Green space and sustainable stormwater management in a denser city

- An analysis of future scenario for urban development in Gothenburg

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Abstract

Population growth and urbanization increase the housing demand in cities. Densification with limited expansion has environmental and social benefits and is therefore a common development strategy. However, many interests must be balanced in urban planning and spaciousness, and green space especially, is important for sustainable and livable cities. Green Infrastructure (GI) provides Ecosystem Services (ES) that can be integrated with stormwater management in Sustainable Urban Drainage Systems (SUDS). SUDS are open systems for stormwater management that benefit from ES and improve resilience against flooding, which is a growing concern in many cities due to climate change.

Due to the shortage of housing in Gothenburg a project (BoStad2021) was established to test if an intensified planning process was suitable to enhance development. The aim of this study was to investigate the development potential for urban growth in Gothenburg and predict if GI and SUDS can be integrated in an intensified planning process. Six limiting criteria for housing development were identified from a policy document analysis and used to determine the potential for housing development through a Multi-Criteria Evaluation in a geographical information system. Planning strategies observed in approved detailed development plans in BoStad2021were then used to predict a future scenario for how GI and SUDS can be integrated in the development.

The result showed that not all land is needed for the planned growth of the city. Preservation of green areas are positive both for social, ecological and resilience aspects, especially since little land is dedicated for SUDS in the development plans. Furthermore, such trends are possible as the population density still would be lower than recommendations. However, the analysis also showed that green space often gets developed and even areas of importance for the mentioned aspects. However, traffic infrastructure is over-dimensioned in the potential area and there is interest for reducing the soil sealing which could generate sustainable development.

Keywords: Densification; Green Infrastructure (GI); Urban Planning; Geographical Information System (GIS); Sustainable Urban Drainage Systems (SUDS); Multi-Criteria Evaluation

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1. Introduction

There has been a rapid population growth throughout the world since 1950 and the biggest increase has occurred in cities, where over half of the world's population now lives (54% in 2014) compared with 30 percent in 1950 (UNDESA, 2014). The urbanization trend puts pressure on space in cities which together with climate change increases the need to transform how cities are built and actively work for "Sustainable cities and communities", which is one of the Sustainable Development Goals (SDG 11) in Agenda 2030 (UN General Assembly, 2015). The growing pressure for land in and around cities affects the availability and distribution of green space or urban green infrastructure. Green infrastructure (GI) was introduced as a concept to give a holistic approach to green space in planning and emphasize the importance of an inter-connected structure (Sandström, 2002). GI is vital since nature provides services that directly or indirectly contributes to satisfy human needs, so-called Ecosystem Services (ES) (De Groot, 1992). Some ES can only be provided at-site, such as recreation, and others are largely affected by the surrounding landscape and are hence dependent on connectivity of GI (Andersson *et al.*, 2014). ES make cities more livable, sustainable and increase the capacity to withstand and recover from disturbance (resilience) (Andersson et al., 2014; Jim and Tan, 2017). The more high-tech societies that we have today are also more sensitive and this together with climate change makes ES increasingly important (Sörensen, Persson, *et al.*, 2016).

The annual precipitation as well as the frequency of cloudburst is predicted to increase in Sweden due to the global warming (SOU 2007:60). A sustainable stormwater management is therefore needed, particularly since constructions of roads, parking lots and buildings make urban areas more vulnerable to pluvial flooding, as soil sealing reduces the infiltration capacity (Sörensen, Persson, *et al.*, 2016). Stormwater has traditionally been managed through pipe-based drainage systems, designed to drain stormwater from the urban area as fast as possible (Starhe, 2008). The capacity of a closed system is always limited and the stormwater network in Sweden is dimensioned to handle a rainfall amount that statistically occurs every tenth year, which sometimes will be exceeded (Sörensen, Johansson, *et al.*, 2016). Sustainable Urban Drainage Systems (SUDS) are alternative stormwater management systems constructed to resemble the natural water flow which can reduce runoff peaks by enhancing infiltration and slowing down upstream runoff (Read *et al.*, 2016). SUDS can be a compliment and alternative to the traditional grey infrastructure with stormwater management through pipes (Stahre, 2008). The flexibility of the system makes it more robust against weather extremes and it has the potential of also providing additional ES and becoming a positive resource in the urban environment (Ullstad, 2008). However, with the high demand for urban land, SUDS are not always prioritized in planning (Sörensen, Johansson, *et al.*, 2016).

In Sweden, the proportion of the population living in cities is expected to be around 90 percent in 2050 as compared to 66 percent in 1950 (UNDESA, 2014). Housing shortages is at the same time a problem in many Swedish cities and the contemporary strategy has been to accommodate urban growth through densification (Swedish National Board of Housing, 2017). Densification increases the carrying capacity within the existing city structure which preserves the surrounding land, improves the social sustainability, and decreases the environmental impact (ibid.). Densification can sometimes occur at the expense of green space but availability of nature is important for sustainable and livable cities (Ståhle, 2010). Other types of open space, e.g. parking lots and abandoned land can instead be used and if consciously done, such densification can improve the livability of the urban environment even if the spaciousness is decreased, especially if patches of green are added alongside the new establishment (Ståhle, 2008).

Gothenburg, the second largest city in Sweden, faces development challenges with increased job opportunities that attract new people combined with a housing deficiency. Due to residency constraints the out-migration to the surrounding areas in 2017, was the largest since 1974 (Göteborgs Stad, 2018a). The urban development of Gothenburg until 2035 is focused on densification of the outer sub-urban parts and an area referred to as *Mellanstaden* (Göteborgs Stad, 2018c). *Mellanstaden* is also the study area for this thesis. An investigation of the planning and building capacity in Gothenburg was done in 2014 which showed that the development speed during the 21th century on average had been 2,000 apartments/year, which follows the population increase but is insufficient to reduce the shortage of housing (Göteborgs Stad, 2015a). The initiative BoStad2021 was therefore initiated by the City of Gothenburg (here after also referred to as "the municipality"), aiming to boost the housing market with an additionally 7,000 residencies between 2015 and 2021, when the city is celebrating its 400-years jubilee (Göteborgs Stad, 2015b). To achieve this an accelerated planning process is needed and the project is monitored by an independent research panel from Chalmers University of Technology that analyzes the work to see if the same process can be recommended for other projects in the future (Svensson *et al.*, 2017). The average handling time in BoStad2021 has been reduced from 30 to 20 months compared to the normal process (Svensson et al. 2018). One thing that the researchers have seen is that the time constraints may push other aspects aside such as GI and access to nature, which risk having implications on the overall quality of the development (Svensson *et al.*, 2018).

The aim of this study is to investigate the development potential for housing in Gothenburg until 2035 and to predict if GI and SUDS can be integrated concurrent with the planned urban growth. By setting up a scenario with constraints that were identified in the City of Gothenburg's policy documents, the land potential could be defined using Multi-Criteria Evaluation in a geographical information system. Approved detailed development plans (here after referred to as development plans) in BoStad2021 were analyzed regarding how the development influences the availability of GI and SUDS.

Research questions

- Is the availability of potential land sufficient to accommodate the predicted urban growth in Gothenburg until 2035?
- How can GI and SUDS be incorporated in the development based on the land use and circumstances from approved detailed development plans within BoStad2021?

2. Method

The analysis is separated into two parts, the first comprises the housing development in *Mellanstaden* which is the main area for development until 2035, and the second one is focused on BoStad2021. The two parts are finally combined to predict future scenarios for the housing development in Gothenburg and how GI and SUDS can be expected to be incorporated. The land potential in *Mellanstaden* was analyzed starting with a policy analysis to determine criteria that would be used for a Multi-Criteria Evaluation to identify the available land for housing development. Planning strategies used in BoStad2021 were then identified in the second part by studying approved development plans, both through a document analysis and a geographical analysis. A future scenario for Gothenburg was finally predicted where the land potential and the strategies in the development plans were compared with the municipality's goals for population growth. A summary of the method is presented in a schematic diagram (fig. 1).

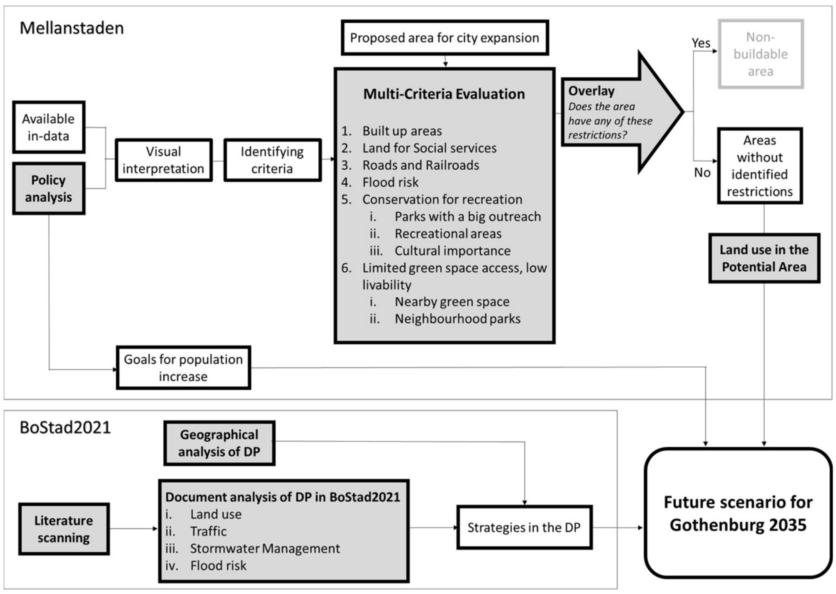

Figure 1: A schematic diagram showing the different steps in the analysis, where grey boxes represent methodological steps and white boxes represents inputs and outputs.

2.1 Case study – *Mellanstaden* in Gothenburg

Gothenburg is situated in the western part of Sweden at the river Göta Älv and is the second largest Swedish city with 564,039 inhabitants (2017) (Göteborgs Stad, 2018c) (fig. 2). The city is growing, and a yearly population increase with on average 7,400 residents are expected until 2035 (ibid.). Plans to accommodate this growth are based on densification within already built-up areas, and the development strategy until 2035 is mainly directed at the outer sub-urban parts, referred to as *Mellanstaden*. Many people are already living in this area which means that there is good access to public transport and mixed functions with workplaces and services, but where further development is still considered possible (Göteborgs Stad, 2014a). *Mellanstaden* is the focus area for this thesis and the boundaries were hence used as the border for the geographical analysis throughout the Multi-criteria Evaluation (fig. 2). *Mellanstaden* is predicted to have a total potential of additional 45,000-55,000 residences and 15,000 out of these are prognosticated until 2022 (Göteborgs Stad, 2014a). The construction time for the remaining residences is uncertain and will depend on influencing factors such as market forces and politics.

Figure 2: Illustration image showing the location of the study area, *Mellanstaden*, in Gothenburg (Göteborg). *Mellanstaden* is the area sourranding the city center.
Gothenburgs position in Sweden are shown to the right. Source: GoogleMaps

2.1.1 Development Strategies

The municipality's goal is a denser Gothenburg with increased accessibility and a viable city life (Göteborgs Stad, 2014a). Liveliness makes cities attractive, but spaciousness and preservation of GI are also important for sustainable growth (Gehl, 2004). UN Habitat (2015) recommends a minimum population density of 150 residents/ha for sustainable urban development where the suitability for biking and walking can be kept even for larger cities. This is also acknowledged as a good city density by the City of Gothenburg, making it possible to have a good variety of shops and working places (Göteborgs Stad, 2014a). Gehl (2004) suggests an even higher city density of 280 people/ha. These numbers can be compared with a middle-sized Swedish city with approximately 40-60 people/ha (including suburbs with private gardens), and the much denser historical Venice with 2000 people/ha with restricted street space for cars and enhanced walkability (Rådberg, 2014; Gehl, 2004).

The City of Gothenburg has composed three strategic documents that stretches until 2035 and should lead the development for *Mellanstaden* besides the legally required comprehensive plan[1], which applies for the whole geographical area. These documents are a General development plan[2], a Traffic strategy[3], and a Green strategy[4] for preserving green qualities. These documents were studied to identify restrictions for housing development. The focus was on: Transportation and parking issues, Flood risk, Stormwater management, and Access to green space. Other policy documents that are important regarding the planning of these issues were further studied. These were: A Policy for parking[5], Guidelines for mobility and parking[6], Suggestion for a comprehensive plan about flooding[7], a Document about stormwater management in plan areas[8] and finally, a Manual for stormwater management in planning[9]. The restrictions are presented in the sections below and later used to, through a Multi-

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[1] In Swedish: Översiktsplan, (Göteborgs Stad, 2009a)

[2] In Swedish: Strategi för Göteborg 2035, Utbyggnadsplanering, (Göteborgs Stad, 2014a)

[3] In Swedish: Göteborg 2035, Trafikstrategi för en nära storstad, (Göteborgs Stad, 2014b)

[4] In Swedish: Göteborg, Grönstrategi för en tät och grön stad, (Göteborgs Stad, 2014c)

[5] In Swedish: Parkeringspolicy för Göteborgs Stad, (Göteborgs Stad, 2009b)

[6] In Swedish: Riktlinjer för mobilitet och parkering i Göteborgs Stad, (Göteborgs Stad, 2018b)

[7] In Swedish: Förslag till Översiktsplan för Göteborg, tillägg för översvämningsrisker, (Göteborgs Stad, 2017)

[8] In Swedish: Dagvatten inom planlagda områden, (Göteborgs Stad, 2001)

[9] In Swedish: Dagvatten, så här gör vi. Handbok för kommunal planering och förvaltning, (Göteborgs Stad, 2010)

Criteria Evaluation determine the land potential for housing development in *Mellanstaden* (section 4.2.3).

Transportation and parking issues

The municipal traffic strategy aims to reduce the car-based transportation in Gothenburg with 25 percent between 2011 and 2035 (Göteborgs Stad, 2014b). This goal will demand active measures and investments in alternative transportation not to instead become a 35 percent car increase (ibid.). Walking and transportation by bike or public transport should be doubled, even if it should still be possible to travel by car, as maintained accessibility is considered important (ibid.). Densification and decreased distances through mixed land use is acknowledged as two ways of reducing the car dependency in Gothenburg (ibid.). The traffic system was largely built during a time when separation of different transportation modes was normal, and the infrastructure is hence often over-dimensioned (ibid.). Transformation of the street space can therefore be used for densification and impediments around traffic structures and ground parking is especially interesting for housing development (ibid.). A more attractive urban environment should be prioritized above car parking and an improved public transport gives room for cutting the number of parking spaces and removing the surplus that exists in some areas (Göteborgs Stad, 2009b). Removing the most visually unattractive parking spaces should be prioritized and the parkings that still are needed should primarily be placed in garages (Göteborgs Stad, 2014b; Göteborgs Stad, 2009b). In new developments flexible guidelines for the number of parking spaces should be applied, with a focus on mobility that reduces the need to own a car, i.e. enhances the possibilities for other transportation modes (Göteborgs Stad, 2018b).

Flood risk

The City of Gothenburg has an ongoing climate adaptation work which so far primarily has been focused on the exposure to flooding for the urban area due to sea level rise and the increased water levels in the river Göta älv (Göteborgs Stad, 2017). A specific comprehensive plan[10] for flooding is about to be implemented (ibid.). This plan also concerns flooding from cloudbursts and smaller watercourses that the municipality so far has not had any strategies for (ibid.). The flood risk due to heavy rainfall is increasing both because of climate change and since improvements along the river aiming to protect low lying areas also affects the runoff (ibid.). The City of Gothenburg uses *planning levels*[11] as a restrictive measure to reduce the flood risks in

[10] In Swedish: Fördjupad Översiktsplan

[11] In Swedish: Planeringsnivåer

new developments, and the planning for cloudburst is suggested to be dimensioned for 0.5-meter floods and an expected return period of 100 years, a so called 100-year event (ibid.). The strategy is to primarily locate new residences in areas without any flood risk and to have climate adaptation through technical solutions only if it is motivated (ibid.).

Stormwater management

Stormwater management should be considered early in the planning process to make room for strategically planning, independent of whether the measures are to be implemented by the public, the estate owner or collectively (Göteborgs Stad, 2010). The main strategy is that the stormwater should be handled locally and as close to the source as possible, preferably at the dwelling unit (ibid.). SUDS are preferable both since the water can be used as a resource in the urban environment and as it helps to preserve the groundwater at a good level (ibid.). However, economic aspects are furthermore important for choosing between different systems and an acceptable solution with the lowest possible construction and running costs should be prioritized (Göteborgs Stad, 2001). The planning description in the development plans is used to specify the need and conditions for the control of stormwater within the planning area. Factors such as hydrogeology, the status of the recipient and the characteristics of the pollutants should be taken into account when deciding on the alternatives for stormwater management and direct transportation to the municipality's pipe network should only be applied if it is the only possible solution (Göteborgs Stad, 2010).

Green Infrastructure

In Gothenburg, larger parks and nature areas are seen as important for the city profile and the municipality's aim is to provide a good access to different forms of green space throughout the city (Göteborgs Stad, 2014c). However, green spaces are not inherently valuable for humans, and the functionality of a place should therefore be considered in planning (Ståhle, 2010). Sociotope assessment is a system that the City of Gothenburg uses as a support tool in urban planning to value and classify GI depending on what motivates people to visit a certain place and its functions. Examples of classes are *"rest"*, *"picnic"* and *"exercise"*. Another categorization used to classify the green space is the size. The four classes used (with decreasing sizes) are: Larger nature and recreational areas, City Parks[12], City district parks[13] and Nearby parks/nature close to people's homes[14].

Larger green areas, such as City Parks and Larger nature and recreational areas, with many sociotope values should be preserved (Göteborg, 2014c). People also appreciate having maintained green areas close to their homes. Furthermore, green space is important for health and wellbeing. The City of Gothenburg works towards a norm that a City district park (larger than 2 hectares) should be within one-kilometers reach from people's homes. In addition, smaller parks or nature[15] (>0.2ha) should be within 300 meters from both working places, schools and people's homes (ibid.). These parks should provide the sociotope values *"rest"* or *"meeting place"* in order to achieve "A good built environment"[16] in accordance with Sweden's National Environment Objective[17] for 2020 (ibid). Smaller green spaces or nature are especially important for elderly and children who generally are less mobile and hence more dependent on the nearby surroundings (ibid.). Accessibility is equally dependent on physical and psychological barriers in the city structure and the City of Gothenburg aims for that parks should be reachable also in this perspective, meaning that larger roads, streams, and topological barriers should not be in the way of accessing the green space (ibid.).

The number of users that share space is a measure to ensure that cities and neighborhoods have satisfactory living conditions (Ståhle, 2010). For Gothenburg a minimum value of 10m^2 green space per person has been suggested (Spacescape, 2013). In the Green strategy it is stated that the total park area should be enough to fulfill the recreational needs of a growing population and still have a well-preserved quality (Göteborgs Stad, 2014c). A measure for user stress is not included in the development strategy however, as this also depends on the terrain of the park and which sociotope functions the park should provide (ibid.)

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[12] In Swedish: Stadspark

[13] In Swedish: Stadsdelsparker

[14] In Swedish: Bostadsnära natur

[15] In Swedish: Bostadsnära parker/natur

[16] God bebyggd miljö

[17] National Environment Objective = Miljömål, number 15

2.2 Multi-Criteria Evaluation for *Mellanstaden*

The land potential was identified using Multi-Criteria Evaluation in a geographical information system (GIS) with identified constraints for urban development. GIS is a common tool for assisting decision makers in urban planning and is especially useful when applied early in the planning process (Criado *et al.*, 2017). There are two methods that typically are used for GIS-based Multi-Criteria Evaluation (Eastman, 1999). The constraint method has previously been the most common especially for analysis of vector data, in which the geographical data is analyzed as map features (ibid.). The second method is more common today as it goes beyond nominal criteria (i.e. "suitable" or "unsuitable") (Gül, Gezer and Kane, 2006). Multi-Criteria Evaluation is a vast task that involves many steps, from data gathering and structuring, criteria identification, evaluation and spatial simulation, especially for the second method, which foremost makes it applicable for long term planning and major projects (Joerin, Thérialult and Musy, 2001). Because of the time constraints for the scope of this study, a vector-based Multi-Criteria evaluation with factors that are constraining housing development was performed. A similar study was preformed by Criado *et al.* (2017) that used restrictive criteria to determine the most environmental suitable sites for urban expansion of Zamora, Spain. In that study, the analysis was taken further by differentiating the suitable areas according to the construction costs (ibid.). The aim of this thesis is to identify the land potential in *Mellanstaden*, economic favorable locations are better evaluated by planners and investors and are hence not considered here. However, the suitability of development regarding to the land use is analyzed and discussed in later stages of the thesis, which is an alternative way to provide some sort of validation within the founded land potential (section 4.2.4).

2.2.1 Identifying criteria

The development potential was estimated based on selected themes that were considered critical for hindering development in Gothenburg. There is no common practice of selecting criteria and the themes vary broadly between different studies. These might include environmental and technical factors, such as geology, hydrology and vegetation as well as economic aspects for suitability (Hill, FitzSimons and Pearson, 2009; Joerin et. Al, 2010; Criado *et al.*, 2017). The criteria selection in one analysis is hence not directly applicable to other studies and the selection should instead be based on the specific context, which also provides flexibility (Gül, Gezer and Kane, 2006). Decisionmakers are often consulted to identify criteria but the advanced task gives ground for the evaluator to make these decisions independently (Joerin, Thérialult and Musy, 2001).

The land potential in *Mellanstaden* was evaluated based on six constraints which were identified from the findings in the policy analysis of the City of Gothenburg's strategy documents (flood risk, conservation for recreation, and green space access), and furthermore selected based on their restrictiveness for new housing development due to practical reasons (built-up areas, land with social services, and roads and rail roads). The selection was also restricted to the available data found during the course of this study. The themes are neither comprehensive nor do they represent the only possible criteria and a broader approach would potentially improve the results but also require more resources (Hill, FitzSimons and Pearson, 2009). With a large spatial scale, which is the case for this study, a high level approach is adequate as localized issues are not the most prominent aspect for the assessment (Watson and Hudson, 2015). A fine-tuning site location considering locally important variables can instead be performed by the decision maker at a later stage (ibid.).

2.2.2 Input data and method for visual interpretation

The geographical data for the analysis was either provided directly from contact with the City of Gothenburg or downloaded from electronic sources (table 9 in appendix). Most of the input data derives from the electronic source "Geodata Extraction Tool" provided by the Swedish University of Agricultural Science (SLU). Decisions about the classification of the in-put data were sometimes required and this was done through comparing the geographical data with an aerial photograph of the city. The aerial photograph that were provided from the City of Gothenburg was captured in 2015 and more recent satellite images in Google Earth Pro was therefore at times also used (Google Inc, 2017). This method of looking for elements of recognition and use e.g. size, shape and shadows to manually extract information from images are called visual interpretation and is a common technic in GIS (Olsen, 2007). Visual interpretation is a time-consuming process and it was hence not possible to fully cover the whole study area. The visual interpretation was instead done through a stratified selection by generating random coordinate locations[18] within *Mellanstaden* and thereafter creating circular investigation zones around the midpoint[19] (table 10 in appendix). A restriction of a minimum distance of 1 kilometer was used to fit an expanded area with a 500-meter radius around the coordinates, this gave room for 25 sites (fig. 3).

[18] *Data management Tool - Create Random Points*

[19] *Analysis Tool – Proximity - Buffer*

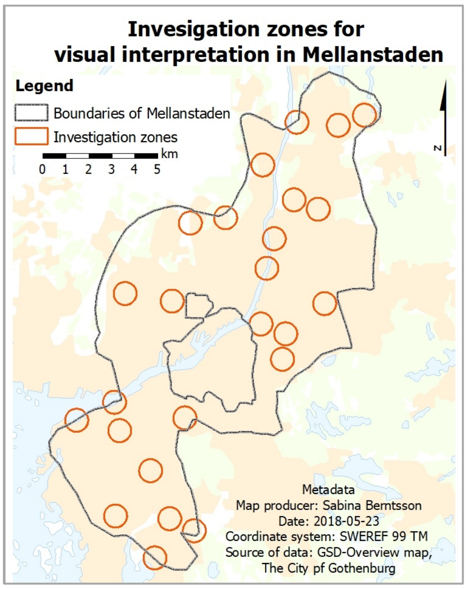

Figure 3: The location of the 25 investigation sites in *Mellanstaden* that were used for the visual interpretation of the input data.

2.2.3 Geographical Analysis of the different criteria

The different criteria were first analyzed individually, and the GIS-process for doing so is described in the sections below.

Existing built-up areas

Already built-up areas are for practical reasons generally not open for new development and were removed from the land potential. Houses classified as "*residences*", "*business*", "*industries*", or "*public functions*" were identified and a buffer distance of 8 meters was applied around these buildings since this is the legally allowed minimum distance between buildings because of fire security reasons (BBR 5:61). Polygons classified as "*accessory buildings*" were not included in the analysis since the visual interpretation revealed that this class commonly consisted of small annex buildings and garages that might be possible to replace with an increasing demand for housing.

Land for social services

A larger restriction for development was applied for areas used by the national defense and emergency services (hospitals, fire departments, and police stations) because its importance for the society and a greater need for accessibility. The whole property area was therefore removed from the analysis. The surroundings around schools were furthermore treated differently due to the importance of providing playground areas. The visual interpretation of buildings marked as schools revealed that the buildings often were part of larger dwelling units that also included structures with other primary functions. Bigger schools were named in the sociotope map which hence enabled a more restrictive selection, and the whole dwelling unit was only removed if "school" was included in the name in the sociotope map which was performed by Attribute Selection in GIS[20].

Roads and Rail roads

Transport infrastructure is necessary for mobility and roads and railroads were hence removed from the development potential. The most accurate datasets for the location of the infrastructure were available as line layers and needed to be transformed to an area which was done in different ways for roads and railroads. Railroads were identified by combining the land use classification dataset with the more precise line layer aiming to improve the selection. Areas classified as *"Rail"* were hence only removed if they intersected with the overlaying line layer. The dataset for roads had attribute information about width which could be used to determine the area by using the *Buffer tool* where a buffer was created based on the attribute field with the halved road width.

Flood risk

The City of Gothenburg have, as a prevention strategy, mapped the risk of flooding from cloudburst and aim to restrict new development from the hazard zones in order to reduce risks. The planning level that should be used is 0.5 meter for 100-years events (Göteborgs Stad, 2017). This was hence used as limiting for new housing development in this analysis. Results from a stormwater modelling were downloaded from a web page[21] provided by the municipality. The stormwater model is based on a 2D-hydraulic runoff model and is supposed to be used in planning strategies. The dataset was classified into two categories depending on if it is suitable to exploit or not according

[20] Query: "*Sociotopna*" LIKE '%*skola*%'. After the Swedish word for school, "skola".

[21] Vatten i staden - https://www.vattenigoteborg.se/home?site=sky

to the set dimension level[22], the cells that could be developed were then transformed to vector format[23] and used to remove unsuitable parts of *Mellanstaden*[24].

Conservation for recreation

Areas important for recreation are valuable to preserve, and parks that have an big outreach, churches and graveyards and finally larger sportsgrounds were hence considered restrictive areas for development. The sociotope map was used to remove the highest ranked parks, which are parks that have a and are important for people living in the city district or the whole of Gothenburg[25]. Churches and graveyards were identified both based on surface area classification of the GSD Topographical Property Map and if the name in the sociotope map contained the word "church"[26]. Other recreational areas were considered restrictive for development if they were located in areas that also were classified as important for the neighborhood in the sociotope map[27].

Green space access

Access to green space is important to ensure satisfying living conditions in new developments and both smaller parks closer to the home and larger parks in the neighborhood should be provided. Smaller parks were identified from the sociotope map based on an attribute selection of areas that were classified as *"rest"* or "*meeting places"*[28] both within and outside of *Mellanstaden*. Polygons smaller than 0.2 hectares were removed from the selection and thereafter were buffer zones of the restriction of 300 meters applied around the polygons. The same practice was also done for the larger parks but using a size limit of 2 hectares and 1-kilometer distance instead.

The parks should furthermore be reachable without any blocking larger roads, water or steep slopes. However, slopes were not included in this analysis due to limitations in data processing time since this showed to be a highly demanding data analysis.

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[22] *Spatial analysis – Reclass - Reclassify*

[23] *Conversion Tool – From Raster – Raster to Polygon*

[24] *Analysis Tool – Overlay - Erase*

[25] *Select by attributes* in the Attribute table

[26] Query: "*Sociotopna*" LIKE '%*kyrk*%'. From the Swedish word for church, "kyrka".

[27] *Select by Location* – Spatial selection method – *Intersect the source layer*

[28] Query:"Sociotopvä" LIKE '%Vi%' OR "Sociotopvä" LIKE '%V' OR "Sociotopvä" LIKE '%Mp%'
"Vi" or "V" for the Swedish word for rest, "Mp" for the Swedish word for meeting place

Access in relation to water was investigated in the same way for both nature types using water surfaces and watercourses wider than 6 meters. Roads were considered more limiting for the smaller parks that should be easily accessible for children to allow spontaneous play and the selection was done based on the road type[29], where roads with a speed limit more than 50km/h were considered a barrier to the neighborhood parks. The obstructive roads were saved in a separate file and used for splitting the zones around the two park types[30]. The parts that connected to the parks were then selected[31] and stored in a new layer. The same procedure was done with water barriers before the two layers were merged[32]. The policy is that both larger parks and smaller green spaces should be accessible and was hence necessary to identify[33]. Other parts can of course also be developed, but the planning should in that case also include constructing of new green areas. The layer with high nature values was finally combined with the identified areas that have satisfactory access to nature, to show a combined potential considering green space and recreation.

2.2.4 Combining the criteria

All areas without restriction from the geographical analysis of the different criteria were combined in a multi-way analysis[34] to a map of the total land potential (fig. 4). One restriction was consider enough to eliminate the area from urbanization (Criado *et al.*, 2017). If the answer was *"Yes"* to the question "*Does the area have any of these restrictions?"*, the area was excluded from the land potential in *Mellanstaden*. That one single constrain hinders development can be motivated when the city does not have problems with space for expansion which makes it possible to live up to all requirements to achieve a sustainable expansion that also provides a good livability (Criado *et al.*, 2017).

[29] *Wider public roads, Motorways and Through streets.*

[30] *Select the splitting features. Advance Editing – Split polygons*

[31] *Select by Location – Spatial selection method – Intersect the source layer*

[32] *Data Management - Merge*

[33] *Select by Location – Spatial selection method – Intersect the source layer*

[34] *Data Management - Merge*

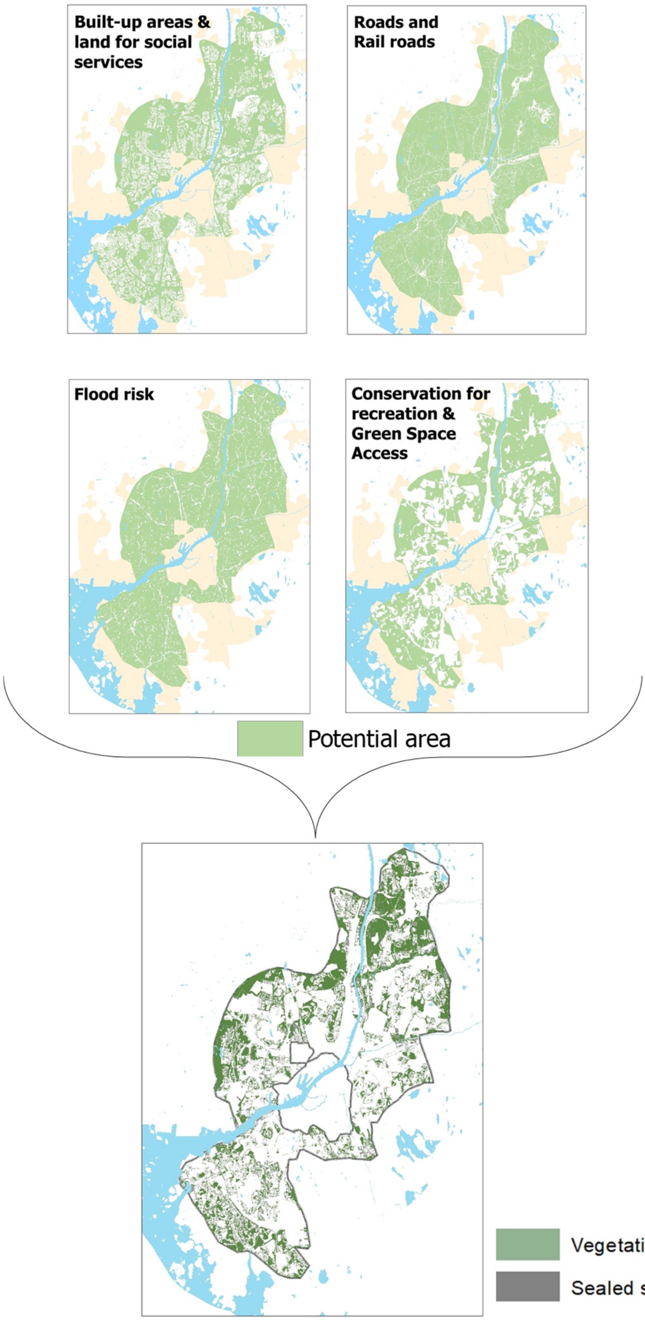

Figure 4: Illustration of the potential area of the different cotraints separeted in four different maps, and how they were combined to get the proportion of vegetation and sealed surface in *Mellanstaden*.

2.2.5 Land use in the Potential area

The properties of the land potential were further investigated by determining the current distribution of buildings, other sealed surfaces and vegetation. The first step was to reclassify the data set of the existing land use. In this reclassification the classes *"gravel"*, *"paved"*, *"road"* and *"rock"* was reclassified as *"sealed surface"*, *"forests"* and *"other vegetation & pervious"* was reclassified as *"green space"* and finally the class *"buildings"* which already was a class in the original dataset. The proportion of sealed surface contra vegetation in the potential area for development within *Mellanstaden* was then determined by extracting the area without any constraints from the reclassified land use data set[35].

2.3 Analysis of BoStad2021

2.3.1 Literature scanning

For the second part of the analysis that regarded the development plans in BoStad2021, a literature scanning was performed to create a theoretical basis before the document analysis and get an insight into how GI and SUDS can be integrated in a city concurrent with densification. Several literature searches were done in the bibliographic database *Web of Science Core Collection* by combining different search words into queries with Boolean operators. The database tracks the research impact of the articles and these statistics were used to single out highly cited articles or literature reviews to get an insight into the field and to understand core aspects, i.e. to find descriptions of different types of measures for SUDS, which made it possible to identify important search words. The literature search was then narrowed down by refining and modifying the results to get a workable number of relevant articles. The title, keywords, and the abstract were primarily used for the selection, as the aim was to obtain an overview of the field rather than complete cover of certain subjects or aspects. The qualitative focus made it possible to stop whenever theoretical saturation was perceived which for this study was considered as the empirical material concerned similar themes or didn't raise any new central aspects (Bryman, 2008). Cited references for the different articles were furthermore reviewed to make use of previous research and broaden the search field through the so-called "snowball effect". A disadvantage with the snowball effect is that it is solely applicable to distinguish earlier published articles,

[35] *Analysis tool - Extract - Clip*

but with the combination of more recent literature is it nevertheless a suitable method (Harboe, 2013).

2.3.2 Document analysis of development plans in Bostad2021

The development actualized in BoStad2021 was attained through a document analysis of valid development plans deriving from findings in the literature scanning and the selected themes and search words that were investigated are summarized in table 2. The document analysis was conducted at the end of January 2018 and covered 14 development plans that had gained legal force at that time. The planning documents were available online through a portal at the City of Gothenburg's web page (Göteborgs Stad, n.d.). The selection was done based on the project name *"BoStad 2021"*, limited to *"Current Establishment Projects"*[36] and *"Valid Plans"*[37] and resulted in 28 development plans. Of those, 14 development plans had the stated status *"Legally binding"*[38] and were hence selected for the analysis. The documents were primarily analyzed based on the planning description that is a text document linked to the development plans. The planning description is not legally binding, compared to the plan map, but the implementation of the plan map depends on the planning description (SFS 2010:900, 6 ch. 2§), which describe the aim of the plan, potential issues regarding the implementation, expected consequences and finally suggestions of how they are supposed to be managed (SFS 2010:900, 4 ch. 33§). Through the planning description it is possible to in detail describe how issues such as stormwater management are supposed to be handled and which end-effects that are desired, but regulations are only applicable if they are motivated based on that the municipality are responsible to ensure that the ground is suitable for construction both due to the conditions in the area and in consideration to e.g. water issues and human safety (SFS 2010:900, 2 ch. 4-5§) and since the municipality is responsible for the sewer system (LAV 6§). The City of Gothenburg lifts the planning description as important for the planning process, and stresses that the need and conditions for *Source Control*, i.e. local retention and infiltration of stormwater management in the area should be raised (Gothenburg, 2010).

[36] In Swedish; *"Pågående byggprojekt"*

[37] In Swedish; *"Gällande planer"*

[38] In Swedish: *"Laga kraft"*

Table 2: Framework used to analyze the themes, Land Use, Traffic and Stormwater Management, for the planning documents around the development plans. The themes are further separated into topics to describe the context around of each Swedish search word.

Theme	Topic	Search words
Land use	Strategies for urban growth	Addition to existing buildings (*påbygg**), Demolishing of current structures (*riv**) Transformation of open space (*gård, grön*, naturm*, gräs, park*, lekplats, rekr*, boll, grus, asfalt, gångv**)
	Compensation arrangements	Compensate (*kompensera*)
	Influence on trees	Tree (*träd*)
Traffic	Land use for parking lots	Parking (*parkering*)
	Opportunities for reduced parking need	Agreements for reduced parking (*grönplan, reducerad)* Public transport (*kollek**).
Stormwater management	General conditions	Stormwater (*dagvatt**) Pipe system and the capacity (*ledning, komb*, kapac*).
	Stormwater management measures	Onsite Control (*lokalt* and *LOD*), Transport (*avled**).
	Extreme events	Heavy rainfall (*skyfall*)

Each planning description was analyzed based on the representation of three main themes; Land use, Traffic and Stormwater Management. Specific search words within every topic were determined based on the literature scanning and used to limit the scope of the analysis (table 2). Changes in urban land use were interesting since building density and the provision of green space directly affects the infiltration capacity and hence stormwater run-off (Thoni, 2017). Traffic issues covered how parking space was supposed to be managed and if any agreements to reduce the mandatory parking minimums have been initiated, both as parking lots can be used for urban development and since it is land demanding and leads to soil sealing with reduced infiltration capacity. Other mobility alternatives were further included by access to public transport. Finally, stormwater management was identified in the planning description and through the Stormwater Investigation[39] that had been compiled as a decision basis for all except two development plans (Plan-1 and Plan-4).

[39] In Swedish; Dagvattenutredning

Stormwater investigations are commonly conducted prior to the establishment of the development plans to more deeply investigate how the stormwater can be managed and was studied here to get a better picture of which measures that were suggested and on which level they would be applied (*Source Control*, *Onsite control*, *Slow transport* or *Downstream control*).

2.3.3 Geographical Analysis of the development plans

The geographical analysis of the development plans in Bostad2021 was performed to extract the old land-use distribution that was categorized as *"buildings"*, *"sealed surface"* or *"green space"* before becoming developed into houses and parking. In this section the GIS technicalities are explained further.

Predicted land use changes were analyzed in areas planned for new residencies as well as areas for parking spaces that would need land-surface. The in-put data for the analysis are presented in table 3 below. Illustration images for the establishment plans in the development plans were downloaded as PDF-files and transformed to make them applicable for geographical analysis. The process was to capture an image of the illustration and change the format using MS-Office. The image was then added into the geographical information system and geographically located through georeferencing with two or three control point's connected to a reference layer that was an aerial photograph uploaded in a geodetic reference system. The accuracy of the links was evaluated, and the image was rectified and saved in a data format that contains spatial information (TIFF). This file was used to digitize the map objects of interest into a shapefile using the tool *Create features* in the Editor toolbox.

Table 3: Information about the input-data used for this part of the analysis.

Dataset	Content	Source
Illustration images of development plans	Plans for establishment	Göteborgs Stad
Aerial photograph	Captured in 2015	Göteborgs Stad
Land use classification	Land use data produced by photogrammetry based on the aerial photograph	Göteborgs Stad, DHI

The land use changes were evaluated in the next step based on a dataset with a classification of existing land use that had been reclassified into *"buildings"*, *"sealed* *surface"* and *"vegetation"* (described in section 2.2.5). The accuracy of the classification within the plan areas was investigated prior to the analysis using the aerial photograph from 2015 and more recent photos in Google Earth to assure its validity since the file had been produced by automatic classification. A change in land use was found for Plan-3 where a parking deck had been demolished and replaced by ground parking on a gravel surface.

The digitized layer over the planned changes was combined with the existing land use into a single layer by a method that keeps all information in the attribute table[40]. The surface area of the different map classes was then calculated[41] and stored in an added field in the attribute table[42]. This data could then be exported to Excel[43] and used to calculate statistics and percentage of different forms of land use changes.

2.4 Future scenario for Mellanstaden

A future scenario for *Mellanstaden* was predicted based on the available land without any of the restrictions, the land use in the area and the potential for urban growth which the City of Gothenburg have estimated to possibly reach up to 45,000-55,000 new apartments (Göteborgs Stad, 2014a) (fig. 1). The average household size has steadily increased in Gothenburg during the last seven years, from 2.08 people in 2010 to 2.14 people in 2017 (SCB, 2017). The statistics represent the whole city but gives an indication of the household size in *Mellanstaden* and since the increase have been consistent, the latest number of 2.14 people were used in the calculation. This, together with the mean value of 50,000 new appartments, results in an estimation of a population increase of 100,000 people in *Mellanstaden*. The available ground to accommodate this growth was obtained from the geographical analysis and is 4,086 hectares of land. This gives a population density of 24 people/ha if all land would be used for urban development.

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[40] *Overlay - Intersect*

[41] *Calculate Geometry Tool* in the Attribute Table.

[42] *Table options - Add field*

[43] *Conversion Toolbox - Table to Excel*

3. Result

3.1 Potential in *Mellanstaden*

Based on the analysis of the restrictions for exploitation, 4,086 hectares of land is available to accommodate the population increase in *Mellanstaden*. About 79 percent, consists of land that currently are covered with some sort of vegetation (fig. 5). Almost all the remaining land (20%) are in the class for sealed surfaces (excluding buildings) that mainly consist of parking lots. There are also a small proportion (1%) of supplement buildings for example garages (fig. 5).

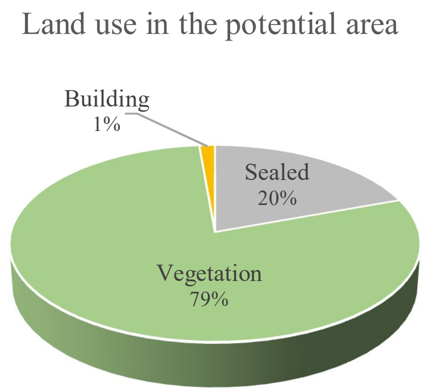

Figure 5: Pie chart showing the land use distribution in the identified potential area of *Mellanstaden*. The three classes used are: vegetation, buildings and other sealed surfaces.

3.2 Planning strategies in BoStad2021

The size of the development plans BoStad2021 varies from 55 residencies in the smallest development plan (Plan-5) to over 500 in the largest plans (table 4). Plan-10 is the largest plan with 550 new residencies but it is going to be exploited in parts and only 310 apartments are included in BoStad2021 which instead makes Plan-12 the largest plan with 530 new dwellings. The City of Gothenburg is a big land owner within *Mellanstaden* and possess most of the land for the development plans in BoStad2021 (11 out of the 14 Plans), (Göteborgs Stad, 2014a).

Table 4: Basic information about the development plans in BoStad2021 that were analyzed. The property code is an identification number used by the City of Gothenburg.

Development plan	Property code	No. of apt.	Land owner	Densification Strategy
Plan-1	BN0815/14	97	The City of Gothenburg	Infill
Plan-2	BN1052/15	197	Privat	Re-generation
Plan-3	BN0516/14	307	The City of Gothenburg	Infill
Plan-4	BN1099/15	180	The City of Gothenburg	Additions
Plan-5	BN0424/13	55	Privat	Infill
Plan-6	BN0667/14	320	The City of Gothenburg	Re-generation
Plan-7	BN0351/14	178	The City of Gothenburg	Infill
Plan-8	BN0559/14	80	The City of Gothenburg	Infill
Plan-9	BN0541/13	290	Privat	Infill
Plan-10	BN0441/14	550, (310)	The City of Gothenburg	Infill
Plan-11	BN0557/14	125	The City of Gothenburg	Infill
Plan-12	BN0349/14	530	The City of Gothenburg, Privat	Infill
Plan-13	BN0350/14	500	The City of Gothenburg, Privat	Re-generation, Infill
Plan-14	BN0363/14	114	The City of Gothenburg	Re-generation, Additions, Infill

The literature scanning revealed that the methods for densification are diverse and does not always require exploitation of land. On the contrary, it can occur by increasing the capacity of structures within the existing city e.g. by adding additional floors in a building (Additions), through the furnishing of attics or by demolishing current buildings and constructing new on the site (Re-generation) (Swedish National Board of Housing, 2017). Transformation of open space is an additional method for densification which either can be done through infill, when unused land is redeveloped without changes in the present city structure or by extensive city transformations such as the redevelopment of abandoned brownfields or industrial sites (ibid.). The most common densification method for the development plans in BoStad2021 is infill and it is used for nine development plans and part of the strategy for additionally two (table 4). Two of the development plans includes additions, Plan-4 is entirely constructed by adding new floors on existing apartment buildings and in Plan-14 is the need for new parking spaces solved by increasing the height of the existing P-deck (table 4). Plan-2 and Plan-6 are done through Re-generation of current structures where Plan-2 is planned on a previous industrial site and Plan-6 at the land of a closed school.

3.2.1 Transportation and parking issues

The analysis of development plans in BoStad2021 showed that the existing parking stock generally is underutilized and hence possible to optimize as the new areas are developed, both by removing parking lots but also by building new residencies without constructing any new parking. For nine of the fourteen development plans, a surplus of parking space is available adjacent to the plan area (table 5), which hence be utilized to live up to the given parking number by the municipality. Parts of Plan-3 is located at the site of a previous parking deck that was demolished due to a reduced demand amongst the residents in the area, this made it further possible to develop the area with a reduced parking number. However, new parking lots are nevertheless necessary in this development plan due to the new establishment, which are planned to be solved by construction of a P-deck and large areas of ground parking, which have been motivated because of repeated car vandalism in the old garage. Ground parking is land demanding and are commonly not used, parking spaces are instead often located in underground garages, which is the case for six of the development plans (Plan-2, Plan-6, Plan-8, Plan-10, Plan-12, Plan-13) (table 5). The construction cost for underground parking solutions is larger, and the developers have in several cases therefore been interested in using mobility arrangements e.g. provide access to car pools to reduce the parking needs amongst the tenants and thus develop the area with a reduced parking number after agreement with the municipality (table 5). The City of Gothenburg plan to focus on mobility in new developments and a policy document about how to use flexible guidelines for parking spaces in detailed development planning was recently approved (Göteborgs Stad, 2018b). In one of the development plans, Plan-10, an agreement of a green mobility plan between the developer and the municipality is in place, which made it possible to reduce the parking needs with 20 percent (table 5).

Table 5: Information about transportation and parking issues in the development plans in BoStad2021 that were analyzed.

	No. of P needed	No. of P constructed	Comment	P solution	Public transport
Plan-1	43	0	P available		Good
Plan-2	78	83		Underground garage	Very good
Plan-3			Low P demand. An old P-garage had been demolished	Garage Ground Parking	Very good
Plan-4	130	0	P available (172)		Good
Plan-5		14	Servitut agreement		Good
Plan-6	185	-	Applied for reduced P-no.	Underground Garage	Good
Plan-7	201 + 169	169 + 179		Ground Parking	Good
Plan-8	< 112	112		Underground Garage (86) Ground Parking (26)	Good
Plan-9	177 + 293			P-deck (209) Underground Garage (200) Ground Parking (56) (for visitors)	Good
Plan-10	845	676	Aggrement of -20%.	P-deck Underground Parking Ground Parking	Very good
Plan-11	75 + 424	79	P available (447)	P-deck (73)	Good
Plan-12			Possibly reduced P-no.	P-deck (700) Underground Garage (225) Ground Parking (25) Street Parking (40)	Very good
Plan-13	650	520	Possibly reduced P-no.	Underground Garage (520)	Good
Plan-14	96	106	P available	Existing P-deck (28) Underground Garage (43)	Good

3.2.2 Flood risk

Eight of the development plans are planned in areas that in some parts risk to be flooded with rainfall that has a 100-years return period. One of the plans, Plan-13, has a large risk of flooding since the topography leads the water towards the buildings and cut off possible stormwater passages. The ground is presently slowing down the runoff and the establishment will hence lead to an increased exposure for the adjacent area. Larger topographic depressions in both Plan-7 and Plan-12 risk to be flooded with a 100-year event. The changes with Plan-7 are furthermore problematic since an underground walking passage is planned to be removed, which will change the runoff patterns that currently are drained through the tunnel.

The drainage system is separated between sewerage water and stormwater for most of the development plans and only four sites have a combined system (table 6). This is positive in a flooding perspective since it reduces the risk of contaminated overflow from an overloaded pipe system which can have both health and economic implications *(Field, et al.*, 1998). The pipe network should be dimensioned for events with 10-years reoccurring time, but the capacity is limited at four sites which increase the need for measures for alternative stormwater management.

Table 6: Information about the flood risk and status of the pipe network for development plans in BoStad2021 that were analyzed.

	Status of Pipe network	**Risk of flooding**		**Status of Pipe network**	**Risk of flooding**
Plan-1	Combined	Low	**Plan-8**	Combined	Existing
Plan-2	Good	Existing	**Plan-9**	Good	Existing, outside the plan area
Plan-3	Good	No change	**Plan-10**	Limited	No change
Plan-4	Good	No change	**Plan-11**	Combined	Existing, small
Plan-5	Combined	No change	**Plan-12**	Good	Existing
Plan-6	Good	Existing	**Plan-13**	Limited	Large
Plan-7	Limited	Existing	**Plan-14**	Limited	No change

3.2.3 Stormwater management

The measures for SUDS can be separated into four categories depending on the size and where in the landscape they occur, and a summary of the different levels is presented in figure 6 below. The first category is *Source Control*[44] that consists of smaller measures to take care of stormwater run-off on private land (Stahre, 2008). The second one, *Onsite control*[45], is similar to *Source control* but occur on public land, which hence the municipality are responsible for. *Slow transport* is a term used for measures to slow down the runoff, e.g. through canals and ditches, which both increase infiltration and avoids peaks at the SUDS facilities (Marsalek and Chocat, 2002). The last category is *Downstream control* where the stormwater is assembled in larger volumes and managed on public land (Stahre, 2008). This is the lowest stage in the drainage system and usually consists of large water surfaces such as ponds and wetlands that receive stormwater from several plan areas (Marsalek and Chocat, 2002). Several SUDS measures can also be arranged in sequences which are called treatment trains (ibid.).

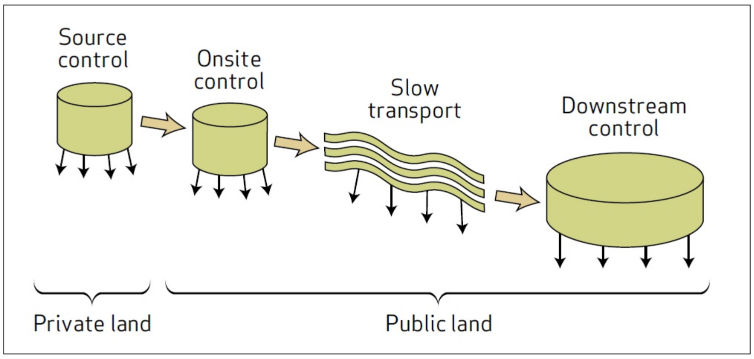

Figure 6: Four levels of Sustainable Urban Drainage System (SUDS) distributed from most upstream to downstream over private and public land. Source: (Stahre, 2008)

Developments often result in increased surface sealing and this is also the case for all but two of the development plans in BoStad2021 (Plan-2, Plan-6), which are re-generation projects and hence will reduce the amount of impermeable ground (table 4). The municipality is responsible to ensure that the development plan is safe and

[44] In Swedish; *Lokalt Omhändertagande, LOD*

[45] In Swedish; *Fördröjning nära källan*

possible to implement and have the mandate to impose safety measures according to the planning and building act (SFS 2010:900, 4ch.12§). In Plan-7 it is stated in the regulations of the plan map that no additional buildings are allowed on the backyard and that a volume of 2300m^2 should be possible to retain in the area. Municipality also have the authority to decide about the elevation and how the ground should be prepared (SFS 2010:900, 4ch.10§ and 16§1), which are fundamental for planning and a useful intervention for stormwater management. The City of Gothenburg have used this regulation in one case to explicitly regulate that a part of the public area in Plan-10 must not be sealed, and for two other development plans it is used to dedicate ground for SUDS. In Plan-3 the inner-courtyard in between some of the buildings is reserved for stormwater management and large parts of the private land that is not planned for residencies in Plan-6 should be available for stormwater management.

The documents revealed that the municipality require that stormwater runoff are reduced within the development district[46], with a minimum volume that is equivalent to 10mm/sqm of the expanded sealed surface due to the establishment. The retention demand is stated in the legally binding plan map for six of the development plans (Plan-2, Plan-3, Plan-6, Plan-7, Plan-8 and Plan-11) but without any specified quantities. The suggested SUDS are based on these values, which hence would be requirements for receiving building permission. Some of the establishments implies increased soil sealing on both public and private land which are treated separately since the municipality is responsible for the stormwater management on public land while the developer is responsible for installing measures on private land. Stormwater investigations have been done for all except two development plans and these twelve development plans have concrete suggestions for how the stormwater should be managed which are summarized in table 7. The development plans that do not have any specific suggestions for SUDS are Plan-4 that is development through additional floors in existing buildings and Plan-1 that is one of the smallest development plans with 97 new student apartments (table 4). Plan-4 does not increase the sealed surface and SUDS are hence not considered necessary. The information about stormwater management are furthermore limited in Plan-1 (table 7). The reasons for this are that no polluted runoff is expected, the high elevation makes the flood risk small and finally that the geological conditions makes it difficult to take care of stormwater onsite.

All the other development plans have suggestions of SUDS on private land and the two most common *Source Control* measures are *Bioretention areas*[47] and different forms

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[46] In Swedish: på kvartersmark

[47] The definition in Swedish are both *Växtbäddar* and *Regnbäddar*

of *Underground stormwater detention*[48], which are proposed for ten and eight of the development plans respectively (table 7). *Underground Stormwater Detention* is a common name for different forms of temporally storage of stormwater underground, and is an effective way of handling stormwater when the available land is limited (Marsalek and Chocat, 2002). The different types have different qualities depending on the material and some are foremost used for reducing pollutants while others have a large pore volume and can store large volumes of water (ibid). *Bioretention areas* are vegetated depressions where stormwater is gathered and managed by ground infiltration and water uptake in the vegetation (Matlock and Morgan, 2011). A layer of porous backfill are common under the *Bioretention areas* which filters the water from pollutions (ibid.). It is an effective way to reduce runoff, manage peak flow and to purify runoff on a small space, especially from commercial, industrial or residential sites (Wright *et al.*, 2016; Matlock and Morgan, 2011). Smaller versions of the *Bioretention areas* are called *Rain Gardens* and are normally located close to buildings and collects rainwater from the roofs and other impervious areas while at the same time providing decorative plantations (Matlock and Morgan, 2011).

Another measure to minimize the amount of sealed surface is to use *Permeable ground material* for infrastructures such as roads, walkways and parking lots (Blecken *et al.*, 2017). This is used as a *Source Control* in four development plans in BoStad2021 (Plan-3, Plan-7, Plan-12, Plan-13) (table 7). A problem with *Permeable material* is that the infiltration capacity is reduced over time without maintenance, as the material is getting clogged (Blecken *et al.*, 2017). Runoff from roofs can be reduced in a similar way by incorporating *Vegetated* or *Green Roofs*. The infiltration capacity of vegetated roof is dependent on the thickness and a greater depth can hold larger plants and more water (Matlock and Morgan, 2011). *Green roofs* are suggested as *Source Control* for two development plans (Plan-2, Plan-11), and for *Onsite Control* for additionally one (Plan-14) where a small building with a transformer station should be constructed with a *Vegetated roof* (table 7). Stormwater management as *Onsite Control* are necessary for 7 development plans in total as the impermeable surface on public land are increased (table 7). For all these are different types of *Underground stormwater detention* for *Onsite Control* also suggested (table 7).

Measures for *Slow transport* are by the definition located on *Public land* (fig. 6) but in BoStad2021 open drainage systems are planned both on private and public land where the purpose is to cut out runoff from the developing sites and increase the infiltration onsite. The aim is to direct and slow down runoff to avoid peaks in the stormwater systems (Marsalek and Chocat, 2002). It can furthermore reduce the stormwater by infiltration, either through bioretention e.g. swales, or by designed infiltration systems

[48] The tree types used are in Swedish named *Biofilter*, *Stenkista* and *Makadammagasin*

such as *Infiltration Trenches* that are backfilled with stones to enhance the infiltration and has the advantage of also improving the water quality as oil and grease are removed when the water is infiltrated through the ground (Matlock and Morgan, 2011). *Infiltration Trenches* are proposed on private land in five development plans and public land for three development plans in BoStad2021 (table 7). Another way of managing *Slow Transport* is by *Tree Box Filters* that usually are located around street trees and both provide temporary storage and pollution control for street runoff and are furthermore effective to ensure that the trees will achieve enough moisture (Matlock and Morgan, 2011). *Tree Box Filters* is suggested on private land for one development plan and public land for two development plans in BoStad2021 (table 7). Lastly open channels are planned to be implemented in eight development plans and foremost close to the buildings.

As a last stage, the stormwater is commonly drained in pipes which for the development plans in BoStad2021, often drains directly to in recipients such as streams, rivers or lakes and ponds. These are examples of *Downstream Control,* the forth category for storm water management (fig. 6). Other forms of SUDS measures for *Downstream Control* are more difficult to manage on a detailed development plan level, and it is only purposed in one of the development plans (Plan-3) as a possible compliment (table 7). Plan-10 is located close to a larger communal location for *Underground stormwater detention*, which is possible to use for stormwater management from the plan area, even if the aim is to primarily slow down the stormwater on-site (table 7). Modifications in the elevation to form larger depressions in the landscape that are dedicated for *Temporary flooding* where stormwater can be managed by infiltration and storage, are furthermore proposed as an alternative on private land for four development plans (Plan-3, Plan-6, Plan-12 and Plan-13) and on public land for two development plans (Plan-12 and Plan-13) (table 7).

Table 7: Stormwater management solutions for the development plans in BoStad2021. The measures are separated between the four levels of stormwater management (fig 6). In the table, the abbreviation UGSD is used for "*Underground stormwater detention*".

	Source Control	**Onsite Control**	**Slow Transport**	**Downstream Control**	**Area needed**
Plan-1					
Plan-2	Green roofs UGSD Bioretantion				Bioretention (320m^2)
Plan-3	UGSD Bioretantion Temporary flooding Permiable material Channales	UGSD	Infiltration Trenches		Förslag 1: Bioretention (572m^2) Temporary flooding
Plan-4					
Plan-5	Infiltration Trenches Channales				Infiltration Trenches (19m^2) Channels (8.4m^2)
Plan-6	UGSD (2) Temporary flooding (1) Infiltration Trenches (2)	UGSD		Possible Bioretention	Temporary flooding (110m^2 + oklart om yta i område 2) Makadamdike (366m^2)
Plan-7	Bioretention Permiable material Channales				Bioretention (1277 m^2) and Bioretention (537 m^2) Temporary flooding – mange 100-years event
Plan-8	UGSD - (1) Bioretention (3) Infiltration Trenches (2)				Not specified
Plan-9	UGSD Bioretention	UGSD			Bioretention (143 m^2) UGSD (146m^2)
Plan-10	UGSD Bioretention	UGSD		UGSD Tree Box Filters	Bioretention (1072m^2)
Plan-11	Bioretention Green Roof		Infiltration Trenches		Not specified, small.
Plan-12	UGSD Bioretention Temporary flooding Permiable material	UGSD Tree Box Filters	Infiltration Trenches	Temporary flooding	Bioretention (17m^2)
Plan-13	UGSD Bioretention Temporary flooding Permiable material Channels Infiltration Trenches	UGSD		UGSD Temporary flooding	Temporary flooding (1130m^2) – manage an 100-years event for parts of the area.
Plan-14	UGSD - (1) Bioretention (2)	UGSD Green Roof			Bioretention (146,5m^2)

3.2.4 Previous land use of the exploited areas

Which type of land that is exploited varies between the different development plans and is presented in figure 7. The total development of new houses and parking spaces in BoStad2021 is: 43 percent on vegetated land, 37 percent on sealed surfaces and finally 20 percent located at already built-up areas (fig. 9).

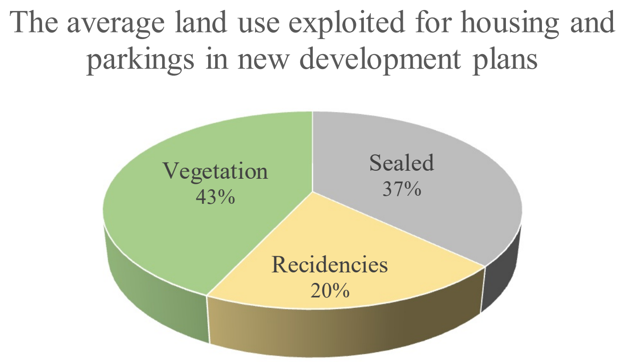

Figure 7: Pie chart showing the avarage land use distibution for areas that are planned to be exploited for housing and parkings in development plans in BoStad2021. The three classes used for current land use are: vegetation, buildings and other sealed surfaces.

It is primarily the development plans that consist of additions on existing land and regeneration that represent the statistical share that is located on already built-up areas (table 4, fig. 7). Many of the development plans are built on vegetated land and half of the plans (Plan-1, Plan-3, Plan-5, Plan-7, Plan-8, Plan-9 and Plan-11) use more than 50 percent from previously vegetated areas (fig. 8). The development that occur on already sealed surface is commonly at sites that previously were used for parking, which is the case for seven of the plans (Plan-3, Plan-7, Plan-9, Plan-10, Plan-11, Plan-12, Plan-13). The need for new parking spaces was also investigated and is presented in table 5. The variation of how much land that is used for parking spaces is large between the different development plans. The highest proportion, which is found in five of the development plans, is where more than 30 percent of the exploitation are due to construction of different forms of parking solutions (Plan-3, Plan-7, Plan-11, Plan-12, Plan-14) (fig. 8).

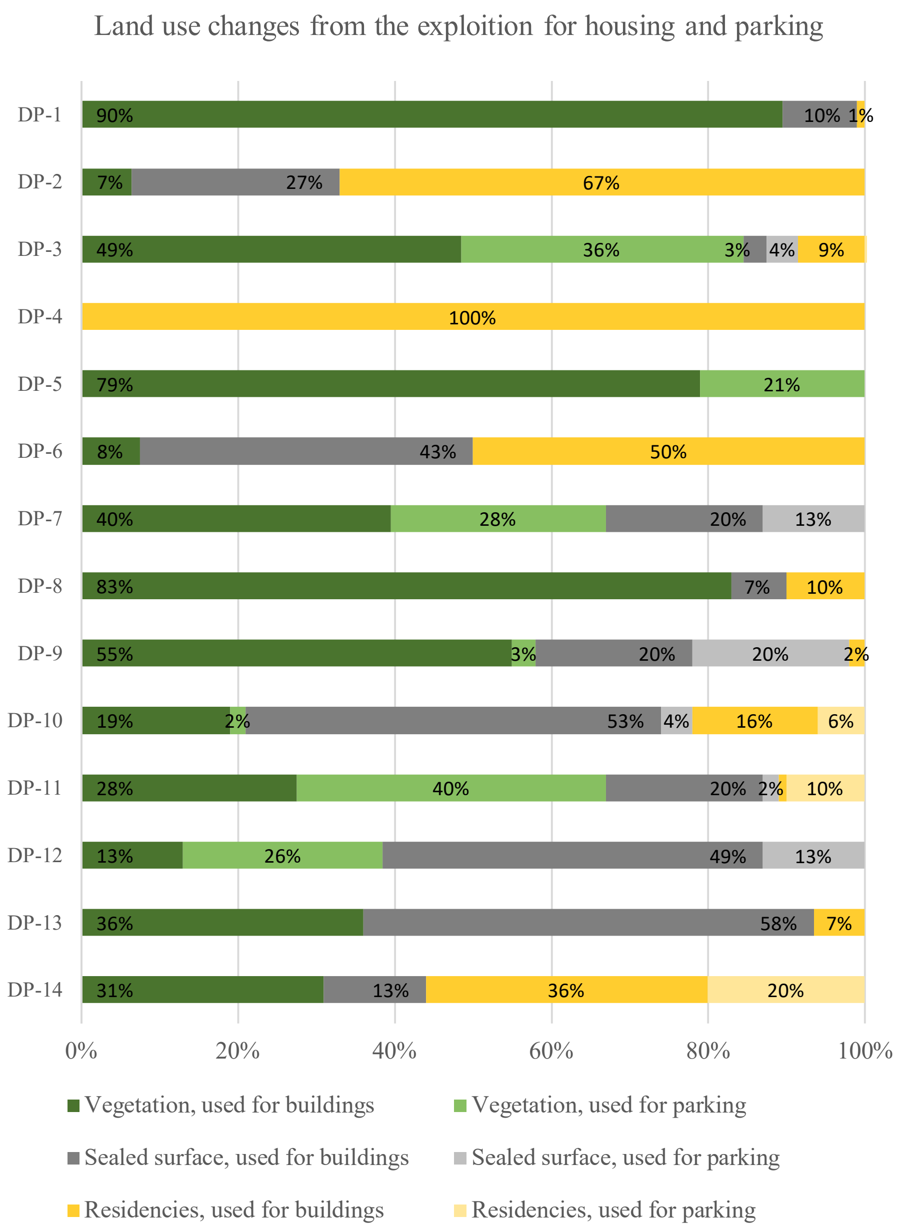

Figure 8: Bar chart of the land use changes due to exploition for housing and parking in the 14 studied development plans in BoStad2021. Statistics for land, both used for buildings (darker colors) and parkings (brither colors), are presented. The three classes used for current land use are: vegetation, buildings and other sealed surfaces.

The development often occurs at green spaces with low user and nature values, i.e. grass covered backyards in Plan-8 and areas with steep topography and a thin soil cover in Plan-1 and Plan-5. But there are also examples on exploitation of green spaces that have higher sociotope values. Agreements about compensation from the impact are sometimes established even if this is not legally required and this has been done for seven on the development plans (table 8). Plan-3 is using vegetated land for more than 80 percent of the constructions and 57 percent of this development is located at land that have recreational values that are attracting people from the whole city district (fig. 8). The impact is going to be compensated by biotope improvements inside the plan area and enhanced accessibility to a site for recreation outside the plan area (table 8). In Plan-7 a green space with higher user values is exploited as well. Parts of it is a sports field that should be replaced outside the plan area and the exploiter should furthermore compensate for the loss by improving the connection to an adjacent nature area (table 8). Even Plan-12 and Plan-14 is partly located on green space with high sociotope value even if most of the construction in this development plan is done on already sealed surface (fig. 8). In Plan-14 a green corridor is affected and the exploitation of a playground area in Plan-14 should be compensated through construction of a new one outside the plan area (table 8). Compensation measures are also suggested for Plan-13 were biotope provision should reduce the loss of nature values (table 8). Compensation agreements is suggested in three additionally development plans due to that trees are removed for the development which should be replanted (Plan-9, Plan-10, Plan-12).

Table 8: Information about compensation agreements suggested in the development plans in BoStad2021 that were analyzed.

	Impact that needs compensation	Compensation agreements	Location
Plan-1	-	-	-
Plan-2	-	-	-
Plan-3	Exploitation on a nature area that in parts is suitable for playing.	Biotop improvements, Walkway and street lights for accessibility to recreation at the site with acient remains.	Inside the plan area, Outside the plan area
Plan-4	-	-	-
Plan-5	-	-	-
Plan-6	-	-	-
Plan-7	Exploitation on a nature area, Removement of a sport ground.	-	Outside the plan area
Plan-8	-	-	-
Plan-9	Removment of a biotope protected tree row.	Plantation of a new tree row on public land.	Outside the plan area

Plan-10	Removment of a biotope protected tree row.	Plantation of a new tree row in a public park.	Outside the plan area
Plan-11	-	-	-
Plan-12	Removment of two biotope protected tree row.	Plantations of new trees roads, i.e. along a road.	Inside the plan area
Plan-13	Exploitation on a nature area which leads to a estimated small impact.	Biotope imporvements by putting up nesting boxes and preserving snags.	Inside the plan area
Plan-14	Removment of playground area	Construction of a new playground	Outside the plan area

3.3 Summary of the future scenario in *Mellanstaden*

The City of Gothenburg plans a development in *Mellanstaden* that approximately represents 100,000 new inhabitants. The total land potential that could be used for this development according to the used criteria is 4,086 hectares and the population density would hence be 24 people/ha if all the land would be used for urban growth. This is a low density compared to the recommendations from literature (Gehl, 2004; Rådberg, 2014; UN Habitat, 2015). The City of Gothenburg has also communicated that there is a risk that the population density in *Mellanstaden* will be too small for providing a viable city life if changes lead to that planned development is not fully accomplished (Göteborgs Stad, 2014a). Some land is therefore likely to be preserved and in this analysis two scenarios are tested; no increased soil sealing, and secondly, the development will be restricted from areas that already are utilized.

The potential area in *Mellanstaden* consist of vegetated land to 79 percent (fig. 5), which gives a population density of 31 people/ha if no construction would occur on areas where there are already buildings or where the surface has been sealed for other reasons. This would hence lead to a density that is lower than a normal middle sized Swedish city with 40-60 people/ha (Rådberg, 2014). The opposite scenario with no increased surface sealing is also possible which would result in 117 people/ha which is still lower than the recommendations for planning for a livable city from litterature (Gehl, 2004; UN-Habitat, 2015). The parking strategies in BoStad2021 indicate that there generally may be a surplus of parking spaces in *Mellanstaden* and that the City of Gothenburg tries to limit further soil sealing, both through development on underutilized parking space but also through locating new garages underground if possible (table 5).

In general, not much land is dedicated for SUDS in the plan areas (table 7). Climate adaptation will thus become more important to avoid the flood risk if the development continues in a similar direction for a larger area, such as the whole of *Mellanstaden*. Keeping vegetation is one way to decrease the need for stormwater management as it reduces the surface runoff (Thoni, 2017). A potential future scenario with limited development on vegetated areas can therefore be considered suitable in this perspective. It is also possible since the common development strategy in BoStad2021 have been densification through infill and generally as extension and additions within already build-up areas (table 4). Exploitation without connection to the current city structure, direct or through good public transport access, have been avoided and large proportions of the vegetation in *Mellanstaden* are detached from the current urban areas. However, the observed land use changes indicate a different pattern where vegetated areas are the most common to be developed (fig. 7, fig. 8).

4. Discussion

4.1 Future scenario for *Mellanstaden*

The projection showed that there is a considerable land potential in *Mellanstaden*, which is the area to where the City of Gothenburg foremost wants to direct new developments. It is not needed to develop the whole available area from the Multi-Criteria Evaluation to achieve a suitable population density for a bikeable and walkable city (UN Habitat, 2015), and a sustainable development is hence possible with the right priorities. The City of Gothenburg is a big land owner within *Mellanstaden.* This gives mandate to influence the implementation of the development plans by establishing land allocation agreements and demand arrangements that goes beyond what is required by the law i.e. for stormwater management and parking solutions, which also have been done in BoStad2021. The future scenario for the development is further discussed in four sections below.

4.1.1 Previous land use of the exploited area

Vegetated land is often removed due to developments in BoStad2021, and the smaller green areas that are claimed for development at several sites are adding up to quite large quantities for all development plans (fig. 7). All human needs must be fulfilled in a sustainable city, and green space is important to create good living conditions (Swedish National Board of Housing, 2017). A decline in green space is negative for the well-being of the citizens and the need for green space in cities is also increasing with a more urbanized and stressed population (Arnberger, 2012). Not all green spaces are increasing the livability in a city though, and the user value should therefore be considered in planning (Ståhle, 2010). A sociotope assessment system for green areas is used in Gothenburg, but the analysis showed that some of the development plans still were located at sites that had high classification values in the sociotope assessment support tool. The reduction of green space has sometimes been followed by compensation agreements to improve other green areas. The same ES might hence be provided at the alternative site but an urban design where GI is integrated throughout the city structure is important (Andersson *et al.*, 2014). The local conditions and availability of green space is important in a stormwater management perspective, as it e.g. provide areas to direct excess runoff water towards during extreme events (Sörensen, Johansson, *et al.*, 2016). Furthermore, the spatial distribution of GI enhances peoples everyday contact with nature which have positive health benefits and also leads to increased planned visits as the residents will get more familiarized with the nearby green areas (Ståhle, 2010).

GI can be optimized to facilitate the provisioning of multiple ES at the same place, e.g. stormwater management and recreation, which makes it possible to benefit from ES even in a denser city (Zhou, 2014). However, it is also important to consider that some ES are dependent on the surrounding landscape. Reduction of green spaces with a low provisioning of ES might disturb interconnections in the GI which reduce the resilience of the ecological system (Borgström, Cousins and Lindborg, 2012). The analysis of BoStad2021 showed that the development sometimes leads to fragmentation of green areas, (section 3.2.4). Development of smaller green areas might lead to that even larger preserved green areas risk to become isolated with a following decline in biodiversity (Borgström, Cousins and Lindborg, 2012). The heterogeneity provided through many smaller green areas is further important for ES, and sites without user values e.g. brown fields may still contribute to the resilience and reduce stormwater runoff (Andersson *et al.*, 2014). The potential of small scale green areas is often neglected in planning (ibid.). This seem to be the case also in BoStad2021, as these questions are not brought up in the studied development plans.

Smaller green areas and a growing urban population are also increasing the pressure on existing parks which might become degraded because of the overuse, a risk that is increasing with densification (Arnberger, 2012). Crowding are furthermore influencing the attractiveness of the green space and the social carrying capacity can at times be exceeded (ibid.). This might lead to that people decide to travel to more distant places for leisure which is problematic since increased transportation often have negative climate impacts (ibid.). The City of Gothenburg has nevertheless chosen so far not to specify minimum requirements for the share of green space per person in new developments, with the argument that the conditions vary from site to site which makes absolute numbers ineffective (Göteborgs Stad, 2014c). Availability of green space is important for sustainable cities and is one of the goal targets for the Sustainable Development Goals (SDG 11.7) in Agenda 2030 that Sweden needs to live up to and should not be neglected in planning (UN General Assembly, 2015).

4.1.2 Flood risk

The future scenario for *Mellanstaden* was established from the findings in the policy documents which emphasize that new development should be located at areas that are not expected to be flooded from a cloudburst with a 100 years reoccurring period. However, several of the development plans situated in BoStad2021 are situated in areas where such flood risk exists. A new policy document about how to handle the flood risks in planning is about to be implemented which might lead to a better integration of GI and SUDS in the future (Göteborgs Stad, 2017). There are attempts to improve the climate adaptation work also at the national level and the government is currently developing a National strategy for climate adaptation (Prop. 2017/18:163). The aim with the strategy is to make climate adaptation more integrated into planning and the first suggestion is that the law should oblige municipalities to e.g. consider the flood risk in the comprehensive plan (ibid.). The second change is that municipalities should be able to prohibit changes that reduce the infiltration capacity in the plan areas (ibid.). This is important both due to reduce the risk of un-planned increased soil sealing i.e. on private properties, and to reduce the risk of damages on surrounding properties because of altered runoff patterns (ibid.). The possibility to control surface sealing is in a longer perspective an important measure for handling the flood risk as it reduces the need for stormwater management (Sörensen, Persson, et al., 2016).

4.1.3 Stormwater management

The amount of land that are used for SUDS in BoStad2021 are in general relatively small and not dimensioned to handle larger events i.e. 100-years events (table 7). The City of Gothenburg tries to limit the accumulated stormwater runoff by demanding *Onsite Control* for stormwater management. The common strategy is to demand that increased soil sealing needs to be followed by measures to reduce the runoff. However, this does not improve the current condition. Implementation of SUDS can sometimes be costly but new developments could provide an economic opportunity to distribute the cost. This is especially interesting since construction of pipe networks has become increasingly expensive as densification also reduces the space underground (Sörensen, Persson, *et al.*, 2016). Different forms of bioretention cells for stormwater management are commonly suggested in BoStad2021 but only if there is enough unutilized space. Underground stormwater detention are otherwise suggested as an alternative but does not have the potential to improve the urban environment in the same way. If SUDS are constructed in a way that also facilitate the provisioning of multiple ES it may be easier to motivate their implementation from an economic perspective (Read *et al.*, 2016). However, ES are not raised in the studied documents around the development plans. The possibilities to quantify additional benefits from ES would also be necessary to provide decision makers with a better knowledge basis for decisions concerning the implementation SUDS (Prudencio and Null, 2018).

4.1.4 Transportation and Parking issues

The future predictions for *Mellanstaden* indicate that the population density would be lower than the recommendations for livable cities even if the development solely would occur on already sealed surfaces. In Sweden, just as in other parts of the world, there is currently a movement of trying to work towards reducing the car use and the government have introduced goals about having a vehicle fleet that is independent of fossil fuels by 2030 (SOU 2013:84). The traffic system is over-dimensioned in parts of *Mellanstaden* and the City of Gothenburg states that the traffic structures and car parking are suitable to utilize for new housing developments as it also improves the urban environment (Göteborgs Stad, 2014b; Göteborgs Stad, 2009b). Several development plans are located at sites that previously were used for parking and this transformation might increase in the future. Also, on the national level there are tendencies of an increased political will to intensify the reclaiming of land from the traffic system, which could foster a continuing development in this direction, especially if alternative mobility modes are getting more accessible (Skr. 2017/18:230). The City of Gothenburg has a vison of trying to benefit from the close links to research within transportation and establish a closer cooperation with the development side and making Gothenburg a test arena for new interventions (Göteborgs Stad, 2014b).

The City of Gothenburg has recently adopted a policy for flexible guidelines for the number of parking spaces that are going to be used in planning, with the aim to reduce the citizens need of owning a car (Göteborgs Stad, 2018b). The access to alternative mobility made it possible to develop several sites with a reduced parking number. A higher population density gives economical possibilities to improve the use of public transport which might decrease the car use even more (Newman & Kenworthy 2015). New parking lots have often been placed in underground garages for the development plans in BoStad2021, which is positive since it reduces the space need. Underground parking solutions are expensive to construct though, and higher in Gothenburg compared to other Swedish cities due to the geological circumstances (Envall, 2013). This have motivated the exploiter to use other interventions to reduce the parking requirements in development plans where underground parking is suggested. The construction costs for parking are normally allocated amongst the tenants and does not directly reflect the prize for renting a parking space (Envall, 2013). This inflates the rents regardless if the residents own a car or not, and expensive solutions might hence lead to higher rents than normal for the whole establishment which might lead to gentrification and that only people with a certain socio-economic status afford to move into the new developments.

4.2 Method and uncertainties

The study builds on a fictive future scenario where the land potential is based on six selected constraints that were identified in policy documents and considered of main interests for this study. There is not a specific method for finding criteria for a Multi-Criteria Evaluation and this selection is hence always subjective. Cooperation with planners in Gothenburg could have improved the criteria selection but it is an advance task and decision makers are not always in a better position for making the selection (Joerin, Thérialult and Musy, 2001). The time constrain for this study made it unfeasible to consult decision makers and a criteria selection based on the policy documents was therefore considered the best alternative to give an indication of the land potential. More policy documents could also have been studied for finding additional criteria, such as the flood risk from the river and other watercourses, contaminated ground, or the access to public transport. Alternations or additions of supplementary criteria would affect the result. However, the large land potential in *Mellanstaden* indicates that the land might still have been enough and in the opposite way may some criteria not be as restrictive as they are considered in this analysis. A reduced car dependency can for example be a way to reduce the land needed for infrastructure.

The future scenario for the population density is looked at based on two different assumptions: no increased soil sealing or no development of areas that already are utilized. A mix of the two is probably closer to the reality but the scenarios were made to give a basis for the discussion. The estimations consider *Mellanstaden* as a whole, but the housing development will likely be concentrated in some parts which hence are getting a higher density. The City of Gothenburg hasalso mapped out some locations that are considered especially suitable for development (Göteborgs Stad, 2014a). It is a simplified scenario that is used for this analysis, and the current inhabitants in *Mellanstaden* or the surrounding areas are further not accounted. The spatial limitations influence the result and a high current density might advocate a lower density in *Mellanstaden*, at least in areas that are located close to current establishments.

The future scenario for GI and SUDS are based on findings from the analysis of BoStad2021 where only fourteen development plans were looked at. The small selection is due to that the study was limited to approved development plans, which was done as the plans can be reversed up until they are legally improved. The limited scope does not make it representative for how the development is done in Gothenburg in general and all issues are also not suitable to handle at the planning level of detailed development plans. Studies have shown that it can be difficult to find room for large scale stormwater management in already built-up areas (Sörensen, Johansson, *et al.*, 2016). Stormwater management might instead be considered on a larger scale, e.g. at watershed level, which also makes it possible to combine several measures (Marsalek and Chocat, 2002), or established with other densification strategies than infill which was the most common for the studied development plans in BoStad2021. However, the development plan is an important planning level as the runoff optimally should be taken care off as close to the source as possible and it is important to consider the capacity in the whole drainage system since water accumulates in depressions and increase the flood risk (Sörensen, Johansson, *et al.*, 2016).

4.3 Future research

Suggestions for further research could be to understand the reasons behind why GI and SUDS are not getting a greater focus in BoStad2021. There are multiple barriers that can hinder the implementation of SUDS which are usually rather institutional than technical i.e. lack of coordination, the regulatory framework or the organizational structure (Brown and Farrelly, 2009). The investigation team that are following the project have found indications of that the time pressure may be the reason behind a quality reduction (Svensson et.al., 2018). However, previous research has shown that planners often are unsure about the advantages of open stormwater systems, even though there are support within research (Brown and Farrelly, 2009; Haghighatafshar *et al.*, 2018). Therefore, it would be interesting to look further into these obstacles and identify key barriers. Especially since the intensified planning process can be a method to reduce the problem with a lack of housing and are planned to be used for other projects in the future.

In this study, the same restriction value is used for all criteria and at the whole area of *Mellanstaden* and the method does therefore not give any information about which areas that are most suitable to develop. A more comprehensive and descriptive result could have been generated by using continuous variables for the Multi-Criteria Evaluation (Eastman, 1999). However, generating a relative classification of the criteria on a comparable scale is a difficult process and it is also recommended to apply at least two methods for combining the criteria as they are known to give varied results (Watson and Hudson, 2015; Myšiak, 2006). Such thorough analysis was not possible within the scope of this study. The study could also have been taken further by making a deeper investigation and also look at demands from the housing market or construction costs for necessary infrastructure investments to see which areas that are preferable in the developers perspective, which are suggestions of further research (Criado *et al.*, 2017).

5. Conclusion

The analysis provides an insight into the project BoStad2021 which is important to study as the project method, with an intensified planning process, is suggested to inspire other projects in the future aiming to improve the housing situation in Gothenburg and other cities. The identified land potential in *Mellanstaden* indicates that not all the available land is needed for the planned population growth. The City of Gothenburg is a big land owner which gives possibilities to direct the urban development to more sustainable solutions. However, the analysis showed that there is a general reduction of green space and also for green space with high values. This is negative in an ecological and social perspective. Green space provides ES such as stormwater management which is important, especially since not much land is dedicated for SUDS in the individual detailed development plans. The stormwater management in the development plans are dimensioned for 10-years events and only to reduce the runoff due to increased soil sealing in the plan areas. A better integration of the ES concept may improve the sustainability.

According to constraints used in the Multi-Criteria Evaluation a development solely on already sealed areas in *Mellanstaden* would still give a lower population density than the recommendations for a sustainable city development. The analysis of the development plans indicates that the municipality is interested in reducing the soil sealing and a policy for flexible guidelines for parking are about to be implemented. Underground parking garages are furthermore commonly suggested in the development plans and a higher construction cost gives incitement for the developer to provide other mobility alternatives to reduce the land used for parking. Hopefully, these are tendencies that more city space used for cars will be transformed into GI and SUDS in the future, and provide a more sustainable and livable urban environment, in Gothenburg and in cities globally.

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Appendix

Table 9: Information about the in-data used for the Multi-Criteria Evaluation.

Dataset	Content	Source	Used for
BY GSD Topographical Property Map, Scale 1:5,000 – 1:20,000	Buildings as surfaces with info about usage functions.	Lantmäteriet (The Swedish Mapping, Cadastre and land Registration Authority)	Built-up area and Social services
AY GSD Topographical Property Map, Scale 1:5,000 – 1:20,000	Dwelling units as surfaces.	Lantmäteriet (The Swedish Mapping, Cadastre and land Registration Authority)	Built-up area and Social services Green space and Recreation
JL GSD Topographical Property Map, Scale 1:5,000 – 1:20,000	Railroads as lines.	Lantmäteriet (The Swedish Mapping, Cadastre and land Registration Authority)	Important infrastructure Green space and Recreation
VL GSD Topographical Property Map, Scale 1:5,000 – 1:20,000	Roads as lines.	Lantmäteriet (The Swedish Mapping, Cadastre and land Registration Authority)	Important infrastructure
MV GSD Topographical Property Map, Scale 1:5,000 – 1:20,000	Water as surfaces (lakes and larger water courses).	Lantmäteriet (The Swedish Mapping, Cadastre and land Registration Authority)	Green space and Recreation
NVDB - Nationella Väg Databasen (The National Road Database)	Roads as lines with info about road width and driving speed.	Trafikverket - Lastkajen[49] (Swedish Transport Administration)	Important infrastructure
Sociotope map	Classification of the user functions for different forms of GI.	Göteborgs Stad	Built-up area and Social services Green space and Recreation

[49] http://www.nvdb.se/sv/kund/hamta-data-pa-lastkajen/

Cloudburst	Raster layer showing the risk for 0.5m flooding from rainfall with a returnperiod of 100-years, generated from a 2D-hydralic runoff model.	Göteborgs Stad - Vatten i Staden[50]	Flood risk
Aerial photography from 2015	Ortophoto produced from a mosaic of several aerial photographs.	Göteborgs Stad	Visual interpretation
Land use classification	Land use data produced by photogrammetry based on the ortophoto described above.	Göteborgs Stad, DHI	Important infrastructure

Table 10: The coordinates that were randomly generated for the visual interpretation.
Projection SWEREF 12 00.

Locations	N	E		Locations	N	E
1	6405645.988	151143.395		14	6408965.711	152922.758
2	6399812.172	151037.643		15	6395969.625	150089.219
3	6404736.260	148201.176		16	6404438.295	146816.619
4	6405286.192	152211.922		17	6409019.563	146678.364
5	6398703.673	150945.231		18	6409455.546	151116.644
6	6395293.370	144007.195		19	6400191.491	154036.988
7	6401017.029	146038.439		20	6395660.122	149944.448
8	6403919.954	150355.541		21	6391578.023	142117.562
9	6393615.194	145426.999		22	6407099.663	143990.240
10	6391090.242	147441.569		23	6401252.703	149718.427
11	6401198.996	152671.612		24	6396514.435	143979.319
12	6389837.505	145782.707		25	6396514.435	143727.780
13	6391567.819	146351.121				

[50] https://www.vattenigoteborg.se/home

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