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REYKJAVÍK'S ROADSIDES

Using roadside vegetation as a source to increase biological diversity in urban environments

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/ Hrönn

Reykjavík, May 2018.

What are the current conditions for biodiversity in roadsides in Reykjavík, Iceland? How to improve urban biodiversity and create a more sustainable road environment?

ABSTRACT

With the expansion and densification of urban environments, natural and man-made, open and green areas get lost for buildings and transportation systems. It is therefore crucial to take care of the green areas and ecologically favourable environments to support urban biodiversity. Proper plant selection, species composition, sustainable stormwater management and respect for ecosystem services and the planning site itself, are essential links to promote sustainable and biologically diverse urban environments, which at the same time preserve the city's aesthetical values.

The Reykjavík roadsides and the Icelandic flora play a leading role in this master thesis. Roadsides and the overall street environment in cities, plant community function and Icelandic conditions are addressed together with the research question: **What are the current conditions for biodiversity in roadsides in Reykjavík and how to improve urban biodiversity and create a more sustainable road environment?**

Three different planting design approaches, **Plant signatures**, **Alternative lawn** and **Go wild/Spontaneously vegetation**, were chosen as a foundation for the formation of the conceptual design proposal for chosen intersections in Reykjavík, Hringbraut. These approaches all have different methodology regarding planting design, but they all aim at the same goal, at creating a naturalistic planting that enriches biodiversity.

The results from the theoretical research and the conceptual design are that there is a great need for further studies in Reykjavík, regarding reclamation of native vegetation in roadsides and the urban area in general. Street vegetation in Reykjavík is homogeneous, and knowledge in the field is lacking so further appropriate actions can be taken. Therefore, creation of testing ground for native plant use in Reykjavík's roadsides is a convenient way to gain knowledge regarding the subject and get to know how people working with the urban environment can use that platform for further experiments and at the same time disseminate knowledge. By obtaining knowledge regarding the development site, respecting it and its capacity and celebrating the existing material, successful results can be achieved in the field of naturalistic planting design in roadsides in Reykjavík.

Hver er núverandi staða líffræðilegs fjölbreytileika í götuumhverfi Reykjavíkur? Hvernig má auka líffræðilega fjölbreytni í borgum og skapa sjálfbærara götuumhverfi?

SAMANTEKT

Með þenslu og þéttingu byggðar glatast náttúruleg og manngerð, opin og græn svæði fyrir byggingum og samgöngukerfum. Það er því lykilatriði að huga vel að þeim grænu svæðum sem eru til staðar til að styðja við líffræðilega fjölbreytni og vistfræðilega hagstætt borgarumhverfi. Rétt plöntuval og tegundasamsetning, ofanvatnslausnir, tillit til vistkerfa og nærumhverfis er stór hlekkur í því að stuðla að sjálbæru og líffræðilega fjölbreyttu borgarumhverfi sem um leið gefur boginni fagurfræðilegt gildi.

Götuumhverfið í Reykjavík og íslenska flóran eru í aðalhlutverki í þessu verkefni og er öll grunn hugmyndavinna miðuð út frá þeim. Veghelgunarsvæði og götuumhverfið í borgum er tekið fyrir og er varpað fram spurningunni: **Hver er núverandi staða líffræðilegs fjölbreytileika í götuumhverfi Reykjavíkur? hvernig má auka gildi** þess **og skapa sjálfbærara götuumhverfi?**

Þrjár mismunandi aðferðafræðir, **Plant signatures**, **Alternative lawn** og **Go wild/Spontaneously vegetation** voru valdar fyrir verkefnið sem undirstöður að hugmyndavinnu fyrir hönnunartillögu af gatnamótunum við Hringbraut. Þessar nálganir miðast allar að því að skapa náttúruleg plöntusamfélög sem auðga líffræðilega fjölbreytni, en á mismunandi hátt.

Niðurstöður rannsóknarvinnu og hönnunar eru að mikil þörf er á frekari rannsóknum í Reykjavík á sviði endurheimts staðarsgróður í götueyjum og borgarumhverfinu almennt. Götugróður í Reykjavík er einsleitur og þekking á sviði endurheimts innlends götugróður í borgarumhverfinu er ekki nægilega mikil svo að hægt sé að hrinda af stað viðeigandi aðgerðum. Því eru tilraunareitir til ræktunar innlends götugróður við Hringbraut hentug aðferð til að komast að því hvað það er sem virkar og hvað ekki, hvernig aðilar sem vinna með borgarumhverfið geta nýtt sér þann vettvang til frekari tilrauna og um leið miðlað þekkingu. Með því að kynna sér umhverfið, virða það og getu þess og fagna þeim efnivið sem er til staðar, má ná fram árangursríkari niðurstöðum í garðyrkjuhönnun og sjálfbærara götuumhverfi í Reykjavík.

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INTRODUCTION

In this chapter the main subjects of the thesis will be introduced. A brief description of the subject´s background will be presented, along with main objectives and methodology to achieve them.

The thesis consists of several different methodological approaches that will be described in each chapter.
The thesis is ordered as follows:
Introduction, Theoretical studies, Inventory and analysis and Conceptual design proposal.

BACKGROUND

Balanced state of biodiversity protects against erosion and drought. It affects the chemical composition in the atmosphere and soil. It strives to maintain the survival of species, as diminished genetic diversity increases the risk of reproductive difficulties of animals and plants (Hughes, et al., 2008). Biodiversity keeps ecosystems in balance, where living organisms are dependent on each other for survival. Currently, global biodiversity is being threatened by climate change, pollution, habitat reduction, invasion of exotic species and overuse of resources (Convention on Biological Diversity, 2016)

There are many factors affecting biodiversity. Environmental globalization is one, where signatures of dominant cultures are spread around the world, which have had a significant impact on urban's appearance worldwide. Western culture, ideas, and lifestyles were brought to non-western countries in the 20th and 21st century with the consequences of monotone urban environments worldwide and severe decrease of biodiversity. Today´s issue regarding environmental globalization in urban environments may be connected to the use of similar materials in design for construction as well as outdoor and green environments. Furthermore, the native biotope has been lost at a substantial rate with the introduction of non-native plant species, which have led to biodiversity crisis (Ignatieva, 2010).

The urban population worldwide is approximately 4 billion people (The world bank, 2016). By 2050 the population in urban settlements is estimated to be 6,3 billion people, that is roughly 70% of all worlds population. With the exponential increase in human population the biodiversity crisis will only get worse. Conversion and degradation of natural habitats due to human interventions have led to overuse of resources. These losses in biodiversity and associated changes in ecosystem services is a global threat that is affecting cities all over the world (Secretariat of the Convention on biological diversity, 2012). This massive expansion will mostly affect and take place in smaller sized cities (Secretariat of the Convention on biological diversity, 2012). Therefore, it is essential to design these areas with a long-term perspective, as they will shape the cities of our future.

This thesis addresses the issue, the loss of biodiversity and habitation for plants in urban environments, a settlement with high population density. It presents the need for change in the field of planting design, with the introduction to sustainable planting solutions in roadsides, as one link in the process of increasing urban biodiversity. The thesis addresses the need for researching, education, cooperation and engaging the citizens for further positive progress, regarding that matter (Secretariat of the Convention on biological diversity, 2012).

THE CASE IN REYKJAVÍK

One of many cities that will be affected by the vast population growth, is a small city in the middle of the Atlantic Ocean, called Reykjavík. Reykjavík is the capital of Iceland. It is a young city, still in its infancy (Iceland.is, 2016). Reykjavík is developing fast. 88% of the county's population growth the past 25 years has occurred in the capital and

adjacent towns. Statistics Iceland predict that population growth will increase by approximately 35% by 2040 (Sævarr & Þorsteinsdóttir, 2014). The city's densification is a big topic at Reykjavík's municipality, and as a result, open green spaces and other open areas will go under constructions of buildings (Reykjavík Municipality, 2014), thus reducing the city´s biodiversity. High awareness has occurred in Reykjavík regarding urban biodiversity. Authorities are realizing the importance of preserving the city´s biodiversity, due to vast increase of the city´s population, with a development of a policy called „Reykjavík biodiversity policy" (Department of Environment and Planning, City of Reykjavík, 2016).

PAST STUDIES

Studies regarding urban biodiversity and native flora reclamation within Iceland´s urban areas are limited. Reykjavík is a car-friendly city. The most convenient way of traveling is by personal car. After the creation of Reykjavík´s master plan 1962-1983, which was a significant milestone for Reykjavík´s planning history, the main emphasis regarding transportation was on the private car. Large traffic infrastructures where constructed throughout the capital, especially in the city center and adjacent areas (Reykjavíkurborg, 1966). These traffic infrastructures dominate vast spaces and are accompanied by significant roadside areas. These roadsides are mostly made of grass lawns, made from imported grass seeds or cultivated grass turfs, that require high maintenance, are cost efficient and lead to monotonous cityscapes (Bernharðsson, 1998). These homogeneous urban environments often lead to degradation of biodiversity, species richness, ecological function, aesthetic values and people-friendly environments. By restoring the local natural environment and the sense of place, with use of native plants, that require less management and maintenance, the achievements will have positive social, environmental and economic impact (Department of Environment and Planning, City of Reykjavík, 2016).

The studies performed domestically have emphasized on reclamation of the Icelandic flora in roadsides, restoration of plants after road constructions, in rural areas and the countryside. These studies have mostly been done by a collaboration between The Icelandic road and coastal administration and The Agricultural University of Iceland. The different study methods are for example: Using the top layer of the soil surface area of the construction site to quickly form vegetation that protects the soil from erosion, distribution of moss in appropriate areas, use of wild growing heath and rangeland turfs, and seed cultivation. Restoration in roadsides and the preservation of urban biodiversity is a needed but challenging task, still at a very early stage (Jón Guðmundsson, 2016).

Photo. Tipical road environment in Reykjavík, Iceland.

As mentioned, few studies have been done regarding reclamation of the Icelandic flora in roadsides in Reykjavík. Since the knowledge and the experience is lacking, the need for trials and researchers are highly required, considering the vast growth of urban densification development projects, with the consequence of fewer open and green areas and denser road system. Therefore, the need for the knowledge regarding well designed and ecologically and biologically beneficial green environments is essential in Reykjavík for further future developments.

THE ROLE OF RESEARCH

The role of research within in the field of urban biodiversity is vital for successfully designed environments. The development of the urban biodiversity and design (URBIO) is a scientific network for education and research that fosters scientific change between stakeholders, practitioners, and researchers in the field of urban biodiversity and design. URBIO along with other programmes, for example, Low impact development (LID), Low impact urban design and development (LIUDD), and Naturalistic planting communities help to unite urban biodiversity researchers in practice to hinder the continued development of monotone urban environments, with low biodiversity.

The need for well-designed urban green spaces, where the emphasis is on sustainable plant communities, local ecosystems and habitation is a vital factor to increase urban biodiversity. Humans are in everyday contact with urban flora and fauna and the pressure on preserving and protecting cities biodiversity is vital, considering vast growth of human population (Secretariat of the Convention on biological diversity, 2012). In recent years, a remarkable change in knowledge and awareness has been on the importance of sustainability and maintenance of biodiversity in cities (Pyšek & Jarošík, 2005). Further researches will increase the knowledge and understanding regarding the subject. It will enable further progresses and developments.

AIM

This study aims to introduce different design approaches for sustainable planting design in roadsides and to make a conceptual design proposal for a chosen intersection in Reykjavík.

This thesis focuses on planting design in roadsides, their role as a source for the city's flora and urban biodiversity. The emphasis in plant use will be on the local flora and the opportunities and challenges it brings. The conceptual design proposal aims to create a testing ground for plant use in Reykjavík's roadsides. Three different planting design approaches namely Plant signatures, Alternative lawn and Go wild/ Spontaneous vegetation will be used to achieve different outcomes, test different strategies, and implement them to Icelandic conditions. These approaches were thought to be beneficial for the study and the conceptual design proposal. In addition, the plant's origin, natural habitat, site condition, and management are just a few of many factors that need to be taken into consideration when designing sustainable and biologically beneficial plant communities. In addition, the plant's origin, natural habitat, site condition, and management are just a few of many factors that need to be taken into consideration when designing sustainable and biologically beneficial plant communities.

RESEARCH QUESTIONS

What are the current conditions for biodiversity in roadsides in Reykjavík and how to improve urban biodiversity and create a more sustainable road environment?

Sub-questions for consideration:

- How to make space for biodiversity in urban areas?
- How can roads be used as a link to increase urban biodiversity?
- Which design approaches could be used and what are specific recommendations for planting design in roadsides?

LIMITATION

Restoration of the Icelandic flora as a street vegetation has never been practiced in Reykjavík this way and therefore this project is the first of its´ kind. There is little experience and knowledge regarding this topic in Icelandic urban areas and consequently, the literature is scarce. Therefore, foreign sources from similar projects successfully conducted will be used as a reference. At the time of the projects site analyzation and plant identification, the study area was mowed, which made the identification of plant species on the roadsides more challenging.

TARGET GROUP

The content of this thesis aims to inspire and make an example for Reykjavík´s municipality, the Icelandic road-and coastal administration, Icelandic landscape architects and garden designers how different planting design approaches can affect and improve the city's biodiversity, increase design versatility and reduce maintenance costs.

The main international target group is people working with outdoor environments, especially the road environment. Civil engineers, landscape architects, architects, gardeners, landscape engineers, ecologists and environmental scientists will all be able to utilize the results for further development in their areas.

Photo. Tipical Icelandic vegetation. Here can for example be seen White Dryas, the national flower of Iceland.

METHODOLOGY

Below follows a description and a reason for chosen methodology.

THEORETICAL STUDIES

The theoretical studies had a dual purpose. firstly, to increase understanding of the subject and enhance its knowledge of the subject's history, expansion and general importance of the issue regarding biodiversity worldwide and in urban environments. Secondly, the literature was used to educate and deepen the knowledge concerning different planting design methodologies regarding the road environment itself. Icelandic conditions were studied, both concerning the Icelandic flora and ecosystem services in the city Reykjavík and around its local environment.

Knowledge gathered from the literature was merged into a concrete result in the form of conceptual design proposal which represents biological beneficial planting design in a roadside in Reykjavík.

The collected literature and references come from articles, books, reports, and other documents (web pages), searched for example through google scholar and Research Gate. References were also received from SLU-library, google search and recommended literature from a supervisor. Related researches, textbooks on biological diversity, urban biodiversity, roadside ecology, different planting design approaches and the Icelandic flora were researched.

Six conceptual keywords were chosen and they are:
Urban biodiversity, Roadside vegetation, Reykjavík´s roadsides, Ecological design, Planting design and Native flora.

SITE STUDY, ANALYSING, AND MAPPING

An analysis was made both at case site and on vegetation in Reykjavík´s roadsides and in Reykjavík´s ecoregion. The analysing was done in the form of photographing, notes, and sketching, regarding species richness, plant community combinations and habitat conditions. It enabled a deeper understanding of ecological function and growth conditions for the Icelandic flora in Reykjavík's roadsides and it gave a clearer groundwork for future planting design work.

Vegetation analysis was made in six areas in Reykjavík, two areas in Reykjavík´s ecoregion, in the heaths next to Reykjavík to get a good example what kind of heath vegetation is normal in Reykjavík´s ecoregion and next to the ocean to get an example of what thrives in salty and windy conditions around Reykjavík´s ecoregion. The four Reykjavík´s roadside areas that were analyzed were picked randomly, given that there was t least 1,5 km distance between them to get varied results.
Chosen plants were mapped and photographed. They were analyzed further through literature, the nomenclature of the Icelandic flora (1983), through the website www.floraislands.is, and scientific research that had been made on the Icelandic flora, regarding growth condition, robustness, shape, and size, flowering periods and more. These studies gave a great example of what can thrive in Reykjavík´s roadsides and were used as a guide for the conceptual design project. The chosen plants that were analysed further were chosen considering for being signature plants in the plant community and for its hardiness, with hope that the suggested vegetation in the testing site will develop to be more robust than indigenous natural vegetation.

The site analysis and mapping were done on two different days. These days were chosen with regard to weather conditions. The first day was on July 5th and the weather conditions were good, 17°C and a light breeze. The second site visit was on August 20th, the weather was mild, 13°C and cloudy. One limitation disturbed the analyzing work. Before the site visits mowing had been done in some of the study areas. Despite from that, enough data was collected to be able to continue with the project.

The inspiration of the methodology for the analysis was obtained from *Garden revolution* by Larry Weaner and Thomas Christopher (2016). The analysis is specialized for planting design projects. They disclose that it is a common mistake to start a project with a clear and comprehensive vision of the desired outcome that the designer or architect wishes for, without further researching it are attempted to impose this vision.

Instead, it is recommended to stop for a second and ask the following questions; "where are we, ecologically speaking, in both time and space?" or in other words, "what are the existing environmental conditions of the area?" and "what plants naturally inhabit in those conditions?".

The site analysis was performed as follows:

1. Determine the ecoregion of the site
2. Identify the habitat type or types that exist
3. Sunlight/shading inventory
4. Soil analysis
5. Topography
6. Hydrology

The vegetation analysis was made as follows:

1. Inventory of existing vegetation on site (Hringbraut)
2. Inventory of vegetation around the local environment in Reykjavík

STRUCTURE OF APPROACHES

The chosen design approaches are Plant signatures, Alternative lawn and Go wild/Spontaneous vegetation. These approaches all have different methodology regarding planting design, but they all aim at the same goal, at creating a naturalistic planting that enriches biodiversity. When using these approaches, the right choice of plants is valid, and each approach has different methods and technique regarding structuring of plant communities. They are well-known and recognized methodologies among gardeners, landscape engineers, landscape architects and other ecological designers.

These approaches were chosen regarding their differences in methodology and structure. By choosing three different design approaches it is believed that the obtained results, regarding structure of the testing ground for plant use in Reykjavík's roadsides, were more diverse and provided more information than if only one approach would have been chosen.

Alternative lawn:

The methodology of the alternative lawn is to enhance each site´s biological diversity and ecological function. Multiple versions of alternative lawns are available but in this assignment three alternative lawn approaches were used, *Grass free lawn*, *Naturalistic herbaceous planting* and *Native meadows,* and different plant community designs were structured for each approach. In these plant community designs up to eight plants were chosen, that were thought to be suitable and complementary for the site´s biological function.

Go-wild/spontaneous planting:

The methodology of Go-wild/spontaneous planting is to make the area develop as naturalistically and to be as reflective of its local environment as possible. This approach reflects its local environment conditions where the plants appear without any design inputs, with minimum control of what comes in, native or exotic. One area on the site was seen as suitable for this approach, along with few areas on the site that have blended function, as it being designed and planned at first, but then let free. The area on site that was chosen for this approach is around storm water receptor, or storm water swale. This area was considered challenging to manage and therefore it was decided to let this area develop on its own.

Plant signatures:

The methodology of the plant signature approach is to highlight and magnify the site´s characteristics through the design. For this approach three different plant signature plant community designs were structured, *Plant signatures rock garden slope (A)*, *Plant signatures rock garden slope (B)* and *Plant signatures meadow*. In these planting designs four to five plants were chosen, for each plant community, that were thought be naturally progressive and have high aesthetical values, that could enhance the site's visual qualities and identities.

IMPLEMENTATION OF CONCEPTUAL DESIGN PROPOSAL

The main design work was done during the analysis and project writing. Although that inspiration, sketches, and noting of ideas had been an ongoing process through the conducting of the project.

Digital illustrations were mainly done using Adobe Photoshop CC 2017 and Adobe Illustrator CC 2017. Orthophotos and maps from National Land Survey of Iceland were studied and used as a base for master plan illustration. All photographs in the thesis are privately owned.

WORK PROCESS

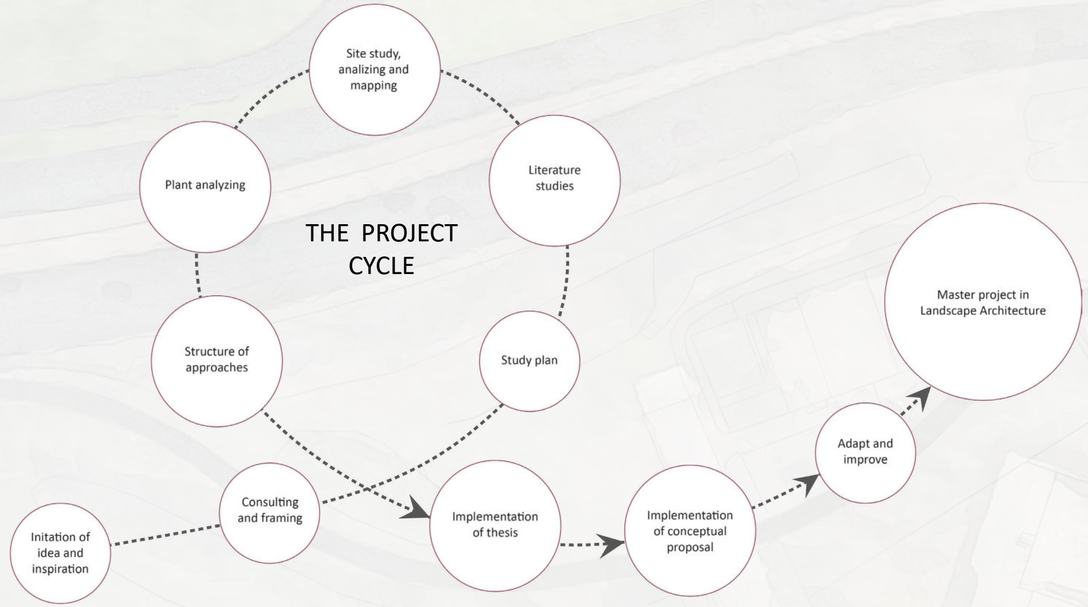


Figure. Explanation of work process.

Figure. Illustration of Iceland, showing the situation of Reykjavík.

Figure. Reykjavík and the situation of the case study area.

THE CASE

ICELAND

Iceland is one of the Nordic countries and has been inhabited since the year 875. It is located 63°-66°N in the North-Atlantic Ocean between Greenland, Faroe Islands, and Norway. Iceland is 103.000 km2 and is the second biggest island in Europe, after Britain, with a population of about 330.000 people. Iceland's capital is Reykjavík, situated on the south-west coast (Iceland.is, 2016).

REYKJAVÍK

The capital of Iceland, Reykjavík, is the largest city in Iceland with approximately 123.000 inhabitants, but if we include the towns in the capital area, that are connected to Reykjavík, the inhabitants are about 217.000, which gives us that nearly two thirds of Iceland's population are in the capital area (Hagstofa Íslands, 2017).

HRINGBRAUT INTERSECTIONS

Hringbraut is one of the busiest roads in Reykjavík. It connects the city in the west to the city in the east. The traffic is hectic around rush hours. The city's busiest workplaces surround the road such as, two universities, Reykjavik´s hospital, the city centre, and the Reykjavík airport for domestic air traffic. The road was developed about 15 years ago, and further constructions are scheduled in the near future due to densification of nearby urban areas (Línuhönnun, 2003).

The chosen intersection for this assignment is situated on the east end of the road and connects the city from all directions. Pavements and bicycle lanes are crossing over and under the intersection and the vegetation is moved lawns, trees, and perennials. Further description of vegetation and appearance will be made in the chapter, Inventory and analysis.

Figure. Hringbraut instersection. Dark-green areas represent the case study area that will be used in the conceptual design proposal.

THEORY

This chapter presents the result of the theoretical studies regarding biodiversity, ecological design and roadside vegetation. It presents Iceland and the state of biodiversity in Reykjavík. Descriptions and definitions stated and presented in this chapter are the ones used as a conceptual foundation in this thesis.

"BIODIVERSITY is the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems" (Umhverfisráðuneytið, 2008)

BIODIVERSITY

Convention on biological diversity 1992 defines biodiversity as "*the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems"* (Umhverfisráðuneytið, 2008).

One of the world's most valuable resource is biodiversity. It is necessary for ecosystem services and therefore for human wellbeing. It provides us the essential things that we could never live without, the food we eat, the clean filtered water we drink, the fresh air we breathe, and it is also a big part of vital and essential natural resources that provide us necessary things, like medicines. Furthermore, it is essential in maintaining genetic variation in both wild and agricultural organisms (Convention on Biological Diversity, 2016).

GLOBALIZATION

The decline of biodiversity is a slow-moving process. This development has occurred for hundreds of years with coming and going of globalized trends in landscape architecture and gardening, with tremendous effects on overall global biodiversity (Ignatieva et al., 2013). Humans have transported exotic plant species over the centuries which has affected the local and urban biodiversity. Plants have been transported for cultural and ornamental purposes and some of those plant species, approximately 10% have become naturalized (Reichard and White, 2001), and the numbers of naturalized plants are even a more significant problem on isolated inhabited islands (Ignatieva, Meurk & Nowell, 2000).

Varied styles have shaped the landscapes of the world from celebrating naturalness to the development of botanical gardens where the main emphasis is artificiality and extravagance where the use of non-native plants and tropical and subtropical was preferred (Zuylen, 1995). These trends are continuously occurring change that transforms the environments into something superficial and unnatural. The landscape styles that were brought to Europe by the colonists of the New World, the English landscape, and Gardenesque styles, were brought to change the landscape to something familiar. These landscape styles are one of the most potent styles that have occurred over the centuries, with an introduction of numerous non-native species of flora and fauna. The changes on the local biodiversity in these colonies were dramatic and persisted (Thacker, 1979).

The world is still, fortunately, evolving and now we stand at a place where great revival has been, and the knowledge about the importance of sustainability and maintenance of biodiversity in cities is increasing (Ignatieva et al., 2013).

URBAN BIODIVERSITY

Biodiversity is a vital factor in the urban environment. But what is "urban biodiversity"? The definition is clear and comprehensible, "*the variety or richness and abundance of living organisms (including genetic variation) and habitats found in and on the edge of human settlement"* (Müller, 2010), meaning that urban biodiversity is all species range from the rural fringe to the urban core.

The cities flora and fauna are the everyday natural factors that most humans are in daily contact with. It is assumed that cities and rich biodiversity are not exclusive, but the fact is that many cities have high species richness. When measuring urban biodiversity age and size much be taken in to account (Pyšek, P., & Jarošík, V., 2005). The thumb rule is that in general non-native species are more common in older and larger urban landscapes and younger and smaller urban landscapes have higher native species richness. That gives us that decline regarding urban biodiversity is a more significant problem in older and medium to large-sized cities. Other factors than size and age that are influencing and affecting overall urban biodiversity are the ownership of the land. Usually, most of the urban areas are privately owned, and the owners choose and control the structure of the vegetation (Pyšek et al., 2004)

Understanding that biodiversity is an essential factor in maintaining diverse ecosystems in cities, landscape architects and gardeners have implemented more native species in a landscape- and garden design. Also, ecologists realize that gardens, not just large preserved areas, may play a critical role for native species refuge in the advent of climate change by facilitating the migration and seed dispersal (Rudd, Scaefer & Vala, 2002).

A vital element to creating sustainable infrastructure is the incorporation of native biodiversity. Planting native plants in new and existing parks, roads1ides, green walls, and rooftops, creating areas for rain and stormwater management, such as ponds, swales, and small wetlands fulfill and serve multiple functions in addition to enhancing urban biodiversity. Even backyard gardens can harbor significant biodiversity (Secretariat of the Convention on biological diversity, 2012).

Urban green environments are all environments that provide some expression of green infrastructure or vegetation and can be divided into different categories, green space, a brownfield site, private gardens, balconies, and grey spaces. Grey spaces are defined as built environments and are that area of the city that will be in focus in this thesis. These areas were usually looked upon as areas that could by no mean have any positive influence on biodiversity and therefore almost never designed with that concept on the mind (Bennan & O'Conner, 2008).

Photo. Wild grown urban vegetation in Reykjavík, Iceland.

ECOLOGICAL DESIGN

Sim Van Der Ryn and Stuart Cowan, the authors of Ecological design, define ecological design as "*any form of design that minimizes the environmentally destructive impact by integrating itself with living processes*." It can be described as a successful adaption for the human being to interweave natural processes with the human environment. It cannot be defined as a trend or a style of design. The concept inclines to increased cooperation with nature, which is today an essential aim for whole humanity. It is a foundation for a new way of thinking in design. The design itself should respect species diversity, reduce waste emissions, and preserve natural cycles of water and nutrients, conserve habitat quality and aim for all other motives that promote human and ecological health (Cowan & Van de Ryn, 2007). Ecological design is a discipline that, fortunately, many specialists are starting to acquire. By thinking about ecology as a foundation for every design, it will give the possibilities to minimize the use of energy demanding materials, it reduces pollution and preserves habitats, and at the same time, it strengthens the community, health, and appearance (Cowan & Van de Ryn, 2007). There has already been significant progress in ecological design in the field of landscape architecture and urban design. Stormwater management, designing for biotopes and sustainable landscape architecture, where the emphasize have been on, for instance, green roofs, green walls, and lawn free projects are all critical and at the same time challenging projects that all require complex methods and approaches in planting design (Kingsbury & Oudolf 2013). To be able to succeed in design with the ecological approach in mind, when designing with plants, there is a significant need for understanding the origin of where the plant comes from and take a close look at the working area. By understanding and realizing that the plant has an origin and has needs that the gardener and the architect must fulfill, the pathway to ecological design gets much clearer (West & Rainer, 2015). In next chapters, definitions and different approaches will be described in the matter of what it is that makes a planting design an ecological design.

ECOREGION

The ecoregion is the big picture as some might say. It is a rather large geographical region of land and water, which possesses similar physical factors, for example, climate, soil, type of landscape and ocean condition. Within every ecoregion, there is a biological diversity that is a characteristic combination of flora, fauna, and ecosystems which makes it distinguishes from other ecoregions (Christopher & Weaner, 2016). In theory, there is an acceptable dimension of variation within every ecoregion. That dimension is somewhat undefined subject, but one must remember and take into consideration that regional borders or land borders never define ecoregion, it is a geographical area that occurs by natural forces. Within every ecoregion, many different types of ecosystems and habitats promote and influence regional biological diversity (Bailey, 2014).

HABITAT

To be able to succeed when using ecological approaches in design, one must consider that it is all about interaction between the landscape and the plants. It is not only that the landscape decides what can be grown there and not, but it is also that the plant must find its niche, their spot, their habitat (Kingsbury & Oudolf 2013). When considering improving biodiversity in particular areas, the need to take in mind where we are situated each time is the most logical first step in that process. What thrives here and in what condition? A landscape or a garden can preserve various types of habitats in one area. The lawn, an open area that is exposed by sunlight most of the day, a rocky slope with dry soil, and the shaded area under a bush or a tree. All of this is considered to be a different type of habitats for a different kind of plants, with different needs and demands regarding the environment (Christopher & Weaner, 2016).

It is the place that fulfills the needs and demands of the plant and that the plant grows there under natural circumstances. The physical conditions that each habitat can be distinguished by are various and equally important, for example, soil type, temperature, moist, and the contrast between sunlight and shade, to name a few (Kingsbury & Oudolf 2013).

To be able to read in the landscape and analyze different type of habitats and understand a different kind of needs that each plant species demands are an essential foundation for plant use and in the creation of plant communities (Kingsbury & Oudolf 2013).

NATIVE

Native plants are indigenous to a specific area. These plants have developed there or occurred for natural reasons, rather than with a human interference (Christopher & Weaner, 2016). With the current growth of population, the loss of natural and wildlife habitats is increasing. By creating new habitats for native plants in cities, the loss can be balanced (NC State University, n.d.). When using native flora in design the concept is about where the plants come from (West & Rainer, 2015). By getting inspiration from their natural habitat, the design will be balanced and inspired by plants that already naturally occur together (New Urban forestry, 2017). These combinations of plants have already been, what we can call, "battle tested". The plants can survive in similar environmental conditions, stresses, and disturbances. These native plant species have a natural balance in competitiveness that has been tested for hundreds of years, if not thousands (West & Rainer, 2015).

The benefits of using the native flora as a reference point and a concept for designing a plant community is that it can simplify the design process since as previously mentioned, they already have a natural balance in competition and do need the same conditions for surviving. The idea is however not to think that the native flora has an innate superiority. Despite all the positive ecological benefits that the native flora has to offer, non-native plants, which have adapted to the region and have shown positive ecological performances, can play an important role when designing and formatting a plant community. The apparent threat is when the non-native species get invasive and have

the potential of spreading out beyond the site and in that case, disrupt or displace native plant communities (West & Rainer, 2015).

ECOLOGICAL PLANTING

Ecological gardening, also known as, wildlife gardening or naturalistic gardening, is a long-known conceptual idea of a way of planting, called ecological planting. There is a long European tradition of the desire and motive to create wild-looking and naturalistic plantings in designed landscapes. Giving to limited knowledge and understanding of the ecological processes and the competition between plants the plantings were often challenging to manage and sustain (Hitchmough, 2008). There are several ways to approach and illustrate ecological planting, and it varies how far one is willing to take the concept. Everything from being "stylised nature", an approach that is built upon esthetical values that seeks inspiration to wild plant communities, where the gardener or the designer plants each plant individually, but self-seeding is allowed, to "biotope planting" that approaches all the qualities of a natural wild habitat and the structure of the landscape assembles all the features, for the most part, that the natural habitat of the plant has. In this case, though all the plant mixtures and seed mixtures are specially designed with esthetical values in mind along with the ecological fitness, that the plant has in these habitat circumstances. The third approach that will be mentioned is the "habitat restoration", where the goal is to create an environment that resembles wild habitats in all mean (Kingsbury, 2004).

When it comes to ecological planting, it is though not only about seeking inspiration to nature. It is about understanding it. It is about understanding the environmental processes and the ecological factors that represent how the natural habitat contributes how the plant manages, acts, and survives, or not. By dedicating such an approach and combining one's abilities and skills with natural processes to establish a natural cycle, the success in bringing forward and triggering the plant's characteristics and qualities will be higher. It will acquire much healthier plant communities and soil, more dominant landscapes and above all area in need of less input and maintenance. By doing so and letting the native plants edict the plant selection and, hopefully, the seeding also, you will achieve natural and humanized landscape that flourishes without any avoidable inputs, excessive watering, and fertilizers and is better qualified to handle weeds and pests (Christopher & Weaner, 2016).

Those environments that have the characteristics of a natural looking environment do not only provide beneficial circumstances for wildlife and protect biological diversity. They can act as stepping stones across the urbanized environment that are dominant in human, unnatural structures (Saura, Bodin & Fortin, 2014).

PLANT COMMUNITY

A Plant community is a group of plants that have developed and prospered together within the same habitat. Those plants are co-workers in the way that they each have something to give to the community and play an important role to maintain the ecological cycle, to create a successful plant community (Christopher & Weaner, 2016). The concept of the designed plant community is a translation of a wild plant community into the urban and cultural world. It is a mixture of ecology and horticulture where the touch of humility is still needed (West and Rainer, 2015). The big issue is though that we tend to think of a plant as an individual and we tend to want to tame nature and natural elements, such as the high maintained shrubbery and the mowed lawns. We need to loosen up, play more. Be more frivolous. We tend to forget that every plant, initially comes from a natural habitat, as previously mentioned. In our gardens or other planted grounds, the plant often lacks its vigorous conditions even though we lavish them with fertile soil, water and weed control (West and Rainer, 2015). Plants are individuals, but they come from a plant community and we can think of a plant as a social creature, everything about the plant is a reaction and adaptability to its social network. The tendency to plant plants far apart, with the bare soil underneath is a common, but unnatural way of planting. Unrelated plants, from different plant communities, are planted and arranged in a way just for an aesthetic purpose, which leads to a high requirement of maintenance since every plant has a different need. By looking at a plant as a part of a community the conceptual way of planting will turn out very differently (West and Rainer, 2015).

PEOPLE'S PERSPECTIVE

One of the issues with this conceptual way of planting is people's perspective. People tend to perceive ecological planting as messy, orderless and unappealing (Cowan, 2013). To make a wild looking plant design attractive it must look like it has been taken care of, that there is someone out there that has put great thought into the site and that someone cares, to make the wild look like it has been designed. One way to do that is to create sharp and clear edges between zones or areas of plantings with Corten steel, stones, mowed lawn, or gravel, to name a few. Other attempts might be using colorful plants, water, and signs for informative reasons (West and Rainer, 2015).

It is not only that with creative design people might appreciate natural looking planting better. Often the case is that native plants have a special place is people's heart. It differs between people which kind of sceneries and landscapes they grew up with or are attached to (Scannell & Gifford, 2010). A person from the west coast of Iceland might appreciate something that a person from the south coast does not see as valuable. By reading in the area you are working with, and by analyzing the spirit of the pace, what is native in that area or the most common mixes of plant communities, it is more likely that a successful design will be made (West & Rainer, 2015).

SENSE OF PLACE

Cities are post wild worlds that have changed and developed through the centuries. Think of the city that you live or lived in and then try to imagine the landscape that existed there thousand years ago. The urbanization has completely changed the scenery, and the urban and suburban landscape has changed the environmental conditions significantly from its original form (West & Rainer, 2015).

Photo. Hawkweed, often seen as unwanted weeds when situated in urban environments.

We do not need to seek nature in distant mountaintops, the post-wild world is right there in front of us, and there is a way to embrace it. Each site is unique, with its function of light, weather, winds, and soil. That site favours certain plants with specific needs and stress levels (West and Rainer, 2015).

Instead of preparing a site by busting up the organic matters in the soil, making the soil moist, construct shelters and avoid all shades, why not just embrace the working materials that are already there and use that as a starting point when designing a plant community. By doing all this preparation work, we are just eliminating the qualities of the site. Those qualities are the once that create the sense of place (West & Rainer, 2015). Wetland, dry roadsides and rocky lava fields are all very different from each other and do all have its own, valuable, sense of place. Instead of draining the wetland, watering the roadsides and sow grass on the lava, it can be preserved just the way it is by using plant materials that embraces these sites.

DESIGNING SUSTAINABLE PLANT COMMUNITY

To design a natural looking and sustainable plant community there are several different concepts and approaches to choose from. Each of them should enhance biodiversity and natural processes, reduce negative human effects and homogeneity of the urban environment, at the same time as is creates and boosts up the city's natural identity (Ignatieva, Meurk & Stewart, 2008). As mentioned above, the primary goal is to elevate and enhance native plant communities and transform them into urban human settings. These tasks can be challenging and demanding, but what can be learned from all of this, is that it is all about respect and understanding the environment. The concepts that will be mentioned are all approaches that are thought to be suitable for this assignment and will be described for their specificities.

Plant signature

Plant signature was developed by Robinson, it can be described as an expression of place´s identity which is enhanced through a combination of plants that offer a remarkable and memorable design. Along with the positive effects that the usage of native plants in a design has on the environment and that those plants are adapted to the sites environmental conditions, plant signature highlights and magnify place´s characteristics through the design of the neighbourhood's road infrastructures, intersections and roundabouts, stormwater swales, private gardens, public parks, and other public areas (Ignatieva & Stewart, 2009). The chosen plant combinations are naturally progressive and do have high aesthetical values that could enhance the visual qualities and identities for each site. It is an abstraction from the original identity or the plant community that offers and expresses the quality of the place. These feelings and factors can vary between designers, and it is in their hands to analyze each site's identity and the essence of the place (Robinson, 1993).
According to Robinson, (1993) the most efficient way is to design a plant combination that does not contain more than three to four plant species, that all have that in common that they are prominent and

noticeable in their natural environment (Robinson, 1993). As plant signature is first of all used to express and enhance the site's identity the design is very often placed by historical or essential grounds, universities, museums, parks and by entrances (Ignatieva & Stewart, 2009).

Alternative lawn

Lawns are one of the most visible green infrastructures in urban environments worldwide. The lawn has a long history and has been designed and used for various purposes over the centuries. Today it is seen as a vital link for urban citizens for play, recreation, park culture and as an aesthetically important factor in green spaces (Ignatieva, 2017).

Lawns, in general, are high maintained areas with selected one layered grass species with a high demand for regular mowing, watering and fertilizing. They are expensive to manage and maintain, but at the same time, they are monotoned infrastructures with low species richness and low value of biodiversity (Grass free lawns, 2014).

Now a day the demands for more sustainable and liveable urban environments are higher, and the need for more creative and environmentally friendly alternatives that fulfill these needs, and demands are greater than ever (Secretariat of the Convention on biological diversity, 2012).

Implementation of new approaches does not need to be complicated and demanding. One alternative is for example less frequent cutting. Alternative lawn approaches are overall sustainable solutions with a higher species richness and with a less need for maintenance and management. Alternative lawns are more suitable for stormwater management than traditional lawns since they absorb rainfall much faster (Grass free lawns, 2014). The alternative lawn approach aims to introduce a sustainable methodology in planning and design in both urban and rural environments. This approach suggests rather simple changes, and there do not need to be significant redesigning projects to be established (Ignatieva, 2017).

The alternative lawn is a diverse approach with multiple versions of methods depending on intended outcomes, place, space, and ecological region. Three alternative lawn approaches will be discussed in this thesis as they are thought to be suitable for this assignment (Ignatieva, 2017).

Grass free lawn

The grass free alternative lawn approach is a method developed in the United Kingdom. The approach is inspired by the common flower-rich meadows in Great Britain and is thought to be a good replacement for traditional lawns (Ignatieva, 2017). It is established from specific mowing tolerant perennial plant species that do best with no added fertilizers and have good drought tolerance. Grass free lawns are thought to be environmentally friendly with less need for maintenance, high species richness and high level of biodiversity (Grass free lawns, 2014). Grass free lawns have high aesthetical values, with blooming, colorful, and often scented appearance and the opinion of the public is generally greatly positive towards them (Ignatieva, 2017).

Like most other alternative lawn approaches, grass-free lawns do though need minimum care to keep required appearance (Grass free lawns, 2014).

Naturalistic herbaceous plantings

Naturalistic herbaceous plantings emphasis, as the name indicates, on naturalistic appearance. They are meadow like plant communities with high aesthetic value with bright and diverse colored plants that attract wildlife and people's eyes when blooming. They differ from for example pictorial meadows, that need to be re-sown annually as naturalistic herbaceous plantings are made from perennials, native as well as exotic grasses and forbs, that do not need to be re-sown annually (Ignatieva, 2017).

The approach is well-liked at the Sheffield landscape architecture school where the focus is to come up with different types of plant mixes with native and exotic plant species that all have that in common to increase local biodiversity, have high aesthetical values and low maintenance need (Hitchmough & Dunnett, 2004). The most known example of naturalistic herbaceous plantings is most likely when the approach was used, along with others, at the London's Queen Elizabeth Olympic Park (Ignatieva, 2017).

Native meadow

The native meadow approach has more traditional appearance than for example grass-free lawns and is a perennial mix of native flowering- and grass species. The native meadow approach is often suggested as a creative way for restoration or conservation and to make space for biodiversity in urban environments (McCargo, 2017).

Common landscapes where this approach has been established are for example industrial wastelands, newly constructed neighborhoods and even as a replacement for traditional lawns in private gardens (Ignatieva, 2017).

As with other approaches, the choice of species entirely depends on the site's local environment, soil, and overall area conditions. To embrace the known conditions and to use it as a starting point in a planting design is the only way to successfully create a native plant community, like native meadows (Ignatieva, Meurk & Stewart, 2008). The most common mixtures of plants in native meadows are 20-30% flowering plants and 70-80% grass but can vary between sites. Increase of biodiversity, little and quite easy maintenance and commonly appreciated appearance is the approaches' highest qualities (Ignatieva, 2017).

Go wild – Spontaneous vegetation

The spontaneous vegetation approach is likely the most controversial approach. It is an important habitat resource, but it might not be appreciated as one by the public, since in many eyes these plant species are seen as weeds but are meant for an ornamental and environmental purpose (Hitchmough & Dunnett, 2004).

This approach reflects its local environment conditions where the plants appear without any design inputs, and there is minimum control of what comes in, native or exotic. This approach is mostly used on wastelands and redesigning of industrial areas and construction sites (Ignatieva, 2017).

This approach has a special value in Germany where the idea is “to use spontaneous plant communities for landscape architecture purpose”. The approach came after the significant land destruction during the Second World War, and after the war, every little appearance of nature had value in people’s heart. It has given rise to further development and researches regarding naturalistic planting community approaches in Germany (Ignatieva, Meurk & Stewart, 2008).

Go wild is a similar approach where the emphasis is to do as little as possible, and to make the development area as naturalistic and as reflective of its local environment as possible. The approach is originally from the United Kingdom. It is different from the spontaneous vegetation approach in that way that the development areas are in most cases traditional lawns that are left alone and let to “go wild” (Ignatieva, Meurk & Stewart, 2008).

Photo. Example of wild grown Icelandic meadow.

ROADSIDES

Roads play an essential role in modern society. They are people's everyday environment and are the main connections between people and places. Roads do not only have a visual impact on that everyday environment, but they also affect ecosystem services, species diversity, and habitats. Roads cut the land into smaller units and break up habitats for flora and fauna. In general, the smaller and more scattered the units are, the fewer species it can sustain. Therefore, it is said that breach of habitats is one of the greatest threats to biological diversity (Landis et al., 2007).

One factor in reducing environmental impacts from road constructions is to incorporate them as possible into the local environment, and this applies to the local landscape and vegetation. Most of the roads that assist today were constructed before the time of modern perspectives about conservation of nature and ecosystems. Safety and economy were and still are the focus points in road constructions, and ecological impacts are often neglected (Landis et al., 2007).

Roadsides are usually vegetated for the purpose of stopping and avoiding soil degradation (Johnson, 2008). The tradition is to graft roadsides by sowing grass species, as the aim is to make the roadside tidy and economically beneficial in construction (Aradóttir & Óskarsdóttir, 2015). This often follows a great need for care and maintenance, mowing, herbicide, fertilizing and, often watering. All this is done for increased and denser growth, but at the same time, it can have a significant negative impact on local biodiversity (Person, Puig & Villarroya, 2014).

Many factors control how sensitive area's ecosystem is for the effects from roads and road constructions. The results are various, such as habitat disruption, erosion, noise, pollution, change in plant composition and negative impact on ecological processes (Aradóttir & Óskarsdóttir, 2015).

Roads do not only affect its closest environment. Roads can also have an effect on plant composition at a distance, for example, spreading of exotic and invasive species, which have been planted in the roadsides. Exotic and invasive species tend to thrive well in disturbed areas and can have a great impact on the propagation of invasive species (Quarles, 2003).

A big part of road constructions today is mostly maintenance and development on current existing roads, rather than constructions on new roads. This creates an opportunity to remedy the roads that could have been done better, reclamation of older road construction projects and to create more sustainable road system (Wilkinson et al, 2008).

Before continuing with this chapter, it is necessary to explain further what roadside is and the definition of the word. Roadside is a strip of land situated next to the road. Roadsides also known as road verges, often play that role to be an essential source for food and shelter for many species, especially around the highways. In urban areas, roadsides consist mostly of mowed grassy vegetation and in some cases street trees. Roadsides cover a great deal of land all over the world, and due to increased urbanization, the extent of roadsides will increase further (Evans, Holt, O'Sullivan & Warren, 2017). Globally estimated increase is 60% from 2010-2050 (Laurance et al., 2014). Therefore the need for radical changes, considering roadside vegetation is needed, to preserve and increase urban biodiversity and for overall health beneficial human urban environment (Kowarik, Säumel & Weber, 2016).

ROADSIDE VEGETATION

Naturalistic and healthy grown road environments can play the role to be a protector for local ecosystems, can increase drainage, reduce erosion (Johnson, 2008) and in some cases, lessen the effects of a disintegration of habitats (Landis et al., 2007). Naturalistic vegetation in roadsides also creates habitats for various organisms, improves the driving experience and, as previously mentioned, can reduce maintenance needs (Johnson, 2008). Researchers have shown that by using native flora and by the reclamation of local vegetation, in most cases is what promotes healthy and environmentally friendly roadsides (Landis et al., 2007).

Roadside vegetation in urban areas is often very different from roadside vegetation in the countryside or rural areas. It is usually easier to reclaim local vegetation around roads in the countryside, since the local vegetation and the local ecosystem has not been under as much disturbance as in urban areas. Urban areas are post wild worlds which have gone through dramatic changes over the centuries (Aradóttir & Óskarsdóttir, 2015).

Road vegetation serves a diverse role in the urban environment, all from being there for aesthetic reasons, increasing biodiversity, local ecological services and have positive effects of citizens health and experience in the urban environment (Kowarik, Sämuel & Weber, 2014). Road vegetation lives in harsh conditions, pollution, salt from roads and in many cases with too little root space, which is mostly the case for street trees that have to live with unrealistic expectations and requirements about beauty, look and growth. The soil in roadsides is often oxygen deprived, too moist or too dry and saturated with salt and heavy metals (Garðarsdóttir & Harðarson, 2016).

Roadside vegetation must live with the harsh conditions to be either exposed from sunlight and winds or live in shadowed streets or alleys in areas where the microclimate has been altered. Consequently, the plant choice for roadsides can often be a complicated process. By narrowing the choice down to native species, it can make the process simpler in these habitat conditions (Garðarsdóttir & Harðarson, 2016).

For now, though the easy way is seeding of imported grasses, it is efficient and with a low start-up cost. When imported grass seeds are used for reclamation in roadsides, the seeds are easily accessible on a general market and relatively inexpensive compared to seeds from native plants. Also, the method of seeding grass is well known, usually relatively quick and does not require much labour. That is most likely the reason this method has been as popular as it is today. This "traditional" method may, however, cause various problems. Among other things, it may follow high maintenance costs due to a continued need for mowing, fertilizers or use of toxic substances (Neufeld, 2008).

High grasses alongside roads can cause accumulation of snow, at the same time as they can have sedative effects (Wilkinson et al., 2008). As previously mentioned, seeding of one or few imported grass species can cause reduction of biodiversity due to the existence of fewer natural habitats and the risk of those imported species to get invasive (Neufeld, 2008). These problems can be prevented by putting more emphasis on reclamation of native species. It is often thought that this approach should be engaged to reclamation projects in for example wetlands or forests. It is a well-proven fact that this can be used as well in the design of rainwater swales, green-roofs, parking lots and in roadsides, to name a few. This way of thinking will increase ecological values and reduce possible negative effects on local ecosystem due to poor plant selection and at the same time have positive benefits on economic and social factors (Simmons, Venhaus & Windhager, 2007).

MAINTENANCE

When it comes to general maintenance around green infrastructures in urban landscapes, it is primarily employees experience and knowledge that promotes right practices and workmanship in roadsides. Where rainwater swales and bio-swales are often integrated, it is in the hands of the staff to be aware of possible damages done by equipment and contact with pollution. Management and maintenance of vegetation in urban landscapes needs training, planning, and equipment to gain an effective outcome (Aronson et al., 2017).

In urban areas, roadsides are mowed frequently to maintain a short grass height, to prevent the formation of withered grass, which can, as mentioned before, be a threat due to snow elevation next to the road (Wilkinson et al., 2008). Roadside maintenance in urban areas is cost efficient and requires some management all year around. In Reykjavík, as mentioned before a big part of the green environments are green corridors next to road infrastructures. In total, there are 474 hectares of green areas mowed on 9352 different areas in Reykjavík every summer, assuming 2-6 cuts per season, costing approximately 1.700.000 EUR per year (Reykjavík, 2016). Including to cutting there is, pollution and damages done by the equipment, fertilizers, monotone environments, and allergic reactions to pollen from the grass which are all factors affecting the urban area and citizens.

AIR QUALITY

Pollution connected to traffic in cities is a significant problem which affects all urban citizens worldwide. The need for actions in those matters is becoming significantly more important by each day passing by (Kowarik, Säumel & Weber, 2016). Roadside vegetation is a particularly important source when it comes to the matter of increasing air quality beside roads, which are the primary cause of urban pollution (Evans, Holt, O'Sullivan & Warren, 2017).

Urban trees are an essential link to increase citizens quality of life by reducing pollutants and other particulate matters that are obtained from traffic (Evans, Holt, O'Sullivan & Warren, 2017). Well-structured and diverse species of indigenous herbaceous plants are

Photo. Colorful Europian hawkweed in road environment in Reykjavík.

also considered as an important source to increase habitat qualities in cities (Kowarik, Säumel & Weber, 2016). It is necessary to keep in mind that herbaceous plants can cause allergic responses. The choice of species needs to be done with care due to allergenic pollen from the plants that cause health problems. This can also be applied to trees. Birchwood (*Betula pubescens*) for example, can cause allergic reactions (Evans, Holt, O'Sullivan & Warren, 2017) and has it been increasing over the years (SÍBS, 2016).

When it comes to street trees, there is a great need to think about the densification of the vegetation. Densely planted street trees or shrubbery can reduce wind movement and wind speed in narrow streets and thereby increased local air pollution. Therefore, projects that only aim for condensing urban vegetation can be misleading. The best solution, when managing urban air pollution, is the use of both street trees and herbaceous plants that are adapted to local environment and conditions (Evans, Holt, O'Sullivan & Warren, 2017).

STORMWATER MANAGEMENT

When creating and designing a sustainable street environment, permeability, and stormwater management play an important role. The benefits of incorporating sustainable stormwater systems is a healthier and greener environment in towns and cities, as well as sustainable water resources. Sustainable stormwater management systems have been widely used and are in some countries the standard way of treating stormwater (Alta, 2016).

When settlement rises, the land's surfaces become denser with buildings and concrete and asphalt surfaces, such as streets and pavements. It causes rainwater and ablation water to accumulate on these dense surfaces, rather than saturating into the soil naturally. The traditional solution is to drain the water down to pipes underground, away from the settlement and into the receptors, such as sea, rivers, or lakes (Brennan, C. & O'Conner, D., 2008). This disrupts the natural cycle of water and groundwater level decreases with a significant negative impact on the ecosystem and water resources in general. Soil, wetlands, rivers, and lakes dry up, and ecosystems and biotopes get contaminated. The stormwater will rinse the surface on its way and will carry dirt, oil, tearing of tires and other contaminants into the receptors (Alta, 2016). Instead, with sustainable stormwater management, the water is led down to the soil close to where it falls, and the surface is made as porous as possible. The soil, together with the vegetation will clean the water from contaminants. The circulation of water will become more visible in the local environment. It will enrich the urban environment biosphere, aesthetical values, make the urban space greener and more valuable (Brennan, C. & O'Conner, D., 2008).

In Iceland, seasons have more impact on the performance and function of sustainable stormwater management systems than in countries where seasonal changes are less extensive. It is necessary to take into account these seasonal conditions when designing and implementing stormwater management systems in Iceland. The circulation of water in cold climates is more complex than in warmer climate, and other challenges will follow, this may include frost in the soil, and when water freezes it expands by 10%. Then there is a particular caution that must be considered regarding frost and ice clogging in pipes, ice in waterways, snow melting, spring thaw and rain falling on snow (Garðarsson, Gunnlaugsdóttir & Sveinsson, 2008)

In cold climate, snow melting has far more dramatic consequences than summer rainfalls. Snow melting can last for days and even weeks. Precipitation that falls on snow can also cause heavy floods. Under such conditions the snow cover acts as a reservoir that is released when the rain falls on the snow and on addition there is most likely frost in the soil, so the water cannot flow down to the ground (Semadeni-Davies, 2003).

Despite these challenges mentioned above, many studies have shown that sustainable stormwater solutions are well suited in cold climate and that their performance in winter conditions is good (Garðarsson, Gunnlaugsdóttir & Sveinsson, 2008).

ICELAND

Iceland has been shaped by extreme forces of nature through the centuries and is continually changing. Eruptions, floods, storms, salty winds, and avalanches are all part of Icelandic geological history and give the country its unique appearance (Guðmundsson, 2016). The beauty lies within the country's diversity. Wherever you go, you will experience a new type of scenery. The unvegetated or partly vegetated habitats are dominant and cover more than 60% of land area. Volcanic areas constitute 16%, Glaciers 18% and inland area with rocks and bare fields the remaining 66% (Normander et al., 2008).

Iceland is the most sparsely populated state of Europe. Only a quarter of the country, about 25.000 km^2 constitutes as built. The settlement lies mostly as a narrow strip along the coastline and in valleys. It is almost entirely below 200 m above sea level, but even under 200 m there are large uninhabited areas, for example on sand and lava fields in southern Iceland. 60% of the country is about or above 400m above sea level. That part is mostly highlands with only mountains and few large Ice cap mountains. When higher in the country the panorama view gets prominent where the mountains define the removed horizon and the color scheme, with the combination of color and forms (Árnason et al, 2010).

ICELANDIC HABITAT CONDITIONS

Right under the arctic circle the country's nature and environment reflect in its coordinate position, and the fact that the country is an isolated island far from a mainland reflects in the country's biosphere. These forces shape the Icelandic landscape in addition to particular internal and external factors that help with the making of the Icelandic landscape. On the one hand, there is volcanic activity, geothermal energy and the interaction between fire and ice. On the other hand, it is the sparse population, low cultivation level and intermittent vegetation (Árnason et al., 2010).

Iceland is largely exposed from vegetation which is contributed by all the factors previously mentioned, but also ever long overuse of natural resources, with the outcome of vegetation that is small in size and scattered (Árnason et al., 2010).

Iceland is one of the most volcanically active countries in the world. It erupts about or more than 20 times a century. The volcanic activity comes in varied forms, and in Iceland, there can be found all types of volcanoes known on earth, which is the main cause of the various color schemes in the landscape (Guðmundsson, 2016). The colors and the strong forms are intertwined together with water-rich sceneries, from ice to lakes and from slow water streams to rushing heavy rivers and waterfalls, together with the low vegetation, that creates green splashes or islands in the landscape it creates the Icelandic landscape (Árnason et al, 2010).

One of the most significant factors on the island's ecosystem is the gulf stream. Due to the gulf stream, a warm ocean that rises from the southern coast of America, the weather in Iceland is much milder than its location and name imply. The winters are rather mild, and the summers are fairly cool, which contributes to a quite low average temperature per year. Climate varies considerably between regions, and the oceanic climate which is common along the south coast causes long rain periods, longer plant growth time and milder winters. The southern and the western coast benefits from the gulf stream when a branch of it flows along the coasts and manage the climate. However, this means that the weather in Iceland is frequently changing when the Atlantic air gets in contact with colder arctic air. Furthermore, this means that the weather can be quite dramatic and versatile (Icelandic Met Office, 2008). Climate, especially the low average air temperature and the countries isolation together limit the county's biological diversity and influence most of the country's natural appearance and vegetation (Árnason et al, 2010).

Varied woody vegetation characterizes isolated islands in a cool oceanic climate. Strictly speaking, no island can be found that is comparable to Iceland in terms of the three elements that primarily shape the island's biosphere: size, coordinate position, and isolation. The islands that are most similar to Iceland are in the southern hemisphere, south-east and south of New Zealand. There can be found akin isolated islands in a similar climate, but they are all much smaller than Iceland and with different geographical history (Árnason et al, 2010). Characteristic species in the flora of the isolated sub-Antarctic islands are endemic mega herbs, but woody species are not found (Wardle, 1991). There can be found some endemic species in the Icelandic flora, but the only one that can be compared to the mega herbs on the sub-Antarctic islands is the Garden angelica (Angelica archangelica). It that spreads out where the land is protected from grazing, in fjords, along rivers and lakes (Árnason et al., 2010).

All studies indicate that dramatic changes have been occurring since the land was settled in the 9th century. Forests and shrublands have been destructed, and today the country is nearly forest free, which has let to vegetation- and soil erosion. This scenario has no parallels in other countries with a similar climate but can be compared to land-use in dry and hot countries, for example, close to the Mediterranean ocean and in North Africa (Arnalds et al, 1977).

Iceland changed from being well-vegetated land, with several vegetational layers with plants in varied forms and fertile organic soil to a desert with about 1-5% of robust plant species with minimal primary productivity a no organic soil. On the other hand, in Iceland the cultivation level is low. Grain farming is significantly reducing, with only 0,03% of the land being used for grain crops. Farmlands are mostly hayfields and grazelands. That kind of land use involves much less deterioration in biological diversity than in grain crops and not as radical transition in species composition. In that respect, agriculture has had a lower impact on the biosphere and the appearance of land in Iceland than elsewhere in Europe. However, cultivation and spreading of imported species, such as conifers and Nootka lupine (Lupinus nuutkaensis) are likely to change the country's appearance a lot over the coming decades (Þórhallsdóttir, 1997).

ICELANDIC FLORA

With the settlement, it is believed that a third of Iceland was covered with birch wood (*Betula pubescens)* (Skógrækẗin, 2014). The arrival of humans disrupted the delicate ecosystem with forest exploitation and overgrazing of livestock. Also, volcanic activity, glacier movement, and unfavorable climate caused soil erosion, as previously have been mentioned (Guðmundsson, 2016). Current estimates indicate that only 28% of the country is considered vegetated and that forests are 1200 km^2, which indicates that forest covers only 1.2% of the country. These forests are partly planted or about 360 km^2 while 850 km^2 are natural forests, mainly birch which is the only local tree that forms forests (Snorrason, 2011). Where the wild birch forests can be found it is a sign and an example of an original or minimally disturbed vegetated area (Aradóttir, Arnalds, 2015). The Icelandic birch is usually a mix breed between *Betula pubescens* and dwarf birch (*Betula nana*) and has the name *Betula x intermedia* and is the reason why it is so small and tangled (Snorrason, 2011). The Birchwood, dwarf birch and willow form together a typical Icelandic scrubland. It is believed that willows, especially the woolly willow (*Salix lanata*) and tea-leaved willow (*Salix phylicifolia*) had been widespread around the country before settlement and would again grow widely if the heathlands would be protected from grazing (Árnason et al., 2010).

The other 26,8% of Iceland's vegetation is the Icelandic flora. No one knows for sure how many species the Icelandic flora contains, in the widest sense of the word, but it is considered that the flora of Iceland comprises about 5610 species. Of these 5610 plants, only 489 plants are vascular plants, flowers, and ferns, where 31 of them are protected (Flóra Íslands, 2016).

Mossy lava fields are one of Iceland's vegetative specialties with very few parallels around the world. Woolly fringe-moss (*Racomitrium lanuginosum*) on the other hand, forms wide spreads in cold oceanic climate (Longston, 1988) for example on lava in Jan Mayen (Russel & Wellington, 1940) and on some glaciofluvial drifts in Svalbard (Hodkinsson, Coulson & Webb, 2003). However, it never becomes as widespread or as prevailing as on the lava fields in the south and southwest of Iceland (Árnason et al., 2010).

The number of plant species in Iceland is relatively low compared to many other areas with similar weather conditions. The explanation is the isolation of the country, which creates an island ecosystem, and the short time since the last Pleistocene glaciation which eradicated many species, some of which have not been returning. About half of the 489 vascular plants are regarded as survivors of the last glaciation (Flóra Íslands, 2016). Some might think that arctic plants characterize the Icelandic flora, but the character of the Icelandic flora is more Scandinavian and North European than arctic. About 97% of these species are found in Norway and about 66% in Greenland (Normander et al., 2008).

The vegetated areas in Iceland can be split up into different categories, wetlands, heathland (Meager heaths and rich heaths), woodland, meadows (grass- and flower land) and moss land and sparsely vegetated land (Aradóttir, Arnalds, 2015).

Wetlands are one of the most important ecosystems on the earth. They temper water flow and reduce the risk of floods and droughts in rivers. Wetlands are the foundation for diverse wildlife, both above land and under, where the most common vegetation are sedges. The wetlands in Iceland are very special on a global scale, because of the volcanic ash in the soil around it. A big part of the wetland in Iceland has been drained, but some of it is considered extremely important for biodiversity and ecological diversity and is protected today (Aradóttir, Arnalds, 2015). Heathland is the most common type of vegetated land in Iceland. It can be found widely since that land has changed through the centuries because of the land use, for example where there used to be forests, as previously mentioned (Aradóttir, Arnalds, 2015). Heathlands are dominated by alpine and arctic plants where ericaceous species such as crowberry (*Empetrum hermaphroditum*), cowberry (*Vaccinium vitis-idaea*) and bilberry (*Vaccinium myrtillus*) cover large areas. Grasses and flowering plants are also a big part of the vegetation, including mosses and lichens, to name a few (Normander et al., 2008). Heathland can be split up into two different categories, meager heaths, and rich heaths (Aradóttir, Arnalds, 2015).

Woodlands, as previously mentioned, used to cover a big part of Iceland. Today eleven wild grown tree and bush species belong to the Icelandic flora. Some species are not as common as other, for example, aspen (Populus tremula) can only be found in eight places in Iceland, and the burnet rose (*Rosa pimpinellifolia*) has just been discovered in under twenty places and is today protected (Flóra Íslands, 2016). Protection of the wild woodlands in Iceland are declared as government's goal. The ecosystem in the birch woodland is extremely rich in organic nutrients and is very important for protecting the land against soil erosion. At the same time as it has an important ecological value, the woodland has a great recreational value for people (Aradóttir, Arnalds, 2015).

INVASIVE SPECIES

Invasive species of both flora and fauna are considered one of the greatest threads regarding biodiversity in the world. To name a few, it threatens biodiversity in many ways by causing diseases, acting as competitors, changing habitats, and crossbreeding with local species (Encyclopedia of life, 2012). Invasive species are especially a significant threat to native biodiversity in urban areas. Many foreign species are imported, where some of them scatter into the wild and become invasive. The diversity of foreign plants is particularly high in Reykjavík where they have been planted in parks and private gardens. The number is increasing, but only a few can replace the native flora and thus are considered invasive. These include for example the cow parsley (*Anthriscus sylvestris*) and the Nootka lupine (*Lupinus nootkaensis*) (Department of Environment and Planning, City of Reykjavík, 2016).

Cow parsley got transmitted to the country at the beginning of the 20th century. It grows wild in Asia and Middle-Europe and was brought far beyond its natural habitation for cultivation in private gardens but got established very quickly and is now spreading out on its own. Cow

Photo. Nootka lupin coloring the urban environment purple.

parsley seeks after forming consecutive wides that nothing can stop. It is not suitable for grazing, and it grows well in shaded areas and covers forest's grounds. Now the Cow Parsley is gradually overrunning the spreads of Nootka Lupine, as its ideal habitat is fertile soil, that the lupine produces (Náttúrufræðistofnun Íslands, n.d.).

Nootka Lupine has over the past years been coloring the land purple. It has spread out very quickly and is covering a great part of the land and puts a strong appearance on the land wherever it settles. It grows wild in North-America, and it is thought that it came here first around 1895. After it was brought in to the country for land reclamation in the 50´s and after reduction of sheep grazing, it started to spread out intensely all over the country. Around the capital area, the biggest Nootka Lupine areas are situated to east in the heaths and to east in the lava fields. In these areas, there is no sheep grazing and almost nothing that impedes the spread of the lupine, except for direct actions, with mowing and chemical use. If this development will continue as it is today, the Nootka Lupine will conquer big part of the Reykjanes-bay. Where the Nootka Lupine settles, and it forms wide spreads over the land, it will completely change the nature of soil and vegetation (Náttúrufræðistofnun Íslands, n.d.).

REYKJAVÍK

Reykjavík is a young city that is still in its infancy. It has a small urban core and spreads out into the suburbs. Mountains, meadows, lava, and ocean encloses the city and forms a frame around it, which gives it a high value. The beauty isn't lacking, and nature is in walking distance for citizens. The city offers beautiful and diverse areas for outdoor activities and some of which are preserved and protected. Wetlands, rivers, lakes, woodlands, coastal areas and even mud flats (Umhverfisstofnun, n.d.).

This uniqueness gives a reason to preserve these valuable natural elements that are situated so close to the city. But what about the green infrastructure that citizens are living within every day? On their way to work or outside playing with their children. Are the quality and diversity reflected within the city as it is in the city's local environment? As mentioned earlier the city is rather green and has an unusually high percentage of green open spaces, but their quality might not coordinate with their vast numbers. In a comparative survey conducted between the Nordic countries in 2003 showed that in Reykjavík there are about 703 m^2 of open green spaces per citizen, but about 115 m^2 in Malmö. But there are no connections between quantity and quality. A European study shows that 30% of people in Reykjavík are happy about Reykjavík´s open green areas, while the proportion is 58% in Malmö (Silfverberg et al., 2003). Many of these green areas are grass areas between districts, next to transport infrastructures and institutional lands and are dominating in the urban landscape (Reykjavík, 2017). These areas can be homogeneous and cover the city like green carpet that costs money and labour to maintain.

DEVELOPMENT OF GREEN INFRASTRUCTURE

The history of horticulture and gardening in Iceland is short but unique. In times of hardship and migration from the country, because of poverty and cold weather conditions during the 19th century, gardening, and the thought of caring for the environment were the least worries that people had at that time (Guðmundsson, 2010).

Researches about the history of horticulture and landscaping in Iceland in the 19th and 20th centuries are therefore rather new. In fact, almost no Icelandic research has been made. It is questionable to attempt to connect the history and development of Icelandic parks and gardens to foreign garden history. It is also unrealistic to try to see the characteristics of different styles from the garden history in Icelandic horticulture landscapes that were built in the middle of the 20th century. Those who organized and created those environments did not know either the European garden history nor the ideology of different garden styles (Bragason,2014).

However, following the industrial revolution, there was an awareness awakening, and discussions about the importance of hygiene and general health in cities and one of the emphasis were the importance of public parks and urban green environments as a benefit for citizen's health (Lucey, 1973). The debate was brought to Iceland at the beginning of the 1900s, and it was in 1870 that Reykjavík realized that they would have to take action and clean the city and part of it was to establish health beneficial green areas which resulted in the first public park in Reykjavík being built (Friðriksson, 1991).

During this time, people started to try a different kind of gardening, bearing in mind that those individuals who wanted to grow trees and herbs at this time were optimistic and had a lot of belief in progress. In addition to cold and salty winds, poor nutrition in soil and sheep grazing, the weather was unusual in the 9th and 10th decade of the 19th century. Summers seemed like winter, and the coastal line was often covered with ice (Guðmundsson, 2010).

In mid-twentieth century most towns had begun to plant trees, flowers and other vegetations. Summer flowers were also becoming prominent both in flower beds and around streets and squares. Icelandic towns had changed greatly since the turn of the century (Friðriksson, 1991).

In 1974, a so-called green revolution began in Reykjavík, where the outlying green recreational areas of the city and large green spaces were organized as one large whole throughout the city. The green revolution dealt with a cultivation of open spaces in the city, cleaning, organizing of smaller spaces inside the neighborhoods and laying bicycle and pedestrian lanes. This revolution was, in fact, a response to the so-called black revolution, when streets in Reykjavík were asphalted after the creation of Reykjavík´s master plan 1962-1983 where the main emphasis regarding transportation was on the private car (Bernharðsson, 1998).

Reykjavík has been through significant changes in just a few decades. That what has been characteristic regarding vegetation design in green areas in Reykjavík in recent years, or decades are simply what works and what people know, and little has been done regarding researches and experiments on plant use and planting design. The main characteristic of the flora in the city is grass species such as *Arctic fescue (Festuca richardsonii), Blue grass (Poa pratensis)* and *Perennial ryegrass (Lolium prenne L).* Over the years other plant species have arrived in these areas and changed the appearance to the better (Óskarsdóttir, 2014).

The Black cottonwood (*Populus* trichocarpa) represents 90% of all street trees in the city and is it because that tree that has performed best as a street tree in Icelandic conditions. It can easily be said that biodiversity is not the dominant factor considering species choice and planting design in Reykjavík (Garðarsdóttir & Harðarson, 2016). However, awareness is taking place. Emphasis on sustainable development, enrichment of biodiversity and ecologically beneficial exploitation of land are global revolutions that cities have had to acquire and become a part of. Reykjavík is not excluded, and Reykjavík has been developing policies regarding these subjects the past years. In 2016, Reykjavík issued a policy on biodiversity (Department of Environment and Planning, City of Reykjavík, 2016) and in 2017 an action plan was developed on how to handle the issues that could be better addressed. Part of that policy was about changing the focus in green environments in the city, regarding plant use and reducing maintenance (Umhverfis- og skipulagssvið Reykjavíkur, 2017).

The past years, an Icelandic entrepreneurial turf company has been developing production of turf obtained from Icelandic nature, and the city of Reykjavík has been implementing these turfs in new design projects in the city. These turfs are heath-turfs that are cut in the heathlands. The vegetation consists of ordinary Icelandic heather plant species, such as a variety of moss species, small-grown grass species and single flower crops, such as Wild thyme (*Thymus praecox*), Alpine lady's-mantle (*Alchemilla alpine*) and Slender bedstraw (*Galium nomanii*), as well as Crowberry (*Empetrum nigrum*), Scotch heather (*Calluna vulgaris*) and most often Bog bilberry (*Vaccinium uliginosum*). But the vegetation of the heath turf can vary greatly depending on where they are cropped. The other type is rangeland turf. They are carved from a self-grown land and contain only Icelandic grasses and flower species. They are suitable everywhere, where the emphasis is placed on a natural finish that does not require high need of maintenance. The main species are Icelandic Sweet vernal grass (Anthoxanthum odoratum), Arctic fescue (Festuca richardsonii) and Sheep's fescue (Festuca vivipara), Common bent (Agrostis capillaris) and Brown bentgrass (Agrostis vinealis) and Icelandic flower plants such as Wild thyme and Rubiaceae- and Potentilla flowers are usually included (Jónsson, 2011).

Hopefully, even more, development will take place next years regarding research and development in this field. Reykjavík is a young city, which must be preserved along with all the densification developments that are an ongoing process in the city. When there is a high level of housing demand, the mistakes and failures are more likely to happen, but with greater knowledge, education and public interest in this area, there is a hope that the future developments will protect the specificity of the city, its nature and biological- and area diversity (Boverket, 2017).

ANALYSIS AND INVENTORY

This chapter presents the result of inventory and analysis at chosen site, in Reykjavík´s roadsides and around Reykjavík´s ecoregion.

Where are we, ecologically speaking, in both time and space?

SITE ANALYZING

WATER AND TOPOGRAPHY

Because of Iceland´s global position rainy days and snow melting are very common. Usually the rain-water is drained through pipes underground and into a receptor, which in this case is the ocean.

The chosen intersection is fairly permeable, but it is mostly made of mowed lawns, which do not have as good drainage as naturalistic vegetation.

The sites topography enables creation of stormwater receptors which could absorb rain water and snowmelt and let the water saturate into the soil naturally.

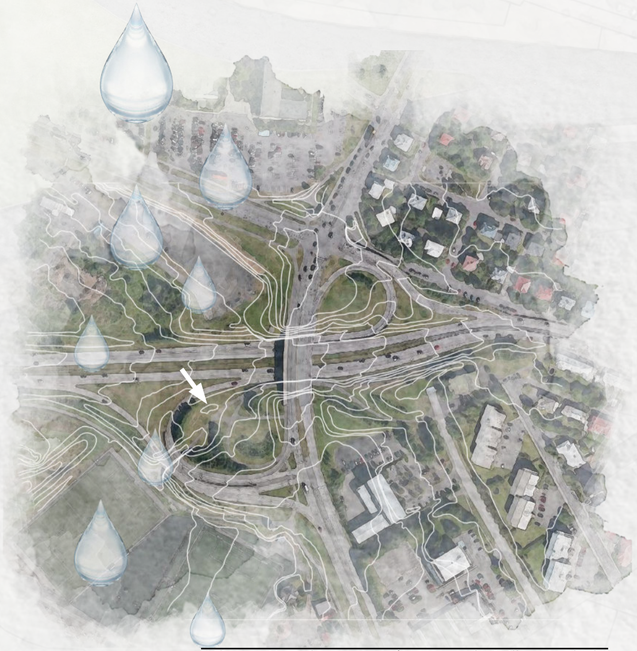


Figure: Here the case area´s topography is illustrated. The arrow on the figure points at the areas lowest point. The lowest point tells us that this area would be suitable as stormwater management reseptor.

SUNLIGHT AND WIND

Summerdays in Iceland that are considered good are few. The sun shines brightly all day around during summertime but rises over the horizon just for few hours during high winter.

The chosen intersection is facing north and south. The site facing south catches more sunlight during the day.

According to the Icelandic met office the strongest wind directions, average per year, are the north and south-eastern. The most common wind ditection during winter time is coming from east and over the summertime it is coming from south-east (Icelandic Met Office, 2008).

Figure: Here is the area´s most common wind directions illustrated, along with the sun´s cycle. The north site of the case area is facing south, which is then more exposed to sunlight than the south site.The existing vegetation also creates shadow effects.

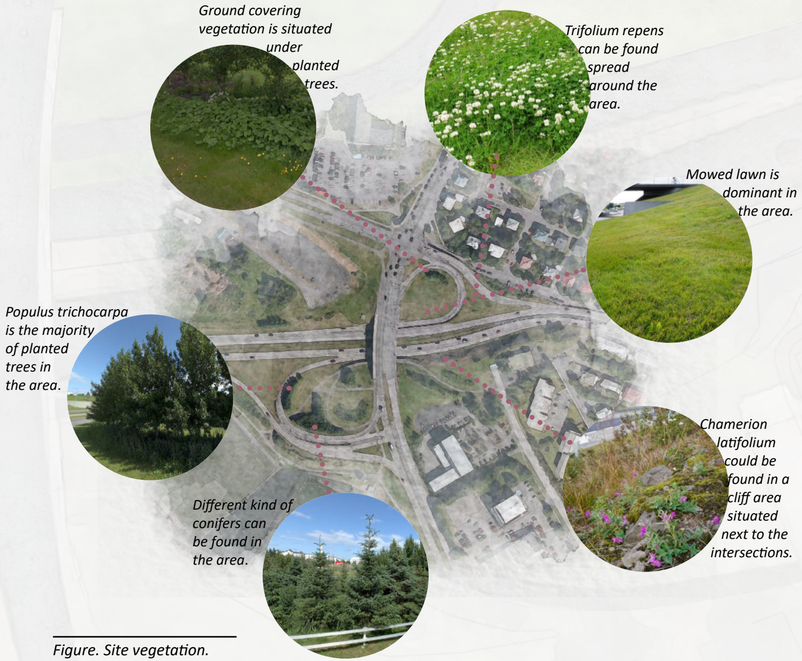


Figure. Site vegetation.

Photos. Site conditions and vegetation

VEGETATION ANALYZING

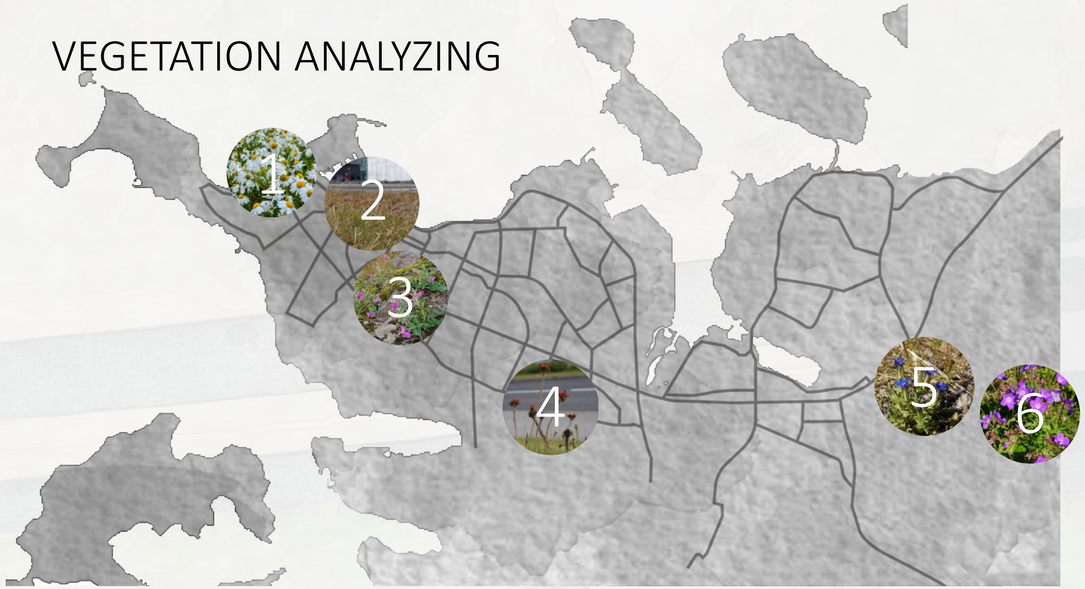


Figure: Vegetation analyzing was made in six areas in Reykjavík.
The marked areas above illistrate where the vegetation analyzing was done. Site 1 and 6 are the areas where vegetation in Reykjavík´s ecoregion was studied and analyzed. Area 6 is located in the heaths next to Reykjavík and gave a good example what kind of heath vegetation is normal in Reykjavík´s ecoregion. Area 1 is situated next to the ocean and gave a great example of what thrives in salty and windy conditions around Reykjavík´s ecoregion.
Area 2, 3, 4 and 5 are the areas where roadside vegetation was studied and analized. Those areas were picked randomly, given that there was minimum 1,5 distance between them to get varied results.

Chamerion latifolium - Broad-leaf fireweed

Gentiana nivalis - Alpine gentian

Anthyllis vulneraria - Ladies' Fingers

Galium verum - Lady's Bedstraw

Achillea millefolium - Yarrow

Pilosella aurantiaca - Orange hawkweed

Trifolium pratense - Red clover

Equisetum arvense - Field horsetail

Plantago maritima - Seaside Plantain

Trifolium repens - White clover

Tripleurospermum maritimum - Sea mayweed

Ranunculus acris - Meadow buttercup

Photos. Example of plants found in Reykjavík´s roadsides.
Surprysingly diverse flora was found in Reykjavík´s roadsides. The plants found tell us that they tolerate dry and harsh condisions around the road environment. Images above represent only few of the plants found in the roadside areas.

Empetrum nigrum - Crowberry

Geranium sylvaticum - Woodland geranium

Dryas octopetala - White Dryas

Hieracium alpinum - Alpine hawkweed

Alchemilla alpina - Alpine lady's-mantle

Galium normanii - Slender bedstraw

Salix phylicifolia - Tea-leaved willow

Calluna vulgaris - Heather

Thymus praecox- Arctic thyme

Salix lanata - Woolly willow

Silene uniflora - Sea campion

Armeria maritima - Sea thrift

Photos. Example of plants found in the ecoregion of Reykjavík. Diverse flora can be found in Reykjavík´s nearest environments. Example of ecotypes in Reykjavík´s ecoregion are illustrated on page 54.

ECOTYPES IN REYKJAVÍK´S ECOREGION

In every ecoregion there are many different kinds of ecotypes depending on flora, fauna, soil and climat (Náttúrufræðistofnun Íslands, 2018)

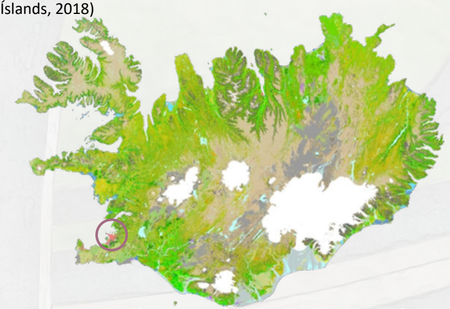


Figure: Iceland´s ecotypes. © The Icelandic Institute of Natural History.

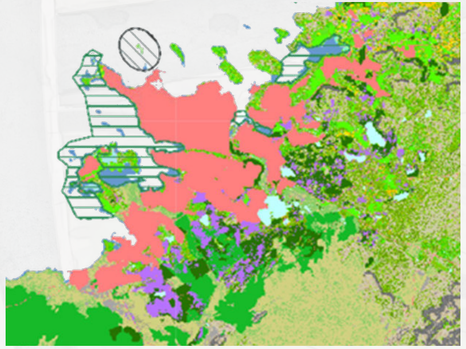


Figure: Here it can be seen how Reykjavík´s ecoregion is divided into different kind of ecotypes. © The Icelandic Institute of Natural History.

Urban and other manmade areas

Settlements and structures which belong to them; cities, towns, villages, industrial areas, roads, harbours, airports, waste and landfill areas, and so on.

Planted woodland

Planted woodland areas planted with foreign leaf trees and/or conifers.

Nootka lupine (Lupinus nootkatensis)

Ecotype where the Nootka lupin is the dominant plant specie.

Water

Diverse groop of well vegetated water areas on a lowland.

Birch woodland

Low-grown and scattered woodland with birch and heath vegetation. Soil is rather meager to rather moist.

Heath grassland on a lowland

The ecotype is diverse and represents many different kinds of heath grasslands on a lowland. The land is well vegetated, with low grown vegetation. Vascular plants are dominant and the land is also rich of moss and lichens.

Mossy lava

The ecotype consists of rather few vascular plants and lichens but is very rich in moss species. The soil is shallow and meager.

Grassland/Flowering grassland

Very rich grasslands on a lowland and in slopes. The ecotype is rich of vascular plants but has very few moss or linches species. The area is rich of flowering plants where there is good shelter and sunny hillsides (Náttúrufræðistofnun Íslands, 2018).

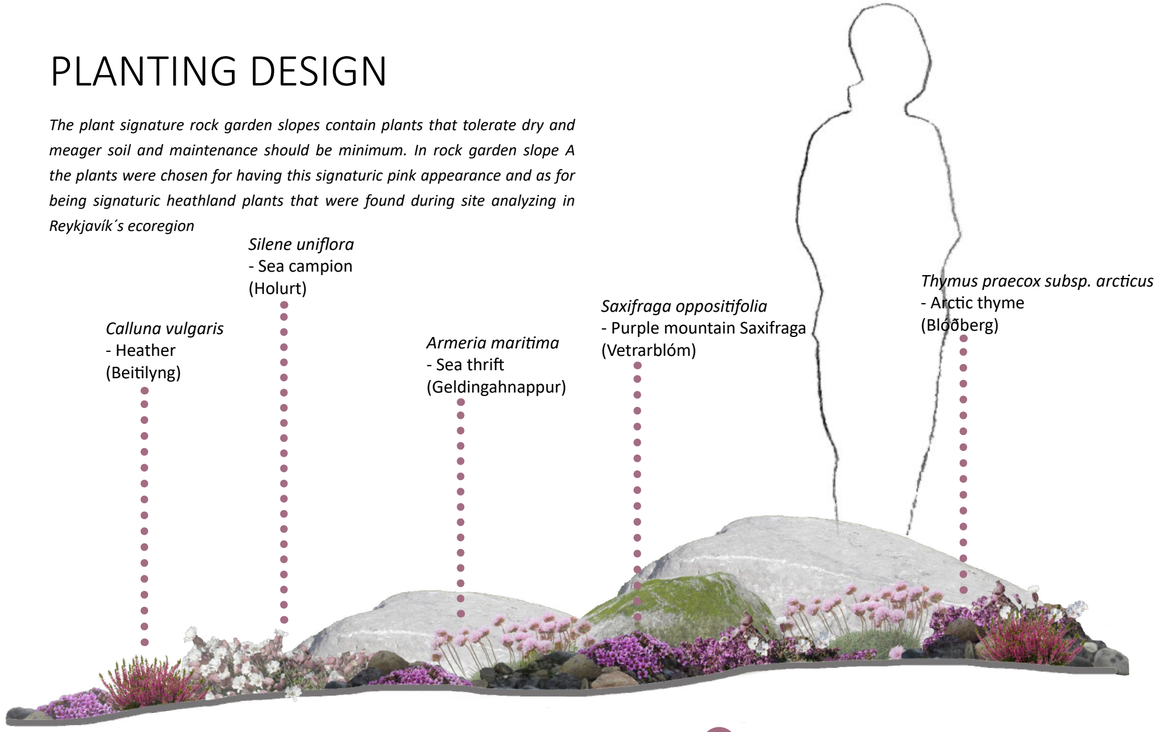
DESIGN

This chapter presents the main conceptual design ideas.

The conceptual design proposal aims to create a testing ground for plant use in Reykjavík's roadsides. Three different planting design approaches will be used to achieve different outcomes, test different strategies and implement them to Icelandic conditions.

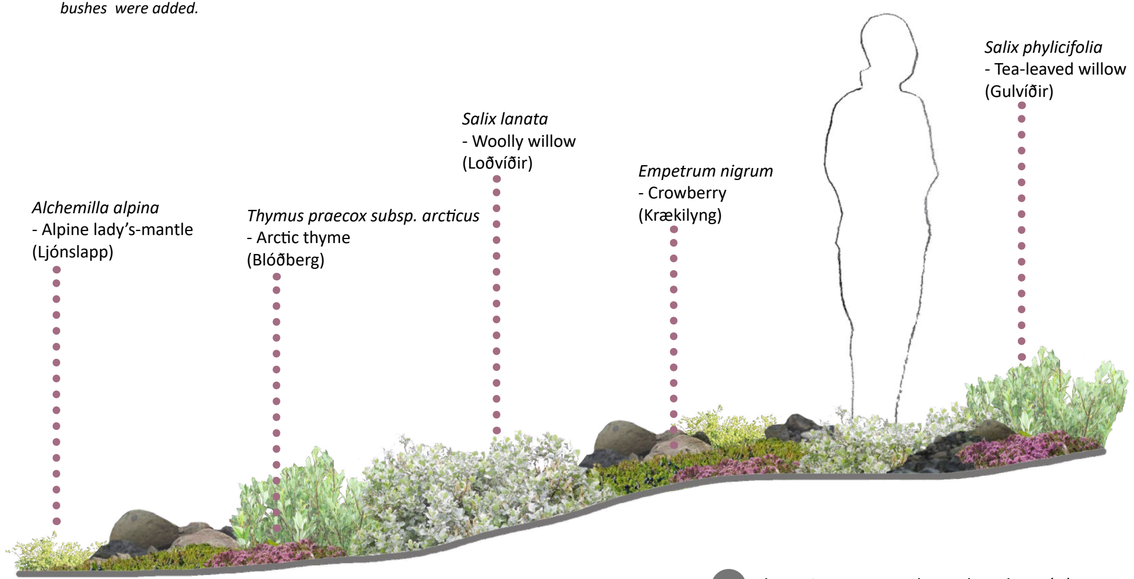
PLANTING DESIGN

The plant signature rock garden slopes contain plants that tolerate dry and meager soil and maintenance should be minimum. In rock garden slope A the plants were chosen for having this signaturic pink appearance and as for being signaturic heathland plants that were found during site analyzing in Reykjavík´s ecoregion



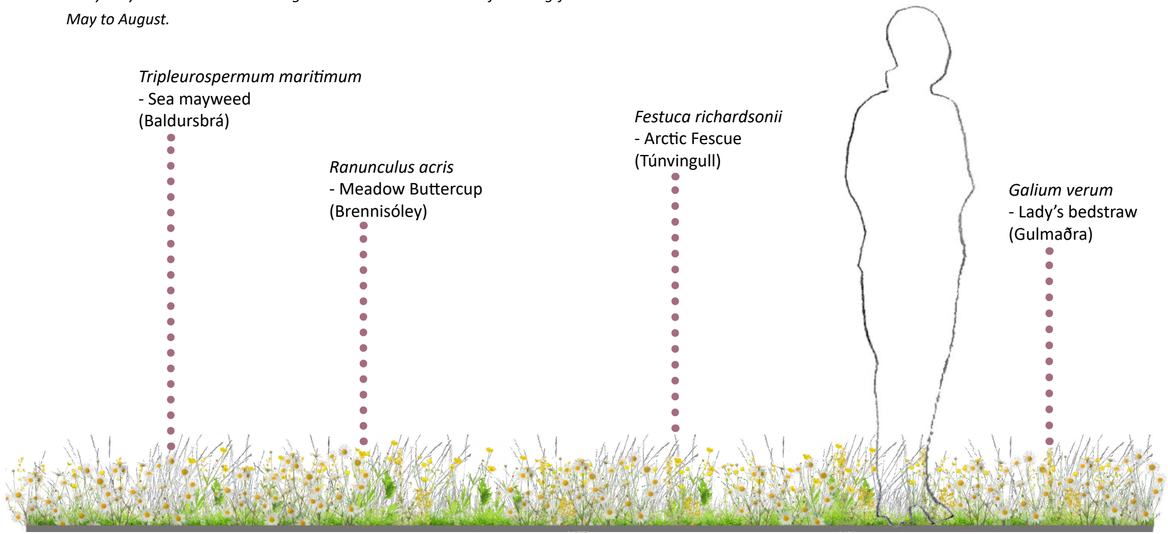
1 *Plant signature rock garden slope (A)*

The plant signature rock garden slopes contain plants that tolerate dry and meager soil and maintenance should be minimum. In rock garden slope B same approach was used as in A but in this case signaturic heathland willow bushes were added.



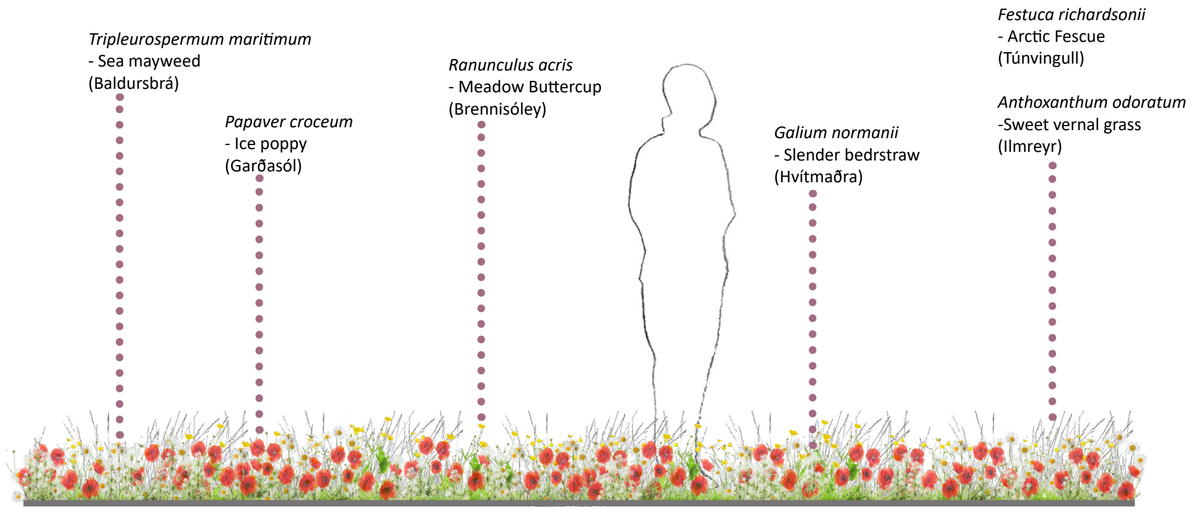
2 *Plant signature rock garden slope (B)*

Here the emphasis was on creating a simple design but with plants that represent the sense of the place. This is a signaturic Icelandic meadow, everybody knows it. The Plant signature meadow should be flowering from May to August.



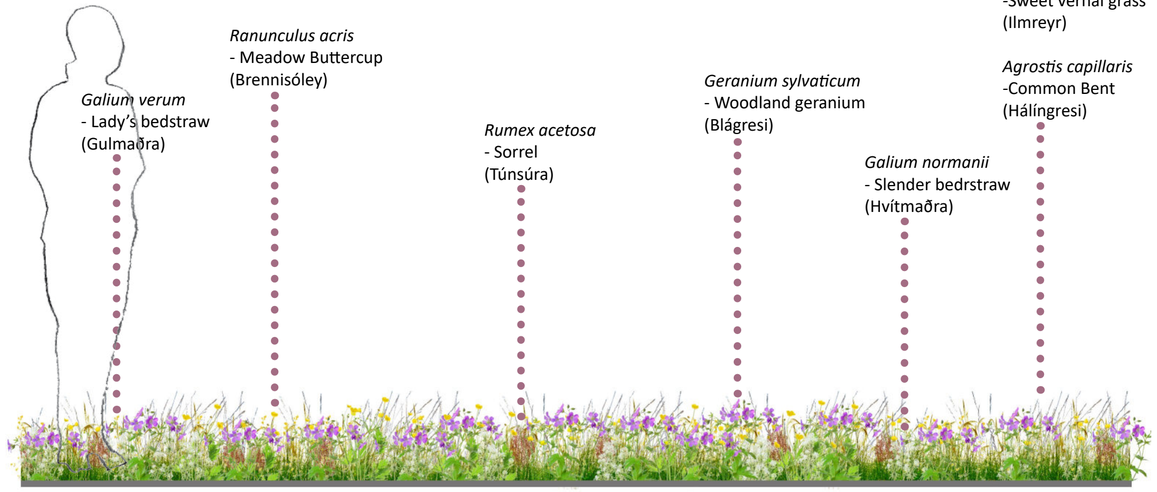
3 *Plant signature meadow*

Naturalistic herbaceous plantings emphasis on naturalistic appearance. It is a meadow like plant communities with high aesthetic value with bright and diverse colored plants that attract wildlife and people when blooming. The Naturalistic herbaceous planting should be flowering from May to August.



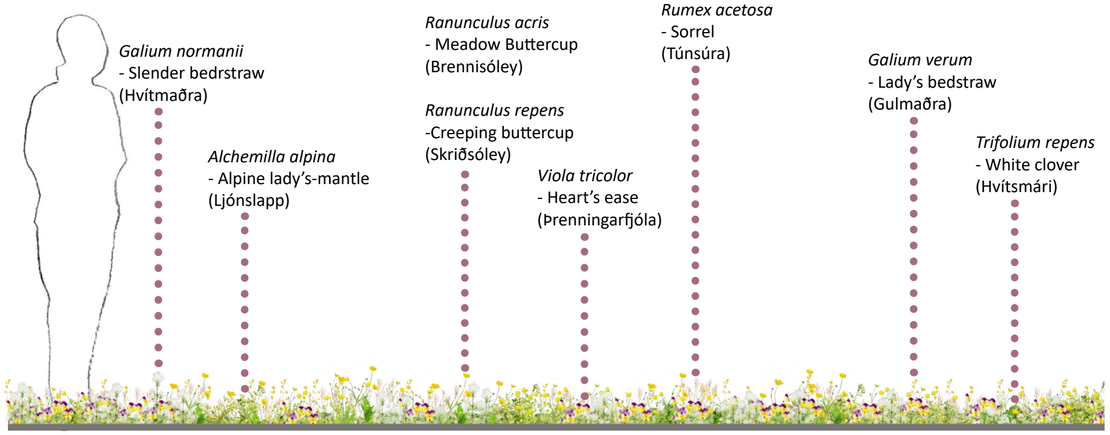
4 *Naturalistic herbaceous planting*

The native meadow approach has more traditional appearance than for example grass-free lawns and is a perennial mix of native flowering- and grass species. This native meadow is a copy of a plant community analyzed in the heaths around Reykjavík´s ecoregion. The native meadow should be flowering from May to August.



5 *Native meadow*

Grass free lawns are thought to be environmentally friendly with less need for maintenance, high species richness and high level of biodiversity. Grass free lawns have high aesthetical values, with blooming, colorful, and often scented appearance and the opinion of the public is generally greatly positive towards them. The grass free lawn should be flowering from May to September.



6 *Grass free lawn*

CONCEPTUAL DESIGN PROPOSAL

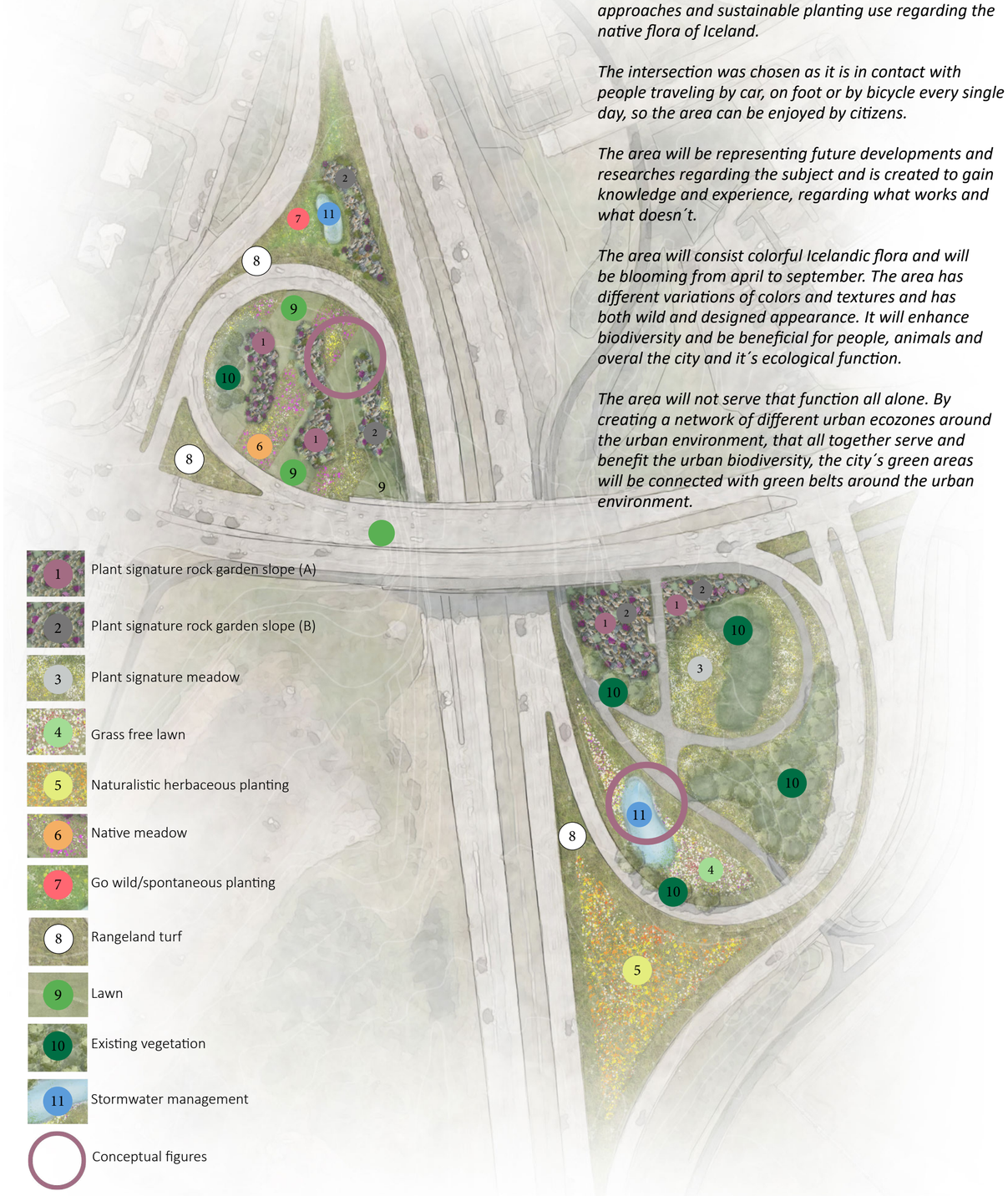
This conceptual design proprosal represents a testing ground in Hringbraut Reykjavík, for different design approaches and sustainable planting use regarding the native flora of Iceland.

The intersection was chosen as it is in contact with people traveling by car, on foot or by bicycle every single day, so the area can be enjoyed by citizens.

The area will be representing future developments and researches regarding the subject and is created to gain knowledge and experience, regarding what works and what doesn´t.

The area will consist colorful Icelandic flora and will be blooming from april to september. The area has different variations of colors and textures and has both wild and designed appearance. It will enhance biodiversity and be beneficial for people, animals and overal the city and it´s ecological function.

The area will not serve that function all alone. By creating a network of different urban ecozones around the urban environment, that all together serve and benefit the urban biodiversity, the city´s green areas will be connected with green belts around the urban environment.



Testing ground for sustainable plant use in Hringbraut intersection, Reykjavík. For a larger figure see appendix 1.

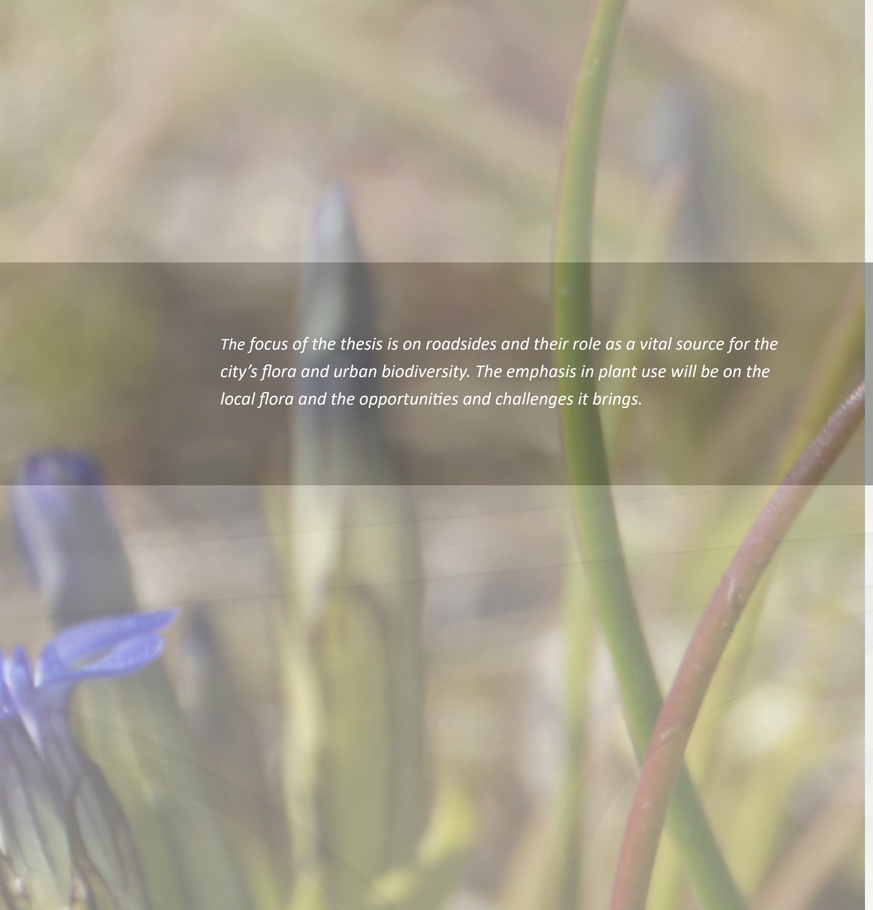
Scale: 1:1000 (A3)

Conceptual figure. Plant signature rock garden slope and Native meadow. Colors and naturalistic appearance enriches the site´s biodiversity and aesthetical values. By adding mowed lawn the area will get more designed appierence, which has positive effect on peoples opinion towards the area.

Conceptual figure. On rainy days the stormwater pond serves an important role as a stormwater management system and leads the water in it´s natural cycle down to the soil. On the figure there can be seen Grass free lawn around the stormwater swale, Plant signature meadow and Plant signature rock garden slope, behind the trees. Hopefully by time wetland vegetation will inhabit in the stormwater pond.

CONCLUSION

This chapter consists of reflections and and discussion about different aspects of the thesis and the conceptual design proposal.



The focus of the thesis is on roadsides and their role as a vital source for the city's flora and urban biodiversity. The emphasis in plant use will be on the local flora and the opportunities and challenges it brings.

REFLECTION

The objective of this study was to introduce different design approaches for sustainable planting design in roadsides and to make a conceptual design proposal for a chosen site in Reykjavík. The aim was to study roadsides and their role as a source for urban biodiversity, where the main emphasis in plant use was on the local flora and the opportunities it brings. The purpose of the conceptual design proposal was to create a testing ground for sustainable plant use in Reykjavík's roadsides. Three different planting design approaches were introduced to test different strategies, achieve different outcomes, and implement them to Icelandic conditions.

Two complementary questions were laid to emphasis on the thesis's hypothesis role and as a helping tool to structure the aim of the theoretical part of the thesis:

- Will the Icelandic weather and the island's ecosystem be an influential factor for improving Reykjavík's roadsides?
- Can the Icelandic flora be restored in Reykjavík's roadsides?

The thesis was meant to work as a study ground for future sustainable development projects in roadsides in Reykjavík. With a creation of a testing ground for planting design the workmanship and planting methodology could be tested and developed further to fit Reykjavík's conditions.
Mixture of theoretical and practical study, in the form of study trips, outdoor explorations and desk study were used to obtain knowledge for the development of the conceptual design proposal. One main question was asked, together with three sub-questions. The sub-questions were meant to complement the main question and help with the process of answering the main research question.

Research question:

What are the current conditions for biodiversity in roadsides in Reykjavík and how to improve urban biodiversity and create a more sustainable road environment?

- How to make space for biodiversity in urban areas?
- How can roads be used as a link to increase urban biodiversity?
- Which design approaches should be used and what are specific recommendations for planting design in roadsides?

Current conditions for biodiversity in roadsides in Reykjavík -
The current conditions for biodiversity in roadsides in Reykjavík were studied though literature and field study. As literature study indicated the staid cannot be referred to a positive. The main plant use in roadsides is imported grass species and the most common street tree in Reykjavík, the Black cottonwood (*Populus* trichocarpa) represents 90% of all street trees in the city. Ecological plant use in roadsides is an understudied field in Reykjavík, but the awakening is there. The implementation of wild grown turf, heath-turfs and rangeland turf, to roadsides is a big positive step towards a more sustainable road environment.
The field study indicated that much more variation of species could be found than ever could have been assumed. The results from that fact is though not that the city of Reykjavík is putting much effort in to

restoration of native species. Those plants that were found are mostly native colonizers in the road environment, which indicated that more can be done and more can be restored than already is done.

Improving urban biodiversity -

To be able to improve urban biodiversity the overall city's vision and approach regarding the subject needs to reflect in actions. Reykjavík is a young city and therefore the opportunities in future developments are many. With the expansion of the city opportunity is to implement strategies to improve and promote urban biodiversity in to the action plan. Sustainable road environment, where emphasis is on sustainable plant use, rain water management and low need for maintenance is only a small, but vital, step in the direction towards improvement of urban biodiversity. Overall, the subject is much bigger and deeper. People's perspective regarding implementation of sustainable approaches, to improve urban biodiversity needs to be positive and people must be willing to cooperate and be open minded for different approaches. If the people are ready to improve, the city will improve.
Cities that are in the phase of losing large number of natural habitats of flora and fauna are encouraged to incorporate sustainable and ecologically beneficial gardening approaches. Therefore, the need for younger cities, that are still not dealing with the consequences of massive habitat reduction, to gain proper knowledge and to incorporate sustainable planting approaches is vital before the damage is done.
Creating a more sustainable road environment-

As mentioned, implementation of sustainable plant use, where the emphasis is on ecosystem services, habitat function, restoration of the native flora and low maintenance need is a big and vital step in the right direction for sustainable road environments. Naturalistic and healthy grown road environments can play the role to be a protector for local ecosystems, it can increase drainage, reduce erosion and in some cases, reduce the effects of disintegration of habitats. Naturalistic vegetation in roadsides also creates habitats for various organisms and improves driving experience. Researches showed that by using native flora and reclamation of local vegetation, is will promote a healthy and environmentally friendly roadside. Roadside vegetation, trees and herbaceous plantings are also a particularly important source when it comes to the matter of increasing air qualities beside roads, which are the main cause of urban pollution.
When creating and designing a sustainable road environment, permeability, and storm water management play an important role. The benefits of incorporating sustainable storm water systems is a healthier and greener environment in towns and cities, as well as sustainable water resources.
Creation of testing ground for sustainable plant use in Reykjavík's roadsides would be a vital source to gain knowledge and education to be able to implicate and improve these approaches further in the city.

Was the aim of the study met?

The theoretical study led to picking of three different design approaches, which were used as a groundwork for the conceptual design proposal. As previously mentioned the aim was to study roadsides and their role as a source for urban biodiversity. With a detailed theoretical study which observed the core of the subject. The theoretical part started by identifying the origin of the problem, continuing with exploring of keywords and questions the theoretical part narrowed down to the main subject, Reykjavík's roadsides.

By doing research on site, regarding Hringbraut, Reykjavík roadsides and overall Reykjavík's ecoregion and by studying the flora that existed in Reykjavík roadsides, the knowledge and understanding, regarding the subject got clearer and more concrete for further thesis work. By applying the found strategies, data and approaches in theoretical and analyzing work to the conceptual design proposal it is thought that the aim of the study was met.

Was the aim of the conceptual design proposal met?

As mentioned previously the aim and purpose of the conceptual design proposal was to create a testing ground for sustainable plant use in Reykjavík's roadsides. In the proposal no detail design in made, the purpose was to use the illustrations to introduce possible outcome and clarify conceptual results. The proposal shows how three different planting design approaches could be used in roadsides, where the most suitable spot for receptors for storm water is and how to incorporate the Icelandic flora in roadside areas. Since the proposal is a proposition how the implementation of restoration of native flora could be practised in Reykjavík's roadsides and that the proposal shows possible composition of plant communities, signature elements that are representable for Icelandic nature and possible outcome, I believe that the aim of the conceptual design proposal was met.

Literature

The purpose of the literature study was to analyse further theoretical backgrounds, previous studies, to get inspired and gaining knowledge regarding the chosen site, the road environment, roadside vegetation, creations of plant communities and ecological design solutions where the emphasis was on urban biodiversity. The theoretical study was then implemented to the creation of the conceptual design proposal.

The studied literature was in form of books, articles and research papers. It was challenging to access enough literature regarding roadside vegetation since the chosen site is in the Northern-Hemisphere and limited amount of literature is available, especially for urban areas. That indicates that there is a great need for further researches in the field of sustainable planting design in Iceland.

Approaches and choices

The need for doing all and anything and wanting to explore every aspect of the subject became too big for me. It was a challenge to narrow the subject down and focus on the aspects that I wanted to analyse and study further. Therefor I chose to study three design approaches that I thought to be complimenting for the project. By doing so I was able to structure and control the project better. I do think that the chosen approaches, the alternative lawn approach,

go-wild/ spontaneous planting and plant signature approach all offer different methodology in designing a natural looking and sustainable plant community. The approaches were easy to use and helpful with the formation of planting communities for the conceptual design proposal. If I would have chosen different types of planting design approaches, I believe the obtained result would have been different. What I chose not to focus on in the planting design was the plan composition, considering microclimate etc. I chose to look at in a bigger picture and focus on the combination of plants and their original environment, even though the results might have been more concrete.

Inventory and analysis

The analysing and inventory part gave a greater understanding of what plants thrives in Reykjavík's roadsides. It would have though been helpful to do the analysing at several different times over the growing season, to make analysing and mapping of plant species easier and more reliable. The analysing and inventory was done on three different sites, the ecoregion Reykjavík, Reykjavík's roadsides and at the chosen site, Hringbraut. Analysing plant in the Reykjavík region was easier than around the road environment since most of the roadsides were newly mowed. To narrow down and structuring the analysing part was demanding and therefor the need for an approach as a foundation for the analysing and inventory part was needed. By gaining an inspiration for the methodology of the analysing from the book *Gardening revolution* the task got much clearer.

Conceptual design proposal

In the beginning of the thesis work I had another and different design proposal in mind. The goal was to create a design proposal for three sites in Reykjavík, where the aim was to use one planting design approach at each site. With further literature and analysing work, I realized that there is no experience or knowledge regarding ecological planting design in Reykjavík or regarding use of different naturalistic design approaches in roadsides. The result was that I needed to create a conceptual design proposal for a testing ground for plant use in Reykjavík's roadsides. The aim in the beginning was always to emphasis on the biodiversity aspect of it and what it is that makes a road environment beneficial for biodiversity, therefor the decision of changing the design plan in the beginning only complements and gives a clearer view of what it is. By implementing all three design approaches on one site and incorporating other sustainable solutions such as storm water management the results become more visual and trustworthy.

Native vs. exotic

It was an interesting process to study the difference between using native or non-native plant in planting designs. I started this project with a narrow vision about the negative effects that implementation of non-native plant species has on the urban environment. In the beginning I did not see myself using non-native plants in the design, since I thought it would be a paradox to the sustainable design approaches. I though learned that I was wrong, non-native plants, that have adapted to the region and have shown positive ecological performance, can play an important role when designing and formatting a plant community.
In the conceptual design proposal, I though decided to focus on the native flora, since the aim was to create a testing ground for the Icelandic flora in roadsides in Reykjavík.

Species origin

Species origin became a big topic throughout the thesis. It could be interpreted as one of the main results in this project, that the species origins and habitat conditions are greatly vital in sustainable plant community design. By initiate a propriate approach and not having unrealistic demands on urban vegetation, considering growth, shape and appearance the achievements will be greater in design of green environments, including roadsides. Plants are individuals, who live and thrive in a certain environment, under certain conditions, but they come from a plant community and we can think of a plant as a social creature, everything about the plant is a reaction and an adaptability to its social network. These factors contribute the plant's growth and its niche and by incorporating them into the process of design and creation of plant communities, better results will be achieved (West and Rainer, 2015).
It was not a great challenge to find reliable literature sources for this subject because the clear majority of those who had committed themselves to investigating this subject found the same conclusion, that we make unrealistic demands to vegetation, we are not well aware of the environmental conditions that we are working with and do not take them in to account in the design.

Biodiversity

The obtained literature about biodiversity was mostly from international sources and recommended literature from the researcher and supervisor of this thesis, Maria Ignatieva. Literature was limited and not all of it was valid for this thesis. Biodiversity is a big topic today and a lot of researches and literature is available, but not all of it reliable. The literature that was studied helped a lot with the creation of the thesis and was much used as an inspiration for further work. The most influencing literature in the thesis regarding biodiversity, *Patterns and trends in urban biodiversity and landscape design* (2013), where the researchers reflect on city's opportunities and abilities to maintain great variety of species and habitats and the unique biotope it can provide. There they say, "*To support native biodiversity, landscape architects, conservation biologists, and other groups are linking landscape design with ecosystem structure and function to create and restore habitats and reintroduce native species in cities*". With this thesis work and with the conceptual design proposal, where the aim was to create a testing ground for sustainable plant use in Reykjavík's roadsides, I believe that this support is met.

DISCUSSION

When analyzing ways to improve city´s ecological function and sustainable abilities the major environmental factors and their effects must be taken into account, for long term and short.

Vehicle transportation is one of the main pollutants in Reykjavík. They cause both air pollution and noise, as well as contributing to global climate impact.

Part of Reykjavík´s future goals are to increase the focus on sustainable transportations. Greatly increase public transportation as well as infrastructure and accessibility for pedestrians and bicycle users. Currently, Reykjavík is an automobile-efficient city and the most convenient and time saving way of transport is by a private vehicle. With altered traditions of transportation, urban densification and reducing carbon footprint, a more sustainable habitat for both the environment as well as the population is promoted.

Roadside vegetation is an important part to promote an ecologically beneficial and sustainable road environment. However, it´s use and function is often neglected. Increased knowledge and awareness regarding plant use and function will lead to a higher standard of urban environments. Native, sustainable plant communities increase ecological function as well as contributing to cleaner atmosphere and stormwater.

Reykjavik municipality plans on enforce their status as a green city in spite of their greater emphasis of densification, which often leads to decline of open and green spaces. Therefore, the municipality will have to have the highest standards for their work, and not forget the fact that green environments are not the same as ecological environments. As previously stated, for example grass lawns are often unsustainable environments regarding biodiversity, as well as having great need for maintenance and management. Grass lawns dominate Reykjavik´s green infrastructure.

Increasing roadside biodiversity will not entirely change the whole cities biodiversity but contribute a part of the whole solution. The planning of green areas involves a continuous web of open areas that intertwines with the cities landscape. Together, the transportation infrastructure and the open and green areas form a unit that connects different functional parts of the city. Connection between neighbourhoods and versatile recreational areas, together with maintaining environmental biodiversity of the ecosystem that form together a whole city´s natural environment. That environment involves the whole urban flora and fauna, all the green areas, grown or wild within the city´s limits. This network is a web of smaller and larger green-, natural-, and recreational urban areas. In recent years, the importance of green areas has risen due to increased competition for land, in and around urban environments.

As previously mentioned, Reykjavik is full of green areas, but their numbers do not correspond to their quality. The solution is not to eliminate man-made and unnatural areas, but to create enough space for the ability to increase urban biodiversity. By implementing ecological planting design approaches where the cities biodiversity is preserved, a knowledge is gained on plants functionality, what as a positive ecological effect, we can create urban areas that are more versatile and increase ecological and aesthetical values, with positive effects on the environment and it´s inhabitants.

The design approaches introduced in this thesis are Plant signatures, Alternative lawns and Go wild/Spontaneous planting. By researching various planting design approaches, the knowledge span of designers will vastly increase. These approaches are not definite to be suitable for all situations. By following a certain design approach, a concept is kept in mind throughout the design process. It is possible to choose a design approach by plant choice, for example by only choosing native species, making the process more simple and efficient.

As the knowledge of the use of native plant species in Reykjavik is of limited amount, the use of the previously mentioned approaches were experimental, and could benefit further research of the subject. These approaches are though well known in other countries, with different environmental and weather conditions and are open and easy to adjust further.

Future opportunities and developments

The future is now, and the possibilities are endless. I believe that we stand at crossroads and it is no longer a matter of whether, but how and when it will be an obligation to aim at an ecological and sustainable solution in urban design and planning. As mentioned, our cities are post wild worlds that have been through extreme and dramatic changes through the decades, for example regarding reduction of habitat and species combinations. The purpose of sustainable and biologically beneficial design approaches is not to restore all the former existing nature or replacing all paved surfaces with herbaceous lawns and flower beds. The purpose is that we stop using our natural resources as they are endless. We need to guarantee that the upcoming generations will receive and experience the urban environment as viable and healthy and that there is a possibility for humans and the flora and fauna to evolve in harmony with the environment.

In Reykjavík there is a need for further development in the right direction, and in order to do so, knowledge and skills need to be available. This assignment could just be the beginning of an interesting journey. Further development projects could for example be:

- Development and construction of sustainable planting design testing grounds in roadsides in Reykjavík.
- Further investigation on restoration of the Icelandic flora in Roadsides, since the subject is very understudied.
- Reykjavík urban biodiversity project, where the emphasis is on measuring and observing the state of urban biodiversity in Reykjavík.

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CONCEPTUAL DESIGN PROPOSAL

Testing ground for sustainable plant use in Hringbraut intersection, Reykjavík (A3).

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