EVALUATING GREENERY IN URBAN TYPOLOGIES

- A Study with a Mixed Method Approach in Gothenburg, Sweden

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Abstract

A growing number of cities are experiencing challenges with adapting to stresses originating from a changing climate, such as an increase in air temperature and extreme weather events, where urban greenery has shown mitigating qualities. Apart from offering a strategy for climate mitigation and adaptation, added greenery in cities can also contribute to a large variety of ecosystem services, where qualities for human wellbeing are enhanced. To understand the spatial distribution of greenery in cities, a few studies have connected urban greenery with urban structure, but detailed data of greenery on a neighborhood scale is still limited, where more research is needed to better understand the interurban differences in qualities of greenery. This study uses a mixed method approach of spatial analysis, detailed mapping of greenery and interviews with urban planners to scrutinize the composition of greenery in urban typologies in Gothenburg, Sweden and the strengths and challenges related to these compositions. The chosen typologies were based on how Swedish planning ideals have been implemented in Gothenburg and consisted of the typologies; Mixed City, Million program, Nordic functionalism and Traditional neighborhood city. The results showed that the Million program and the Nordic functionalism typology consisted of a large share of vegetation which is a strength in relation to heat stress mitigation, since vegetation can provide shade and a cooling effect. The Mixed city and the Traditional neighborhood city were instead composed of highly designed dense environments with less vegetation, where space and good growing conditions for vegetation was limited. This variety in compositions of greenery creates different starting points for the typologies in offering heat stress mitigation, as well as other services, where the knowledge of this distribution can contribute to a more effective implementation of greenery.

Acknowledgements

During my academic studies, I have always been fascinated by the many qualities that greenery brings, both to the city environment as well as to inhabitants. With this 30 credit master thesis, I had the opportunity to form this interest into a project, where I now have developed a deeper understanding of the importance of greenery in cities, and how greenery can be used to adapt to future challenges.

This thesis would not have been successful without the help from my supervisors, the master students in my class and the planners which I had the opportunity to interview. Firstly, I would like to express my gratitude to my supervisors Fredrik Lindberg, Sofia Thorsson and Oskar Bäcklin for all the support and feedback during this work process.

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Cornelia Wing

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1. Introduction

1.1 Background

A growing number of cities are experiencing challenges with adapting to stresses originating from a changing climate, such as an increase in temperature and extreme weather events (Ward, Lauf, Kleinschmit & Endlicher, 2016). Most urban areas are composed by low albedo materials, a compact building structure, a high degree of anthropogenic heat and little vegetation, which constitutes for some of the reasons to the formation of the urban heat island (UHI) (Oke, Mills, Christen, & Voogt, 2017; Balany, Muttil, Muthukumaran, & Wong, 2020). With a slow cooling of the urban environment in the evening, the UHI effect describes how cities can become warmer in comparison to the surrounding rural areas, where high night time temperatures in cities, which are increased during heat waves, can cause heat stress for inhabitants (Coutts et al., 2007; Thorsson, 2012). With an expected warmer climate in the future and more frequently occurring heat waves, these issues will most likely be exacerbated, which together with the UHI composes an increased challenge for cities where the possibility for inhabitants to cool down is reduced (Ward, et al., 2016). In addition to the UHI, many cities face challenges in dealing with heavy precipitation due to the large amount of paved surfaces and the problem of heavy precipitation is, similarly to the one of heat, most likely to be intensified by a changing climate (IPCC, 2014).

To tackle these climate related challenges, there is a growing need to understand how mitigation and adaptation strategies can be implemented with urban planning (Meerow, 2020). One planning strategy that has gained an increased attention is the implementation of urban greenery (Balany et al., 2020). This due to its potential for water management and reducing heat stress, where greenery can act as a strategy both for adaptation and mitigation for climatic challenges in cities (Demuzere et al., 2014). The impact of urban greenery on heat stress is depending on the urban climate, where the effect in colder climates is not as well understood as in warmer ones, due to more previous research carried out in cities with a warm climate (ibid; Ward et al., 2016). This since heat has been a problem during a longer period of time in warmer climates, while colder cities are more recently affected by heat due to climate change and a higher frequency of heat waves (Yang et al., 2020).

Apart from offering a strategy for climate mitigation and adaptation, urban greenery contributes to augmenting greenery in cities, which can induce a higher degree of biodiversity and availability of ecosystem services (Zinko et al., 2018). Incorporating urban greenery is nothing new to urban planning, but the spatial distribution is not always clearly defined, as smaller areas of greenery often are misclassified as built-up land (Sjöman-Deak, 2016). A few studies have implemented methods which connect urban greenery to the urban structure, but detailed data of greenery on a neighborhood scale is still limited, where more research is needed to better understand the interurban differences in qualities of greenery. (Rusche, Reimer & Stichmann, 2019; Mathey, Hennersdorf, Lehmann & Wende 2021). This knowledge will not only benefit research, but a better understanding of the composition of urban greenery can be used in urban planning to obtain a more efficient implementation of greenery (Yang et al., 2020).

1.2 Aim and research questions

This study utilizes a mixed method approach to gain a rich picture of the strengths and challenges regarding composition of greenery in four urban typologies, and further contribute to a better understanding of interurban differences of greenery in the city of Gothenburg. The composition of greenery is examined through spatial analysis, detailed mapping of greenery in twelve study sites and interviews with urban planners. The aim of this thesis is to evaluate the composition of greenery in four urban typologies in Gothenburg and qualities these forms of greenery offer, with focus on heat stress mitigation. To fulfil the aim, following research questions will be used:

- How is greenery composed in neighborhoods of the four urban typologies of Mixed City, Million program, Nordic functionalism and Traditional neighborhood city in Gothenburg?

- Which strengths and challenges can be seen with the composition of greenery in the urban typologies today, and for the future?

2. Literature Review of Key Themes

2.1 Urban Climate

With rapid urbanization and a major change of land use in urban areas, the climate of cities has become dissimilar to the rural ones (Oke et al., 2017). The difference can be seen in surface cover, fabric and structure and these factors largely influence a site's climatic conditions (Coutts et al, 2007). The physical aspects have a large impact on the urban climate, but the anthropogenic influence is equally relevant to acknowledge (ibid). Emissions from combustion of fuel in traffic and industries, and the need for heating and cooling of buildings are examples of how human activities impacts the climate (ibid, Oke et al., 2017)

When it comes to the surface cover of an urban area, it is affected by land use, and whether a city has a high degree of greenery or built-up land, the local climate will be affected differently (Coutts, et al., 2007). This is due to the surface properties, where surfaces differ in how well they absorb, emit and reflect radiation. The urban environment is dominated by paved materials with low albedo and high emissivity, and this will increase the amount of absorbed short-wave radiation (Oke et al., 2017). Additionally, the urban fabric is generally composed of materials with a high thermal admittance, which contributes to a high degree of heat storage. These aspects contribute to a large degree of stored heat in the materials in daytime, where energy is released from the materials during night which warms the lowest parts of the atmosphere (ibid). Having a lot of dry surfaces in cities also influence the local climate, since evaporation from water surfaces and transpiration from vegetation contributes to a cooling effect (Ward et al., 2016). This due to energy in the atmosphere being used to transform water into vapor, and with a general trend of having little vegetation that can transpire and few water bodies in cities, there is often a low amount of water available for evapotranspiration (Sun & Chen, 2012).

The urban climate is apart from the urban surfaces and the urban fabric, affected by the urban structure and this through the formation and orientation of buildings and streets (Erell, Pearlmutter & Williamson 2010). Urban canyons can for example trap radiation and thereby increase the absorbed radiation as well as reduce the amount of outgoing radiation (ibid). The orientation of buildings will also affect when surfaces are sunlit, which can affect how much radiation that is reflected or absorbed (Erell & Williamson, 2007). Taken together, there are a lot of parameters which modify the urban climate, but processes take place on different scales. The cooling effect from vegetation is often measured at the boundaries of green elements or green surfaces and this will influence the micro climate (Demuzere et al., 2014). To understand how urban areas differ in their microclimate, the ratio of the paved materials and the green elements can be used as a guideline (Kleerekoper, Kluck, van den Dobbelsteen, 2017**).** Even if the effect of green elements mainly are researched on a micro climatic scale, the cooling effect can influence the local climate as well, since this scale refer to the influence of blocks and neighborhoods and the related greenery (Oke et al., 2017).

2.1.1 The urban heat island effect

When comparing the urban and rural climate, the ability to absorb and store heat in cities stands out (Public Health Agency of Sweden, 2019). This difference is as previously discussed in the section of 2.1 Urban Climate formed by the large human influence in cities, the urban structure, as well as less vegetation in urban areas compared to rural ones (Coutts et al., 2007). Additionally, these factors contribute to why cities generally are warmer than the adjacent rural areas, which is called the urban heat island (UHI) effect (Erell et al., 2010). The UHI effect can be studied from different scales (ibid), where to which are relevant in regards to the cooling effect of greenery are the Surface urban heat island (UHI_{Surf}) and the urban canopy layer heat island (UHI_{UCL}). The UHI_{Surf} relates to the differences in air temperature between a rural and an urban area in the air layer closest to the surfaces (Oke, et al, 2017). Cities often have a smaller degree of vegetated surfaces in comparison to the amount of paved surfaces, and this results in less transpiration during the day at urban surfaces, compared to rural surfaces with more vegetation. This contributes to the development of the UHI_{Surf} and this phenomenon is most apparent in daytime on clear and calm days when radiation is strong, especially in summer (Oke, et al, 2017).

The urban canopy layer heat island describes the air temperature differences between the urban canopy layer (UCL), which is the atmospheric layer from the ground up to the mean height of buildings and trees, and the air layer in the same height as the UCL in a rural area (Oke et al., 2017). Determinants of the UHI_{UCL} are street geometry, urban fabrics, impervious surfaces and added anthropogenic energy. The magnitude of the UHI_{UCL} varies and is depending on the local attributes of the city and the compared rural area, but is also correlated with the urban density (Erell & Williamsson, 2007). This since urban canyons contribute to a larger amount of absorbed radiation and trapped outgoing radiation, than rural areas (ibid). UHI_{UCL} is mainly a nocturnal phenomenon where the largest UHI can be expected on clear and calm nights (Oke et al, 2017). This is due to an absence of clouds and a larger amount of incoming radiation in the day and increased outgoing radiation in the night in cities. On these clear and calm days, the cooling of the atmosphere will be much faster after sunset in the rural area, since less heat has been stored during the day than in the urban area (ibid). The urban environment will not be cooled as quickly as the rural ones and this results in higher air temperatures in urban areas at night and the formation of the UHI_{UCL}.

2.2 Heat stress and human thermal comfort

Human thermal comfort describes when a human body experiences a state of not being cold nor hot, but in balance (Oke et al., 2017). When humans are faced with too much heat, or heat for a longer period of time, the body works hard to regulate the increase in body temperature, which puts stress on the body and this creates thermal discomfort (ibid). The impacts of heat stress on human health are extensively researched, where heat stress can induce water and salinity deficiencies, exhaustion, cardiovascular issues or death (ibid;Ward et al., 2016). In cities, the problem with heat is twofold, with one issue being the generated stress derived from high daytime temperatures, and the other the lack of possibilities to cool down during night, due to the UHI_{UCL} (Public Health Agency of Sweden, 2019). These issues are especially dangerous for humans who do not have a functional cooling system, such as elderly, children, and people with certain illnesses (Public Health Agency of Sweden, 2018).

How humans experience heat is dependent on several factors, where one is the climate a person lives in, since this influences the temperature interval the human body is used to (Rocklöv & Forsberg, 2008). Inhabitants living in cold climates are generally not used to heat, which leads to an increase of heat related mortality at lower temperatures than in warmer climates, where inhabitants are more used to heat (ibid). Additionally, cities located in warm climates often have experience of heat related issues, where measures have been developed to protect inhabitants from heat stress, for example by offering water stations or elements that provides shade in the public environment, but this is generally not the case for cities in colder climates (Public Health Agency of Sweden, 2019). The lack of adaptation to heat stress in cities in colder climates contributes to a high degree of vulnerability, which further will be increased since heat events are expected to occur more frequently in the future (Ward et al., 2016).

To provide outdoor environments that induce human thermal comfort during hot days, there needs to be predictors of heat stress and knowledge of which urban environments that are prone to heat stress (Coccolo, Pearlmutter, Kaempf, & Scartezzini, 2018; Lindberg, Holmer, Thorsson, & Rayner, 2013). T_{mrt} relates to the sum of all incoming and outgoing radiation from the surrounding environments a human body is exposed to, and has the largest influence on human thermal comfort of all meteorological parameters during summer days with clear and calm weather conditions, (Lindberg, Thorsson, Rayner, & Lau, 2016);Thorsson, 2012). The amount of radiation that will reach a surface is affected by the building structure and geometry, making T_{mrt} a viable measure for understanding how building structure influence human thermal comfort (Thorsson, 2012). High T_{mrt} can be seen in areas where radiation is permitted to reach a surface, for example open spaces, as well as places where much of the radiation is reflected and emitted, such as sunlit building walls (Lindberg et al., 2016). Low T_{mrt} can be found in shaded spots, where elements which induce shade can be implemented to reduce T_{mrt} (ibid).

2.1 Qualities of urban greenery

In many cities, urbanization and development programs of densification have led to a decreased amount of greenery as well as an increased fragmentation of greenery (Haaland & van den Bosch, 2015). However, urban greenery has both in research and urban planning gained attention due to the potential of providing qualities that can induce a higher degree of sustainability and climate adaptation in cities (Dorst, van der Jagt, Raven, & Runhaar, 2019). The multifunctional qualities of greenery are often described in relation to ecosystem services, which is a concept that entails the services which ecosystems offer for human wellbeing (ibid; Demuzere et al., 2014). The contribution of services from greenery to human health can be understood both in terms of more direct health benefits of recreation, improving air quality and increasing human thermal comfort, but also with benefits for more long term climate regulative services, such as carbon sequestration and reductions in CO_2 levels (Demuzere et al., 2014; Meerow, 2020).

The benefits of green spaces for recreational activities are valuable social qualities, since green spaces often are connected to outdoor exercise as well as relaxation, which both are vital aspects for human wellbeing and public health (Demuzere et al., 2014). Studies have also shown that greenery can strengthen community bonding and be places for social interaction, which further highlights the importance of greenery in enhancing social sustainability (ibid). One issue for achieving a higher degree of social sustainability with greenery is the uneven distribution of greenery in urban environments, which leads to an unequal access between inhabitants to the multifunctional qualities (Mathey, Hennersdorf, Lehmann, & Wende, 2021; Meerow, 2020). This is an issue that has gained recognition in urban planning, where added greenery can be one part of making greenery more accessible, but where a greening of residential areas also can contribute to gentrification, and act counteractive to the intended goal (Dorst et al., 2019; Meerow, 2020) .

Making urban environments greener thus requires careful consideration of where the implementation should take place, and what type of implementation that would yield the most optimal effect (Mathey et al., 2021). With the uneven distribution of greenery in cities, the desired qualities might differ between neighborhoods (Meerow, 2021), but where highly paved environments which are very exposed to climate related hazards and lack the multifunctional qualities of greenery, would especially benefit from a larger degree of vegetation (c.f Oke, et al, 2017). This can be seen in relation to events of heavy precipitation, where the impervious surfaces of paved environments prevent water from infiltrating the ground, with the result of large runoff, a higher risk of flooding and damage to the urban environment (Omitaomu, Kotikot, & Parish, 2021). To add vegetation in these highly paved places can form adaptive measures for extreme events, not only concerning heavy precipitation, but also the issue with heat stress (Demuzere et al., 2014).

2.1.1 Providing Human Thermal Comfort with Greenery

The Public Health Agency of Sweden (2018) has stated recommendations to decrease heat stress in Swedish cities, where several include implementation of green elements in the urban environment. With an increased vegetated surface cover, there will be more water available for evaporation and when energy is consumed for vaporization, it will have a cooling effect on the local environment (Yu, et al. 2020A). Due to this cooling effect, and since vegetated surfaces generally are cooler than paved surfaces, adding vegetation in cities can be a measure to mitigate the UHI_{Surf} in the day (Oke et al., 2017). Since transpiration continues during the evening, vegetation can affect the nocturnal temperatures, and due to less heat being stored in vegetation than built materials, added greenery can also be used to mitigate the heat stress generated by a strong UHI_{UCL} (Balany et al., 2020; The Public Health Agency of Sweden, 2018). The effect of vegetation as a mitigating option for heat stress can also be visualized in relation to T_{mrt}. Lindberg et al. (2018) investigated the relationship between T_{mrt} and vegetation volume in Stockholm at 2p.m. where T_{mrt} was lower in places with a large vegetation volume and respectively higher at places where there was a lower vegetation volume. This indicates that adding vegetation to the urban environment can reduce T_{mrt} and be a way to mitigate heat stress (ibid).

In cities, dense areas provide a large amount of shade during the day, which can be positive for thermal comfort, but if these environments are sunlit, they cool down slowly during night (Thorsson, 2012). A lot of elements that induce an increased thermal comfort during the day, often have a negative effect during the night, which emphasizes the need of implementing different green elements with different effects in cooling in the urban environment (Public Health Agency of Sweden, 2018). It should also be noted that the efficiency of green elements can vary depending on the climate, season and local context, as well as the form, the location and size of the green element (Yu, et al.,2020B; Balany et al., 2020). Related to size is also the aspect of connectivity, where larger connected green areas show a higher cooling effect and if areas become fragmented, the cooling effect is decreased (Kong et al., 2014).

2.1.2 Potential of Green Elements

When it comes to the cooling effect from vegetation, trees are the most researched green element due to being a green element with a large potential for heat mitigation. This since trees offer shading on the ground below the tree, as well as a cooling effect from transpiration (Konarska et. al, 2015; Bowler, Buyung-Ali, Knight & Pullin, 2010). Trees are very efficient in producing shade since the canopy blocks radiation from reaching the ground, which contributes to low T_{mrt} below trees (Middel & Krayenhoff, 2019). Foliated trees with dense crowns, will block a high amount of the radiation from reaching the ground, but even if the tree is defoliated, much of the radiation will still be hindered to reach the ground (Konarska et al, 2013). The size and the foliage of the canopy is hence largely influencing how much shade a tree can provide, as well as influencing a trees cooling efficiency since more leafs supports a larger transpiration (Balany et al., 2020;Yu et al., 2020B). Regarding the placement of trees and increased cooling, the optimal placement is in sunlit areas which do not already have vegetation or only a small amount, since trees then can contribute to shade (Lindberg, Holmer, Thorsson, & Rayner, 2013;Lindberg, Thorsson, Rayner & Lau, 2016). Furthermore, for trees to be able to efficiently cool and provide shade, it is important that they have access to water and have enough room to grow so that they reach their expected size (Thorsson, 2012).

Trees are often stated as the most effective type of green element for mitigating heat stress (Balany et al., 2020), but a mix of vegetation is desired to improve shading and cooling possibilities from greenery (ibid;Thorsson, 2012). This is important for several reasons, where one is adding different forms of greenery which can contribute to a larger vegetation volume, and thereby increase the cooling potential (Thorsson, 2012; Park et al., 2017). For example, one study showed that a mix of grass, trees and shrubs can decrease the average air temperature with up to 2 °C (Sashua-Bar et al., 2007) and another study showed a decrease of 2.29 °C (Srivinit & Hokao, 2013). The effect of shrubs in decreasing air temperature is similar to trees depending on the size of the element, since a larger shrub will provide more shade and transpiration. Since shrubs are smaller than trees, the cooling and shading effect is not as prominent as with trees, and a literature review of studies evaluating different green elements effect on heat mitigation, showed that bushed have a low to moderate effect on influencing the microclimate (Balany et al., 2020). Grass lawns have been shown to be cooler than paved surfaces, but the effect on air temperature and human thermal comfort is relatively small compared to trees and shrubs (ibid; Bowler et al., 2010). Grass can though, as already mentioned, work well with other green elements for mitigating heat due to an increase in cooling intensity (Lobaccaro & Acero, 2015; Vaz Monteiro, Doick, Handley & Peace 2016).

Regarding green roofs, these can decrease surface temperature substantially, and thereby have a mitigating effect on the UHI_{Surf}, but the influence on air temperature is relatively small (Bowler et al., 2010; Li, Bou-Zeid & Oppenheimer, 2014). Green roofs are beneficial in terms of reducing energy consumption, and increasing the indoor thermal comfort, due to the cooler surfaces of green roofs in comparison to conventional roofs (Thorsson, 2012). There are different kinds of green roofs where extensive green roofs, with a shallow soil depth and plants such as sedum and moss requires less maintenance compared to the more intensive green roofs (SMHI, 2019). Intensive roofs can differ in soil depth depending on the choice of plant species, but does generally have a deeper soil layer than extensive roofs. Intensive green roofs are used to create roofs where greenery and recreation is combined and can be described as small parks or gardens on roofs, where a combination of trees, shrubs and flower beds can be found (ibid).

As mentioned in the section 2.1 Urban Climate, most research on greenery and cooling is based on the cooling effect at the boundaries of specific green elements, which impacts the micro climate (Demuzere et al., 2014), but studies of larger parks and natural areas have shown a decrease in air temperature outside of the boundaries of the green area (Thorsson, 2012; Park et al., 2017). This since larger parks and natural areas form cool spots in the urban environment, which can be up to a few degrees cooler than surrounding environments, but where the cooling effect also is transported by wind, and reaches the neighborhoods located close to these spaces. This cooling effect is apparent both at day and at night, where the cooling distance depends on the size and which elements the park is composed of (ibid).

2.4 Urban Typologies

The concept of urban typologies can be viewed from different perspectives, where one is through physical form (Berghauser Pont, 2018). With this perspective, typologies refer to "*specific combinations of spatial properties*" and how these spatial properties are formed and function (ibid). Urban typologies can visualize how certain areas share similarities in their spatial expression, and be used as a perspective for understanding interurban differences (ibid). This lens acknowledges the resemblance of neighborhoods, rather than aiming to map uniform characteristics, which highlights a more accurate picture of neighborhoods than other forms of classifications as there are no environments that share the exact same characteristics (ibid). Urban typologies can be used in planning processes to understand how new implementations or changes affects the urban form (ibid), and since greenery is one attribute of neighborhoods spatial expression, this perspective also includes how changes will affect the form of greenery (Mathey, Hennersdorf, Lehmann, & Wende, 2021). With an increased attention of sustainability and climate adaptation in urban planning, there is a growing need to understand how and if inhabitants can access ecosystem services of greenery, where the local level of urban typologies can contribute to knowledge of the current composition of greenery, as well as how it can be planned for in the future (ibid).

2.4.1 Swedish Planning Ideals

The building structure does in many ways set a basis for where and how greenery can be implemented, where the form of greenery has been largely influenced by dominant planning ideals (Kohout & Kopp, 2020). These ideals have been similar for many European cities (ibid), where this study focus on how prominent Swedish planning ideals have been implemented in the city of Gothenburg.

The city of Gothenburg was established in 1621, with a grid street pattern with moats surrounding the city core (Planning and Building Authority, 2008). In the beginning of Gothenburg's development, most houses were constructed by wood, but during 1870, the city core expanded to provide housing for the upper class, where stone was the new popular building material (The Museum of Gothenburg, The Planning and Building Authority, 1999). This resulted in residential areas with multi story buildings of stone, in Swedish called *"stenstadshus"*, which can be seen in areas like Linné in Gothenburg (Figure 1A) (ibid). To provide housing possibilities for the working class, buildings called *"landshövdingehus"* were built outside of the city core, which are categorized by the lowest floor was constructed by stone or bricks, and the two top floors was constructed by wood (ibid) (Figure 1B).

Figure 1: ***A*** *Photo showing stenstadshus in Linné.* ***B*** *Photo showing landshövdingehus in Kungsladugård.*

These two types of buildings are different in their design, but they share similarities in how neighborhoods are constructed, where there are private areas with buildings and enclosed courtyards, and public areas in form of streets, plazas and smaller parks surrounding the private zones (Planning and Building Authority, 2008) (Figure 2A, 2B). This type of planning structure composes a separation of the private and the public sphere, where spaces are highly planned. The idea was to have connected streets where buildings supported both housing and business possibilities, which constructed a mix of functions in these neighborhoods (ibid).

Figure 2: ***A*** *Conceptual image showing a traditional neighborhood structure. Source: Planning and Building Authority, 2008,* ***B*** *Map covering an implemented traditional neighborhood structure in the area of Linné.*

In the late 1930s, functionalism became the new ideal, with a shift from mixed functions to spaces for each function (Planning and Building Authority, 2008). Roads and streets were separated from residential areas, where buildings were constructed to be light and with a spacious impression. This was due to the focus of this time, creating a higher degree of public health, where the previous ideal was seen as too dense and fostering unhealthy living conditions (ibid). To promote a light and spacious environment, buildings were placed as detached objects in green areas, either as long narrow buildings (Figure 3A) or as multistory buildings (Figure 3B), where the green areas forms a semi-public environment (ibid). The idea of having buildings in the green environment, rather than green spaces in courtyards, is a reason why this ideal sometimes is referred to as the "house in park" ideal (The Museum of Gothenburg, The Planning and Building Authority, 2017).

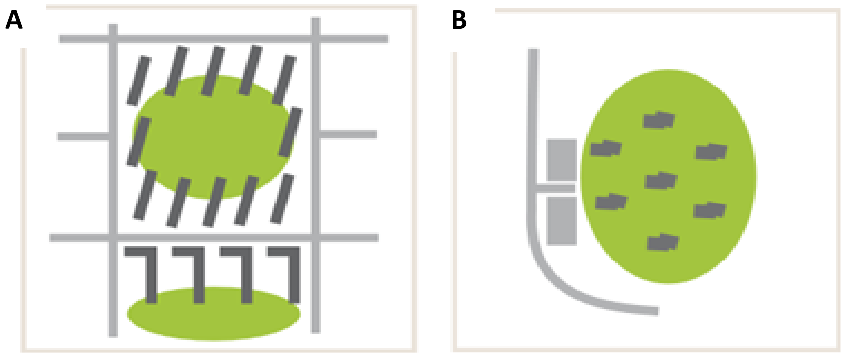

*Figure 3: Conceptual images showing the structure of neighborhoods implemented after functionalism where **A** shows the building structure of narrow buildings in a green environment and **B** shows the building structure of separate multistory building in a green space. Source: Planning and Building Authority, 2008.*

Neighborhoods planned after the ideal of functionalism were developed with nature in mind, where buildings were formed to suit the existing greenery and topography (The Museum of Gothenburg, The Planning and Building Authority, 2017). Instead of having separate parks, such as in the previous ideal, parks were included in the building structure (Figure 4A, 4B), where a focus was put on creating access to outdoor activities close to the home environment, especially for children (ibid). Since there was a focus on increasing public health, kitchen gardens were also a common green element implemented close to the buildings (ibid).

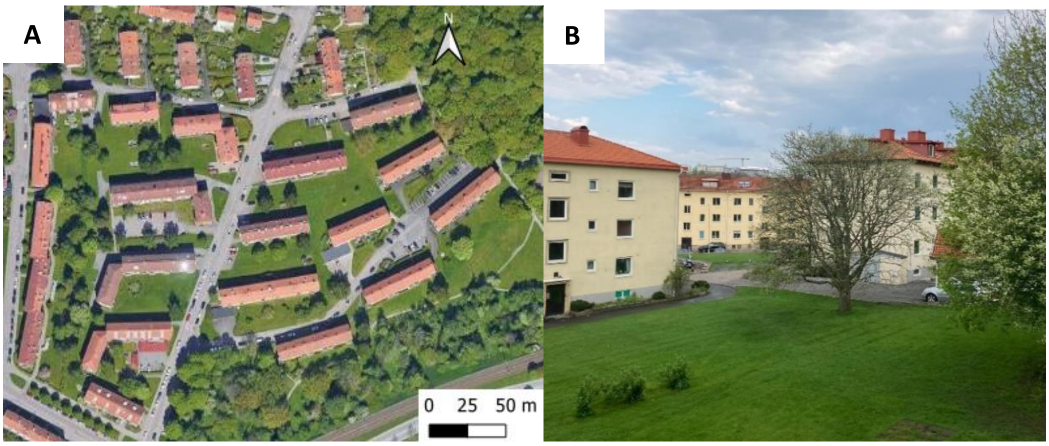

*Figure 4: **A** Map showing an example of a neighborhood structure of functionalism in Kärralund. **B** Buildings with related greenery in accordance with functionalism in a neighborhood in Kålltorp.*

The population of Sweden increased rapidly after World War II, and in 1965 there was a large political interest in providing housing for the growing number of inhabitants in cities, where this political aim was called "*the Million program*" (National Board of Housing, Building and Planning, 2020). To be able to maximize housing, it was important that residential areas were constructed rationally (ibid). This resulted in large residential areas where buildings in the beginning mainly consisted of three floors, but later came to include larger multistory buildings (The Museum of Gothenburg, The Planning and Building Authority, 2017). Similar to the ideal of functionalism, streets and roads were separated from the residential buildings, but where greenery in between buildings was replaced with large courtyards in the center of the building structure (ibid) (Figure 5A, 5B). In these courtyards, a focus was put on children, where playgrounds often made the central point (ibid).

Figure 5: ***A*** *Map showing a typical Million program structure in a neighborhood in Backa.* ***B*** *photo showing a courtyard with playground and greenery in Backa.*

The materials and greenery in the Million program was planned to be robust to be able to implement the ideal in different parts of Sweden (The Museum of Gothenburg, The Planning and Building Authority, 2017). In Gothenburg, some older neighborhoods were replaced with Million program areas, but most of these neighborhoods are located in the outskirts of the city, where larger natural areas could be used for recreational purposes (ibid). The building structure differed in the Million program neighborhoods, but the three main structures were: larger residential areas in green areas (Figure 6A), buildings in rows (Figure 6B) or multistory buildings (Figure 6C).

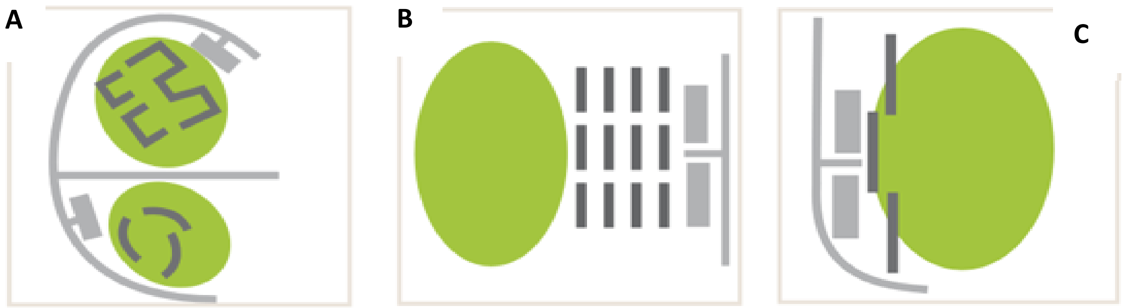

*Figure 6: Conceptual images visualizing the three types of building structures found in the Million program where **A** shows larger residential areas located in park environments, **B** shows the structure of buildings in rows and **C** shows how multistory buildings could be located. Source: Planning and Building Authority, 2008.*

After the Million program, Sweden entered a period of economic recession where the Swedish state cut finances for new development projects (National Board of Housing, Building and Planning, 2007). Instead, in the late 1980s and 1990s there was a focus on maintenance and demolishing neighborhoods that had not been previously refurbished (ibid). Since there had been a lot of newly built neighborhoods, it was not economically profitable to invest in housing, but with a large degree of urbanization, this later resulted in a housing shortage in cities. To manage this problem, new development projects slowly increased after the year of 2000 (ibid), where the Mixed city ideal gained attention (Bellander, 2005). The idea of the Mixed city was as a starting point to get more vivid environments and replace the functionalistic division of spaces, with areas of mixed functions (ibid). The Mixed city ideal focuses on inhabitant's access to amenities and services, where integration of functions is seen as the most desirable form of urban space (ibid). To provide mixed functions, a dense urban environment is required (Figure 7A, 7B), where the public street environment is vital for achieving lively neighborhoods at all hours of the day (ibid). The Mixed city ideal has a focus on diversity, both in form of functions, but also in relation to a diversity of inhabitants and greenery (ibid).

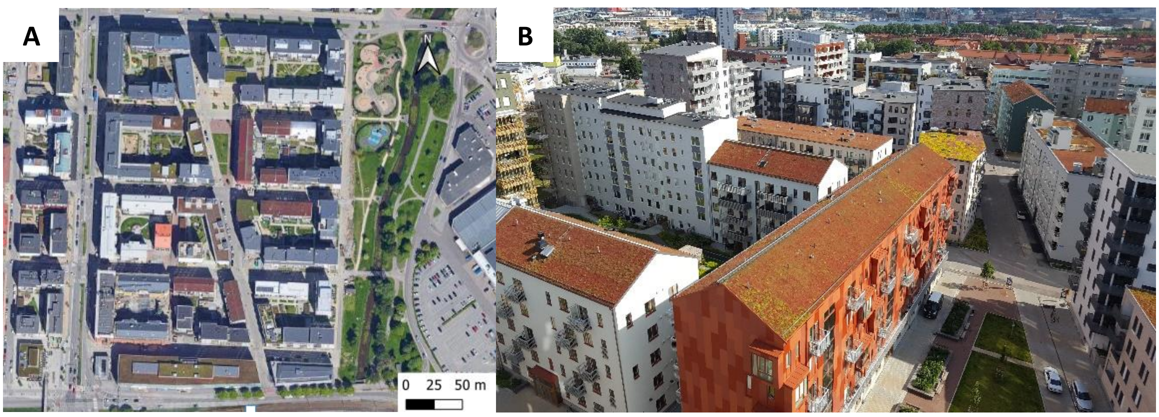

*Figure 7: **A** Map showing a dense Mixed city building structure in Kvillebäcken (East). **B** A photo of the mixed buildings and the street environment in Kvillebäcken (East). Photo: Jonathan Malmberg.*

3. Study Area - Gothenburg, Sweden

3.1 Climate of Gothenburg

Gothenburg is the second largest city in Sweden with about 583 000 inhabitants in the municipality (SCB, 2021). Gothenburg is located in the south-western parts of the country, at the coast (57.708870, 11.974560) and has a maritime temperate climate with mild summers and mild winters (Konarska et al., 2013). The average air temperature (1960-1990) in summer (June to August) is 16.3 °C, and in winter -0.4 °C (December to February) and the average annual precipitation in Gothenburg is 758mm (Thorsson et al., 2017; Konarska et al., 2013). In Gothenburg, the summer mean air temperature, as well as heat waves are expected to increase in the future, where Gothenburg like many other Swedish cities are expected to be especially vulnerable, since these environments have been adapted to a cold climate and not the expected warmer one (SMHI, 2011; Granberg, 2019).

3.2 Characteristics of Gothenburg

The population of Gothenburg is expected to increase, and large parts of Gothenburg will be redeveloped and densified to be able to provide housing and amenities for the growing number of inhabitants (ibid). The city core of Gothenburg was built in a grid street pattern with narrow streets, and consists of both low-rise and mid-rise buildings which compose a relatively dense environment (Konarska, Holmer, Lindberg, & Thorsson, 2016). Parks and green spaces can be seen in the center of Gothenburg, but where the largest green areas are located in the outskirts of the city (ibid; (The Museum of Gothenburg, The Planning and Building Authority, 2017).

3.3 Study Sites

Twelve study sites in Gothenburg were chosen for this thesis, where the study sites representing the Mixed city and the Traditional Neighborhood city are located relatively close to the city center, the three sites representing Nordic functionalism typology are located a bit further from the city core, and the three sites representing the Million program are located close to the outskirts of the city (Figure 8).

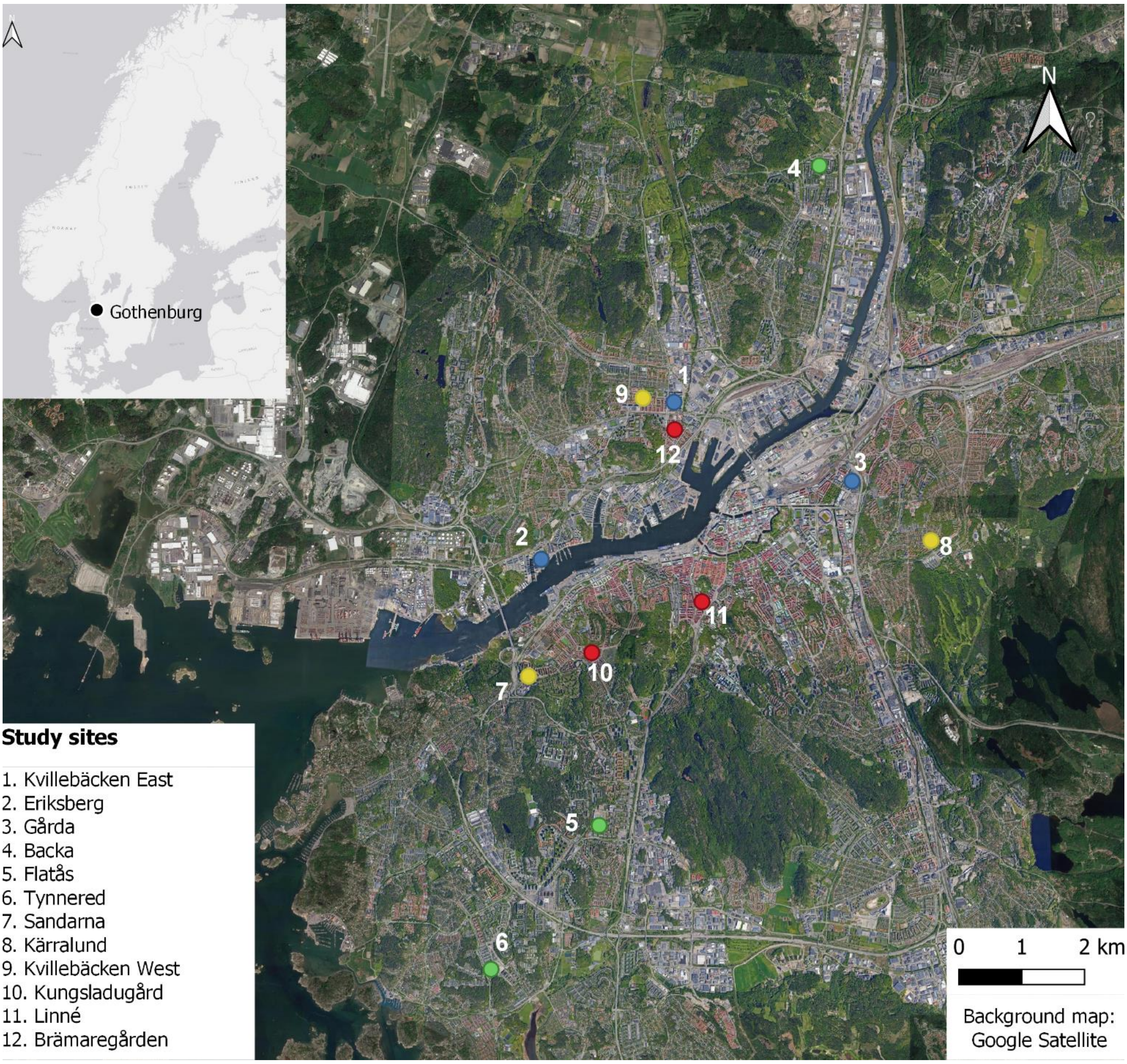

Figure 8: Map showing the city of Gothenburg and the chosen study sites. Blue points represent the study sites in the Mixed city, green points represent the Million program, yellow points represent the Nordic functionalism and red points represents the Traditional neighborhood city. Background map with satellite image from google maps.

4. Data and methods

4.1 Mixed Method Approach

A mixed method approach was in this study formed by the quantitative methods of spatial analysis and detailed mappings of greenery through GIS, and a qualitative method of conducting semi structured interviews with urban planners. A mixed method approach can be used to incorporate a larger variety of possible findings, which would have been excluded by only one method, and further contribute to a more comprehensive view of the researched subject (Bryman, 2012). The qualitative method was used to be able to compare the differences in amount and distribution of greenery in the typologies and where the interviews formed a basis for understanding why certain forms of greenery are seen in the typologies, and the strengths and challenges with the current composition. The first part of this chapter will introduce the methodology of the quantitative part of the study and choice of data, and will be followed by how the interviews and a thematic analysis was conducted.

4.1.1 Defining Urban Typologies

To map the composition and distribution of greenery, the four urban typologies: The Traditional neighborhood city, the Nordic functionalism, the Million program and the Mixed city, were used. The report *"Stadsbyggnadskvaliteter Göteborg"* from the Planning and Building Authority (2008) in Gothenburg, was used as a basis for choosing urban typologies, where each urban typology represents implementations of Swedish planning ideals. A previous mapping of urban typologies in Gothenburg was also used (Table 1), where neighborhoods sharing similar building structure with an urban typology was classified as this typology. This mapping was corrected to better suit the aim of this thesis, where the correction consisted of a removal of two categories; private standalone houses and *"skivhus*". This since these represent building types and not urban typologies. *Skivhus* are narrow, but tall multistory buildings (Figure 6C) and the polygons representing this building type were reclassified into the most suitable urban typology, mainly the Million program. Some of these buildings were also removed due to classification difficulties, for example when information of the building year could not be retrieved. This approach of removing areas which could not be classified with confidence, was also implemented for the neighborhoods representing the urban typologies. This since it was important that the neighborhoods representing each urban typology clearly shared similarities with the typology. The boundary of the polygons representing each urban typology was defined by natural barriers, mainly roads, but also water flows or forests surrounding the area, where the neighborhood was seen to be inside of these barriers. In the end, the layer representing the urban typologies, consisted of all the neighborhoods, in the form of polygons, which had been put into an urban typology.

4.1.2 General Composition of Greenery in the Urban Typologies

To be able to get an overview of the differences in greenery between the urban typologies, calculations of mean tree height, vegetation volume and land cover were conducted with land cover data from NMD from the Swedish Environmental Protection Agency and two CDSMs from the Department of Earth Sciences, University of Gothenburg and (Table 1) (Figure 9**)**

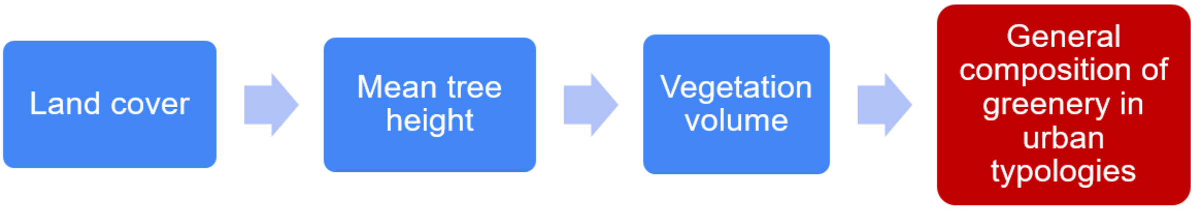

Figure 9: Flow chart representing the work process that enabled an understanding of the general composition of greenery in the urban typologies.

Table 1

The datasets used in this study

Dataset	Date of acquisition	Pixel size (m)	Source	Used for:
Vector layer, with polygons representing urban typologies and building types	May 2020	-	Oskar Bäcklin, PhD student at the department of Earth Sciences, University of Gothenburg	Creating a polygon layer which determined the boundaries of neighborhoods representing urban typologies
Land cover data (NMD)	2018, corrected 2020	10	From "*Nationella marktäckedata*" (NMD) from the Swedish Environmental Protection Agency *(Naturvårdsverket)*	Calculating land cover fractions in the neighborhoods representing urban typologies
Point layer of trees	June 2020	-	Planning and Building Authority in Gothenburg *(Stadsbyggnadskontoret)*	Collecting amount of trees in the study sites, and the share of

				deciduous and evergreen trees
Orthophoto, RGB	April 2019	0.25	Planning and Building Authority in Gothenburg *(Stadsbyggnadskontoret)*	Mapping urban greenery in the study sites
Orthophoto, RGB	May 2017	0.25	Planning and Building Authority in Gothenburg *(Stadsbyggnadskontoret)*	Mapping urban greenery in the study sites
Orthophoto IR, (Infrared, red, green)	2018	0.25	Swedish Mapping, Cadastral and Land Registration Authority *(Lantmäteriet)*	Mapping urban greenery in the study sites
Canopy Digital Surface Model (CDSM), covering Gothenburg	October 2010	1	LiDAR data from the Planning and Building Authority in Gothenburg *(Stadsbyggnadskontoret)* CDSM retrieved from Department of Earth Sciences, University of Gothenburg	Calculating mean tree height in the urban typologies, and collecting the vegetation volume
Canopy Digital Surface Model (CDSM), updated for Kvillebäcken East	April/Mary 2017, updated in April 2021 at the Department of Earth Sciences, University of Gothenburg	1	LiDAR data from the Planning and Building Authority in Gothenburg *(Stadsbyggnadskontoret)* Updated CDSM retrieved from the Department of Earth Sciences, University of Gothenburg	Updating calculations for mean tree height and vegetation volume for the Mixed city typology

Calculations of land cover fractions in the urban typologies was conducted with national land cover data from the Swedish Environmental Protection Agency from 2018, called NMD, where the NMD is based on both satellite data (Sentinel-2) and laser data (LiDAR) (Swedish Environmental Protection Agency's, 2020). This data set contained many different classes of land cover, where some categories were grouped (Appendix I). To be able to get a good generalization of categories, the Swedish Environmental Protection Agency own grouping of categories was used as a guideline (ibid), where for example 17 categories of trees became one category. The land cover was then normalized with the total amount of pixels in each urban typology. The national land cover data (NMD) had a relatively coarse resolution of 10x10m, but was used due to being more recently updated than other available data sets of land cover.

To get a better understanding of the spatial variation in each urban typology, and how well the urban typologies were represented, land cover fractions from NMD data was calculated for all the individual neighborhoods representing an urban typology. This since spatial patterns are connected to scale, and grouping data into larger categories can affect how the results later are interpreted (Jelinski & Wu, 1996, Dark & Bram, 2007). The retrieved information of variation in land cover was then used to form descriptive statistics of the mean value of each land cover class and the standard deviation. This analysis showed that some Mixed city neighborhoods were not accurately represented in the dataset, where a few neighborhoods had to be removed. This resulted in new calculations of land cover in the urban typologies, but will be further discussed in the discussion of methods.

The mean tree height was calculated for each urban typology, derived from a CDSM layer covering Gothenburg with 1m pixels, which was based on LiDAR data from October 2010 from the Planning and Building Authority in Gothenburg (Table 1). The LiDAR data that this CDSM was based on, had an average pulse density of 13.65 m^2 and a footprint diameter of 0.13 m (Klingberg et al., 2017). All no data values in the CDSM were removed. The mean tree height was then multiplied with the amount of vegetated pixels (1m) in the CDSM from 2010 with the boundaries of the neighborhood representing the urban typologies, to obtain the vegetation volume in the typologies. To be able to compare areas of different sizes, the total vegetation volume was divided by the area of the typologies. A CDSM from 2017 was updated by the Department of Earth Sciences for the area of Kvillebäcken East in April 2021, where new calculations of mean tree height and vegetation volume were conducted for the Mixed city typology.

4.1.3 Mapping Greenery in the Study Sites

A detailed mapping of urban greenery in study sites was conducted and resulted in maps showing the composition of greenery in these areas. The generated material that was retrieved from the mapping was also used to calculate the share of vegetation types, amount of trees per m^2 and the degree of connectivity (Figure 10).

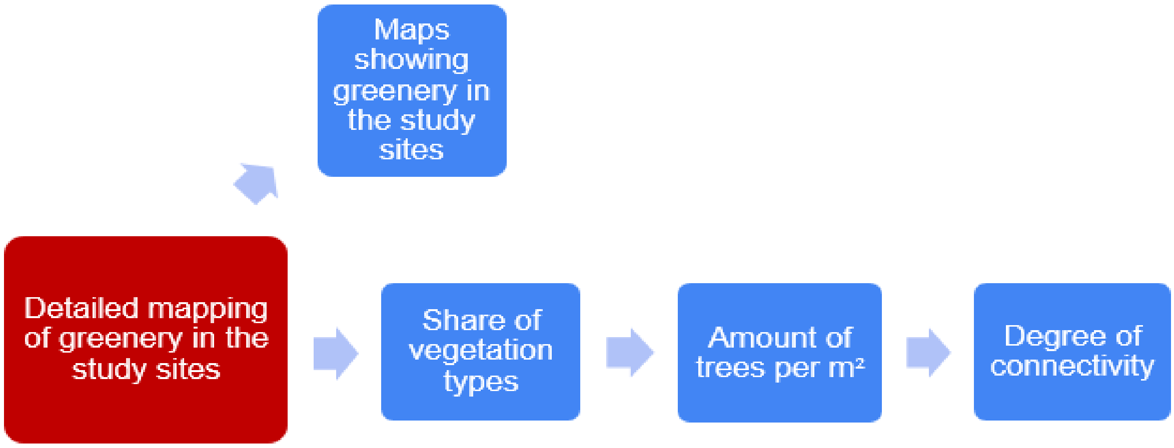

Figure 10: Flow chart representing how the material from the detailed mapping of greenery in the study sites were processed.

The boundaries of the study sites were in most cases already defined by the urban typology layer, but some large areas were redefined into smaller ones to be able to achieve the intended high level of detail. Three study sites representing each urban typology was chosen, generating twelve study sites in total (Table 2) (Figure 8).

Table 2

The study sites chosen as representatives for each urban typology and the area for each study site.

Urban Typology	**Study Sites**	**Area (m^2)**
Mixed City	Kvillebäcken East	120646
	Gårda	29240
	Eriksberg	33630
Million Program	Backa	165862
	Tynnered	29240
	Flatås	37472
Nordic Functionalism	Kvillebäcken West	88935
	Kärralund	28434
	Sandarna	29013
Traditional Neighborhood city	Linné	97085
	Brämaregården	80461
	Kungsladugård	48078

The study sites were chosen by which areas that seemed to represent the urban typology best and where there was good imagery. The aim was also to pick study sites located in different parts of Gothenburg, to show a more diverse and accurate picture of how the spatial form of typologies can be expressed.

RGB orthophotos with a resolution of 0.25m from April 2019 and May 2017, as well as an IR orthophoto from 2018 (0.25m) were used to find vegetation in the study sites (Table 1). The vegetation seen in the orthophotos was manually determined as polygons in QGIS a vector layer representing the vegetation was created for each study site. It was mainly the RGB orthophoto from 2019 that was used, since this was the most updated one. However, since the orthophotos were collected during different seasons, and with some difference in angle, more information about the vegetation could be retrieved when using several ones. This made it easier to interpret the vegetation and favored the confidence of the classification. For example, the IR orthophoto from 2018 was used in the study site of Kvillebäcken East to differentiate artificial grass from real grass, which had not been easily done with only using the RGB orthophotos from 2017 and 2019. For all areas, Google street map and Google satellite with 3D imagery was used to get a better picture of the vegetation and find vegetation that was hidden behind buildings in the orthophotos. All study sites were visited to get a better picture of the neighborhoods, as well as to confirm the accuracy of the classification of greenery. Apart from field study visits, planning documents were used as a complement to photos to retrieve more information about the placement of greenery.

The categories of vegetation were based on what was seen in the orthophotos, or was described in plans, and was not fixed beforehand. This to be able to map all the vegetation in the study site, and not miss vegetation due to limitations of specific categories. As previously mentioned, polygons were created in the shape of the vegetation, but with trees as an exception. This since trees were mapped in a rectangular shape when put in an ordered way (Figure 11A), often the case with street trees, but following the center of the canopy when the trees were placed in green and less structured environments (Figure 11B).

Figure 11: ***A*** *Trees structured in rows in a paved environment.* ***B*** *Trees placed on grass in a green less structured environment.*

This method of mapping trees is not without implications regarding the area of trees, but was suitable since the focus of the study was to show how vegetation was composed and structured in the typologies, which was more visible in maps with this method. Apart from the polygon layer, a point layer of trees from 2020 was collected from the Planning and Building Authority, but was corrected due to some misclassifications in the layer (Table 1). The corrections were mainly based on the removal of points where trees had been cut down, was misplaced or add trees that did exist but was not shown in the point layer. Some incorrect points were visible in orthophotos and some could be spotted during field studies. The point layer was added to later be able to calculate the amount of trees per square meter in each study site.

The CDSM from 2010, was used to see the vegetation height and distinguish trees from larger shrubs. To further reduce the degree of misclassification, uncertain elements were pointed out to later be examined during field studies. Additionally, the difference of hedges and shrubs are not always distinct, but where green elements were classified as hedges when the element was in an ordered structure, often well shaped and in a line, and classified as shrubs when being placed more freely or in a flowerbed. When the classification of greenery in the study sites was done, calculations of the percentage of different vegetation categories in the study sites were conducted, where the area of each vegetation type was divided by the ground area of the study site. This to be able to compare the study sites which were of different sizes, to see which elements that were most prominent. The average percentage of each vegetation type was then calculated from the three study sites in each urban typology. The amount of trees in the study sites was retrieved from the corrected point layer representing trees. Since the study sites vary in size, the amount of trees had to be divided by the area to form an equal comparison of trees per square meter.

The degree of connectivity of the green spaces in the study sites were calculated, as well as the average of the three study sites in each typology. These calculations were based on the areal form factor (AFF) (Gonzales, Alvarez and Crecente, 2004), which can be used to determine the relationship between area and perimeter of green patches (Equation 1).

$$Areal\ form\ factor = \frac{AREA}{\text{PERIMETER}^2} \quad (Equation\ 1)$$

This relationship can be used for understanding connectivity since study sites with large green patches will have a smaller perimeter in relation to the area than study sites with many small isolated green patches, which will have the opposite relationship. A study site with fragmented greenery will with calculations of AFF therefore show a low value, and where a high value indicates a site with connected greenery, which formed the basis for the comparison of connectivity between the study sites. To be able to do these calculations, the polygons representing green elements had to be changed to instead show green patches. Otherwise there would be a high fragmentation for patches including many green elements, since this increases the total perimeter of the vegetation. The perimeter and area of all green patches in an urban typology was then summed and AFF was calculated to be able to see the differences between the urban typologies.

4.2 Interviews

One part of this study consisted of informant interviews, where interviews with four planners working with greenery in Gothenburg were conducted. Three informants were working in municipal offices; with one planner from the Planning and Building Authority and two planners from the Parks and Landscape Administration, and the fourth planner worked at an architectural bureau.

4.2.1 Interview Sample

A purposive sample of interviewees was chosen to be able to find informants that could contribute with first-hand knowledge of the planning of urban greenery in Gothenburg. To be able to provide this in depth knowledge of the role of urban greenery in the city, the focus was to find informants which had extensive experience in the field, either currently working or had been working with greenery in planning practices. Additionally, the aim was to find a group of informants who had somewhat different areas of expertise, although still working currently or previously with planning urban greenery, to get a broader picture of planning practices. It should be noted that even if these planners work with different processes, they do not act as informants for the overall planning practices in Gothenburg, where greenery is only one part of many that needs consideration.

As a first step, three possible informants who were known to have experience in the field, who also had been involved in earlier research collaborations, were contacted. Two of these planners agreed to be interviewed, and a snowball sampling strategy was then used to get more informants. A snowball sampling strategy is useful when a researcher is looking for a specific group of interest, as one can get recommendations from the already chosen informants who work in the specific field (Lewis-Beck, Bryman & Futing Liao, 2004). It can also be easier for the recommended interviewee to agree to an interview if someone they work with and trust is asking (ibid). From the first group of contacted planners, two other planners were recommended and these two were contacted and agreed to be interviewed. In total, four interviews were conducted, with two informants that were contacted in the first group, and two informants that were recommended by this group.

The interviews were conducted digitally, due to the restraints related to the covid-19 pandemic of meeting in person. Three of the interviews were performed during an hour, and one during 45 minutes. A semi-structured interview was chosen since it is a suitable structure to capture experiences and the knowledge of the interviewee (Lewis-Beck, Bryman & Futing Liao, 2012). Municipal documents can be read to understand the overall aim for the planners, but this interview strategy benefits a broader and in depth picture of how planners experience their work with urban greenery, as well as the strengths and challenges with planning for greenery. An interview guide was used as a tool for making sure that the interviews stayed related to the study (Appendix II) where questions were focused on the current composition of greenery in Gothenburg, which qualities greenery brings to the city, and how urban greenery can be planned in the future. The informants were also asked to describe the composition of greenery in the four urban typologies, and discuss the strengths and challenges with these forms of greenery. The last part of the interview consisted of questions regarding a diagram of land cover in the urban typologies (see Figure 13) and a diagram of the change in amount of greenery

(NDVI) in different areas in Gothenburg between the years of 1986-2019 (Blinge, 2021, Figure 15). Even if questions were based on the interview guide, there was a great variance in how the interviews were structured due to the aim of not restricting the informant's answers and further create opportunities to catch valuable but unexpected aspects of the field, which further highlights the benefits of a semi-structured interview. All interviews were conducted in Swedish, but quotes from the interviews were translated to English to better suit the structure of the thesis.

4.2.2 Thematic analysis

After the meetings with the informants, interviews were transcribed from the recordings and a thematic analysis was conducted (Figure 12). In this study, the thematic analysis was based on the work of Braun & Clark (2006), where the analysis is conducted through six steps. The first step is to get familiarized with the data, which was done by transcribing the interviews and reading the transcriptions. The second step is to generate codes, where every discussion or answer is connected to a descriptive word, i.e. a code (Braun & Clarke, 2006). After this step, the codes are analyzed and similar codes can be categorized into themes. The fourth step is then to review the themes, and the fifth step is to label the themes. The final step is to discuss the themes in the result of the study (ibid).

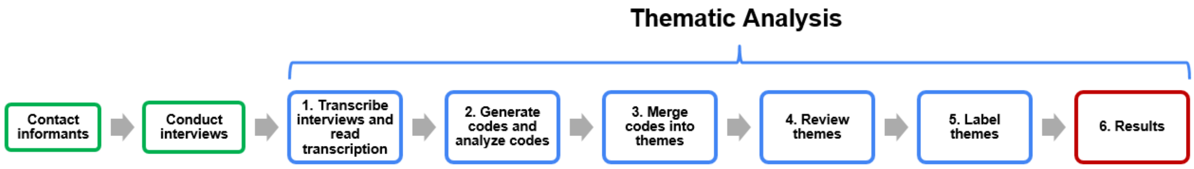

Figure 12: a flowchart representing the working process regarding interviews and the thematic analysis.

A thematic analysis can be used as a method for finding and scrutinizing themes within qualitative data, without being bound to a specific theoretical framework (Clarke & Braun, 2017). Additionally, a thematic analysis can act as a way for the researcher to create structure in the often large amount of data that is collected from transcribed interviews, and be used to explore the data in a systematic way (ibid). This study did not include a specific theoretical framework, and a thematic analysis was thereby suitable for providing a framework that eases the process of collecting recurring discussions. A thematic analysis does not provide an objective lens, since the generation of themes is still dependent on how the researcher views the material, but is useful for minimizing the risk of highlighting already expected themes, and miss out on other valuable themes (ibid). From the material collected through interviews, the following codes generated the themes that are discussed in the results:

Table 3

The themes generated through the thematic analysis

Codes	***Themes***
Goals *Qualities* *Responsibility* *Preservation* *Regulations*	The Importance of Urban Greenery
Distribution of greenery *Urban typologies* *Planning ideals* *Social qualities* *Urban structure impacting greenery*	The Composition of Urban Greenery
Heat stress *Heavy precipitation* *Variation* *Climate adaptation* *Needs of urban inhabitants*	Climate Change Awareness
Densification processes *Conflict of interest* *Exploitation* *Short term perspectives* *Economy*	Challenges Regarding Urban greenery

5. Results

The results will be presented in order of the methodology where the result from the spatial analysis and detailed mapping in GIS is followed by the results from the interviews.

5.1 General Composition of Greenery in Urban Typologies

To understand the general composition of greenery in the urban typologies, this part of the result will present an overview of the typologies, regarding land cover, mean tree height and vegetation volume. When it comes to the green land cover (grass and trees) in the urban typologies, there are similarities between the Million Program and the Nordic functionalism typology. The share of trees is a bit larger in the Nordic functionalism typology, and respectively a bit larger share of grass in the Million Program, but the amount of vegetated land is around 60% in both typologies (Figure 13). In the Mixed city and the Traditional neighborhood typology it is instead paved surfaces and buildings which are prominent, resulting in less green land cover, with about 20,7% in the Mixed city and around 21,8% in the Traditional neighborhood city. The land cover in the Mixed city typology can be seen as relatively mixed, with a larger share of water and bare soil than the other typologies. Several of the Mixed city neighborhoods are located close to the Göta River or smaller water canals, which explains why the share of water is higher than in the other typologies.

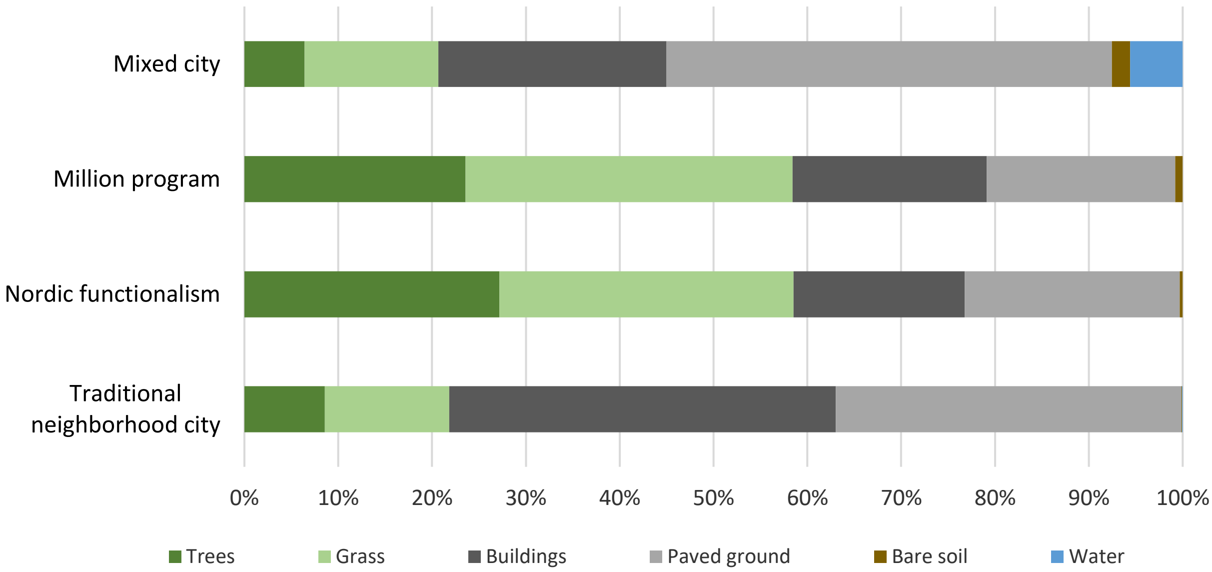

Figure 13: Diagram showing land cover differences between the four urban typologies

The connection between land cover and urban typology can be better understood when analyzing the variance in land cover in the neighborhoods representing the urban typologies. The fractions of land cover were similar for those neighborhoods that were defined into an urban typology, with values close to the mean and a thereby a low standard deviation (Appendix III).

The mean tree height was highest in the Nordic functionalism typology, followed by the Traditional neighborhood city (Table 4). Since these are the oldest typologies, there is probably a larger mean tree height due to trees having reached their maximum size. This can be seen in relation to the Mixed city, which had the lowest mean tree height of the typologies, where there might be a higher degree of young trees, since this typology is the most recently implemented. Regarding the vegetation volume, there was a similar trend as with mean tree height, where the Nordic Functionalism typology showed the largest vegetation volume and the Mixed city the lowest (Table 4). In contrast to the mean tree height, the vegetation volume was larger in the Million program than in the Traditional neighborhood city.

Table 4

Mean tree height and vegetation volume in the urban typologies.

Urban Typology	Mean Tree Height (m)	Vegetation Volume (m^3/m^2)
Mixed City	5.79	0.51
Million Program	6.68	1.36
Nordic Functionalism	7.98	1.99
Traditional Neighborhood City	6.96	0.75

5.2 Composition of Greenery in the Study Sites

When comparing the study sites representing the typologies, a trend of having more traditional choices of greenery, such as grass, trees, shrubs, hedges and flowerbeds was seen in the Million program, the Nordic functionalism typology and the Traditional neighborhood city (Figure 14B, 14C, 14D). In contrast to the traditional greenery, urban gardening was found in all of the study sites of the Nordic functionalism typology as well as one study site in the Traditional neighborhood city, and some green roofs in the study site of Linné. In the Mixed city typology, there were instead a larger variety of green elements, with for example green roofs, rain gardens and sedge in the study sites (Figure 14A). All of the study sites shared a similar trend of having grass as the most prominent green element, but with large differences in how much of the area consisted of grass (Figure 14). Additionally, how greenery was structured differed between the typologies, where the study sites of the Nordic functionalism typology showed a more spontaneous structure of greenery, where trees and shrubs are placed freely, compared to the other three typologies.

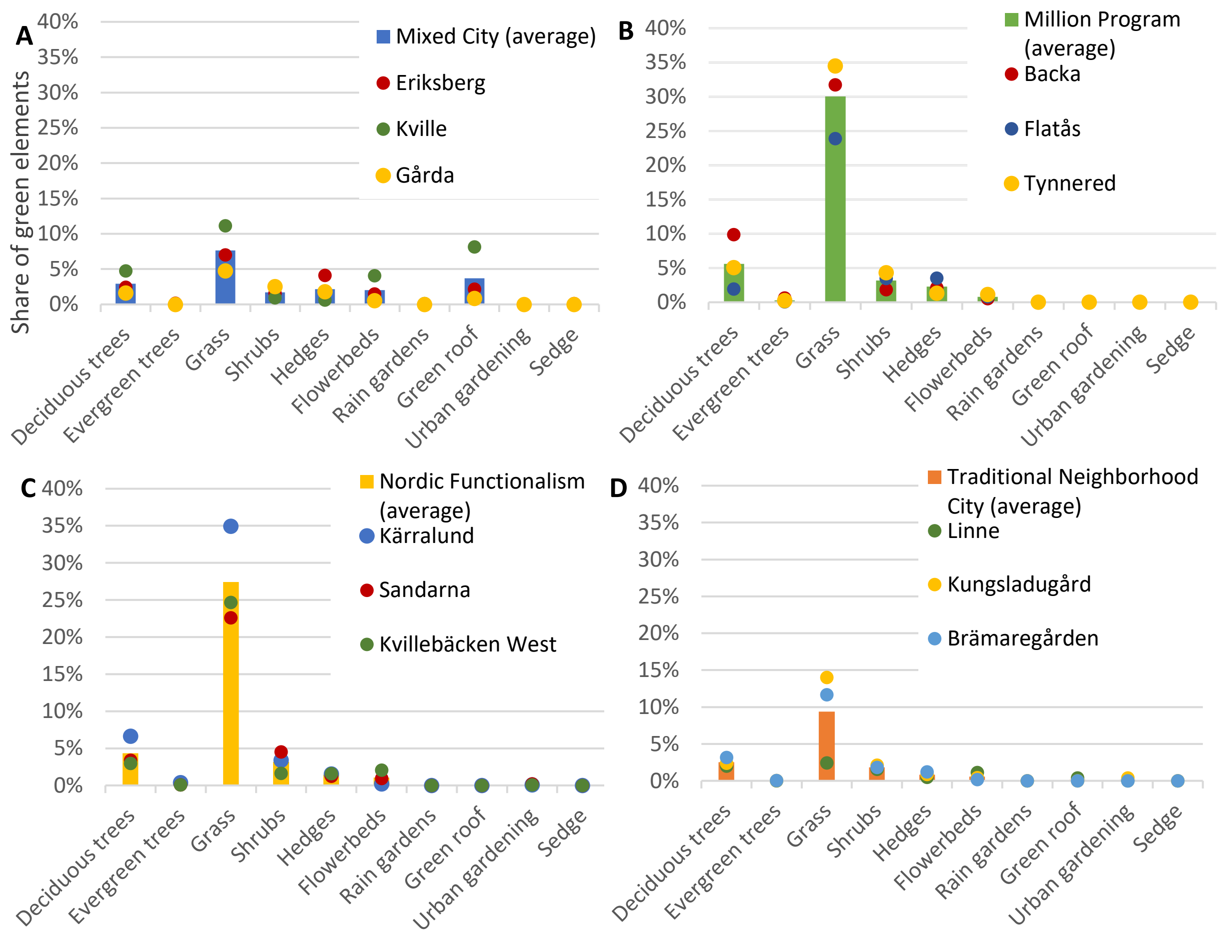

*Figure 14: Comparison between the share of green elements in relation to the total area of the study sites, with averages for each green element from the three study sites of a typology, where **A** represents study sites in the Mixed city typology, **B** the Million program, **C** the Nordic functionalism and **D** represents the Traditional neighborhood city.*

5.2.1 Study Sites of the Mixed City

In the study sites of the Mixed city typology, most of the vegetation could be seen in courtyards with a variety of green elements, and trees were common in the streetscape (Figure 15, 16, 17). Since many of the green elements are structured in different ornamental shapes, this contributes to a highly designed impression in the Mixed city typology. The most prominent element was grass, which on average constituted for 7,62% of the area in the study sites (Figure 14A), but as previously mentioned, there were quite many different types of vegetation, and with some exclusively existing in the Mixed city typology, such as rain gardens and sedge. Except for these two elements, and the more traditional types of greenery, green roofs were seen in all study sites, and was the second most prominent element with an average of 3,7 % (Figure 14A).

The extent of green roofs was most visible in Kvillebäcken East, where almost all complexes of related groups of buildings contained green roofs (Figure 15). The study site of Gårda did not include as many types of greenery as the other two sites, but still shared the highly planned impression with greenery composed in designed shapes (Figure 17). Another difference between the study sites was that Kvillebäcken East included a park, located in the eastern part of the study site, and this park formed more of a natural environment than what otherwise was seen in the built environment (Figure 15). For example, trees in the park were composed in clusters on larger grass lawns, whereas the trees in the built environment mainly were placed in rows. A similarity between the study sites was the proximity to water, where Eriksberg is close to the Göta River (Figure 16) and smaller water canals can be seen in the other two study sites (Figure 15, 17).

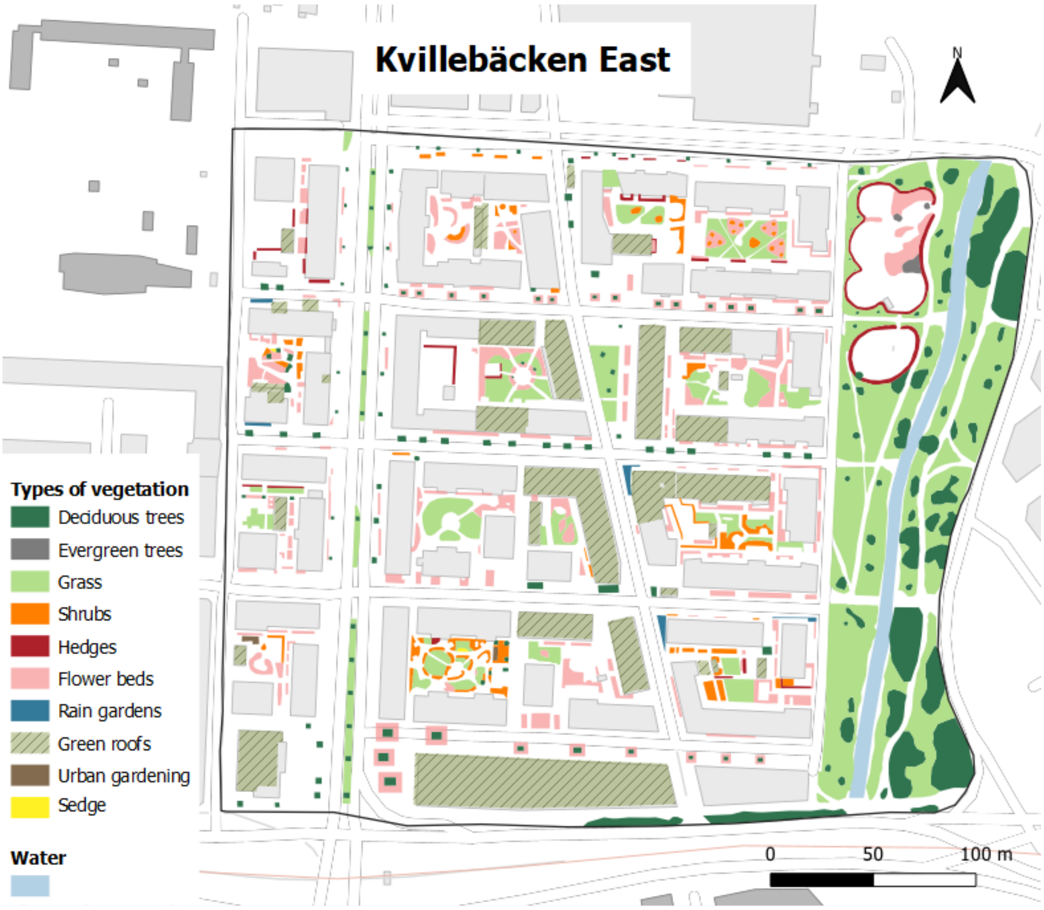

Figure 15: Map showing types of greenery in the study site of Kvillebäcken East

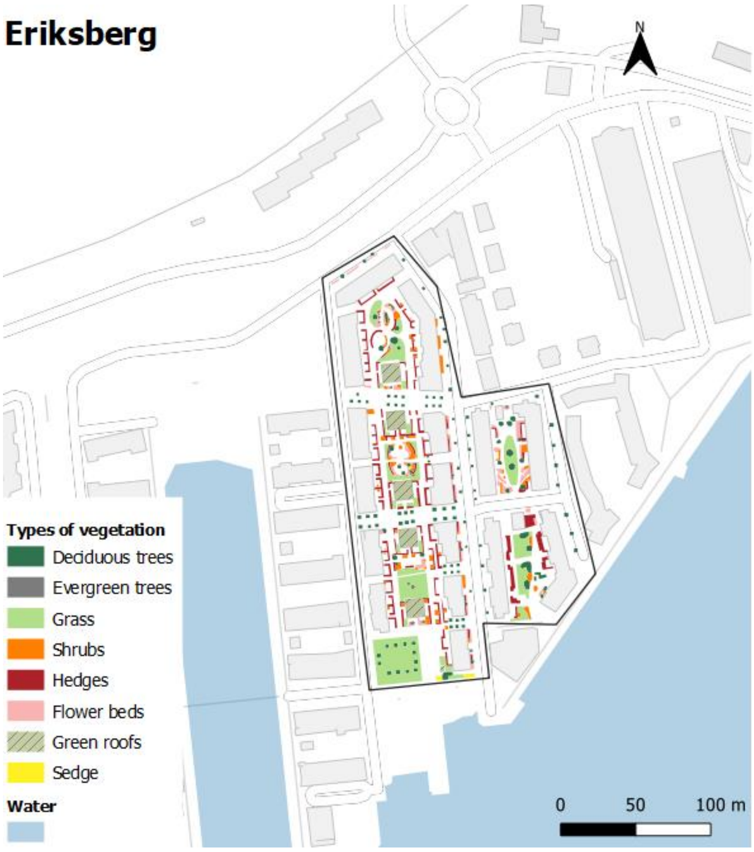

Figure 16: Map showing types of greenery in the study site of Eriksberg.

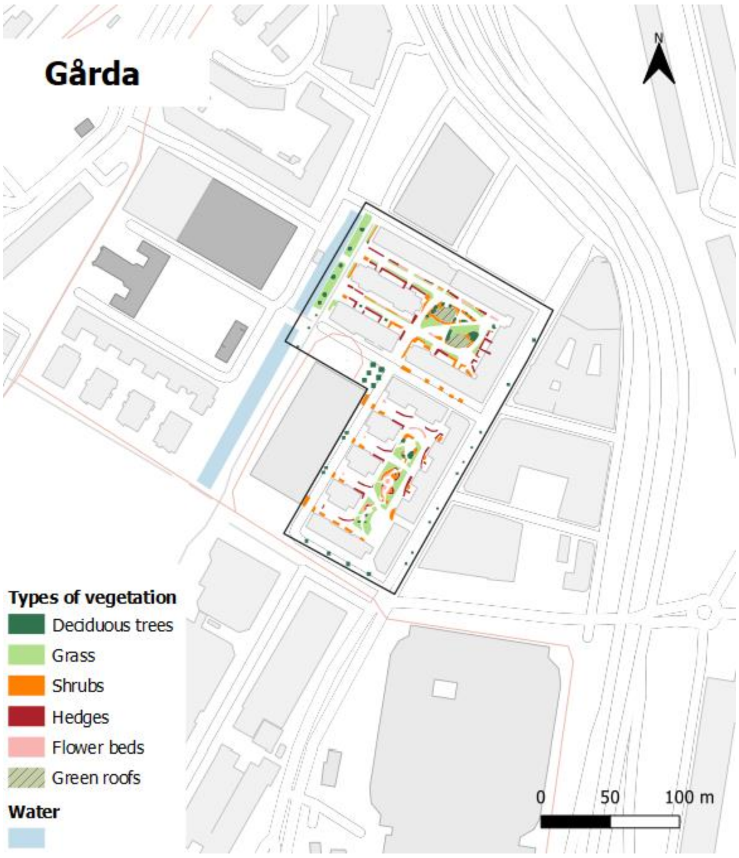

Figure 17: Map showing types of greenery in the study site of Gårda

5.2.2 Study Sites of the Million Program

In all three study sites, structure was formed by hedges connected to every courtyard entry as well as having trees in rows at parking lots or down the streets (Figure 18, 19, 20). Playgrounds existed in the courtyards of all study sites and constituted a central point where greenery surrounded these playgrounds. The greenery in this typology is based on more traditional choices of vegetation, such as grass, trees, shrubs and hedges, where grass was the most prominent green element with an average of 30% of the total area consisting of grass (Figure 14B). In the study site of Backa, large grass lawns with trees and shrubs in clusters are seen in the south and easthern parts of the neighborhood of Backa and compose a more nature like environment (Figure 18). In the study sites of Flatås and Tynnered, these larger green areas surrounding the neighborhood as in Backa are not seen, but grass lawns are still visible as the most prominent green element (Figure 19, 20). In between the buildings in the study sites, there are large open courtyards where trees are placed quite spontaneously on grass lawns, but where the courtyards in Backa are somewhat more planned with trees and shrubs placed to form certain shapes. In Backa, there was also one new plot of very structured greenery, in the south-eastern part of the neighborhood (Figure 18), looking more like the forms of greenery that can be seen in newly built areas.

Figure 18: Map showing types of greenery in the study site of Backa.

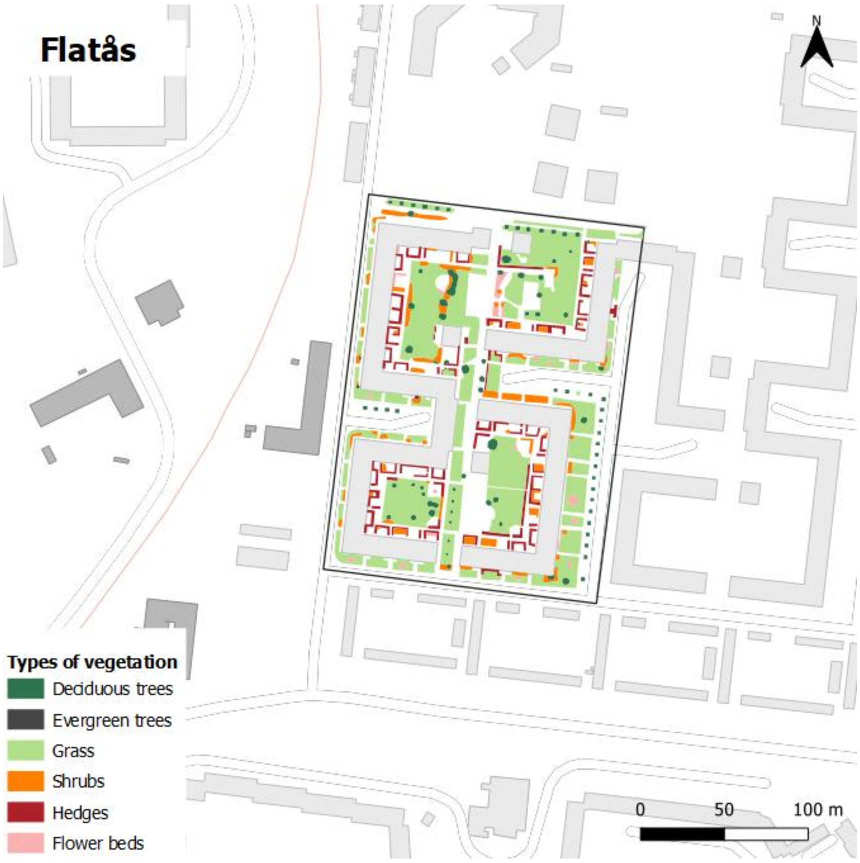

Figure 19: Map showing types of greenery in the study site of Flatås

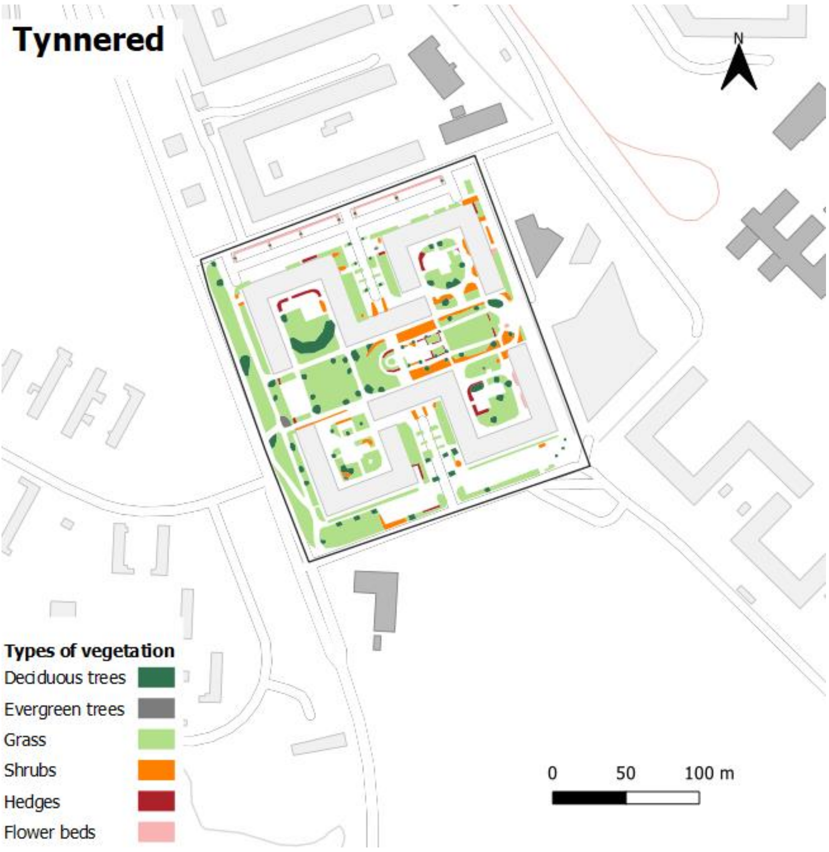

Figure 20: Map showing types of greenery in the study site of Tynnered.

5.2.3 Study Sites of Nordic Functionalism Typology

In the study sites of the Nordic Functionalism typology, spacious grass lawns can be seen located in between buildings (Figure 21, 22, 23). Both deciduous and evergreen trees, as well as shrubs, are placed on these grass lawns in an unordered way, with Kärralund composing the most the most nature like environment on a connected green space (Figure 22). In all study sites, trees can be seen in clusters or scattered on green spaces, with few trees in rows or placed on paved ground, which is different from the other typologies. Hedges and flowerbeds can be seen closely connected to the buildings and forms an ornamental kind of greenery, in relation to the otherwise more spontaneous impression. Similar to the Million Program typology, the type of vegetation is more traditional, but urban gardening was seen in all three study sites of the Nordic Functionalism typology. On average 27,4% of the in the Nordic functionalism typology area consisted of grass, which thereby makes it the most common green element (Figure 14C). Deciduous trees were the second largest vegetation type, where the average of the study sites were 4,3% .

Figure 21: Map showing types of greenery in the study site of Kvillebäcken West

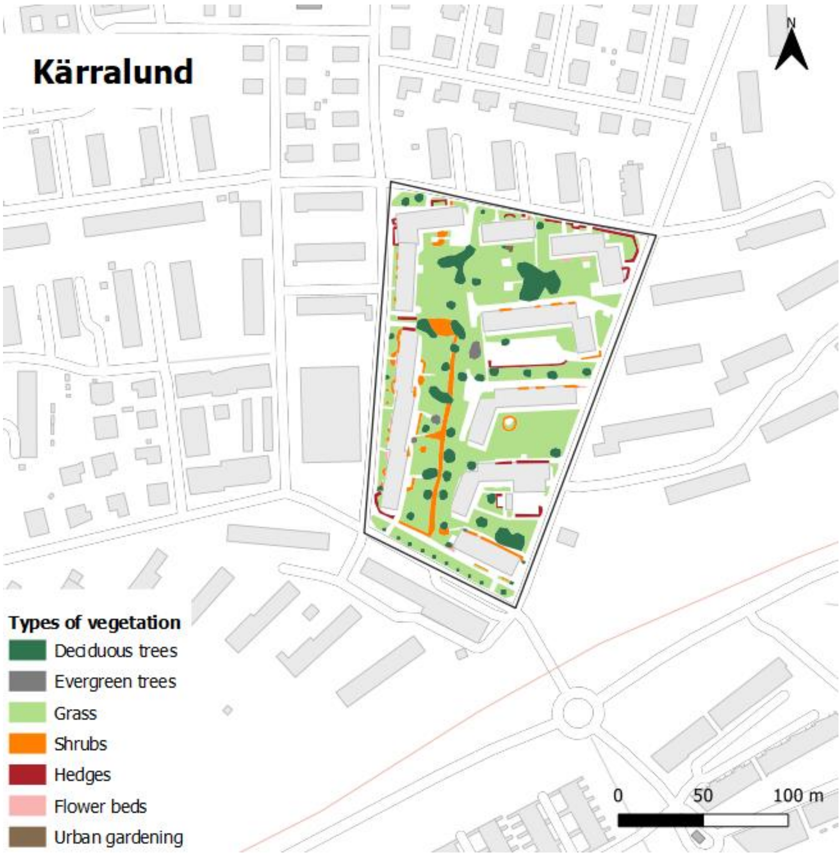

Figure 22: Map showing types of greenery in the study site of Kärralund.

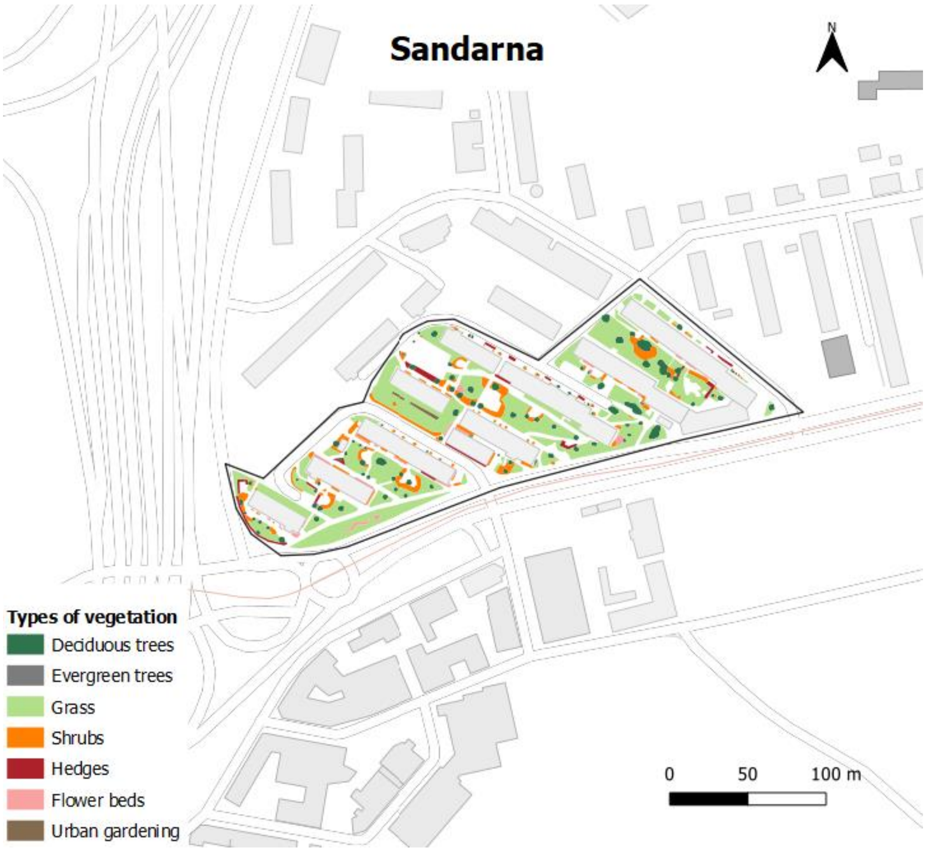

Figure 23: Map showing types of greenery in the study site of Sandarna.

5.2.4 Study Sites of the Traditional Neighborhood City

In the study sites of the Traditional neighborhood typology, most of the greenery is seen in the enclosed courtyards, forming a clear difference between private and public greenery (Figure 24, 25, 26). In the courtyards, it is mainly smaller grass lawns with trees and shrubs, where hedges and shrubs are used to shape the environment in the desired way. The trees in the courtyards are placed more freely whilst the trees in the streetscape can be seen in structured rows. The street environment contains a high degree of paved surfaces where some streets completely lack vegetation, most visible in the study site of Linné (Figure 24). The study site of Linné differs from the other two study sites, with having smaller patches of grass surfaces and very little vegetation in some courtyards. Additionally, green roofs can be found in Linné, but not in the other two sites. The degree of green roofs in relation to conventional roofs is however small, and have mainly been implemented on smaller buildings, such as bicycle garages or storage buildings. Similarly to the other typologies, grass is the most prominent form of greenery, and in the Traditional neighborhood 9,38% of the area consisted of grass (Figure 14D). Deciduous trees represented the second largest share of green elements with an average of 2,5% of the area.

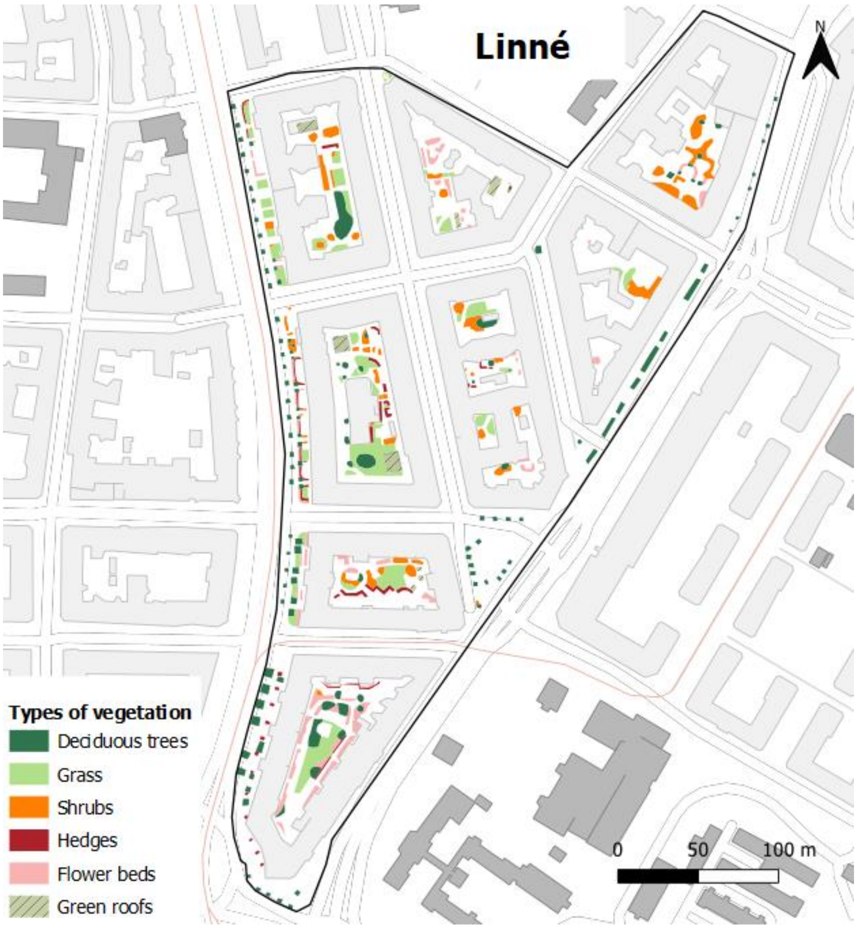

Figure 24: Map showing types of greenery in the study site of Linné

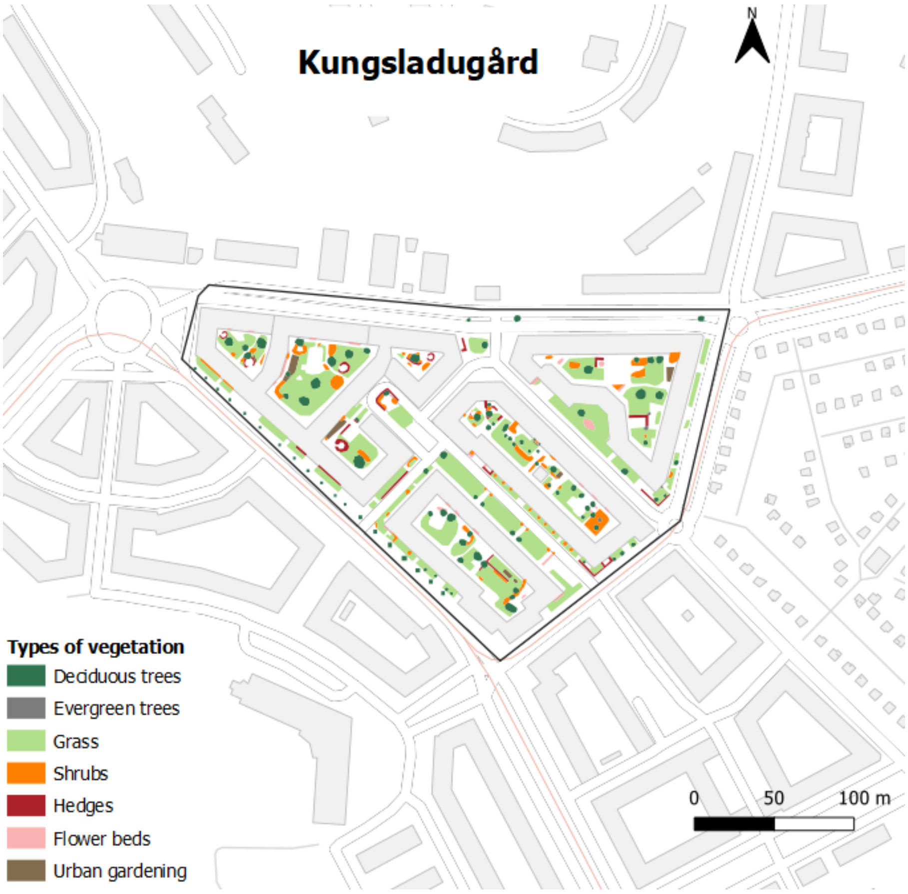

Figure 25: Map showing types of greenery in the study site of Kungsladugård

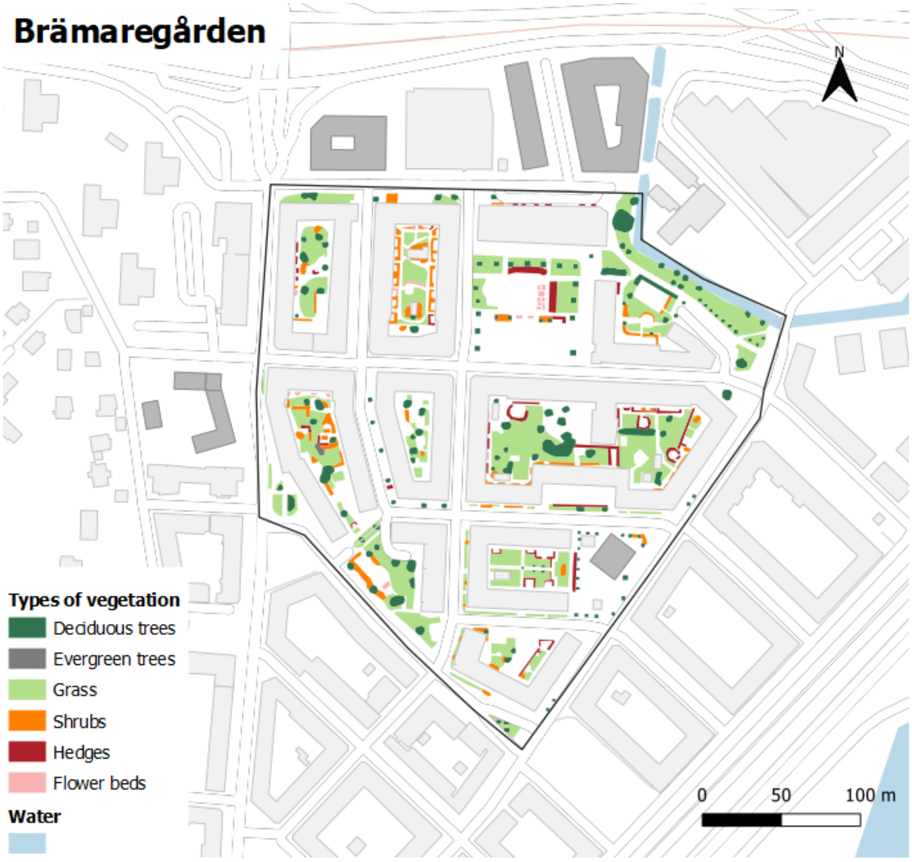

Figure 26: Map showing types of greenery in the study site of Brämaregården.

5.2.6 Amount of Trees in the Study Sites

Regarding the amount of trees in the urban typologies, the Mixed city had the highest number of trees, but only slightly higher than the Million program and Nordic functionalism typology (Figure 27). The Traditional neighborhood city had a much lower amount of trees per square meter than the other typologies (Figure 27). The amount of trees in the study sites differed, where the study site of Eriksberg had the largest number of trees per square meter and the study site of Linné had the lowest amount (Appendix IV).

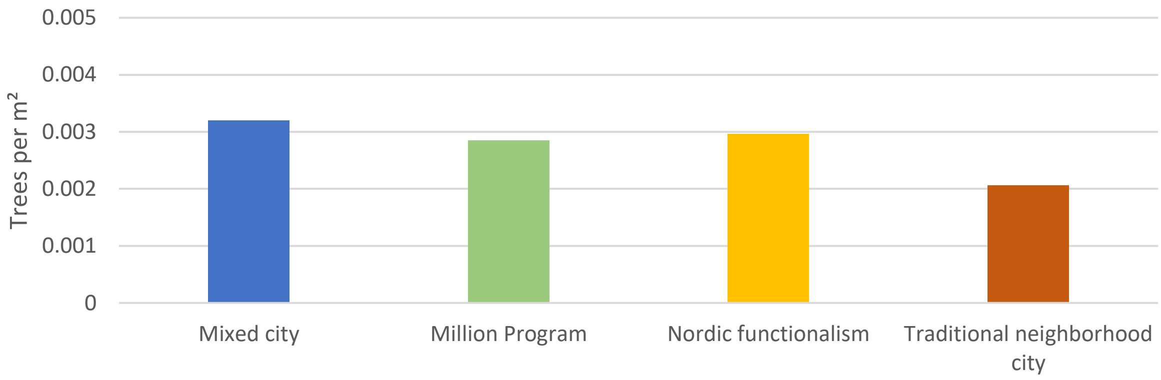

Figure 27: The amount of trees per m^2 in the urban typologies, based on the average from the study sites.

5.2.5 Degree of Connectivity in the Study Sites

When comparing the degree of connectivity, a trend of the having more connected greenery in the Nordic functionalism typology, and less connected greenery in the Mixed city typology was seen (Figure 28). The study sites in each urban typology differed in the degree of connected greenery, where the study site Kärralund showed the highest degree of connected greenery and Kvillebäcken East showed the least connected greenery of all the study sites (Appendix V).

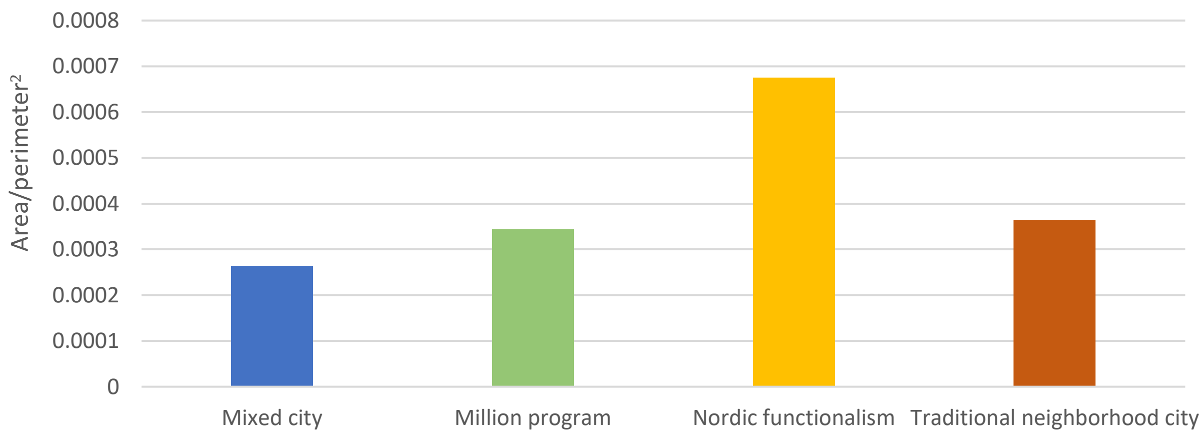

Figure 28: The degree of connectivity in the urban typologies, based on the average from the study sites. A higher value represents well connected greenery and a lower value represents more fragmented greenery.

5.3 Interviews

This part of the results will present the material collected from the interviews with urban planners. To highlight the individual answers of the informants, they will henceforth be referred to as informant; 1, 2, 3 and 4 (Table 5).

Table 5

Working office and Background	
The planning and Building Authority, Landscape Architect	Informant 1
The Parks and Landscape Administration, Biologist	Informant 2
The Parks and Landscape Administration, Landscape Architect	Informant 3
Architectural Bureau, Landscape Architect	Informant 4

The material has been organized through a thematic analysis and the results will be presented by the chosen themes in the following order:

1. The Importance of Urban Greenery
2. The Form of Urban Greenery
3. Climate Change Awareness
4. Challenges for Urban Greenery

5.3.1 The Importance of Urban Greenery

This theme revolves around the view of the informants on the qualities that greenery can provide, and the importance of urban greenery. This theme also relates to the overarching goals concerning greenery, what kind of responsibilities the planners are faced with as well as how the importance of preserving greenery cities.

When answering the question related to the importance of greenery, the most recurring answers were in relation to biological diversity, human health, recreation and climate adaptation where the latter will be discussed in section 5.3.3 Climate Change Awareness. The need of urban greenery for biological diversity was described by Informant 2 with two main arguments. The first referred to the overarching environmental goals for both Sweden and the municipality of Gothenburg concerning biological diversity, where the Parks and Landscape Administration has a responsibility to fulfil these goals. The other reason concerned a current larger responsibility for biodiversity since some species now exclusively are located in city environments, due to a loss of habitat in other environments, generated by decades of extensive forestry. She stated that "*We have got a larger responsibility, which is very clear since these species only exist here, and not in the surrounding forest landscape, and it is an important part that largely controls how our unit works".*

Additionally, the informants discussed how it is important to preserve larger green spaces since this is positive for the animals that thrive in these environments, but there are also benefits for human health if people are attracted to spend time outdoors. For urban inhabitants to be able to do this, the green areas thus need to be accessible and Informant 3 stated that "I *think that an equal access to parks and natural environments, to public places, where one can recover, meet new people, play, children can develop their motor skills, is really important from an health equality perspective".* This argument was also put forward as why it is important to preserve already existing vegetation and promote more green environments in cities, as even if some areas are small, they can still contribute with a lot of social qualities. The planners did however argue that it is a problem when vegetation becomes too fragmented, often related to a trend of exploitation, since some of the ecological and social qualities are lost when dividing green areas into smaller green patches or removed completely. Informant 3 highlighted this problem by stating that *"the ecological and the recreational qualities in the green environments cannot be recreated in other places*", and that if these environments are exploited for other purposes, we will lose these qualities in the city. He also stated that even if greenery is removed in one place, but compensated with a new plot of greenery somewhere else, it takes time to build certain qualities. For example, old trees can have high cultural historical values, as well as producing more shade than young trees, where these qualities will take a long time to rebuild if the trees are removed.

One final aspect that was discussed was that the acknowledgment of the importance of greenery has changed, and gained more attention in planning during the last decades, but with different explanations for why this was the case. Informant 4 thought that this was due to the fact that the overall acknowledgement of the importance of greenery has increased but also that planners need to come up with solutions to mitigate the effects of climate change. Informant 2 also stated that there is a larger awareness of the importance of greenery now than it has been before, but that one explanation for this is a larger awareness by citizens, and inhabitants advocating for more greenery. She did however state that even if many inhabitants care for greenery and want more greenery in Gothenburg, there are also those who do not want greenery and trees, where this polarization of attitudes has increased by time. A last explanation stated by Informant 1 was the entry of the Swedish Environmental Code, which has put more attention on the biological and ecological qualities of greenery.

5.3.2 The Composition of Urban Greenery

This theme concerns how the informants viewed the distribution of greenery in the city, why certain forms of greenery is seen in the urban typologies and strengths and weaknesses regarding these compositions and types of vegetation.

Informant 2 highlighted that Gothenburg is different from many other Swedish municipalities due to the large degree of municipal ownership of green areas. She stated that it is positive that the large areas in the outskirts of the city are left relatively untouched, where the main use is for recreation, as the greenery in the city center is getting more fragmented due to densification. Connected to the densification process is the Mixed city typology, as it is the current planning ideal where the focus is to create dense environments with a lot of different functions close to the inhabitants. The general picture from the planners was that the Mixed city ideal is often promoted as green, but in reality, they stated that there is not much room for vegetation. Informant 1 described the typology as "*it's not a mix really and it is certainly a challenge to get it to work in a good way, and make sure that there is room for greenery, which I cannot see in today's planning*". One example of the lack of space for greenery that was lifted was that streets in this environment often are narrow, and then it is hard to get the amount of sunlight and space that is needed to achieve good growing conditions for trees. Informant 4 described that the structure of this typology is partly a consequence of the high cost of ground space and "*since it costs a lot to build these days, greenery and gardens are often compromised to increase the area possible for buildings".* She stated that this is somewhat of a struggle but that it can lead to finding new ways of incorporating greenery, which can be seen with having green facades and green balconies in this typology. Informant 3 described the typology as "*it's incredibly cluttered, it's very small courtyards, pretty dark, ambitious outdoor environments but everything is very programmed and arranged"* and continued with a description of how each green spot is based on function rather than having green spaces which are more allowing and free.

With the form of greenery in the Million program, a different picture than in the Mixed city was visualized and the informants highlighted that this typology has a lot of large green spaces and that it is positive that the neighborhoods are surrounded by forests and natural areas. The form of greenery was described as aiming to be structured where Informant 1 depicted the environments as wiring diagrams, where spaces are constructed through the lens of function and how people should use the space. The green spaces are often placed in very large open courtyards where doors are located towards the greenery but where planners said that the vegetation might not have the highest ecological qualities. Informant 2 said that *"the actual environments in these Million program areas are not always, let's say developed, it's also a bit of the same kind of grass surfaces and playgrounds"* which highlights the discussed lack of variation of greenery. The vegetation in this typology was described as meager and that neighborhoods in this typology had not been refurbished in a sufficient way, which can result in overgrown or wild growing vegetation. In turn, this was described as a problem as local inhabitants had shared complaints of feeling unsafe due to this form of greenery. Another aspect of safety was described by Informant 3 which said that "*it is hard to keep track of all the people living in the buildings, and who belongs here and who does not"* as these areas often are very large and not enclosed, which can result in feelings of unsafety when you don't have a clear overlook of which people that use the space. He also highlighted that from his experience, the green spaces are not used to a high degree, but if they are used, it is mainly children that use the space. This in turn was stated as a positive quality as it can become a meeting place for children and an easy to access green spaces to play in.

The Nordic functionalism typology was described similarly to the Million program in the way of having larger green surfaces in the form of grass lawns. This was described through the focus of providing social qualities, where people can use the green space more freely, in contrast to for example the Mixed city which has a larger degree of programmed green space. Another aspect regarding this free environment, is that it is a typology which allows change, where Informant 1 stated that "*It is more flexible, and one can change quite a lot regarding greenery without losing the overall impression"*. Informant 3 mentioned that similar to the Million program, these open spaces are meant to form spaces for social activities, but they can sometimes feel a bit too open which results in people not using the green space to the intended degree. The lack of variation in types of vegetation was put forward as a potential area of development and Informant 2 stated that "*it is hard to manage all of these cut grass spaces, they are not bad in relation to biological diversity, and they have a lot of social qualities but maybe a larger variation is needed".* She also stated that studies had shown that these kinds of areas show a lower degree of pollinators than other typologies and where inhabitants wish for more flowering vegetation. An aspect that was stated by Informant 4 was that in the Nordic functionalism typology, as well as in the Million program, *"you get more connected green areas which can create better connectivity",* in comparison to the Mixed city and the Traditional neighborhood city, which she highlighted as positive for the living space for animals and insects.

With the Traditional neighborhood city, the green spaces were described by Informant 1 as "*pretty formal and relatively strict, very well planned*". The collected image of the greenery in this typology was stated by the informants to be somewhat divided where there is private greenery located in enclosed courtyards, and public greenery in the form of street trees and pocket parks. When showing the diagram of the land cover differences between the urban typologies (Figure 13), Informant 4 discussed the similarities between the Traditional neighborhood city and the Mixed city. She thought that the Mixed city probably is inspired by the Traditional neighborhood ideal, where both share similarities in form of a high degree of designed green spaces. Both Informant 1 and Informant 4 highlighted that there are certain differences in the courtyard greenery in this typology due to different building epochs. The older buildings that can be seen in the study site of Linné, are often taller, which results in more shade in the courtyards and perhaps not as much focus on vegetation. The other building type, *landshövdingehus,* which can be seen in the study site of Kungsladugård, instead consist of lower houses where the courtyards are sunlit to a higher degree and where a more greenery can be seen. Since this typology is the oldest of the four, large trees with large canopies can be found in streets as well as in courtyards but it was stated that it can be hard to add new vegetation to this typology as these trees occupy a lot of space underground. It can also be difficult and expensive to add vegetation due to being a highly planned environment, even though it was stated by some planners that there was a lack of vegetation in this typology. Informant 4 argued that "*it feels very separated, it's a kind of city structure where one could work more with green solutions, for example infiltrated rain gardens and rain beds but this is not something that we have done, and it would require relatively large investments to make it greener".*

5.3.3 Climate Change Awareness

This theme collects the views by the informants on climate change awareness in planning processes in Gothenburg and how greenery is connected to climate adaptation and mitigation. This theme also explores examples of green adaptive measures in Gothenburg, but it should be noted that these are only a few examples of many that were discussed.

All of the informants stated in some way that planners have a responsibility to acknowledge the changing climate and find mitigating and adaptive solutions to climate related issues. The two main issues that were discussed were heat stress and heavy precipitation, and how greenery can be used to mitigate these issues. Concerning heat, Informant 2 stated the importance of having trees and larger shrubs as*"It rains a lot in Gothenburg, but we do get heat waves, and then the cooling and shading effect is very important"*. She also stated that even if these two types of greenery are important for producing shade, it is equally important to increase the general vegetation mass to get a larger cooling effect from transpiration. To have a lot of trees in cities is considered positive for many, but Informant 1 described how the Parks and Landscape Administration had to face inhabitant's complaints regularly, with trees blocking the ocean view as well as producing unwanted shade. She stated that some inhabitants have thanked the administration after heat waves for saying no to cutting down trees, but that the work of battling these kinds of complaints with trees is extensive. Informant 3 stated that inhabitants of Gothenburg more often see the problems of rain than heat, and that a common perception of heat stress was that it only occurs in the most southern parts of Europe.

Informant 3 highlighted that a warmer climate does not only produce heat stress, but with a warmer climate, there are new kinds of plant diseases and pests and that can thrive, and thereby form a risk for greenery. To reduce this problem, the administration plants different kinds of species, especially tree species, so that if a pest affects certain species, there is still vegetation left to provide climate regulative services. He stated that " *we need to create a variation and if we don't work with this, it doesn't matter if we plant trees to take care of the heat issues, or preserve parks to provide cooling in the city, because if those trees die from diseases, it doesn't matter anyway"*. He continued by saying that these questions are interconnected and the problems cannot be seen as separate from each other, which he also referred to with adaptation to heavy precipitation. The planner mentioned that instead of working with more traditional grey methods "*we can instead work with green solutions that both create solutions that sustain over time, but also have a lesser environmental impact and also create qualities for people"* where the qualities referred to attractive environments for inhabitants. Informant 2 added that we can see trends of choosing plants that can endure large amounts of rain and contribute to both cleaning and reduced runoff, for example in rain gardens.

Informant 1 said that he has been working with strategic planning of climate adaptation in the last 20 years, where greenery is one part of this work, but that it is more recently that the awareness of a future warmer climate has been incorporated in physical planning. He said that it has taken a long time to raise awareness of these questions, but that we today *”talk a lot about blue-green solutions to adapt to a future warmer climate. Both in the ways of incorporating more greenery, but also as a way of taking care of heavy precipitation events in the built city to reduce the harmful effects”*. In the private sector, Informant 4 stated that it can be difficult for private businesses to motivate the high costs of incorporating greenery as adaptive measures, but that it can be easier from a national and municipal perspective, where the societal costs from climate related hazards are clearly visible in form of for example hospital cost. She stated that there are many companies that want to be in the front of working with climate adaptation, and then it might be easier to motivate the costs, but that focus needs to be put on creating incentives for the private sector to invest in green mitigation strategies. This since we need a collective contribution to be able to adapt and tackle the problems that arise from a warmer climate.

5.3.4 Challenges Regarding Urban Greenery

In this theme, focus will be put on the main challenges and risks that the planners discussed in relation to urban greenery in Gothenburg, and in which ways they felt restrained to incorporate greenery in the perceived optimal way. Some of the challenges concerning greenery were discussed earlier in relation to the urban typologies, but where focus here lies on the perspective of challenges in the larger planning processes and on a city perspective.

The general perception expressed by the informants was that it is important to develop housing possibilities for inhabitants, but that the current political goal of wanting to maximize housing possibilities is perceived as so important that outweigh other interests, where greenery often is neglected. This conflict of interest therefore constitutes a challenge of losing greenery in the city where both of the planners from the Parks and Landscape Administration described that they had to fight for greenery on a daily basis due to this large conflict of interests in the city.

They described the conflict regarding greenery to be twofold where one part was the problem of losing greenery due to exploitation interests and how it is a challenge to preserve greenery in planning processes, and the other part was concerning the challenge to create spaces with good growing conditions for green elements in dense city environments. Informant 2 lifted these challenges by stating that *"the challenge is to have space for greenery. I think that Kvillebäcken,* referring to the study site Kvillebäcken East, *is a quite bad example, it's not much greenery there at all because it is way too exploited, it is too dense, greenery requires a little light".* Furthermore, she described that exploitation and densification processes are expected to continue, not only in the Mixed city but in the other typologies as well, which further can contribute to a decrease in greenery, which was also stated by Informant 1.

Informant 4 described this twofold challenge of planning for greenery with an example of Korsvägen in Gothenburg. She stated that as a starting point "*when you try to push for more greenery in these zones between tram tracks and bus stops and roads, it is a quite limited amount of space, and when you then start to look at what is happening under the ground, then more parts of the possible plantations disappear".* She continued to describe that for each new aspect of the planning process a space possible for greenery is removed, where the end product often results in little vegetation. Informant 1 mentioned a challenge related to the small spaces of greenery where he stated that it is difficult to make sure that the planned spaces of greenery actually are used for greenery after the plans are implemented. He stated that "*with the detailed development plans that my office works with, we can regulate green spaces, but we have a relatively small guarantee that these actually are realized"*. He mentioned that when he during his earlier career had done inventories of certain planned areas, where only a third of the planned green space had been planted vegetation, one third consisted of grass and the third part was used for other purposes such as parking spots. This example illustrates the discrepancy between planning and implementation and a challenge for achieving the intended amount of vegetation in the city.

Another challenge was described by Informant 3 which argued that there is a challenge of working with greenery in the city in relation to the political goals as "*my mission is to have the long term perspective, to think about what happens in 30, 50 and 70 years, but it is very hard when those who make decisions have mandates for four years".* He also stated that current planning focuses on the more short term goal of creating housing possibilities, and that even though he perceived Gothenburg as green today, it is difficult to know if the city will still be green in the future, due to these large densification goals. He mentioned that planners often talk about the short term costs of implementations, where it can be expensive to develop green spaces, but that this excludes a perspective of which qualities that are produced in a long term perspective. The planner stated that this short term perspective regarding greenery can be a risk since we see a lot of changes in society, for example concerning climate change, and a change of behavior due to the covid-19 pandemic, where people now spend more time outdoors, and if we only think in the short term perspective, Gothenburg will be badly equipped to offer other qualities that might be desirable in the future. He also stated that it can be troublesome to think that we have found the most optimal planning ideal with the Mixed city, and plan a lot of spaces in Gothenburg according to this ideal, since *"when these areas are fully developed in 20 to 25/30 years, we will probably look at a city structure that answers to the challenges we face today, but this might not be the solutions to the challenges we see tomorrow, or in 30 years"*.

Informant 1 highlighted that there today is an extensive work of maintaining greenery in the city, especially due to the large municipal ownership of green spaces in Gothenburg. Additionally, there has also been an increase in work assignments for the Parks and Landscape Administration due to the current planning of high maintenance vegetation, but with no extra funding for these types of new responsibilities. She stated that *"this administration will not have the economy to maintain too many ornamental parks with a lot of well moved grass areas, well maintained hedges or trees that needs to be pruned, these areas will be built, but they will not be taken care of later, it's already happening today".* This issue with lack of funding for more extensive vegetation can therefore constitute a challenge for achieving the desired maintenance, and the qualities vegetation has potential to bring.

6. Discussion

6.1 Strengths and Challenges with Greenery in the Urban Typologies

The four chosen typologies were based on how certain planning ideals have been implemented in Gothenburg. An acknowledgement of the aim of these ideals can further contribute to a better understanding of interurban differences in greenery, as well as the connected qualities. In the implementation of the Million program and the Nordic functionalism, social qualities of greenery were dominant ideals, and as a result, there are larger green spaces which are meant to be used for social activities, for example with playgrounds composing the center of the courtyards in Million program areas. In the Mixed city typology and the Traditional neighborhood city there is instead a larger mix of functions, but to be able to fit all of these functions in neighborhoods, the greenery is highly designed and planned. This ideal of wanting to offer a lot of different functions in neighborhoods, might constitute for one reason why there is less greenery in the Mixed city and the Traditional neighborhood city, where greenery only constitutes for one of many aspects that needs to be included. These dissimilarities creates different starting points for adapting to both a future warmer climate, and the accessibility to greenery, where the strengths and challenges in the typologies regarding greenery, with a focus on heat stress mitigation, will be further discussed in the next section.

6.1.1 The Mixed City

The Mixed city consists of dense environments with narrow streets and relatively little, but highly planned vegetation. These dense environments can be positive in terms of buildings providing shade, and can contribute to human thermal comfort in daytime during heat events (Thorsson, 2012). If and when these surfaces are sunlit, much of the radiation will however be absorbed which induce high surface temperatures, and further creates a high degree of heat storage, which will be released later in the evening (Oke et al., 2017). During heat events, this can contribute to human thermal discomfort when inhabitant's possibilities to cool down during night are restricted and highlights the need to incorporate greenery which can give a cooling effect both during daytime and during night (Public Health Agency of Sweden, 2018). This becomes a challenge for the Mixed city typology, since quite little amounts of greenery could be seen in relation to the amount of paved surfaces (Figure 13). The vegetation volume was also the lowest of the four typologies (Table 4), which can construct a challenge concerning thermal comfort, since vegetation volume has shown to be related to a reduction in T_{mrt} (Lindberg et al., 2018). With little vegetated land cover, there is apart from more storage heat, less water available for evapotranspiration and this reduces the possibilities for a cooling effect (Yu, et al. 2020B).

A strength with the Mixed city is the large amount of trees per square meter (Figure 27), since trees can mitigate heat stress both during day and night (Lindberg, Holmer, Thorsson, & Rayner, 2013;Lindberg, Thorsson, Rayner & Lau, 2016). The largest cooling from trees is reached when trees have reached their maximum size, but this typology had the lowest mean tree height (Table 4). This is probably due to many young trees in this newly implemented typology, but in the future when the trees have reached their maximum size, it is positive that there were a lot of trees. However, since the environment is dense it is likely that several trees will be shaded and this will influence the cooling efficiency negatively. The planners also stated that there is a challenge to create good growing conditions for vegetation in this typology since there is little sunlight reaching the green elements and not enough space for greenery to grow. For trees to be efficient in providing shade and a cooling effect, it is important that they have enough room to grow (Thorsson, 2012), which might be a challenge to achieve in the Mixed city.

The planners also highlighted that ground space today is very expensive, where much of the space in the Mixed city is maximized for buildings, which is a challenge concerning adding and keeping greenery, but also leads to the need to find new ways of incorporating greenery. This could explain why green roofs are common in this typology, where a benefit of having green roofs is the lower the surface temperatures and the possibilities to mitigate the UHI_{Surf} (Li, Bou-Zeid & Oppenheimer, 2014). Having a large degree of green roofs compared to conventional roofs, can also create a reduction of energy consumption and create a higher degree of thermal comfort indoor (Thorsson, 2012). The cooling effect of green roofs on air temperature is though very small, especially at night, which means that these does not provide a viable measure for mitigating heat stress generated by the UHI_{UCL} (Li, Bou-Zeid & Oppenheimer, 2014). Even if the there is an aim to try to incorporate green roofs to increase the amount of greenery in areas lacking ground space, it is negative for heat stress mitigation if these are implemented as a compensation for the overall little amounts of greenery, since other and more green elements are needed to provide human thermal comfort at night. The green roofs that were seen in the study sites consisted of extensive green roofs, which also limits the possibilities of creating green spaces where people can spend time and where social qualities can be enhanced, which intensive green roofs or larger green spaces could contribute with.

Vegetation is not the only factor influencing the amount of evapotranspiration, but water bodies can contribute to a higher degree of evaporation, which will cool the environment (Sun & Chi, 2011). The cooling effect of water bodies is not a focus of this thesis, but since all study sites in the Mixed city are located close to water, this could contribute to a higher degree of evaporation and possibly influence a local cooling. In the study site of Kvillebäcken East, rain gardens were located in the street environment, and this could also have some impact on the water available for evapotranspiration. This since rain gardens are implemented to infiltrate water into the ground, with an increased soil moisture as well as an increased evapotranspiration (Hess, Wadzuk, & Welker, 2021). How much evapotranspiration rain gardens can contribute with, is though not clearly demonstrated and requires further research (ibid).

As a future outlook, Informant 3 highlighted that many planners have the mindset of Mixed city being the optimal ideal, and implementing very large development project according to this ideal, without acknowledging a long term perspective. In the future, there might be completely different challenges that the city of Gothenburg face, and then it can be difficult and expensive to change these Mixed city areas. This since these environments have little flexibility, with a large degree of programmed and highly planned space. From the results of the overall composition of greenery, the detailed mappings and the concerns that was discussed by planners, the Mixed city already has some limitations in providing measures that increase thermal comfort, and with an expected increase in heat stress, there might be reason to evaluate these limitations before doing very large implementations.

6.1.2 The Million Program

Neighborhoods in the Million program typology is composed of larger courtyards with incorporated green spaces, which creates a relatively green environment. The vegetation volume was the second largest of all typologies, which together with the amount of green land cover, indicates that there is much vegetation that can transpire and contribute to a cooling effect on the micro climate (Table 4, Figure 13). In the Million program, grass is a prominent green element, taking up about 30% of the area (Figure 14B), which can be positive in terms of low surface temperatures, but has a smaller effect on increasing thermal comfort than trees and shrubs, due to grass not providing shade (Balany, et al.,2020; Bowler et al., 2010). A strength that can be seen in the study sites of the Million program is however the combination of trees and shrubs on many grass lawns, and that the size of many of these green patches are quite large, which can increase the cooling intensity and provide human thermal comfort during heat events, both by day and by night (Park, et al, 2017).

Large grass lawns with many trees and shrubs was most visible in the south-eastern part of the study site Backa (Figure 18), but there were many other grass lawns in the study sites that only consisted of grass, which could be a possible area of development where more green elements could increase the cooling intensity of these green patches (Lobaccaro & Acero, 2015; Monteiro, Doick, Handley & Peace 2016). The large amount of grass lawns were also a concern discussed by the planners, since they stated that there is little variation in types of vegetation and that this leads to lower ecological qualities. The planners also stated that even if grass lawns can be positive in terms of space for children to play, the spaces are not otherwise used to a high degree. This results in both low ecological qualities, and possibly lower social qualities than what was intended in the planning process. This further emphasizes how these areas could benefit from an addition of different forms of greenery, since a variation is positive for both cooling potential, ecological values and creating attractive environments where people want to spend time.

A strength with the Million Program is that these neighborhoods often are located close to larger natural areas. This is a strength since larger parks and natural areas can have a cooling effect beyond the boundaries of the green space, and contribute to lower air temperatures in the surrounding neighborhoods, which can be positive during heat events (Thorsson, 2012; Park et al., 2017). Furthermore, natural areas often consist of many different green elements, which can enhance multifunctional qualities, where the access to recreation is one very important factor for public health (Demuzere et al., 2014). The planners mentioned that there is a large need to refurbish the Million program neighborhoods, both regarding the apartments, but also the outdoor environment since much of the vegetation has not been sufficiently maintained. Even if it is positive if new green elements are implemented in terms of cooling, greening neighborhoods have shown to influence gentrification processes, which highlights the complexity of adding green elements without a careful consideration of the impacts (Dorst et al., 2019; Meerow, 2020). The planners also highlighted complaints in the Million program areas of vegetation causing feelings of unsafety, for example with blocking street lights, and this forms a challenge in how to keep the existing vegetation without compromising aspects of safety. It is of course important to increase feelings of safety, but in regards to thermal comfort, it can be negative if larger green objects are removed or replaced by smaller vegetation, since this reduces the possibilities to provide shade during heat stress. The social qualities of greenery, for example community bonding and relaxation, can possibly also be hindered if people see greenery as negative, as well as people not using the space at all if they feel unsafe. In a future perspective, it is hard to know how well suited the Million program areas will be to heat stress, since many areas are going to be redeveloped and possibly become more dense, which changes the composition of greenery that is seen in these areas today.

6.1.3 The Nordic Functionalism

The greenery in the Nordic functionalism typology is composed by large open green spaces in between buildings, which are formed to give a nature like impression. These spaces create a highly green environment, which was seen both in relation to green land cover (Figure 13), as well as regarding the vegetation volume which was the largest of all typologies (Table 4). This typology also showed the second highest number of trees per square meter (Figure 27), which together with the large vegetation volume and green land cover, indicates a potential for a high degree of transpiration and further a cooling effect (Bowler et al., 2010). Since this typology had the highest mean tree height (Table 4), and the second largest amount of trees (Figure 27), this also indicates several tall trees, which can provide more shade than smaller trees, and with a potential of improving thermal comfort during hot days when shade is desired. Furthermore, the study site of Kärralund showed the highest degree of connected greenery of all the study sites, (Appendix V), and Sandarna the second highest, which can be a strength since larger connected green areas provides a higher degree of cooling than fragmented greenery (Kong, et al., 2014). This is further amplified by the combination of grass, trees and shrubs that is seen in all three study sites, since a mixture of green elements on grass lawns can contribute to a high cooling intensity (Park et al., 2017).

Furthermore, it should be noted that the study site of Kvillebäcken West showed a lower degree of connectivity than the other two study sites, and there was a large variation between the sites (Appendix V). Even if a trend is difficult to confidently interpret, the study site of Kärralund highlighted the ideal of having buildings in a park environment in a very clear way, where greenery formed the base and buildings were constructed to fit this environment (Figure 22).

To have greenery as the starting point is quite unique for urban spaces, and this site did certainly stand out in the degree of connectivity. Since connected green spaces are positive in terms of cooling intensity (Kong et al., 2014), it would be unfortunate if these types of areas become densified in the future, which was expected by the planners. Additionally, as mentioned by Informant 3, it is very difficult to regain the qualities that greenery offers if greenery is exploited for other purposes, since some qualities will be completely lost and others take very long time to build. Concerning the Nordic functionalism typology, it would be very difficult to regain connected green spaces if they become fragmented. Furthermore if trees are cut down in densification processes, there will be less shade, and even if new trees are replanted it would take a long time to obtain the same qualities of shade and transpiration as the current trees have.

The planners did however mention that there is quite little variation in types of vegetation in this typology, and that it is extensive work of maintaining all of these large grass lawns. There were also issues with grass lawns which few residents' use, where some inhabitants have requested more flowering plants. A higher degree of variation in chosen greenery can be a way of making the areas more attractive, where the social qualities of greenery can be enhanced if more people spend time in the green areas. Informant 3 also mentioned that a warmer climate can contribute to new pests in Gothenburg, and if areas consist of little variation in vegetation, much of the greenery might be lost. If large parts of green spaces are lost, it will be difficult to provide climate regulating services from vegetation in the future, and in regards to this there might be reason to implement a higher variation of greenery in the Nordic functionalism typology, as well in other typologies. Connected to future changes, Informant 1 stated that greenery in the Nordic functionalism typology can be changed without losing the overall impression, since these environments are relatively free and spacious. This can be positive in terms of flexibility, where the greenery in the Nordic functionalism typology easily can be changed to provide new desired qualities, if those challenges that we see today are replaced by new ones. This in relation to for example the Mixed city and the Traditional neighborhood city which are relatively fixed environments.

6.1.4 Traditional Neighborhood City

The neighborhoods of the Traditional neighborhood city consists of clear divisions of private and public space, where most greenery is located in enclosed courtyard but with some street trees and smaller parks in the public environment. There is a certain difference between the neighborhoods in this typology, since neighborhoods such as Linné have buildings in the form of *stenstadshus* whereas Brämaregården and Kungsladugård consist of *landshövdingehus*. The planners mentioned how areas with *landshövdingehus* had been better planned for greenery, since the courtyards are larger and with more sunlight than the areas similar to Linné, and this could also be seen in the detailed mappings of greenery in the three study sites. In general, quite little vegetation in terms of land cover and vegetation volume was seen in the Traditional neighborhood city (Table 4, Figure 13) which results in smaller amounts of vegetation that can contribute to a cooling effect in events of heat stress. Regarding trees this typology had the lowest amount of trees per square meter (Figure 27) and this can be seen as negative since trees are very effective in providing shade, which is needed during heat stress (Middel & Krayenhoff, 2019). Even if there were fewer trees in relation to the other typologies, the Traditional neighborhood city had the second highest mean tree height (Table 4). This can be due to the choice of tree species, but also due to being the oldest implemented typology, where trees have reached their maximum size. Having large trees in the Traditional neighborhood city can be a strength in relation to human comfort, since large trees usually have thick trunks and large tree crowns, which provides more shade than a smaller young tree (Balany et al., 2020).

A challenge with this typology is the general lack of vegetation in the smaller streets, since even if buildings can provide shade in streets during parts of the day, they store a lot of heat when they are sunlit, which can contribute to high night time temperatures when the heat is released (Oke et al, 2017). This is why it is important to include vegetation in areas dominated by buildings and a high degree of paved surfaces, and is a future area of development in the Traditional neighborhood city to be able to provide human thermal comfort during heat events.

Regarding the types of greenery in the study sites, green roofs was found in Linné (Figure 24), but not in the other two sites. Linné is the oldest study site and green roofs are not an element originally planned for, but this indicates that new forms of greenery has been implemented in other typologies than only the Mixed city. Informant 3 mentioned that the Traditional neighborhood city is a typology which could be benefitted by a higher degree of green infrastructure, but that it would be very expensive to do these kinds of changes. This is mainly due to the highly planned space, where every space is predetermined and would require a lot of effort to change. Another aspect of the difficulties in adding more vegetation in this typology that was highlighted by the planners, is the lack of space under the ground, where the roots of old and large trees occupy a lot of space, making it difficult to provide good growing conditions for new vegetation as well as contributing to difficulties in changing these neighborhoods. This might be one reason for why green roofs have been implemented in Linné, since this element can be implemented without consideration of the lack of ground space, but as mentioned with the Mixed city typology, green roofs will mainly have an influence on surface temperatures at day, and not mitigate heat stress at night (Bowler et al., 2010; Li, Bou-Zeid & Oppenheimer, 2014). In a future perspective, the Traditional neighborhood typology faces risks concerning heat stress due to the low amount of vegetation, and with little flexibility to be changed, but where neighborhoods built in the same era such as Linné with *stenstadshus* can face larger challenges, due to showing the least amount of vegetation of the three study sites, more fragmented greenery (Appendix V), as well having harsh environments for new vegetation to thrive.

6.2 Discussion of methods

6.2.1 The Lens of Urban Typologies and a Mixed Method Approach

Descriptive statistics of land cover in all the neighborhoods representing the typologies showed that there is quite similar land cover in the neighborhoods classified as one urban typology (Appendix III). This indicates that the four chosen urban typologies are well represented, and that one way of understanding interurban differences of land cover is through urban typologies. Land cover is one important factor for understanding how different environments will contribute to the UHI effect, since a high degree of paved surfaces and buildings will increase the magnitude of the UHI effect, whereas green land cover can decrease the magnitude (Oke et al, 2017). The UHI effect is one contributor to the added heat stress in cities, and by scrutinizing the interurban typology differences of land cover and composition of vegetation, can form a systematic way of highlighting where and how accessibility to the multifunctional qualities of greenery can be increased (Mathey et al., 2021). This can form a first step in planning, but where focus also needs to be put on the place specific context, since typologies are not fixed categories but similar spatial structures (Berghauser Pont, 2018). A benefit of using the four urban typologies; Mixed city, Million program, Nordic functionalism and Traditional neighborhood city is that they are connected to Swedish planning ideals. This constructs typologies which can be used for other Swedish cities than just Gothenburg, but yet again with consideration of the local context.

When looking at the time periods of the planning ideals used in this thesis, there is not an urban typology representing the time period of the late 1980s and 1990s. During this time period, a more post-modernist focus was present in Swedish planning, but this planning ideal has not really put its mark on the neighborhoods of Gothenburg (Planning and Building Authority, 2008). This is due to several factors, where one is the focus on rebuilding and maintenance rather than advocating for new buildings projects, due to a lack of economic finances from the Swedish state during this time (National Board of Housing, Building and Planning 2007). This led to an exclusion of buildings implemented with this ideal, and since all private stand-alone houses also were excluded, this highlights how the perspective of urban typologies will be limited in providing a perspective for the city as a whole.

To be able to provide a rich picture of the urban typologies, a mixed method approach was used in this thesis. A mixed method approach can be used to incorporate findings which cannot be obtained by only one method (Bryman, 2012) where the interviews contributed to a better understanding of the composition of greenery, as well as the strengths and challenges with these forms of greenery, than what could have been obtained by only including quantitative comparisons. Respectively, only incorporating interviews would not have shown the differences between the typologies as clearly as could be done by the detailed mappings of greenery and the related calculations. The limitations with choosing a mixed method approach is however the difficulties of providing the same depth as could have been done with only choosing one method (ibid).

6.2.2 Determining Boundaries and the Issue of Scale

In the general overlook of greenery in the urban typologies, a layer of all the neighborhoods which represented an urban typology was used, but since the boundaries of the neighborhoods determine what is being calculated, it is important to consider what is included inside the boundaries and what is not. To reduce this issue, a systematic approach of determining boundaries after natural barriers, mainly roads, was undertaken, but boundaries are always subjective assessments which will influence how results are interpreted.

Additionally, the spatial expression of each urban typology will also influence the interpretations of the results. For example, in many neighborhoods of the Million program and Nordic functionalism typology, greenery is included in the residential area, whereas smaller pocket parks can be seen connected to but not always inside neighborhoods of the Mixed city and the Traditional neighborhood city. This due to different trends in implementation of greenery, where focus in this thesis has been put on acknowledging the intended plans. One example is the study site of Kvillebäcken East (Figure 15), where a park located in the eastern part of the site was seen as connected to the neighborhood. This since the park was implemented at the same time as the rest of the neighborhood and was possibly implemented to increase the otherwise little amount of greenery inside of the residential area. A different interpretation of the spatial expression could exclude connected parks in the Mixed city and the Traditional neighborhood city, and further lead to an interpretation of less vegetation in these typologies than was shown in this study. With this said, there could also be parks in proximity to neighborhoods in the Mixed city and the Traditional neighborhoods city, but these were not included. These green spaces outside residential areas are still important for heat mitigation and accessibility to greenery, where a different picture of the typologies could be retrieved if greenery in proximity to the neighborhoods were included in the analysis.

Put together, it is important to consider how the results are influenced by grouping neighborhoods into urban typologies, and the matter of scale. When data representing spatial patterns is collected from smaller areas and put into larger categories, the heterogeneity generally becomes smoothened and this can affect the interpretation of the results, as the categories can look homogenous, but have large variations if viewed on a smaller scale (Jelinski & Wu, 1996, Dark & Bram, 2007). Jelinski and Wu (1996) suggests different actions to acknowledge this problem, where one is to recognize the heterogeneity of spatial patterns on the lower scale, and analyze how these patterns are represented when scaling up. In this study, this was done by analyzing the variance of land cover from NMD in all of the neighborhoods to make sure that the urban typologies consisted of neighborhoods with similar attributes, and would be represented in a good way when scaling up these spatial patterns.

6.2.3 Limitations in Choice of Data

The analysis based on the descriptive statistics of land cover in all the neighborhoods representing an urban typology, contributed to a better understanding of the limitations of the chosen data. Regarding land cover in the neighborhoods of the Mixed city typology, there were several neighborhoods that did not include buildings, and in the RGB orthophoto from 2019, it was only demolition work and preparations for these new Mixed city areas that was present. Since the national land cover data (NMD) from 2018 did not represent these areas in an accurate way, some neighborhoods from the Mixed city typology were removed, and new calculations of the land cover fractions in the neighborhoods were conducted. Still, there is a possibility that the mixed city neighborhoods were not as well represented as the other typologies, due to the analysis being based on fewer neighborhoods than the other typologies, and that the vegetation might not have reached the intended expression in the neighborhoods that were included.

Another limitation in the choice of data was the CDSM from 2010. This data represented the vegetation relatively well in the three older typologies of Traditional neighborhood city, the Nordic functionalism and the Million program, as well as the neighborhoods in the Mixed city that have existed for a while, but not for the newly built areas. Some recently built areas had been removed in the process of calculating land cover, and the updated CDSM layer from 2021 covering the recently implemented area of Kvillebäcken East was added to minimize this issue. Even if these actions were conducted, there could still be areas in the Mixed city typology that have changed a lot during recent years, which are not well represented in this layer, and where the vegetation volume and mean tree height should be viewed in light of this possible misrepresentation.

6.2.4 Limitations in Choice of Methods

When analyzing connectivity, the study sites showed a large variation, where it is difficult to confidently say that the degree of connected greenery is related to the form of the urban typology, rather than other factors. Since the planners highlighted fragmentation in relation to typologies, with the Mixed city composed by more fragmented greenery and the Nordic functionalism typology more connected greenery, there might be reason to further explore this relationship, but this could not be shown with the chosen method. The degree of connectivity was calculated through areal form factor (Equation 1), but there are many other methods of calculating fragmentation that could be applicable for understanding connectivity in urban typologies, and further show different results than was seen in this study.

One issue with the classification of the different types of vegetation was the shading in orthophotos. This was especially a problem with the Traditional neighborhood city and the Mixed city typology which consists of dense environments. Additionally, it was difficult to conduct field study visits in these typologies, due to the clear private sphere with enclosed courtyards which. Fortunately, one visit to an enclosed courtyard in the area of Linné, and several in Kungsladugård were conducted and confirmed that most of the greenery was classified correctly. However, as expected, some smaller green elements had been missed alongside the buildings, due to the shading of orthophotos.

Regarding the share of green elements that was obtained through the detailed mappings of greenery in the study sites, the percentage of grass is possibly a bit larger in reality than seen in this study. This since there is often grass below the trees, but this was not considered in the mapping process. The percentage of trees should also be taken with consideration, since there were different methods of mapping trees in rows and the trees standing more freely, as well as difficulties mapping the center of the canopy equally for all kinds of trees. Even if the share of trees could have been affected by the chosen methods, deciduous trees and grass were often the most prominent elements, and a bit smaller or larger degree of these elements would probably not change the trends of greenery that was seen in the study sites.

6.3 Further Research

An area that was touched upon with the forms of greenery in the Mixed city typology, was the possible cooling effect of water bodies and rain gardens. In this thesis, focus was put on greenery and heat stress, but further studies including different kinds of blue-green infrastructure, and the qualities of both heat stress and water management, could benefit a broader perspective of climate adaptation in Gothenburg. With a perspective of blue-green infrastructure instead of only urban greenery, it would also be possible to see which elements that can provide viable measures for different climate related hazards, and tradeoffs with choosing elements that provide heat mitigation in relation to elements which provide water management.

In this thesis, the differences of the urban typologies in providing social qualities from greenery was lifted by the planners. With future in depth studies, it would be interesting to see how greenery in the urban typologies is perceived by local inhabitants, since this can contribute to a better understanding of the social qualities from green spaces. Furthermore, this study used various datasets for obtaining a picture of how greenery was composed in the typologies, but it would be beneficial to compare how the amount of greenery in typologies differ between datasets. The amount of greenery in the city does in many ways determine if the city seems to have enough greenery, or if more should be implemented, where the level of detail and the resolution of the dataset will influence the interpretation of how much greenery that is seen in Gothenburg.

7. Conclusions

With the results from this mixed method study, the Million program and the Nordic functionalism typology were composed of large open green spaces, where a strength for heat stress mitigation is the large vegetation volume and the high degree of green land cover (about 60%). These typologies consisted of more traditional forms of vegetation, where a larger variation in types of greenery can add and enhance qualities from greenery. In the Mixed city, there was a larger variety of chosen green elements, but this typology and the Traditional neighborhood typology were composed of dense environments with little vegetation, where informants stated that it is difficult to provide space and good growing conditions for vegetation. In the latter two typologies, the highly programmed space leads to difficulties in adding new vegetation and with the current small amounts of greenery, this can reduce the possibilities for heat stress mitigation, as well other qualities of greenery. The spacious and free environment in the Nordic functionalism typology can in comparison to the other typologies be more easily changed without losing the intended design, which creates flexibility in adapting to a changing climate. This since it is difficult to know how challenges will turn out in the future, and if the challenges the city face today are replaced by new ones, flexibility acts as a strength. Today, large scale development projects are in accordance with the Mixed city ideal, where densification is expected for both new and older neighborhoods. This is a challenge for all the typologies, since with the low amount of vegetation in the current ideal, it is a challenge to preserve the current multifunctional qualities of greenery, as well as creating space for more vegetation in the future.

References

Balany, F., Ng, A. W., Muttil, N., Muthukumaran, S., & Wong, M. S. (2020). Green Infrastructure as an Urban Heat Island Mitigation Strategy—A Review. Water, 12(12), 3577. https://doi.org/10.3390/w12123577

Bellander, G. (2005). *Blandstaden- Ett planeringskoncept för en hållbar bebyggelseutveckling?* The National Board of Housing, Building and Planning

Blinge, K. (2021). Spatiotemporal changes in Gothenburg municipality's green space, 1986 to 2019. [Master thesis, University of Gothenburg]. Gothenburg University Publications Electronic Archive. https://gupea.ub.gu.se/handle/2077/68178

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Berghauser Pont, M. (2018). An Analytical Approach to Urban Form. In: Oliveira V. (eds) *Teaching Urban Morphology*. The Urban Book Series. Springer, Cham.

Bowler, D., Buyung-Ali, L., Knight, T., & Pullin, A. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health, 10*(1), 456.

Bryman, A. (2012). Social research methods (4th ed). Oxford ; New York: Oxford University Press.

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology*, *12*(3), 297–298. https://doi.org/10.1080/17439760.2016.1262613

Coccolo, S., Pearlmutter, D., Kaempf, J., & Scartezzini, J. L. (2018). Thermal Comfort Maps to estimate the impact of urban greening on the outdoor human comfort. *Urban Forestry and Urban Greening*, *35*, 91–105. https://doi.org/10.1016/j.ufug.2018.08.007

Coutts, A. M., Beringer, J., & Tapper, N. J. (2007). Impact of increasing urban density on local climate: Spatial and temporal variations in the surface energy balance in Melbourne, Australia. *Journal of Applied Meteorology and Climatology*, *46*(4), 477–493. https://doi.org/10.1175/JAM2462.1

Dark, S. J., & Bram, D. (2007). The modifiable areal unit problem (MAUP) in physical geography. *Progress in Physical Geography*, *31*(5), 471–479. https://doi.org/10.1177/0309133307083294

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., … Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*, *146*, 107–115. https://doi.org/10.1016/j.jenvman.2014.07.025

Dorst, Hade, Van der Jagt, Alexander, Raven, Rob, & Runhaar, Hens. (2019). Urban greening through nature-based solutions – Key characteristics of an emerging concept. *Sustainable Cities and Society*, *49*

Erell, E., & T. Williamson. (2007). Intra-urban Differences in Canopy Layer Air Temperature at a Mid-latitude City. *International Journal of Climatology* 27.9 (2007): 1243-255.

Erell, E., Pearlmutter, D., Williamson, T. (2010). *Urban Microclimate: Designing the Spaces Between Buildings*, Taylor & Francis Group

Gabriel, K. M. A., & Endlicher, W. R. (n.d.). *Urban and rural mortality rates during heat waves in Berlin and Brandenburg, Germany*. https://doi.org/10.1016/j.envpol.2011.01.016

Granberg, M.(2019). *Göteborgsregionen och klimatrisker- Klimatanpassning för dåtida och framtida bebyggelse*. Centrum för klimat och säkerhet, Karlstad Universitet.

Gunawardena, K. R., Wells, M. J., & Kershaw, T. (2017). Utilising green and bluespace to mitigate urban heat island intensity. *Science of the Total Environment*, *584–585*, 1040–1055. https://doi.org/10.1016/j.scitotenv.2017.01.158

Hess, A., Wadzuk, B., & Welker, A. (2021). Evapotranspiration estimation in rain gardens using soil moisture sensors. *Vadose Zone Journal*, *20*(1), 1–12. https://doi.org/10.1002/vzj2.20100

IPCC, 2014: Summary for policy makers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Jelinski, D. E., & Wu, J. (1996). The modifiable areal unit problem and implications for landscape ecology. In Landscape Ecology (Vol. 11).

Kleerekoper L., Kluck J., van den Dobbelsteen A. (2017). Selection Support Framework Fostering Resilience Based on Neighbourhood Typologies. In: Leal Filho W., Keenan J. (eds) Climate Change Adaptation in North America. Climate Change Management. Springer, Cham. https://doi-org.ezproxy.ub.gu.se/10.1007/978-3-319-53742-9_20

Klingberg, J., Konarska, J., Lindberg, F., Johansson, L. & Thorsson, S. (2017). Mapping leaf area of urban greenery using aerial LiDAR and ground-based measurements in Gothenburg, Sweden. Urban Forestry & Urban Greening, 26, 31-40

Kohout, M., & Kopp, J. (2020). Journal of Environmental Planning and Management ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cjep20 Green space ideas and practices in European cities Green space ideas and practices in European cities. European Cities, Journal of Environmental Planning and Management, 63(14), 2464–2483. https://doi.org/10.1080/09640568.2020.1716698

Konarska, J., Lindberg, F., Larsson, A., Thorsson, S., & Holmer, B. (2013). Transmissivity of solar radiation through crowns of single urban trees-application for outdoor thermal comfort modelling. https://doi.org/10.1007/s00704-013-1000-3

Konarska, J., Uddling, J., Holmer, B., Lutz, M., Lindberg, F., Pleijel, H., & Thorsson, S. (2015). *Transpiration of urban trees and its cooling effect in a high latitude city*. https://doi.org/10.1007/s00484-015-1014-x

Kong, F., Yin, H., James, P., Hutyra, L. R., & He, H. S. (2014). Effects of spatial pattern of greenspace on urban cooling in a large metropolitan area of eastern China. Landscape and Urban Planning, 128, 35–47. https://doi.org/10.1016/j.landurbplan.2014.04.018

Lewis-Beck, M., Bryman, A., & Futing Liao, T. (2004). Snowball Sampling. The SAGE Encyclopedia of Social Science Research Methods. (Vols. 1-0). Thousand Okes, CA: Sage Publications, Inc. doi: 10.4135/9781412950589

Lewis-Beck, M., Bryman, A., & Futing Liao, T. (2012). Informant Interviewing. The SAGE Encyclopedia of Social Science Research Methods, 493–494. https://doi.org/10.4135/9781412950589.n429

Li, D., Bou-Zeid, E., & Oppenheimer, M. (2014). The effectiveness of cool and green roofs as urban heat island mitigation strategies. Environmental Research Letters, 9(5), 055002. https://doi.org/10.1088/1748-9326/9/5/055002

Lindberg, F., Holmer, B., Thorsson, S., & Rayner, D. (2013). *Characteristics of the mean radiant temperature in high latitude cities-implications for sensitive climate planning applications*. https://doi.org/10.1007/s00484-013-0638-y

Lindberg, F., Thorsson, S., Rayner, D., & Lau, K. (2016). The impact of urban planning strategies on heat stress in a climate-change perspective. *Sustainable Cities and Society*, *25*, 1–12. https://doi.org/10.1016/j.scs.2016.04.004

Lindberg, F., Grimmond, C. S. B., Gabey, A., Huang, B., Kent, C. W., Sun, T., … Zhang, Z. (2018). Urban Multi-scale Environmental Predictor (UMEP): An integrated tool for city-based climate services. Environmental Modelling and Software, 99, 70–87. https://doi.org/10.1016/j.envsoft.2017.09.020

Lobaccaro, G., & Acero, J. A. (2015). Comparative analysis of green actions to improve outdoor thermal comfort inside typical urban street canyons. Urban Climate, 14, 251–267. https://doi.org/10.1016/j.uclim.2015.10.002

Mathey, J., Hennersdorf, J., Lehmann, I., & Wende, W. (2021). Qualifying the urban structure type approach for urban green space analysis – A case study of Dresden, Germany. Ecological Indicators, 125. https://doi.org/10.1016/j.ecolind.2021.107519

Meerow, S. (2020). The politics of multifunctional green infrastructure planning in New York City. Cities, 100, 1–27. https://doi.org/10.1016/j.cities.2020.102621

Middel, A., & Krayenhoff, E. S. (2019). Micrometeorological determinants of pedestrian thermal exposure during record-breaking heat in Tempe, Arizona: Introducing the MaRTy observational platform. Science of the Total Environment, 687, 137–151. https://doi.org/10.1016/j.scitotenv.2019.06.085

The Museum of Gothenburg, The Planning and Building Authority. (1999). *Kulturhistoriskt värdefull bebyggelse i Göteborg, ett program för bevarande Del I.* The Museum of Gothenburg, The Planning and Building Authority

The Museum of Gothenburg, The Planning and Building Authority. (2017). *Moderna Göteborg, Kulturhistoriskt värdefull bebyggelse del III*. The Museum of Gothenburg, The Planning and Building Authority.

The National Board of Housing, Building and Planning. (2020, 3/6). *Under miljonprogrammet byggdes en miljon bostäder*. Retrieved 2021-04-28 from https://www.boverket.se/sv/samhallsplanering/stadsutveckling/miljonprogrammet/

The National Board of Housing, Building and Planning. (2007). *Bostadspolitiken- Svensk politik för byggande och planering under 130 år.* The National Board of Housing, Building and Planning

Oke, T., Mills, G., Christen, A., & Voogt, J. (2017). *Urban Climates*. Cambridge: Cambridge University

Omitaomu, O., Kotikot, S., & Parish, E. (2021). Planning green infrastructure placement based on projected precipitation data. *Journal of Environmental Management, 279*, 111718.

Park, J., Kim, J. H., Lee, D. K., Park, C. Y., & Jeong, S. G. (2017). The influence of small green space type and structure at the street level on urban heat island mitigation. Urban Forestry and Urban Greening, 21, 203–212. https://doi.org/10.1016/j.ufug.2016.12.005

The Planning and Building Authority. (2008). Stadsbyggnadskvaliteter, Göteborg. The Planning and Building Authority

The Public Health Agency of Sweden. (2018). *Värmestress i urbana utomhusmiljöer- Förekomst och åtgärder i befintlig bebyggelse.* The Public Health Agency of Sweden: https://www.folkhalsomyndigheten.se/publicerat-material/publikationsarkiv/v/varmestress-i-urbana-utomhusmiljoer--forekomst-och-mojliga-atgarder-i-befintlig-bebyggelse/

The Public Health Agency of Sweden. (2019). *Värme och människa i bebyggd miljö- Kunskapsstöd för åtgärder som minskar hälsoskadlig värme.* The Public Health Agency of Sweden: https://www.folkhalsomyndigheten.se/publicerat-material/publikationsarkiv/v/varme-och-manniska-i-bebyggd-miljo--kunskapsstod-for-atgarder-som-minskar-halsoskadlig-varme/

Rocklöv, J., & Forsberg, B. (2008). The effect of temperature on mortality in Stockholm 1998—2003: A study of lag structures and heatwave effects. Scandinavian Journal of Public Health, 36(5), 516–523. https://doi.org/10.1177/1403494807088458

Rusche, K., Reimer, M., & Stichmann, R. (2019). Mapping and assessing green infrastructure connectivity in European city regions. *Sustainability (Switzerland)*, *11*(6). https://doi.org/10.3390/SU11061819

Statistics Sweden (SCB). (2021, 2/22). *Folkmängd i riket, län och kommuner 31 december 2020 och befolkningsförändringar 1 oktober–31 december 2020*. Retrieved: 2021-05-04 from https://www.scb.se/hitta-statistik/statistik-efteramne/befolkning/befolkningens-sammansattning/befolkningsstatistik/pong/tabell-och-diagram/kvartals--och-halvarsstatistik--kommun-lan-och-riket/kvartal-4-2020/

Shashua-Bar, L., Pearlmutter, D., & Erell, E. (2009). The cooling efficiency of urban landscape strategies in a hot dry climate. Landscape and Urban Planning, 92(3–4), 179–186. https://doi.org/10.1016/j.landurbplan.2009.04.005

Sjöman-Deak, J. (2016). The Hidden landscape (2016, 3). [Doctoral thesis]. Swedish University of Agricultural Sciences

Srivanit, M., & Hokao, K. (2013). Evaluating the cooling effects of greening for improving the outdoor thermal environment at an institutional campus in the summer. Building and Environment, 66, 158–172. https://doi.org/10.1016/j.buildenv.2013.04.012

Sun, R, & Chen, L.(2012). How Can Urban Water Bodies Be Designed for Climate Adaptation? *Landscape and Urban Planning* 105.1-2, 27-33.

The Swedish Environmental Protection Agency. (2020). *Nationella marktäckedata - ett nationellt system för information om landskapet och dess förändringar.* The Swedish Environmental Protection Agency

Swedish Meteorological and Hydrological Institute (SMHI). (2019, 4/11). *Gröna tak, fördjupning*. SMHI. Retrieved 2021-05-03 from https://www.smhi.se/klimat/klimatanpassa-samhallet/exempel-pa-klimatanpassning/grona-tak-fordjupning-1.116956

Thorsson, S. (2012). *Stadsklimatet Åtgärder för att sänka temperaturen i bebyggda områden*. (FOI-R--3415—SE). FOI, University of Gothenburg

Thorsson, S., Rayner, D., Lindberg, F., Monteiro, A., Lutz Katzschner, &, Kevin, &, Holmer, B. (2017). *Present and projected future mean radiant temperature for three European cities*. https://doi.org/10.1007/s00484-017-1332-2

Vaz Monteiro, M., Doick, K. J., Handley, P., & Peace, A. (2016). The impact of greenspace size on the extent of local nocturnal air temperature cooling in London. Urban Forestry and Urban Greening, 16, 160–169. https://doi.org/10.1016/j.ufug.2016.02.008

Ward, K., Lauf, S., Kleinschmit, B., & Endlicher, W. (2016). Heat waves and urban heat islands in Europe: A review of relevant drivers. *Science of the Total Environment*, *569–570*, 527–539. https://doi.org/10.1016/j.scitotenv.2016.06.119

Yang, G., Yu, Z., Jørgensen, G., & Vejre, H. (2020). How can urban blue-green space be planned for climate adaption in high-latitude cities? A seasonal perspective. Sustainable Cities and Society, 53, 101932. https://doi.org/10.1016/j.scs.2019.101932

Yu, Z., Fryd, O., Sun, R., Jørgensen, G., Yang, G., Özdil, N. C., & Vejre, H. (2020A). Where and how to cool? An idealized urban thermal security pattern model. *Landscape Ecology*. https://doi.org/10.1007/s10980-020-00982-1

Yu, Z., Yang, G., Zuo, S., Jørgensen, G., Koga, M., & Vejre, H. (2020B). Critical review on the cooling effect of urban blue-green space: A threshold-size perspective. Urban

Forestry and Urban Greening, 49(February), 126630. https://doi.org/10.1016/j.ufug.2020.126630

Zinko, U., Ersborg, J., Jansson,U., Pettersson, I., Thylén, A., Vincentz, R. (2018). *Grön infrastruktur i urbana miljöer*. Nordic Council of Ministers

Appendix I

All land cover categories (NMD)	**Grouped categories**
Övrig öppen mark med vegetation *Våtmark*	Grass
Tallskog utanför våtmark *Granskog utanför våtmark* *Barrblandskog utanför våtmark* *Lövblandad barrskog utanför våtmark* *Triviallövskog utanför våtmark* *Ädellövskog utanför våtmark* *Triviallövskog med ädellövinslag utanför våtmark* *Temporärt ej skog utanför våtmark* *Skog på våtmark* *Tallskog på våtmark* *Granskog på våtmark* *Barrblandskog på våtmark* *Lövblandad barrskog på våtmark* *Triviallövskog på våtmark* *Ädellövskog på våtmark* *Triviallövskog med ädellövinslag på våtmark* *Temporärt ej skog på våtmark*	Trees
Exploaterad mark, byggnad	Buildings
Exploaterad mark, ej byggnad eller väg/järnväg *Exploaterad mark, väg/järnväg*	Paved ground
Övrig öppen mark utan vegetation	Bare soil
Sjö och vattendrag *Hav*	Water

Appendix II

Interview Guide (Translated from Swedish to English)

Introduction

- Introduction of me, format of interview, the subject of the thesis and ask if the interview can be recorded
- Showing presentation (PowerPoint) of the urban typologies to confirm similar views on the typologies
- Warm up question about their working position, how long they have worked in the field

Interview

Planning for urban greenery

- Importance of urban greenery in cities
- Distribution of greenery in Gothenburg
- Greenery in new development projects
- Placement of greenery
- Trends
- Functions of greenery
- Conflict of interests

Future perspective

- Inhabitants needs today and in the future
- Heat stress
- Scale
- Climate adaptation
- Changed view on greenery

Greenery in urban typologies

- General form and composition in the four typologies
- Strengths
- Challenges

Showing diagrams

- Informants view on land cover differences in the four urban typologies
- Informants view on how the amount of greenery has changed in Gothenburg from 1986-2019

Appendix III

Table

Descriptive statistics of land cover in the neighborhoods representing the urban typologies.

Mixed City	**Trees**	**Grass**	**Buildings**	**Paved ground**	**Bare soil**	**Water**
Mean	0.097	0.150	0.283	0.443	0.010	0.018
Standard deviation	0.112	0.117	0.118	0.149	0.019	0.051
Range of values	0.471	0.447	0.405	0.670	0.079	0.234
Nordic Functionalism						
Mean	0.260	0.315	0.197	0.225	0.002	0
Standard deviation	0.094	0.087	0.056	0.081	0.004	0
Range of values	0.473	0.407	0.286	0.460	0.020	0
Million Program						
Mean	0.205	0.334	0.232	0.224	0.004	0
Standard deviation	0.094	0.102	0.063	0.105	0.009	0
Range of values	0.511	0.501	0.307	0.530	0.045	0
Traditional neighborhood city						
Mean	0.089	0.133	0.411	0.365	0.001	0
Standard deviation	0.049	0.084	0.082	0.077	0.005	0.002
Range of values	0.213	0.400	0.432	0.426	0.031	0.010

Appendix IV

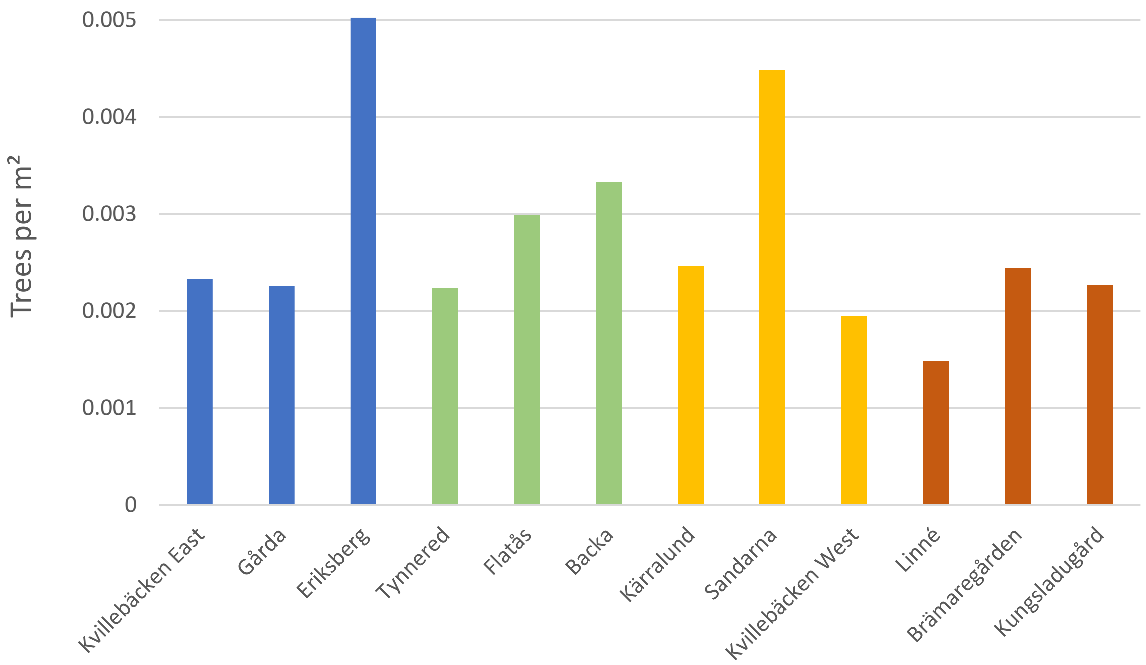

Figure: Diagram showing the number of trees per square meter in the study sites.

Appendix V

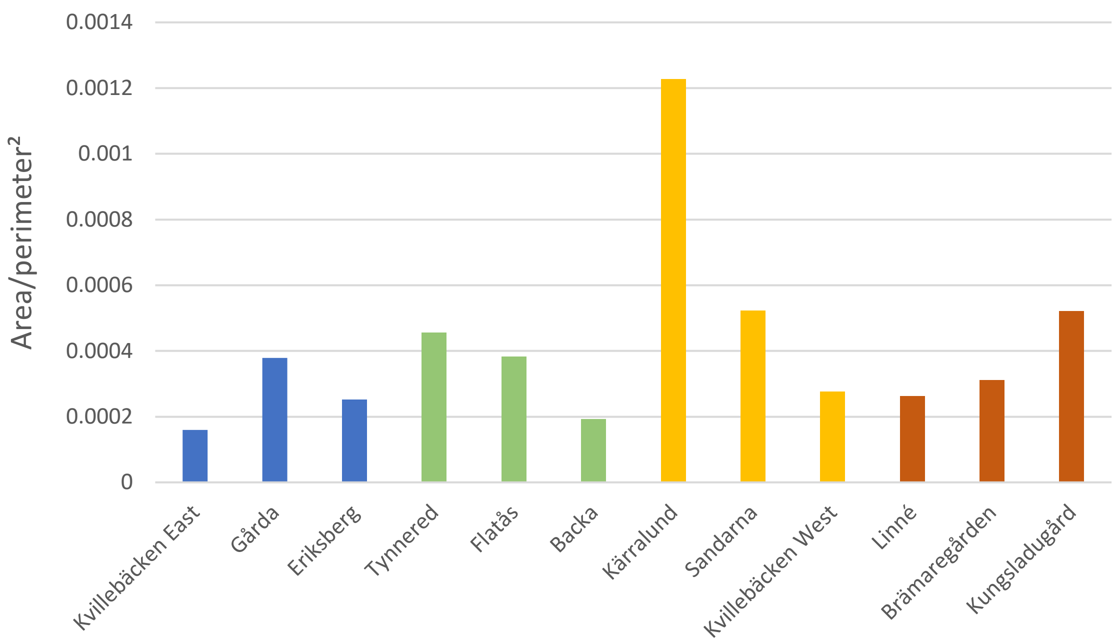

Figure: Diagram showing the degree of connected greenery in the study sites, where a higher value represents well connected greenery and a lower value represents more fragmented greenery.