artskart, 2022), (Mossberg & Stenberg, 2021)
18 (Artskart, 2022), (Mossberg & Stenberg, 2021)
19 (Artskart, 2022), (Mossberg & Stenberg, 2021)
20 (Artskart, 2022), (Mossberg & Stenberg, 2021)
21 (Mayland-Quellhorst et al., 2012), (Mossberg & Stenberg, 2021), (Artskart, 2022)
22 (Artsdatabanken, 2015),), (Mossberg & Stenberg, 2021), (Artskart, 2022)

Possible adjustments for urban use

The previous use of the area was mostly seen through a worn-down path. This path is kept in the final design. Plant species that cover the entire path, while still making the path visible and following a natural passageway of the area. Additionally, the moasic composition makes a visually interesting component, and a interesting passange into the park.

Illustrations of urban vegetation patch for biodiversity

The patch illustrations uses 3d models that are similar looking to the actual plant species. Some species in the models uses accurate 3d models, such as Salix caprea to visualise the final result. The result is a patch that looks interesting, but not systemized like a typical garden. These models are made with Sketchup and Lumion (SketchUp Pro 2022.Ink, 2022; Lumion 12.5, 2022).

11 Discussion

11.1 Summary

In order to combat the global issue of biodiversity loss, landscape architecture should promote biodiversity in urban areas. Therefore, this thesis aimed at creating knowledge and applicable design that could promote biodiversity through urban vegetation patches. The thesis tried to access global applicable factors that should promote biodiversity in an urban vegetation patch. The goal was to create biodiversity with the vegetation itself and create interaction with insects and birds promote biodiversity. The factors was applicated in a case, to exemplify the factors.

The first step was to confirm whether the field of urban vegetation patches was lacking in literature. There was a lot of literature regarding of increasing biodiversity through green corridors in urban landscapes. The ecological landscape architectural approach focuses a lot on 'green' connectivity when applied in urban landscapes. Therefore, much of planning of urban green spaces have connectivity as a main goal. Even though green corridors can carry disease and fire (Haddad, et al., 2014).

Consequently, a literature study of the existing literature was conducted. The literature study concluded there were a knowledge gap in the literature. This knowledge gap led to searching for factors on how to design an urban vegetation patch for biodiversity. Vegetation patches themselves can be a source of species for corridors and other patches, or function as stepping-stone habitats (Beninde et al., 2015). Landscape architecture design for biodiversity is far from new and have many approaches within to create urban green spaces.

11.2 Approaches to create urban vegetation biodiversity in landscape architecture

Biodiversity approaches of landscape architecture can consist of using native species in different assemblages. For example, an urban meadow has many species which are native and low maintenance (Norton, 2019). However, meadows probably only include species often found in meadows. Another approach is more traditional landscape architecture that is typically seen in urban landscapes. It consists of urban green spaces with plant assemblages that are aesthetically pleasing. The structure of these gardens isn't necessarily meant to create structural heterogeneity, as they often have geometrical shapes and symmetry for aesthetic purposes. Although these gardens might have native species, there might be a lack of structural variety.

11.3 Different approach

The approached used in the case of this thesis is an interpretation of following nature's lead in design. This case tries to apply ecology within the frame of urban green space patches to increase biodiversity. The ecological knowledge is categorized into factors of analysis and design.

The ecological interpretation of building after nature, resulted in a design with a mosaic structure. The mosaic structure does oppose the symmetrical and geometrical forms of vegetation that landscape architecture often graduates towards. The variety within the mosaic increase the heterogeneity. This interpretation of ecology within urban spaces creates a patch with internal vegetation heterogeneity seems to work as intended. Concluding from the factors included in this case, the design should create a potencial for interactions with insects and birds.

11.4 What could have been done differently

The choices of plant species are also selected based on traits that can establish and promote native biodiversity. The plant species and vegetation structure can also promote biodiversity through interaction with pollinators, such as birds and insects (Beninde et al., 2015). The literature about favourable traits of plant species within urban environments need more research. The urban adjustment of this design is through a pathway. It was a challenge creating a path that does not split the patch in two. That's why it was important to choose a plant species can handle being stepped on and does not split up the patch and works in this case. In the case of species selection, one of the species could have been swapped for another. Pseudorchis albida and Pseudorchis straminea might be too closely related and might not coexist (Knapp et al., 2008). An alternative species could have been Caltha palustris, which have seeds that can float, and can potentially use the waterbody for dispersal (Pond informer, 2020).

11. 5 Gobal Applicability

The area selected for this case is also a typical urban green space. A lot of land use-changes within an urban area can result in urban green spaces that can have an unclear purpose or become more or less abandoned. Other urban green spaces might be much more inviting and popular by the public. The result is an urban green space that has signs of being worn down, and unmaintained.

Even though the urban green space used in the case design might be common in urban areas, data might not be globally available. There might not exist enough data coverage about plant species everywhere. Although the factors are globally applicable, the lack of information might impede the possibility of using these factors. Therefore, there is no guarantee that this design is a possibility everywhere. Additionally, the design created a potential for biodiversity trough species interactions. Also, there is no guarantee that species will establish interactions with the plant species of the patch. This is dependent on surrounding urban conditions and these can be difficult to predict.

11.6 Theory to practise

This thesis tried to use a commonly found urban green space, with globally applicable factors as a case, in order to make information more practical. The thesis might have a potencial to be used globally, although information might not be available everywhere.

Additionally, practical information and innovation can be more important than ever within landscape architecture. The biodiversity loss is an ongoing crisis. That is why there needs to be more innovation and new ways of interpreting biodiversity design within landscape architecture. More exploration of ways to increase biodiversity through landscape architecture is needed. There should also be an increased focus on urban biodiversity promoting vegetation patches. Cases and practical examples might be a step in the right direction of creating landscape architectural biodiversity promoting design.

Another possible direction for further exploration might be how this knowledge of urban vegetation for biodiversity can be implemented into society. What kinds of measures can be used to make societies apply such landscape architectural techniques? Some counties have laws in order to make sure biodiversity is conserved, and perhaps there should be laws in place to create biodiversity? Maybe there should be an obliged measure in building processes, when biodiversity is lost due to land-use changes, to restore or compentate for the lost biodiversity? There are possibly many interesting dilemmas for implemenation, which would be interesting to study.

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