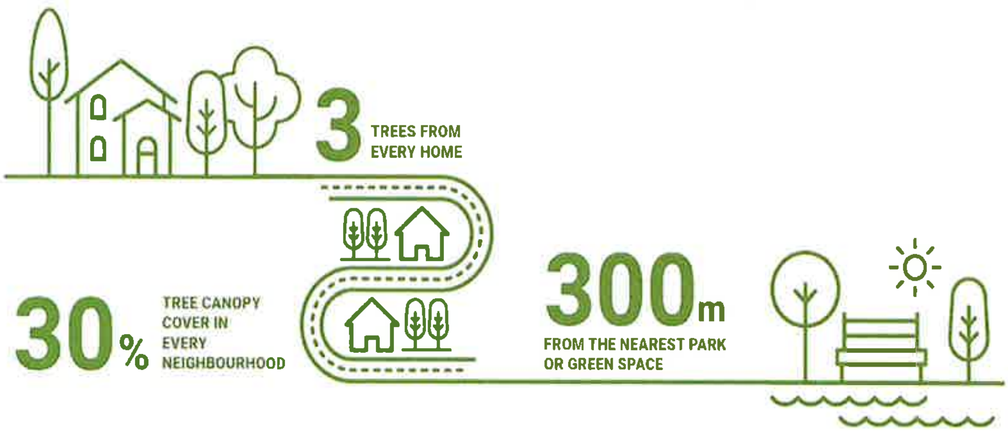
An investigation of the 3-30-300 rule in a Swedish context



(Konijnendijk, 2022)

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with a major in Geography
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Abstract

More than half of the world's population lives in cities and climate change is already an increasing problem in many cities. Climate smart planning is therefore of extra importance and vegetation is considered the single most versatile component to manage climate changes. Nearby and visible vegetation is also found to have positive effects on the mental health and green spaces can furthermore encourage to physical activity. Few efforts have been made to create comprehensive recommendations for urban greening that includes amount of greenery, distance to green spaces and visible vegetation. This has led to the creation of the 3-30-300 rule which is a comprehensive guideline that aims to create greener and healthier cities. The rule states that everyone should see at least 3 trees from their home, every neighborhood should have at least 30% tree canopy cover, and no one should have more than 300 meters to the nearest public green space.

The aim of this study has been to do a broad investigation of the 3-30-300 in rule in a Swedish context, partly through GIS analyses in Gothenburg and partly through interviews with city planners. A new viewshed-based method for investigating visible trees has also been proposed and the accuracy of this method has been investigated. The result from this study shows that it is difficult to fulfill 3-30-300 in the central and industrial areas of the city. The goals of 3 visible trees and 300 meters to a green space is found to be feasible while 30% tree canopy cover is found to be hard. The overall accuracy of the proposed viewshed-based method was good (85%) and can suitably be used to investigate the criterion of 3 visible trees. The city planners are primarily positive to 3-30-300 and highlights that it can strengthen the role of urban greening. There are however some potential challenges that can make it difficult to work with 3-30-300 in the planning sector. These are primarily connected to hard competition, limited legislation about urban greening and low generation of money. The high tree canopy cover goal is also assessed as a challenge and the findings from this study indicate that 2-20-200 is a more realistic guideline in a Swedish context.

Acknowledgement

I would like to thank all my friends and professors at the Department of Earth Sciences, University of Gothenburg, for five enjoyable years. I am extremely grateful for my time here and I am glad I chose to study Geography!

I want to give a big thank you to my supervisor Fredrik Lindberg for patiently listening to all my questions and for guiding me through this master's thesis. Your expertise in GIS has been extremely valuable for this project and has also inspired me to work more with this system. Thank you to everyone at *Radar arkitektur & planering* as well for having me during this project.

Sebastian Daland

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1 Introduction

1.1 Background

Today more than half of the world's population live in urban areas and future projections show that approximately 68% of the world's population will live in urban areas by 2050 (Ritchie & Roser, 2019). The ongoing climate changes we are facing today is already an increasing problem around the world and urban areas are likely to experience amplified climate changes in some respects, especially regarding heat and flooding (IPCC, 2021). Another major problem in urban areas is air pollution. Today almost all of the global population are exposed to air quality belove the guidelines from the World Health Organization (WHO, 2022).

Climate sensitive urban planning and design becomes especially important in order to address these problems. Of all the urban components, vegetation is considered the single most versatile component to manage climate changes (Oke, 2017, p.433). It can be used to reduce air pollution, airflows, run-off, erosion and noise levels. It can also be used to mitigate heat because vegetation and especially trees can provide shade and evapotranspiration. Furthermore, nearby and visible vegetation have been proven to have positive impact on mental health and can lower blood pressure, stress and depression and lead to overall better well-being (WHO, 2016).

Living amongst greenery and having access to green spaces nearby has received substantial attention worldwide because of its many positive effects and has led to specific recommendations regarding amount, quality and distance for green spaces in many cities across the world (Konijnendijk, 2022). Green spaces can for instance encourage physical activity and recreational walking which in turn leads to better health outcomes (Sugiyama et al., 2010). Green spaces can also contribute to social interactions which can have positive effects on the social cohesion and the general mental health (Wang et al., 2022a). The aspect of visible vegetation has however received remarkably less attention and led to vague recommendations although the positive effects are well known. Wang et al. (2022b) did for instance find that visible vegetation was associated with lower levels of negative emotions and higher levels of well-being. These findings could also be found from a working place perspective in urban areas, demonstrating the importance and positive effects of visible vegetation from work (Elsadek et al., 2020).

Most cities are today working with some type of specific recommendation for green spaces. Distance to green spaces is one of the most common ways to work with this and the World Health Organization recommends a maximum distance of 300 meters to a public green space (WHO, 2017). Green space per capita is also a popular way to ensure that a city has enough greenery and is often set to be around 10 square meters of green space per capita although both higher and lower recommendations can be found (Barrera et al., 2023). Tree canopy cover goals, which corresponds to how many percentages of the city that is covered with trees, have also become more popular and it is now possible to do more accurate analyses of urban trees and canopy cover through improved technology within remote sensing (Klobucar et al., 2021). Other more comprehensive ways of ensuring that built-up areas have sufficient greening is to use a scoring system such as the Green Space Factor. The area of interest is then divided into different subareas based on the landcover and these areas are thereafter given a specific score depending on extent and the ecosystem services they can provide (Göteborgs Stad, 2018). Few efforts have however been made to create comprehensive guidelines that combines the importance of living amongst greenery, having access to green spaces and being able to see visible vegetation from home (Konijnendijk, 2022). This has led to the creation of the 3-30-300 rule.

The 3-30-300 rule is a comprehensive guideline for urban forestry developed by Cecil Konijnendijk in 2021 with the aim to create greener and healthier cities with focus on the importance of seeing trees from home and having green spaces nearby (Konijnendijk, 2022). The “rule” states that everyone should see at least 3 well-established trees from their home, school or work, every neighborhood should have at least 30% tree canopy cover, and no one should have more than 300 meters to the nearest public park or green space from their home. These numbers are based on evidence together with “simplicity” to make it easy to understand and give it big communicative power.

Multiple studies have found that people living close to green spaces are more likely to use these than people living further away (Toftager et al., 2011; Neuvonen et al., 2007). The European Regional Office of the World Health Organization are for instance recommending a maximum distance of 300 meters or 5-minute walk to a public green space of at least 0,5-1 hectare as a rule of thumb (WHO, 2017). Many cities across the world have adapted this recommendation, including the city of Gothenburg. Their definition is however slightly different as it states that all residents should have a public green space of at least 0,2 hectares within 300 meters and a bigger public green space of at least 2 hectares within 1 kilometer or 15-minute walk from their homes (Göteborgs Stad, 2022a).

High tree canopy cover is found to have positive effects on microclimate, heat reduction, mental health and human thermal comfort (Yoshida et al., 2015). A recent study that investigated 93 European cities showed that an increase to 30% tree canopy cover could reduce the average temperature with 0,4°C and prevent 39,5% of all deaths related to the urban heat island effect during the summer (Iungman et al., 2023). Many of the most ambitious climate cities, such as Barcelona (Ajuntament de Barcelona, 2017) and Vancouver (City of Vancouver, 2020) have already started with target goals towards a tree canopy cover of 30% within the next decades.

Few Swedish cities have worked with specific goals towards tree canopy cover earlier, but The Swedish Environmental Protection Agency came with a specific goal in 2021 of 25% tree canopy cover in all Swedish cities by 2030 (Naturvårdsverket, 2021). It is however important to remember that the tree canopy cover should be targeted at neighborhood scale rather than city scale. There is otherwise risk for uneven distribution of the tree canopy cover where some areas will have high canopy cover and some areas will have low canopy cover. In order to achieve high tree canopy cover, large trees and the preservation of old trees are of absolute importance. Old trees hold the biggest tree crowns and it takes several years for a young tree to reach maturity, illustrating the significance of planning for large trees and preserving old trees. In areas where it is difficult for trees to grow, a goal of 30% vegetation can be suitable, but with a strong tree component (Konijnendijk, 2022).

To see 3 trees from home or work is the only part of the rule that is not supported by evidence but was chosen to match the two other numbers and give the guideline more "stickiness" (Konijnendijk, 2022). There is no evidence behind the number 3, but the importance of seeing vegetation have been proven to have positive effects on mental health and well-being (WHO, 2016). Chi et al. (2022) found that larger trees effects mental health more positive than smaller trees, which is why the 3 visible trees ideally should be well-established. Some cities have already started with specific targets towards visible trees although this is rare. The municipality of Frederiksberg in Denmark has a specific goal of at least one visible tree from every home in their tree strategy program (Frederiksberg Kommune, 2018).

The 3-30-300 rule has received considerable attention in media since it was launched in 2021. The Center Party (Centerpartiet) in Sweden did for instance use the rule as part of their election campaign in 2022 with the goal of implementing it as norm in Swedish cities (Centerpartiet, 2022). In Gothenburg, the 3-30-300 rule is actually mentioned as a rule of thumb in their green structure plan (Göteborgs Stad, 2022a). The reason why this rule has got so much attention is probably because it is easy to remember and at the same time supported by evidence. It will be interesting to see if the rule has come to stay or if it just is a media hype.

1.2 Aim & research questions

The aim of this study is to do a broad investigation of the 3-30-300 rule in a Swedish context. Mixed methods will be used, partly through GIS analyses and partly through interviews with city planners. The GIS work also includes a new viewshed-based method that will be used to estimate visible trees.

Following research questions will be used to fulfill the aim:

- What are the spatial variations of 3-30-300 in Gothenburg?
- How accurate is the viewshed-based method to estimate visible trees?
- What are the city planners' perspectives on 3-30-300?

2 Study area – Urban Gothenburg

Gothenburg (57°42'N, 11°58'E) is located on the Swedish west coast and is the second largest city in Sweden with 596 539 inhabitants (Göteborgs Stad, 2022b). It is one of the fastest growing cities in Sweden and the population is expected to increase with 120 000 inhabitants by 2040 (Göteborgs Stad, 2022c). The climate in Gothenburg is considered as a maritime temperate climate and consists of relatively mild winters and cool summers. It is located in the nemoral vegetation zone which mostly consists of deciduous trees and is characteristic for the southwestern part of Sweden. The leaves of deciduous trees usually bud out in the spring and falls of in the autumn. Gothenburg is often considered as a rather green city and was ranked as one of the top cities in Europe regarding urban green space availability in 2016 (Kabisch et al., 2016).

The study area for this report is defined to the urban areas of Gothenburg (see Figure 1), which in this study consists of the inner city (*innerstaden*) and the suburban areas (*mellanstaden*). This is also where the majority of the inhabitants in Gothenburg lives.

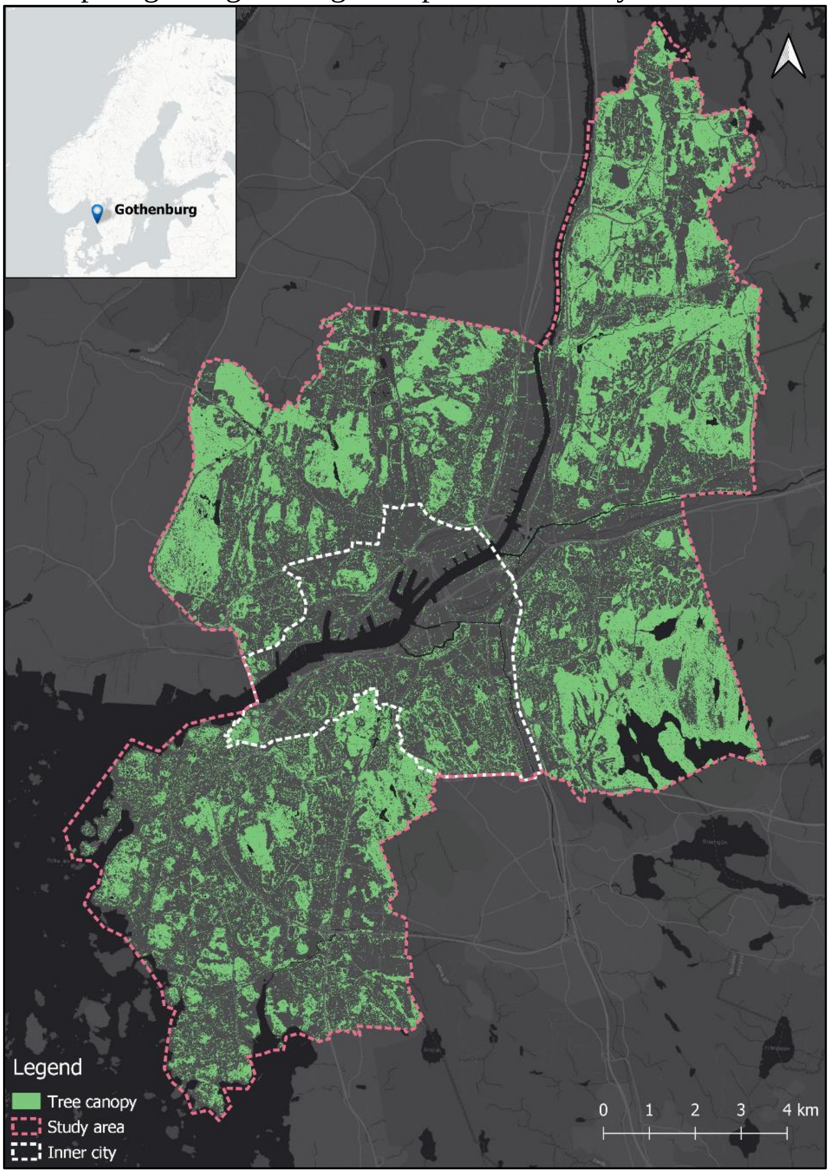

Figure 1. Overview map of the study area. Base map: ESRI Gray (dark).

3 Material and methods

This section consists of a short description of the study design and data used in this report, followed by a more detailed description of the data processing and the methods.

3.1 Study design

This study makes use of a mixed method approach including both quantitative GIS analyses, quantitative field observations and qualitative interviews. The results from the GIS analyses will be showed to the respondents during the interviews while the field observations will be used to estimate the accuracy of the viewshed-based method for 3 visible trees. The combination of quantitative and qualitative methods is in this study used to achieve a more comprehensive understanding of the 3-30-300 rule in a Swedish context. This way of combining quantitative and qualitative methods is referred to as “completeness” and indicates that a more complete answer can be obtained by combining different methods (Bryman, 2012).

3.2 Data

The data used in this study is primarily based on open and national covering geodata. The only geodata that is not open is buildings and properties. This will however become open data within 1-2 years after new orders from the European Commission (Lantmäteriet, 2023a).

Table 1. Data for this study.

Data	Source	Format	Description
Light detection and ranging (LiDAR)	Lantmäteriet* (2022)	LAS	Airborne scanning during late autumn 2019 and spring 2020 in Gothenburg. Point density of 1-2 points per square meter.
Buildings	Lantmäteriet* (2023b)	Vector polygons	All types of buildings.
Forest areas	Lantmäteriet* (2023c)	Vector polygons	Deciduous and coniferous forest.
Water	Lantmäteriet* (2023d)	Vector polygons	Waterbodies wider than 6 meters.
Urban green spaces	Statistiska centralbyrån** (2015)	Vector polygons	Urban green spaces larger than 0,5 hectare.

Motorways	Trafikverket*** (2020)	Vector lines	Roads where the traffic rules for motorways apply.
Railways	Trafikverket*** (2022)	Vector lines	State railways and private railways.

*Lantmäteriet (LM) = The Swedish mapping, cadastral and land registration authority

**Statistiska centralbyrån (SCB) = Statistics Sweden

***Trafikverket (TV) = The Swedish Transport Administration

3.2.1 Data processing – LiDAR data

The laser pulses sent out from the LiDAR sensor is used to classify the objects on the ground and create elevation models. The LiDAR data and the classification from LM have been used in this study. Only class 1 (unclassified) and class 2 (ground) together with a buildings footprint was necessary in order to create a digital elevation model (DEM), digital surface model (DSM) and canopy digital surface model (CDSM).

The DEM layer was created with the ground points since this layer only is supposed to show the bare ground elevation. The DSM and CDSM layer were on the other hand created with a combination of ground points, unclassified points and a buildings footprint. The ground points form the basis with its ground elevation and since a buildings footprint is used, then it is possible to classify all unclassified points within the footprint as buildings and all unclassified points outside the footprint as vegetation. This manual classification of unclassified points made it possible to categories buildings and vegetation as different objects and thus create the two layers DSM and CDSM. All the elevation models have a pixel size of 2 meters which was considered reasonable with regard to the size of the study area and the point cloud density.

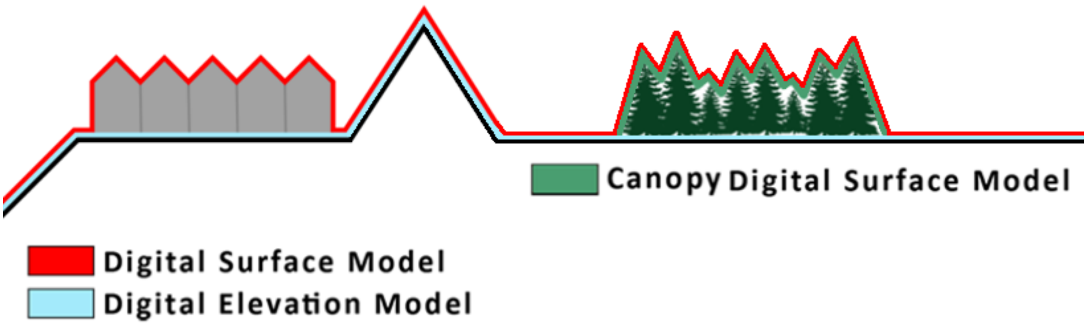

Figure 2. Illustration of the elevation models (Humboldt State University, 2017). Edited to reflect terminology used in this study.

Minimum vegetation height for the CDSM was set to 2,5 meters in order to filter out objects such as humans and cars while the maximum vegetation height was set to 35 meters to filter out objects such as birds and cranes. Most trees in urban settings are also under 35 meters. See Lindberg et al. (2013) for more information about the filters used in this study. Unclassified objects within the height range 2,5–35 meters will still be wrongly classified as vegetation if they are not removed manually.

A buffer of 2,5 meters was set around the buildings footprint to avoid the edges of the buildings to be classified as vegetation. Different values were tested in order to get a suitable result. The entire LiDAR processing was conducted with FUSION and written in Python. After the LiDAR processing, larger areas that clearly had been wrongly classified as vegetation was removed manually. This was primarily a problem at bridges and railways.

3.2.2 Creating trees

Due to inadequate geodata over trees and no universal definition of well-established trees, I had to create and define the trees by myself. A minimum size for tree crowns was set to $15m^2$ from aerial view since this seemed to include most urban trees but still filter out the smallest ones. The layer with trees was made by extracting all continuous vegetation larger than $15m^2$ from the CDSM and is supposed to represent well-established trees in this study.

Many trees are often combined into the same polygon when extracting the vegetation because the trees are located close to each other (see Figure 3). This is also the reason why square meters of visible vegetation will be used instead of number of polygons or points to estimate if you can see more than 3 trees.

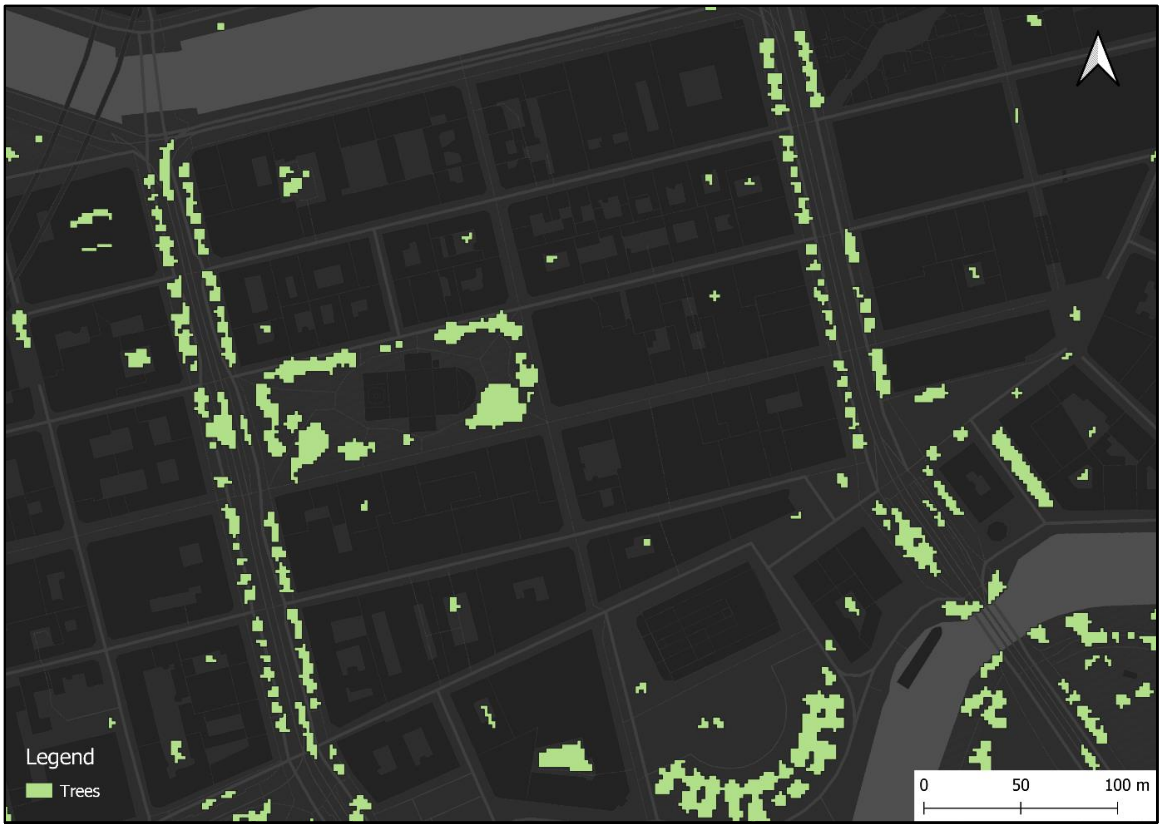

Figure 3. Well-established trees with crown larger than $15m^2$ from aerial view. Base map: CartoDB Dark Matter.

3.2.3 Creating green spaces

Green spaces are in this study defined as continuous areas with vegetation of at least 0,5 hectare. The minimum size of 0,5 hectare is based on the recommendation from WHO (2017). The definition of green space does not take into account whether the areas are pointed out as green spaces in the municipality's comprehensive plan or not. Both grass, park and forest areas are included. Community gardens, farmlands and golf courses are not included.

The green spaces from SCB forms the foundation for my green spaces. This data does however only include urban green spaces and larger forest areas are therefore missing. To address this problem, deciduous and coniferous forest areas from LM was added in order to cover all green spaces larger than 0,5 hectare within the study area.

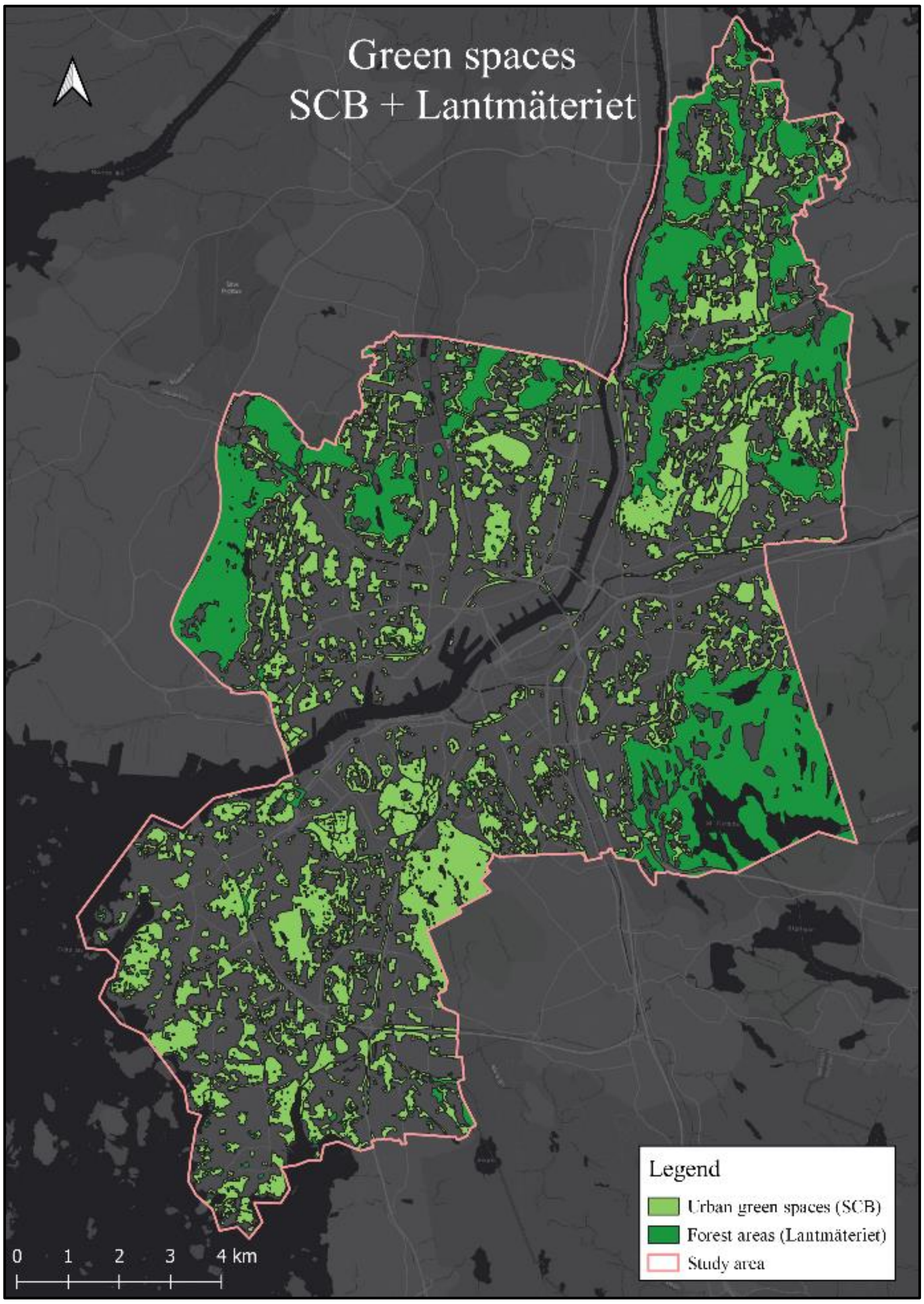

Figure 4. Green spaces create with data from SCB and LM. Base map: ESRI Gray (dark).

3.3 GIS methodology

To investigate tree canopy cover and distance to green spaces can be done with rather simple GIS-analyses while visible trees are more complicated to investigate. A viewshed-based method has therefore been developed and will be used to estimate visible trees in this study. The accuracy of the proposed method for visible trees will be investigated and presented in the result section. Tree canopy cover and distance to green spaces will be analyzed using *Zonal Statistics* and *Cost Distance Analysis* which both are valid GIS-methods and does therefore not need an accuracy test like the proposed viewshed-based method for visible trees.

Viewshed analysis

A viewshed analysis is an algorithm that calculates all visible areas from a specific point based on a raster elevation model (GDAL, 2023). The viewshed tool from GDAL has been used in this study.

In order to conduct the viewshed analysis, observer points first had to be created. A buffer of 2,5 meters was set around all buildings to avoid the points from being placed on the edge of buildings. If a point were placed on the edge of a building it would most likely overestimate the number of visible trees. The points were thereafter placed out around the buildings with a spacing of 20 meters between each point in order to cover most sides of the buildings without ending up with too many points.

The viewshed analysis was conducted for each observer point through a *for loop* and the DSM was used to determine the visibility since this elevation model contains objects such as buildings and trees, which is of interest in an urban viewshed context. A maximum visibility radius of 100 meters was chosen and is in accordance with previous studies on tree visibility (Cimburova et al., 2023; Cox et al., 2019). Trees are perceived as smaller further away and it can be difficult to distinguish the different ecological features of an averaged sized urban tree if the distance is over 100 meters (Cox et al., 2019). The nature experience is then likely to be affected and a maximum radius of 100 meters was therefore chosen.

To calculate visible trees, the viewshed for each observer point was clipped after the tree layer (see Figure 5). This makes it possible to calculate how many square meters of visible vegetation one can see from the observer points and use that as proxy for visible trees. The observer height for the points was set to 2 meters and is supposed to represent the 1st floor in a building. Since you only can see one half of a tree from ground level, it was decided that you only need to see half a tree (8m^2) to be counted as one visible tree. The tree crown does however still need to be at least 15m^2 to be included in the analysis. To fulfill the criterion of 3 visible trees you must thus see at least 25m^2 of vegetation from the observer point.

The observer points were thereafter used to calculate statistics within grids in order to visualize the result on a larger scale. Grids where more than 90% of the points can see more than 25m^2 of vegetation fulfills the criterion of 3 visible trees.

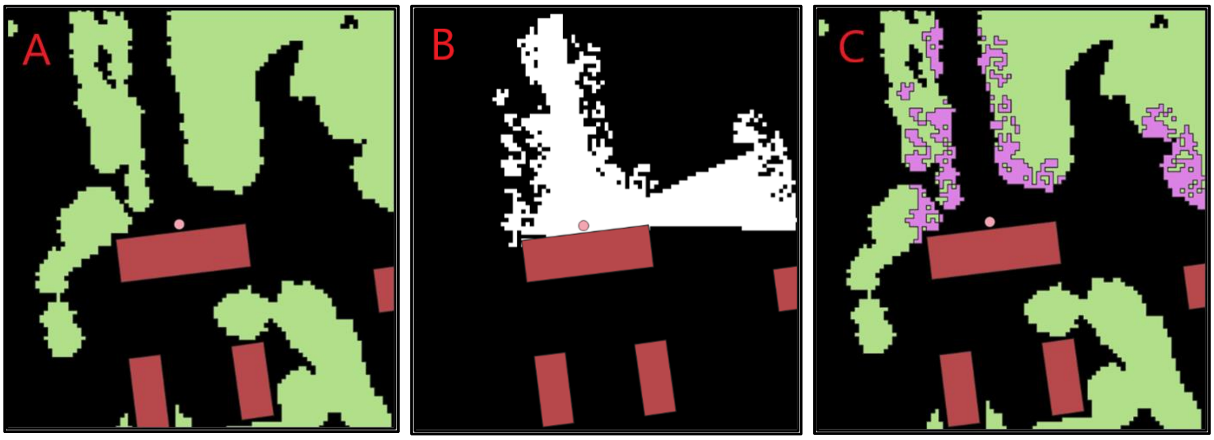

Figure 5. Illustration of how the visible vegetation is calculated. A: Observer point together with buildings and trees. B: Viewshed from the observer point. C: Visible vegetation from the observer point.

Zonal statistics

Zonal statistics is a tool that calculates statistics of a raster layer based on an overlapping polygon vector layer (QGIS, 2023).

The raster layer is in this case the CDSM and the overlapping polygon is a grid layer of the study area. To investigate the statistics of the CDSM layer, all vegetated areas was given value 1 and all non-vegetated areas was given value 0. Zonal Statistics could thereafter be used to calculate the mean value, which corresponds to the percentage of tree canopy cover.

The analysis was conducted within grids in order to investigate the tree canopy cover in depth. There is otherwise risk for uneven distribution of tree canopy cover and misleading results.

Cost distance analysis

A cost distance analysis calculates the shortest weighted distance from each cell of a cost surface raster to the nearest source location (ArcGIS Pro, 2023a). The *r.cost* tool from GRASS has been used in this study.

A cost surface raster is a raster layer where each cell is given a value depending on the cost of travelling through that cell (ArcGIS Pro, 2023b). All barriers such as water, railways, motorways, buildings and slope steeper than 45 degrees was given a high weighting (20 000) to make sure that crossing barriers never would be the best option while everything else was given a low weighting (2). Crossing points over water, railways and motorways had to be created manually and thereafter burned into the cost surface raster with a low weighting (2). The reason for value 2 as low weighting is connected to the pixel size of 2 meters. This makes it possible to get an output where the distance to green spaces is represented in meters for all walkable areas. The weighting of 20 000 for all barriers was chosen because no one has more than 20 000 meters to a green space in an urban area. This value could also be higher to be completely sure that crossing barriers do not give lower cumulative cost than the distance of shortest walkable route.

Source location points, which in this case is points around green spaces, also had to be created. These was created by making a buffer of -2 meters to ensure that the points were located within the green spaces and not on a barrier. All points were placed out around the green spaces with a spacing of 20 meters between each point to cover all sides of the green spaces.

The output from the cost distance analysis shows the cumulative cost. All areas that cross a barrier therefore had to be removed from the output in order to exclude unwalkable areas. The remaining parts shows the distance to nearest green space for walkable areas (see Figure 6). This was thereafter used to calculate the mean distance to green spaces within grids.

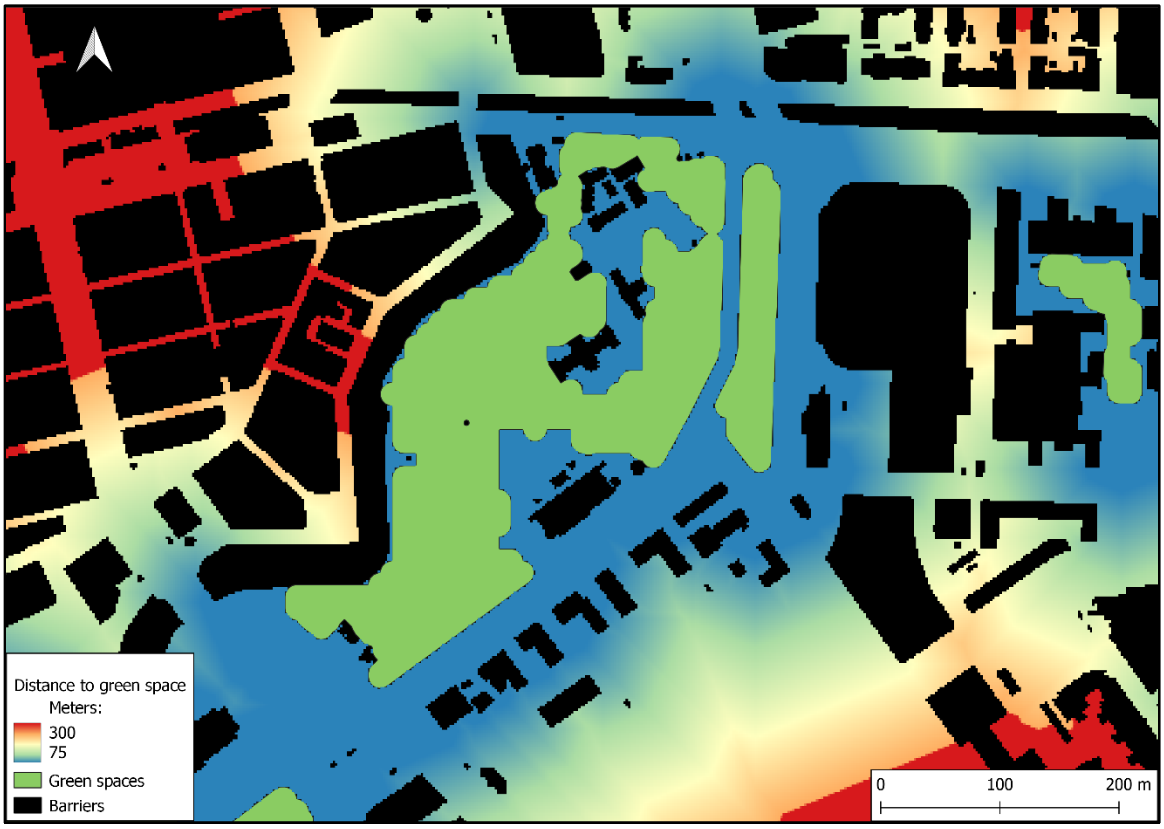

Figure 6. Illustration of cost distance analysis for walkable areas.

3.4 Field observations for viewshed analysis

Field observations is one of the main approaches to observation in physical geography and the focus is often on the form and function of the observed data (Gomez & Jones, 2010).

A smaller field study was conducted 20/03/2023 with field observations as method to investigate the accuracy of the viewshed-based method for 3 visible trees. A total of 80 observer points was randomly selected whereby 20 of the points were located in courtyards. The observer points were thereafter visited in field to investigate if you can or cannot see more than 3 trees. Notes were taken in field and thereafter compared with the results from the viewshed analysis to estimate the accuracy of the method.

3.5 Semi-structured interviews

The interviews in this study had a semi-structured stile with an interview guide that forms the basis for the interview, but with room for flexibility (Bryman, 2012). This makes it possible to ask follow-up questions to the respondents and dig deeper into interesting topics that arise during the interviews. A total of eight interviews were conducted with different types of city planners (see Table 2). The interviews focused on which benefits and challenges that can come with the 3-30-300 rule. Whether the goals are reasonable in a Swedish context as well as what scale one should work with the rule was also in focus during the interviews. The respondents were selected through a purposive sampling strategy and different types of city planners were sought in order to include a wide variety of perspectives within the city planning sector. Five of the respondents works in Gothenburg of which two works within the private sector. The three other respondents work in Trolhättan, Varberg and Alingsås. City planners from different cities was included to widen the perspectives towards the 3-30-300 rule.

The interviews were held as face-to-face interviews at the respondents' offices and lasted for approximately 30 minutes. All interviews began with a short presentation of the 3-30-300 rule together with the results from Gothenburg before the questions from Appendix 1 was asked. The interviews were recorded with permission from the respondents and anonymity was offered for those who wanted. Two of the respondents chose to bring a colleague to the interview in order to provide better answers to the questions.

Table 2. Respondents for the interviews.

Name	Profession	Company
Johan Rehngren	City gardener	Gothenburg Department for Urban Environment
Martin Knape / Tyko Lang	Environmental planner / Strategic environmental planner	Gothenburg City Planning Authority
Hilda Lagström	Strategic urban planner	Gothenburg City Planning Authority
Tobias Noborn	Planning architect	Radar arkitektur & planering
Anna-Karin Sintorn	Landscape architect	Radar arkitektur & planering
Tanja Barrett / Erika Blom	Municipal ecologist / Landscape architect	Varberg City Planning Authority
Matilda Hellman	Landscape architect	Allingsås Department for Strategic Planning
Sebastian Runander	Landscape engineer	Trolhättan Department for Strategic Planning

3.6 Thematic analysis

There are no clear rules on how qualitative data should be analyzed but there are however some broader guidelines that can be followed (Bryman, 2012). One such guideline is thematic analysis where you identify, analyze and describe themes within your dataset (Braun & Clarke, 2006). This is a flexible guideline that is free from a theoretical framework and can generate detailed information from the data into distinct themes. The thematic analysis in this study has an inductive approach and follows a structured although flexible guideline in 6 steps suggested by Braun & Clarke (2006):

1. Familiarizing yourself with your data

2. Generating initial codes

3. Searching for themes

4. Reviewing themes

5. Defining and naming themes

6. Producing the report

Inductive thematic analysis was assessed as suitable method to analyze the qualitative data from the interviews because this method allows for generalizations at the same time as the flexibility within the method makes it possible to include and compare different perspectives, which is of interest since the respondents have different backgrounds and works in different cities. The themes in this analysis is not created based on quantity but rather on interesting and important subjects in relation to the research. These themes are thereafter divided into sub-themes which can be especially useful in order to achieve good structure for large and complex themes (Braun & Clark, 2006).

4 Results

The results from the GIS-analyses and the accuracy of the viewshed-based method will be presented in section 4.1. The result for each criterion of the 3-30-300 rule is presented individually first before combined results are presented. The results from the thematic analysis will be presented in section 4.2 where the themes and sub-themes will be thoroughly analyzed.

4.1 The 3-30-300 rule in Gothenburg

The result for visible trees shows that Gothenburg to a large extent is fulfilling the criterion of 3 visible trees (see Figure 7). The central areas of Gothenburg such as Centrum and Haga as well as parts of the industrial areas Backa and Gamlestaden have lack of visible trees. The other areas are mostly having access to visible trees. In total, 95% of all the observer points and 85,5% of the observer points in the *inner city* can see more than 3 trees.

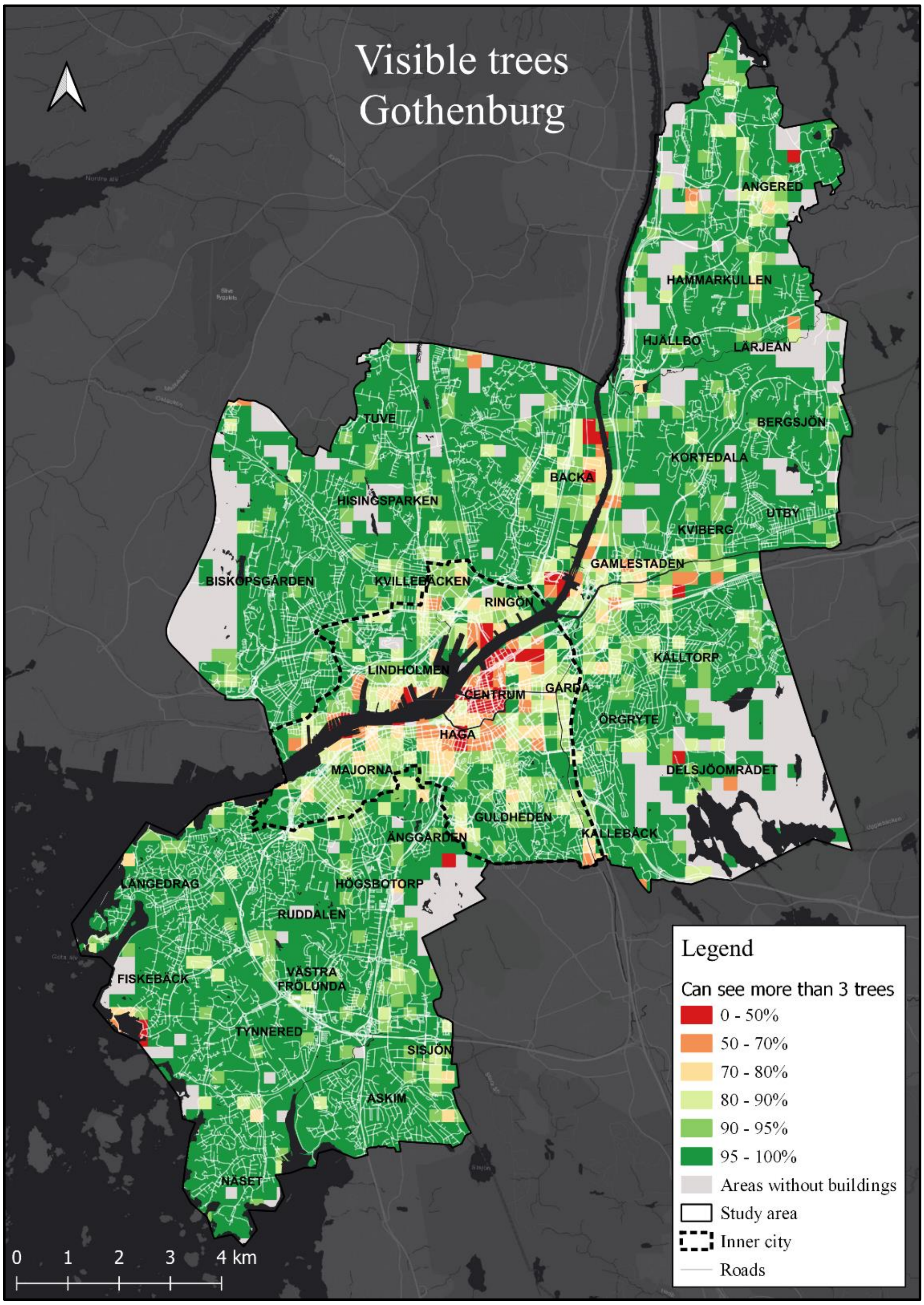

Figure 7. Visible trees in Gothenburg analyzed within grids of 250x250 meters. The result is visualized as percentage of the observer points that can see more than 3 trees. Base map: ESRI Gray (dark).

The result for tree canopy cover shows that large areas in Gothenburg have difficulties to fulfill the criterion of 30% tree canopy cover (see Figure 8). The areas that achieve the goal of 30% tree canopy cover is primarily larger green spaces such as Änggården, Ruddalen, Biskopsgården, Hisingsparken, Lärjeån and Delsjöområdet as well as other areas where green spaces are predominant. The inhabited and central areas of Gothenburg are primarily not fulfilling the goal and the tree canopy cover for the *inner city* is only 16,6%.

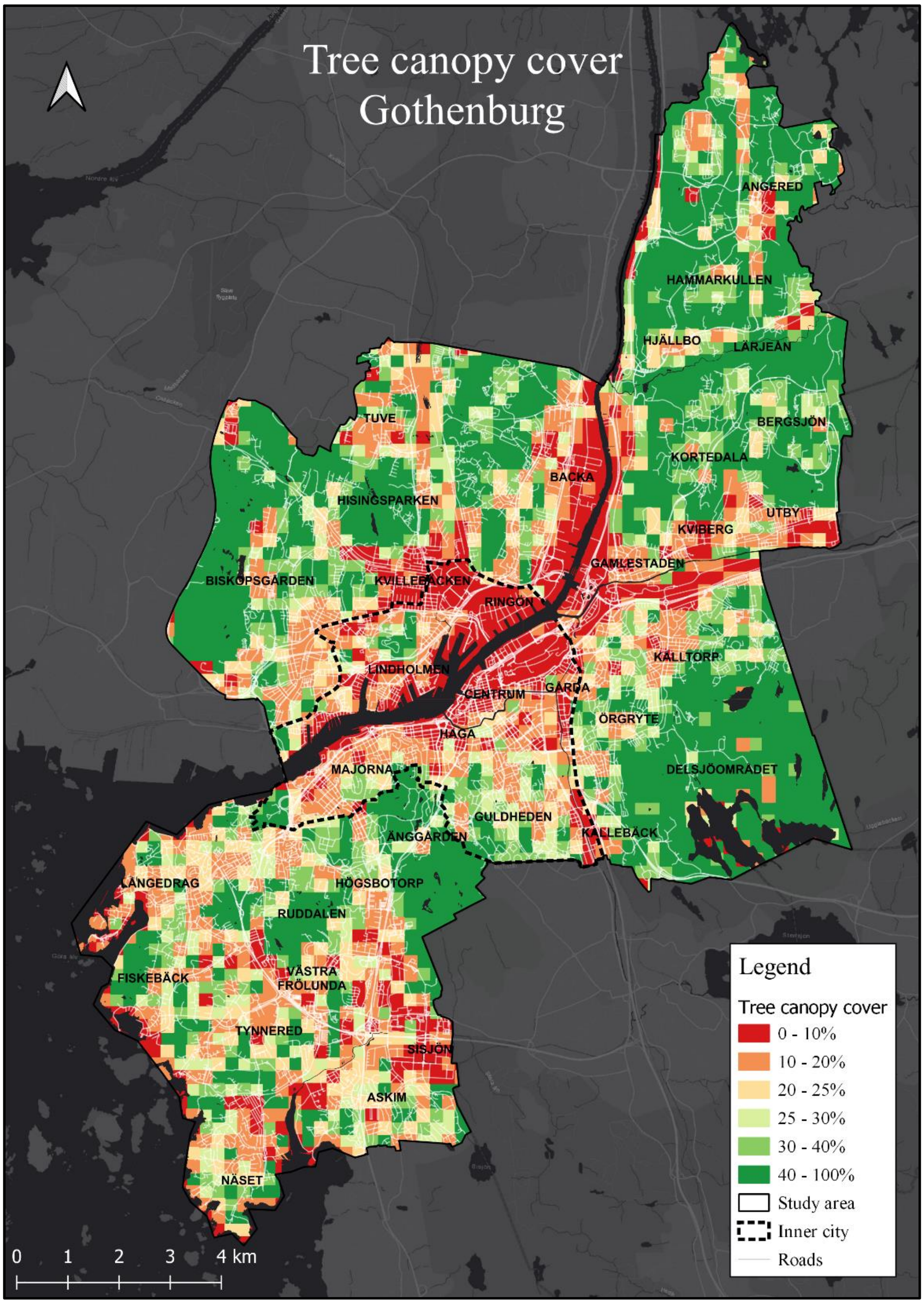

Figure 8. Tree canopy cover in Gothenburg analyzed within grids of 250x250 meters. Base map: ESRI Gray (dark).

The result for distance to green spaces shows that the majority of the inhabitants in Gothenburg has a green space within a walking distance of 300 meters (see Figure 9). Some of the central and industrial areas do however have more than 300 meters to a green space. The average distance to a green space is 92 meters for all buildings and 174 meters for the buildings in the *inner city*, which is way below the goal of 300 meters.

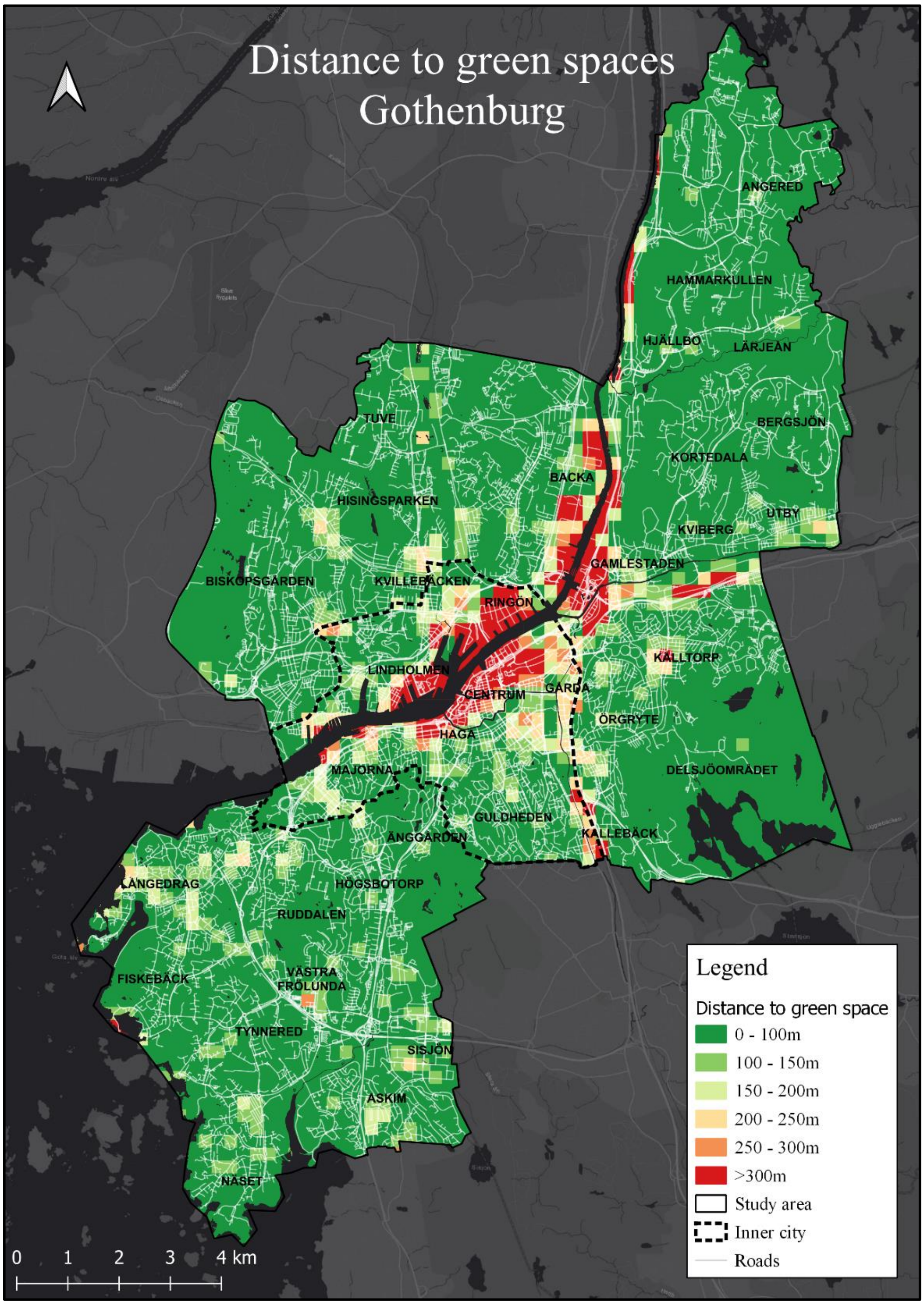

Figure 9. Distance to green spaces in Gothenburg analyzed within grids of 250x250 meters. Base map: ESRI Gray (dark).

The overall result for 3-30-300 shows a clear pattern in Gothenburg (see Figure 10). The central areas of Gothenburg, such as Lindholmen, Haga and Centrum as well as the industrial areas Ringön, Backa and Gamlestaden, are to a large extent only fulfilling one of the criteria and in many cases not fulfilling any criteria at all. The outskirt of Gothenburg shows the opposite result where the majority of the areas are fulfilling 2/3 criteria and several areas are fulfilling all criteria. The larger green spaces in Änggården, Ruddalen, Biskopsgården, Hisingsparken, Lärjeån and Delsjöområdet accounts for a large amount of the areas that fulfills all criteria.

Some combinations seem to be more prevailing than others. One combination, 30% tree canopy cover by itself, is not found anywhere in Gothenburg. This is a fairly logical result since high tree canopy cover almost always implies that you can see more than 3 trees or have less than 300 meters to a green space. The combination 3-30 is of the same reasons as above extremely rare and is only occurring in a small area west of Hammarkullen. The reason for this rare combination is due to the railway that is passing through the area, which gives a long walking distance to the green space. Another rare although more occurring combination is 30-300 and can be found scattered out around in Gothenburg. These areas cannot see 3 trees due to the urban structure or because smaller areas within the grid are pulling down the overall result for 3 trees.

The criteria 3 visible trees and 300 meters to a green space seems to be the most feasible goals in Gothenburg meanwhile 30% tree canopy cover seems to be the hardest goal.

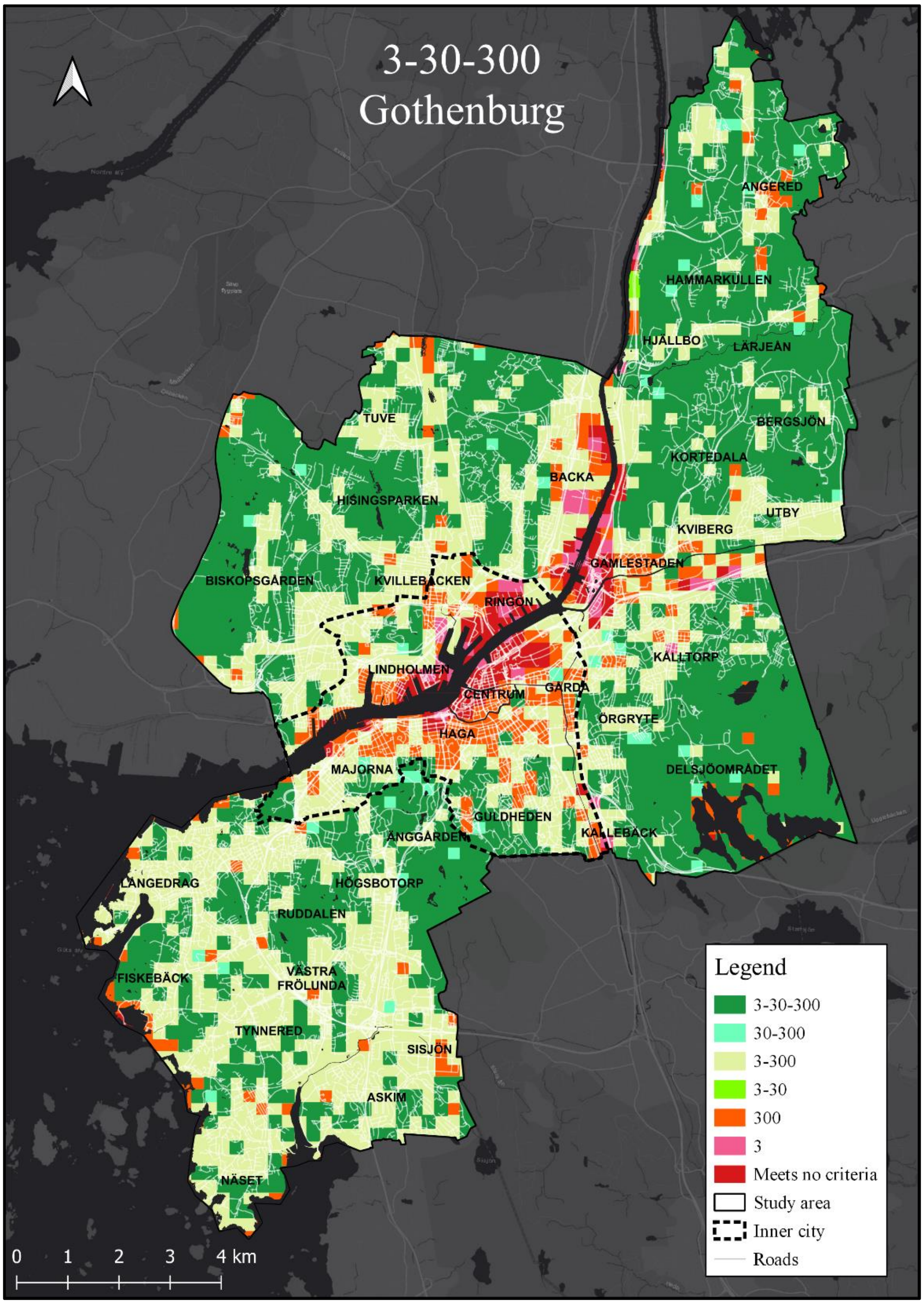

Figure 10. All combinations of the 3-30-300 rule in Gothenburg analyzed within grids of 250x250 meters. Areas without buildings fulfills the criterion of 3 trees if the tree canopy cover is over 30%. Base map: ESRI Gray (dark).

Some areas are sticking out in terms of bad results in otherwise good areas and good results in otherwise bad areas. The industrial areas close to Sisjön and Kallebäck is together with Angered standing out in a bad way and some smaller areas east of Centrum is standing out in a positive way. Angered and Centrum are investigated more detailed at a smaller scale in the next section.

4.1.1 The 3-30-300 rule in Angered and Centrum

Two interesting areas, one in Angered and one in Centrum, was picked out based on the overall results and analyzed more detailed within grids of 50x50 meters.

Angered which stood out as a bad area compared with its surroundings got a better and rather interesting result after the detailed analysis with 50x50 meters grids. It becomes clear that Angered to a large extent fulfills at least 2/3 criteria and that the major problem is the tree canopy cover. Another interesting finding is that built-up areas who cannot see more than 3 trees primarily are located in areas with courtyards. A more detailed analysis like this displays the variation within the area in a better way and makes it possible to find specific explanations to the results. One example from Angered is the southeastern part of the area that consists of a large park with few trees which means low tree canopy cover and since there are no buildings or observer points to analyze, the criterion of 3 trees is neither fulfilled. This area does obviously see more than 3 trees and has big social value, illustrating the importance of site-specific considerations.

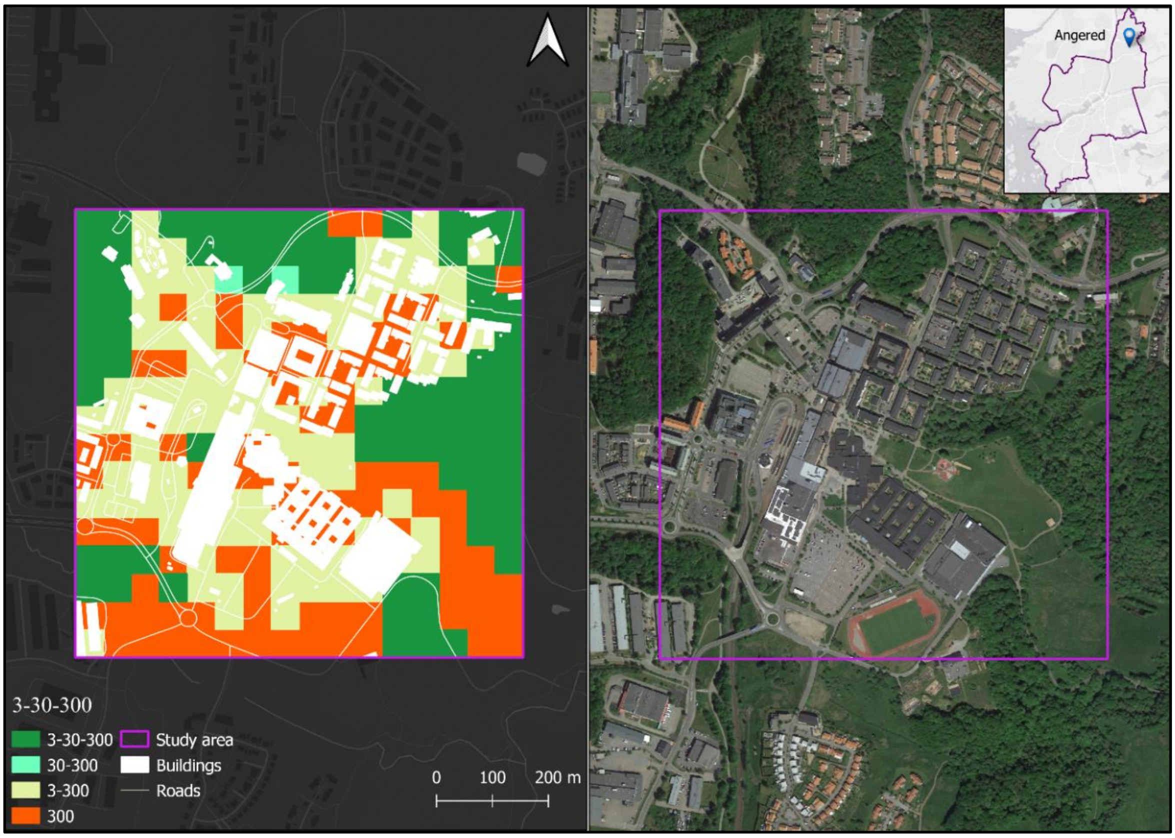

Figure 11. The 3-30-300 rule in Angered analyzed within grids of 50x50 meters. Areas without buildings fulfills the criterion of 3 trees if the tree canopy cover is over 30%. Base map: CartoDB Dark Matter & Google Satellite.

The eastern part of Centrum (Trädgårdsföreningen/Heden) that stood out as a good area compared with its surroundings turned out to have a rather varied result and numerous bad areas emerged after the detailed analysis with 50x50 meters grids. The entire northwestern part and large areas of the eastern part shows up a poor result where only 1/3 criteria are fulfilled and in some cases no criteria at all. The area around Trädgårdsföreningen in the middle fulfills most of the criteria but has rather low tree canopy cover in some places. These places do not fulfill the criterion of 3 trees if buildings are absent because no observer points then have been analyzed, which means that the criterion of 3 trees cannot be fulfilled. This is obviously an incorrect result in Trädgårdsföreningen. Another site-specific consideration is the football stadium in the northeastern corner which is uninteresting from an urban green planning perspective but still pulls down the overall impression of the area in this case.

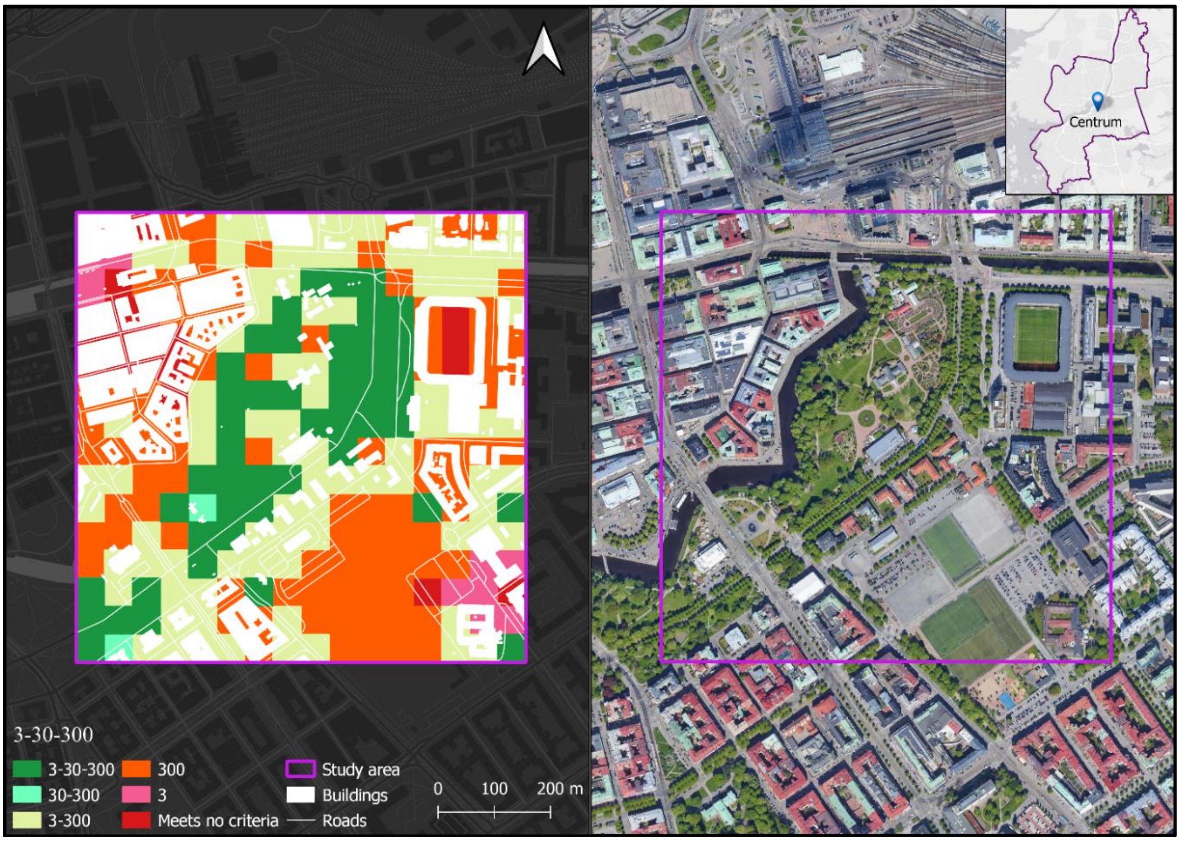

Figure 12. The 3-30-300 rule in Centrum (Trädgårdsföreningen/Heden) analyzed within grids of 50x50 meters. Areas without buildings fulfills the criterion of 3 trees if the tree canopy cover is over 30%. Base map: CartoDB Dark Matter & Google Satellite.

4.1.2 Viewshed accuracy for 3 visible trees

The fieldwork showed that the overall accuracy of the viewshed-based analysis was 85%. The accuracy was lower for courtyards, with an accuracy of 75%, while the street-facing walls showed an accuracy of 88%.

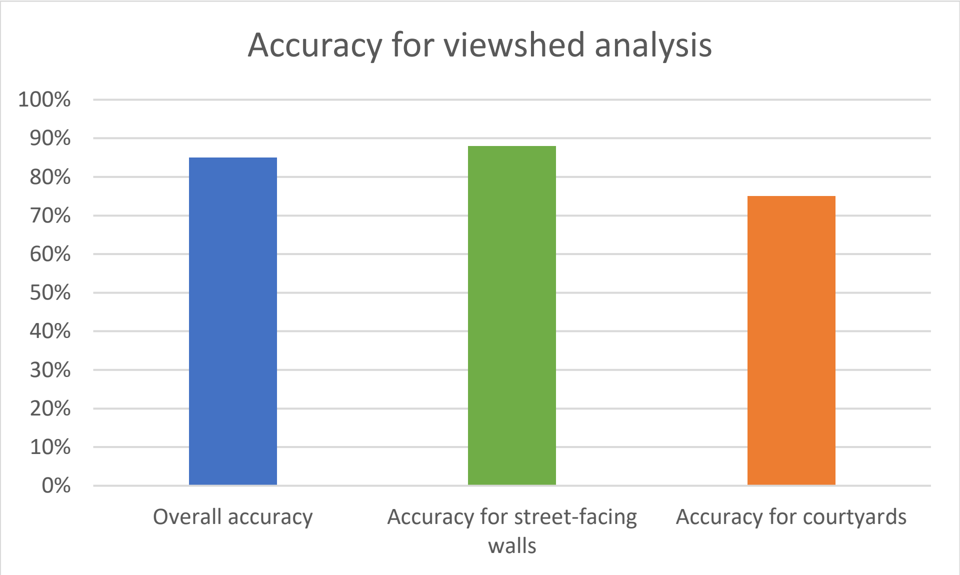

Figure 13. Accuracy for viewshed analysis in different buildings structures.

4.2 Thematic analysis

The themes and sub-themes from the thematic analysis is presented in Table 3 and are thoroughly analyzed in the following subsections.

Table 3. Themes and sub-themes from the thematic analysis.

Theme	Sub-theme
Attitudes towards 3-30-300	Effects Goals Policy
Challenges with 3-30-300	Competition Laws Money
Scale for 3-30-300	Detailed development plan Comprehensive plan City size

4.2.1 Attitudes towards 3-30-300

The majority of the planners are positive to the 3-30-300 rule and highlights that it is comprehensive, easy-to-remember and concrete. The comprehensiveness of the rule gives a wider perspective on what urban greening can provide and shows that greenery can contribute with numerous ecosystem services that improves health and urban climate. Most people are not aware of the value of a tree and this rule can furthermore contribute to more awareness of the value of trees. The rule can also have big impact on the planning sector since it is easy to remember and provides a clear guideline, which is important in order to strengthen the role of urban greening. The concrete goals in 3-30-300 enables comparable analyses over time, can show where measures are needed and makes it easier for decision makers to include urban greening in the planning process.

The goals of 3 visible trees and 300 meters to a green space were considered reasonable by the city planners but 30% tree canopy cover were assessed as difficult to achieve in dense cities. The results from Gothenburg were in accordance with their expectations, but they were positively surprised by how many that could see more than 3 trees and thought it was interesting to see how much that was classified as green space. One of the city planners was however skeptical to the minimum size of 0,5 hectare for a green space and argued that smaller green spaces are more suitable in a dense city.

Different ways of working towards a high tree canopy goal was discussed and one suggestion was to change the goal to 30% vegetation while another suggestion was to exclude industrial areas and have other goals in these areas although vegetation is important even there. To decrease the tree canopy cover goal was also discussed and as one of the city planners said, *"It feels like 30% tree canopy cover is the hardest goal and maybe 25% or 20% is more reasonable. People are talking about 2-20-200, which might be a more reasonable guideline"*. High tree canopy cover is still important since it provides so many ecosystem services and can connect green spaces with green corridors which is important for biodiversity and ecology. High tree canopy cover does however not automatically imply that green structures are connected, and one critique of the rule has therefore been that it is yet another social way of describing urban greening and important ecological aspects can be left out. A suggestion to solve this problem was to incorporate ecological goals to the rule.

The municipal self-government is very strong in Sweden, which means that the municipality itself must decide that 3-30-300 is something they want to work with. To have clear guidelines from large actors such as Boverket or Naturvårdsverket can help to implement 3-30-300 in Swedish cities and is assessed as especially important for cities with lack of knowledge on how to work with urban greening and for those who meets opposition from politicians or impactful companies. The rule should however be perceived as a guideline rather than a strict policy and as one of the city planners said, *"It is always good to have national guidelines to lean on, but I still think the municipalities need to be able to make the necessary adjustments".* The 3-30-300 rule should therefore be adapted to the characteristics of the city, and one should also remember that 3-30-300 is a simplification and different tools are necessary for different purposes. In order to achieve the goals, it is important to include these in the planning process before a detailed development plan, there is otherwise a large risk that the goals are deprioritized.

4.2.2 Challenges with 3-30-300

The 3-30-300 rule is facing a number of challenges. Competition about the space is one of the major challenges in order to achieve the goals and this competition takes place both below and above the ground. The roots from the trees are competing with cables below the ground and as one of the city planners said, "*This is a constant challenge and I think we need to work more cross-sectorally, for example between the water department and the park department*". Trees can also contribute to the stormwater management and the integration of roots and cables below the ground is therefore of extra importance. The competition above the ground is connected to construction and money as described by one of the city planners, "*It is always about maximizing your areas and minimizing the costs for which you do not receive income. You don't get any income from public spaces and development districts, you get income from buildings. For developers, it's all about money".* Trees does not generate money but are instead leading to more costs in terms of planting and maintenance. It is therefore important to communicate the value of trees and how much money trees can save, in order to strengthen their role in the urban environment. Trees and ecosystems are competing on bad terms in the planning sector and more laws around this topic could facilitate the work with urban greening, as described by one of the city planners, *"A common argument for not including environmental goals in projects is that it is not included in the Planning and Building Act and can therefore not be required. I feel that it would be valuable if more of this could appear in the legislation. That would make it easier".*

In addition, the municipalities do not have authority over private properties. This makes it difficult to work towards specific goals such as 3-30-300 and ensure that the goals are achieved when you do not have the possibility to make physical changes. Communication of the positive effects from trees is therefore of absolute importance. Another challenge with quantitative goals such as 3-30-300 is that the numbers often are looked at as a maximum which means that you may not achieve what you strive for, as noted by one of the city planners, *"A policy with a specific number also means a maximum number in the development. If it says 3 trees, then you only plant 3 trees".* This is connected to money as described earlier where trees are viewed as an expense in terms of planting and maintenance. The problem with specific numbers is assessed as biggest for 3 and 30 since these goals are connected to amount while 300 is a distance goal and therefore not competing against other interests as often as 3 and 30.

4.2.3 Scale for 3-30-300

The scale for analyzing 3-30-300 should be different for different purposes. Grids of 250x250 meters was assessed as suitable for analyzing larger areas such as the entire city and can be appropriate to have as support for a comprehensive plan. The scale should be smaller for smaller areas in order to be useful for a detailed development plan as described by one of the city planners, *"In order to be functional and used as support in ongoing planning, then you need to go down a bit in scale to understand where the problems are".* Grids of 100x100 meters or 50x50 meters was considered as suitable for detailed development plans but it is important to recognize that a suitable scale will differ widely depending on the area of interest.

The scale for analyzing 3-30-300 could also vary between different cities, especially if the entire city is to be analyzed. Larger grid size can be suitable for larger cities while smaller grid size can be suitable for smaller cities. The central and urban areas of a city was considered most interesting to analyze but the outskirts were also assessed as interesting, especially for a comprehensive plan.

5 Discussion

5.1 The 3-30-300 rule in Gothenburg and Sweden

The results from the GIS-analyses in Gothenburg shows that the central areas of the city is where it is most difficult to fulfill the 3-30-300 rule. Similar results could be found in Southern Sweden were 3-30-300 was investigated for Helsingborg, Hässleholm, Kristianstad, Landskrona, Lund, Malmö, Trelleborg, Ystad and Ängelholm (Region Skåne, 2023).

The result for 3 visible trees seems to be very good in Gothenburg where 95% of all observer points and 85% of the observer points in the *inner city* could see more than 3 trees compared to the study from Southern Sweden where only 46% of the houses in the nine cities could see more than 3 trees (Region Skåne, 2023). The results differed from 31% in Kristianstad to 61% in Lund. The result in Gothenburg appears to be good compared with international cities as well. A study of 3-30-300 in Barcelona did for instance find that only 43% could see more than 3 trees from their homes (Nieuwenhuijsen et al., 2022). The methods and data used to estimate visible trees can obviously affect the results, but the overall accuracy from the viewshed analysis in this study was however good, with an accuracy of 85%. This indicate that the access to visible trees in fact is high in Gothenburg. The accuracy for courtyards was however lower (75%) and possible explanations for this can be found in the method discussion, primarily under *Trees and tree canopy cover* and *Fieldwork for viewshed analysis*.

The results from the GIS-analyses shows that a tree canopy cover of 30% is the most difficult goal to achieve. The tree canopy cover is 16,6% in the *inner city* and drastic measures are needed in order to achieve 30% tree canopy cover. This is in accordance with the findings in the nine cities in Southern Sweden where the tree canopy cover is 10,4% and Trelleborg only has a canopy cover of 5,8% while Ängelholm has highest canopy cover with 14,4% (Region Skåne, 2023). The goal of 30% tree canopy cover was also assessed as the most difficult goal to achieve by the interviewed city planners. The Swedish Environmental Protection Agency has a goal of 25% tree canopy cover in all Swedish cities by 2030, which might be more reasonable. This goal would however not fit in with the stickiness of 3-30-300 and the proposed adjustment to 2-20-200 might be a better solution in a Swedish context. The differences in providable ecosystem services between 30% and 25% or 20% tree canopy cover should be further investigated.

The goal of maximum 300 meters to nearest green space is the easiest goal to achieve in Gothenburg where the average distance to a green space is 92 meters for all buildings and 174 meters for the buildings in the *inner city*. A similar result could be found in Stockholm where the average distance to nearest green space was 176 meters (Stockholms Stad, 2010). These findings illustrate that 300 meters might be a to defensive goal and that 200 meters can be a suitable goal in a Swedish context. Different methods and different definitions of green space can obviously affect the results. Both this study and the study from Stockholm have however used the same minimum size (0,5 hectare) for green spaces, which makes it more comparable.

The findings from above makes it natural to discuss if 3-30-300 is the right combination or if 2-20-200 might be more suitable. This solution was mentioned during the interviews by one of the city planners and can potentially have some advantages although a decrease from 30% to 20% tree canopy cover is nonoptimal. Lower goals such as 2 and 20 is obviously easier to achieve but can possibly also be easier to include in the planning process. It is conceivable that hard goals and bad results makes it difficult to know how one should prioritize the green planning. Lower goals can potentially make this easier and in turn increase the chances of being included in the planning process. It would also mean less costs, less maintenance, and less competition about space, which is positive since these factors was assessed as some of the challenges for 3-30-300 by the interviewed city planners. A decrease from 300 to 200 meters to nearest green space could potentially lead to an increase of these factors in areas where new green spaces are needed. The results from this study and the study conducted in Stockholm (Stockholms Stad, 2010) does however show that few measures are needed in order to fulfill the 200 meters goal.

A change from 3-30-300 to 2-20-200 might be a more realistic guideline for Swedish cities. It can however be smart to continue with 3-30-300 considering how much attention this guideline has gotten until more research is conducted in Swedish cities and on the difference between 20% and 30% tree canopy cover. It is also important to highlight that the goals only should be viewed as a guideline for urban greening and that local considerations always will be necessary, regardless of whether the 3-30-300 or 2-20-200 model is used as guideline.

The scale used in this study was 250x250 meters grids for the entire study area and 50x50 meters grids for the two detailed analyses in Angered and Centrum. These scales were assessed as appropriate by the interviewed city planners for a comprehensive plan and detailed development plan respectively. The study from Southern Sweden that investigated nine cities used 50x50 meters grids to analyze the tree canopy cover for the cities (Region Skåne, 2023). This is lower than the preferences from the interviewed city planners but could also be connected to the size of the cities, which is smaller than Gothenburg. The scale should always be dependent on the purpose and the area of interest as pointed out by the interviewed city planners.

5.2 Green space qualities

The majority of all continuous areas with vegetation are in this study classified as green spaces. This means that the some of the green spaces might be difficult to access and use, especially for elderly, kids, and people with handicap. A study from the Netherlands (Zang et al., 2015) that investigated two similar neighborhoods with the same amount of green spaces, found that the neighborhood with more accessible and usable green spaces showed better levels of mental health and greater attachment to the green spaces. Similar results could be found in a study conducted in Australia where green space useability was associated with better overall health (Carter & Horwitz, 2014). These findings illustrate the importance of accessible and usable high-quality green spaces. It would be interesting to investigate which green spaces in Gothenburg that are high-quality green spaces and then analyze the proximity to these. This would give a less quantitative approach and lead to a more correct picture of the distance to useable green spaces. It can however be difficult to define what is useable and for whom it is useable since personal preferences can differ widely. Almost all types of green spaces were therefore included in this study. More research would be needed on how green space qualities are perceived by the inhabitants in Gothenburg in order to define useable green spaces in a representative way.

Some green spaces that partly can be accessible and usable are not included as green spaces in this study. Community gardens are for instance not included as green spaces but are often open for everyone to access in Sweden although the areas with cottages and garden plots might be inaccessible. A study from Stockholm (Jonsson, 2022) found that community gardens can offer important ecosystem services, biodiversity, recreational areas and safety for both members and the public. The high biodiversity in community gardens is highlighted as important for recreational use and shows that community gardens can be functional complements to the existing green spaces. Golf courses are also excluded as green space since it is not allowed to use these as green spaces during the golf season. They can however serve important social, mental, and physical values for the golf-users and often be used for recreation by the public during the off-season.

The minimum size of a green spaces is in this study set to 0,5 hectare, which also is the recommendation from WHO (2017). Multiple studies have found a strong correlation between larger green spaces and more physical activity, which in turn leads to better health outcomes. Cohen et al. (2010) did for instance find that park size and organized activities was the two factors that correlated strongest with high numbers of park users. A study from Australia (Sugiyama et al., 2010) found that larger green spaces can lead to higher levels of physical activity and came with a proposition of few but larger green spaces instead of many smaller ones when planning for new green spaces. The same study suggested to increase the attractiveness of the existing large green spaces since attractiveness was considered the most important attribute of a green space in order to increase recreational walking and improve physical activity.

It can often be difficult to find space for larger green spaces in dense cities. Smaller green spaces are therefore also necessary and one benefit with smaller green spaces is that the availability to green spaces is increasing because they can be more outspread. The city of Gothenburg is for instance using 0,2 hectare as minimum size for a public green space (Göteborgs Stad, 2022a). This is smaller than the minimum size used in this study, which means that smaller and important green spaces can have been excluded here. The size of a green space is found to be less important on weekdays while larger green spaces are preferred on the weekends (Bertram et al., 2017). Proximity to green spaces is in the same study found to be more important on weekdays whereas people are willing to travel further on the weekends. Important characteristics for green spaces seem to differ depending on if it is a large or small green space. A study from Spain found visual and sound features to be more important for satisfaction in larger green spaces while social features were more prominent in smaller green spaces (Gozalo et al., 2019). Similar results for smaller green spaces could be found in Copenhagen, where one of the main reasons for using the space was for socializing (Peschardt et al., 2012). Younger people were more likely to use the smaller green spaces for socializing while older people were more likely to use them for recovery. These findings shows that smaller green spaces also are important, especially in a busy everyday life.

5.3 Method discussion

5.3.1 LiDAR data

The overall classification from the LiDAR data was acceptable, especially after the polygons to remove larger areas that wrongly had been classified as vegetation was added. It worked well to classify buildings and larger vegetation but is not as good at identifying smaller vegetation. Lindberg et al. (2013) who compared the LiDAR data from LM with

Gothenburg's LiDAR data found that there is a high risk for vegetation being left out when using LM LiDAR data, primarily due to low point density and bad separation of returns due to the simple classification. Another factor that could contribute to missing vegetation is the scanning period. The LM LiDAR scanning in southern Sweden is conducted during the spring or late autumn because the lidar pulses then can reach the ground more easily, which in turn gives more accurate ground elevation (Lantmäteriet 2022a). This does however also imply that trees do not have leaves, which potentially could make it more difficult to identify small vegetation considering that the trees are smaller without leaves and the point density was low in this study. Gothenburg's own LiDAR data with 10 points per square meter would probably capture more trees, but this data was excluded because I wanted to develop a method that is based on open and national covering data that can be applied to all Swedish cities. The LiDAR data from LM with 1-2 points per square meter was therefore chosen.

Another important aspect regarding classification is to have newly updated geodata, in this case LiDAR data and buildings. There is otherwise a higher risk for wrongly classified data. If the buildings layer is old, there is a risk that new buildings have been added and these will then be classified as vegetation. If the LiDAR data is old, there is a risk that changes have occurred at the surface that will lead to wrongly classified data. It is therefore important to have updated geodata in order to classify buildings and vegetation correctly.

5.3.2 Trees and tree canopy cover

The accuracy of trees and tree canopy cover is in this study depended on the quality and the classification of the LiDAR data.

Smaller vegetation such as trees are sometimes missed out due to low point density and simple classification of the LiDAR data as discussed in the previous section. The buffer of 2,5 meters that was used around all buildings was necessary to avoid building edges from being classified as vegetation. This buffer does however also imply that the trees within the buffer will not be classified as vegetation. This means that trees located close to buildings might not be included in this study and the problem seems to be bigger in courtyards, which partly can be explained by the structure of a courtyard which often consists of smaller buildings within the courtyard that give rise to more buffers. The buildings in courtyards also tends to be low, which means that tree crowns can hang over the buildings and will then be classified as part of the building instead of vegetation. It can therefore be possible to see more than 3 trees in some cases but not be included in this analysis. If the quality of the LiDAR data would have been better, then the buffer could have been smaller and less trees would have been erased.

Trees with crowns smaller than 15m^2 from aerial view are also excluded from the tree layer because the trees ideally should be well-established (Konijnendijk, 2022). The definition of a well-established tree as 15m^2 crown from aerial view is however a simplification and well-established trees can be both smaller and larger than this definition depending on factors such as species and living conditions. No universal definition of well-established trees is therefore to be found. Cobra Groeninzich (2022) in the Netherlands did for instance define well-established trees as trees with crown larger than 25m^2 from aerial view. This definition could also have been used but 15m^2 seemed to include most trees and was therefore chosen in this study. It is however important to recognize that smaller trees also can have big value although they are excluded in this study.

5.3.3 Green spaces

The green spaces in this study are created with a combination of urban green spaces from SCB and forest areas from LM. The urban green spaces from SCB are public, but the forest areas from LM are not necessarily public although most of them probably are. It is therefore possible that some of the green spaces in this study are private and not open for everyone. Another way of defining green spaces and avoid private green spaces could be to follow the suggested method from Region Skåne (2023). This method uses LM landcover map “Topography 50” as base and are thereafter removing areas that do not form a green space. The remaining parts that are wider than 30 meters and larger than 0,5 hectare are the created public green spaces.

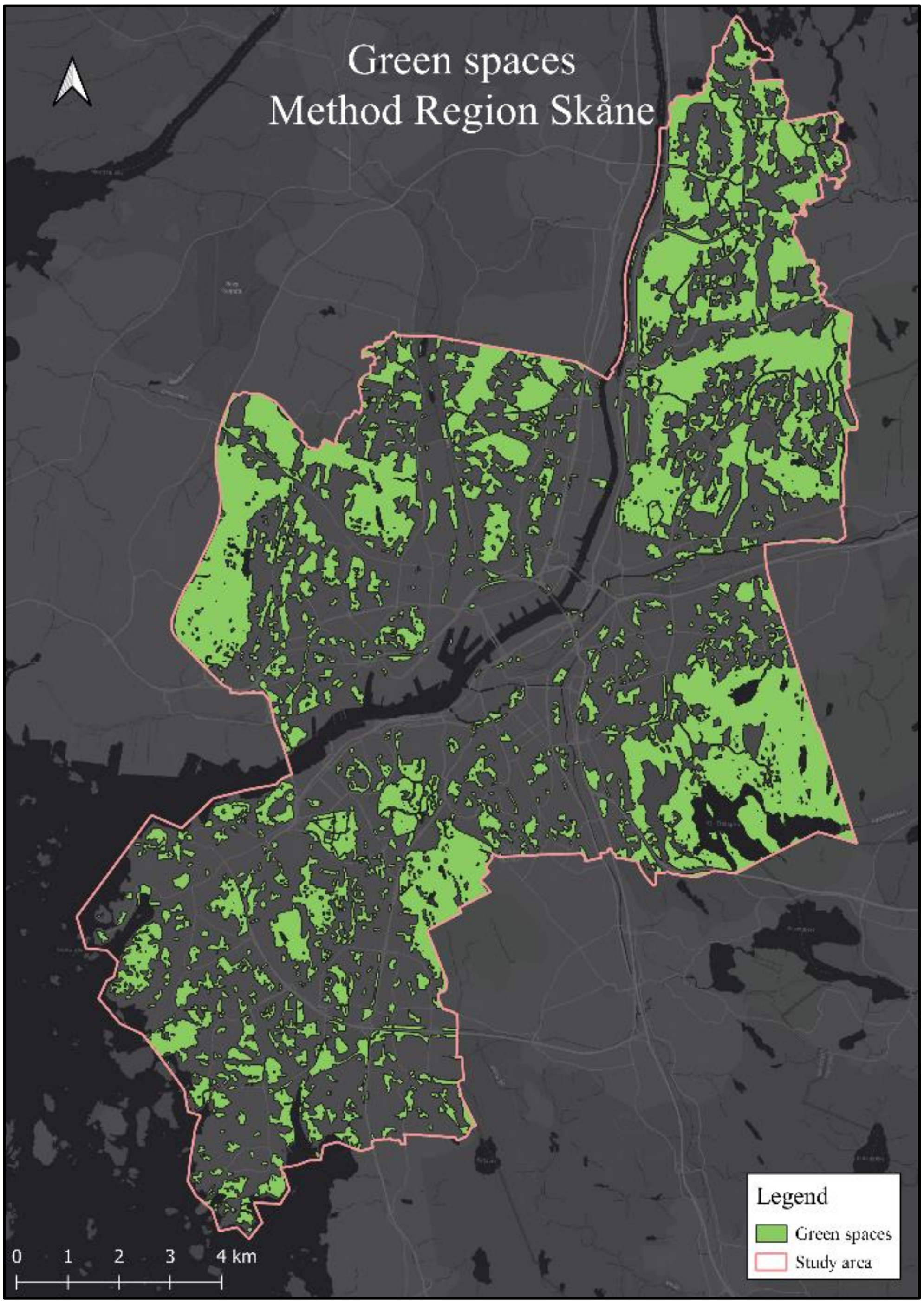

Figure 14. Example of green spaces created according to the suggestion of Region Skåne (2023).

This method is relatively time-consuming and advanced, but a huge strength is that it builds upon open geodata that is frequently being updated. This would therefore be a good alternative since the green spaces from SCB are rather old and it is unclear when and how often these will be updated in the future. Another option could be to use the green spaces from the city of Gothenburg. This data was however excluded because it only contained green spaces that are managed by the municipality, which do not include all green spaces.

5.3.4 Viewshed analysis

Square meters of visible vegetation was in this study used to estimate how many trees you can see based on a viewshed. A shortage with this method is that you do not know for sure that you see 3 trees, it could also be 1 or 2 larger trees. However, the minimum calculation had to be set after the minimum size of well-established trees, it would otherwise be impossible to fulfill the criterion of 3 trees in areas with smaller trees. One could also argue that 1 or 2 larger trees could compensate for 3 smaller trees and give the same effects. Square meters of visible vegetation have in this study been used as proxy for estimating if you can see more than 3 trees but should rather be seen as an indicator of visible vegetation.

The method used to estimate visible vegetation in this study works well with the observer height of 2 meters since the trees always are higher than the observer height. It is only possibly to see the parts of the tree that is facing towards the observer point since the trees has height and width in the DSM layer and thus act as a barrier. It is not possible to see through nor to see under the tree canopy. To use half a tree ($8m^2$) as proxy for one visible tree was therefore decided. It would however be interesting to include parameters such as vegetation permeability. The GIS-based method for incorporating permeability for vegetation in viewshed analyses proposed by Ruzickova et al. (2021) could feasibly be used. It would also be interesting to conduct the viewshed analysis in a 3D representation which would enable visibility under the tree canopies. More research would be needed on how these parameters can be included, how different observer heights can be included and how visible trees then should be calculated.

The method used in this study would be problematic if one wants to estimate visible trees from different observer heights because the viewshed increases with increased height. At some point the observer height will be higher than the trees and you would then have to change the proxy for one visible tree from half a tree to the entire tree. This is difficult because the trees can have different heights and one can therefore not know when the proxy for one visible tree should be changed. A low observer height with a spacing of 20 meters gives a general estimation of how much vegetation one can see from all sides of a building. It is also reasonable to assume that if you can see more than 3 trees from the 1st floor you can most likely see more than 3 trees from a higher floor as well. The bigger problem is however that you probably can see more than 3 trees from a higher observer height in cases when you see less than 3 trees from the 1st floor. This is a shortage with the method and would need more investigation to address.

5.3.5 Fieldwork for viewshed analysis

The fieldwork showed that the overall accuracy of the viewshed analysis was good (85%), but lower for courtyards (75%). Only 20 observer points was investigated for courtyards, which means that it is difficult to draw valid conclusions based on this. The low number of investigated observer points can potentially affect the accuracy, but the biggest impact on the accuracy is probably connected to the buffer of 2,5 meters used around the buildings in the LiDAR classification. This buffer is as described in the chapter *Trees and tree canopy cover* necessary to avoid buildings from being classified as vegetation but also implies that vegetation within this buffer is erased and the problem seems to be bigger in courtyards. The viewshed analysis was therefore underestimating visible trees, especially in courtyards, since trees sometimes were missing in the tree layer. The fieldwork could confirm that this was the problem since the only times the viewshed analysis and the fieldwork not matched was when the result for the viewshed analysis indicated that the observer point saw less than 3 trees, with one exception. The fieldwork also showed that the accuracy for street-facing walls was high, which further confirms that the problem lies in the structure of courtyards and the LiDAR classification.

The view from the observer points is better than from the windows since the observer points are placed out 2,5 meters outside the buildings, which allows for 360-degree view while the view from a window would be more limited. This does not affect the comparison since both the viewshed analysis and the fieldwork is based on the same points, but it could imply that some of the trees would not be visible from a window.

5.3.6 Cost distance analysis

A cost distance analysis with a binary cost surface raster that includes walkable areas and barriers has been used in this study. The advantages with this method is that barriers are included and that it is possible to cross open spaces outside a road network, which can be the case in reality as well. The cost surface raster is however a simplification.

Major roads that are not classified as motorways can for instance be difficult to cross although they are classified as walkable in the cost surface raster. These were included since TV did not have a category for unpassable roads, except for motorways. All forest areas are also classified as walkable in the cost surface raster although they might not be easily crossed in reality. Forest areas can however include important paths that are not to be found as geodata and was therefore included as walkable areas. A more correct representation of the walkability would be to create a more advanced cost surface raster. Areas with good walkability could for instance be given a low weighting while areas with bad walkability could be given a higher weighting. This could be used to give a more realistic picture of how people would walk to the green spaces. It would however be difficult to estimate the distance to green spaces since different areas then have different weighting and the cost distance no longer corresponds to meters but to the cumulative cost of different cell values. A binary cost surface raster was therefore considered best for calculating distance to green spaces.

The source points around the green spaces have a spacing of 20 meters in order to cover all sides of the green spaces. This can lead to an underestimation of the actual distance to some green spaces since a green space not necessarily can be entered from all sides. An optional way of creating enter points could be to only create points where a road is entering the green space. This can however lead to an overestimation of the actual distance to a green space since many green spaces can be entered from more than just the entering roads. It was therefore decided to cover all sides of the green spaces in this study.

5.4 Other ways to investigate 3-30-300

Visible trees

To analyze visible trees is definitely the hardest part of the rule. A viewshed analysis together with tree polygons created from LiDAR data was used in this study. Other ways to investigate visible trees could be to follow the methodology proposed by Cobra Groeninzich (2022) where buffers are created around the trees and the number of visible trees is estimated by how many of the buffers that intersects with each building. This does however imply that trees are to be found as vector data in point format, which often not is the case. Trees managed by the municipality can sometimes be found in vector point format, but these datasets tend to be inadequate since it does not include private trees which makes up a large portion of the trees in a city. One option to include all types of trees could be to use LiDAR data to create points that is supposed to represent trees. Local maxima (peaks) of a CDSM could for instance be used to detect single trees as points. However, smaller trees hidden by larger trees are often missed and trees located close to each other can be taken for one tree while trees with large crowns and multiple peaks often are classified as multiple trees (Reese & Olsson, 2018).

Another way to investigate visible trees could be to do a regression analysis that shows the relationship between visible trees and tree canopy cover in proximity to the buildings. Region Skåne (2023) did this in southern Sweden by manually investigating the number of visible trees for 100 randomly selected buildings and calculating the tree canopy cover within a 50 meters buffer around each building. The relationship between number of visible trees and tree canopy cover was thereafter used to analyze the criterion of 3 visible trees at a larger scale. Errors can obviously occur since the model is based on statistics and this method should therefore be seen as an indicator of which areas that have and not have access to visible trees rather than an exact estimation.

The most accurate way of analyzing visible trees would probably be to do a survey and ask the respondents how many trees they can see. This method would however need an extremely high response rate and can therefore be difficult to use, especially at larger scales.

Tree canopy cover

The tree canopy cover is rather simple to analyze since it only requires to calculate statistics within a given area. How one can produce data with tree canopy cover is therefore more interesting. LiDAR data has in this study been used to produce data with tree canopy cover, but other ways to produce this could for instance be to use high-quality multispectral aerial or satellite imagery. Many different variants of spectral bands, vegetation indices and classification methods can then be used to detect tree canopies. One option could be to use a vegetation index to separate vegetation from non-vegetation and then find a suitable threshold value to distinguish tree canopy from other vegetation such as gras (McBride, 2011). Reference data can thereafter be used to estimate the accuracy of the classification.

Another option in Sweden could be to use a combination of the Swedish landcover data (NMD basskikt) and the complementary height raster (NMD tilläggsskikt objektshöjd) to filter out the tree canopy cover.

Distance to green spaces

The distance to green spaces has in this study been calculated with a cost distance analysis. Euclidean distance and network analysis could also be used to calculate the distance to green spaces but has some disadvantages. The Euclidean distance is for instance not accounting for barriers and therefore underestimating the actual walking distance to a green space. Network analyses gives a good indication of the walking distance and can certainly be used to estimate the distance to green spaces in a representative way. A network analysis is however dependent on complete and detailed networks, it is therefore important to ensure that the quality of the network is good if this method is to be used.

Another option could be to do a space syntax analysis with an axial map. Space syntax is a theory and method that analyzes spatial relationships between humans and the built environment with simple representations of space based on human behaviors such as movement, occupation, and visibility (Tannous et al., 2021). The axial maps consist of the minimum number of sight lines that covers the urban space and each line represents a change in direction. This map can be used to calculate the distance to green spaces but can also say something about the accessibility since routes with high number of direction changes are perceived as longer while routes with few direction changes are perceived as shorter (Sadalla & Magel, 1980).

5.5 Further research

This study has only investigated the spatial variations of 3-30-300 in Gothenburg and the perspectives from city planners located in West Swedish cities. It would therefore be interesting to expand this study and investigate both the spatial variations and the perspectives towards 3-30-300 in more Swedish cities. This can contribute to better understanding of the goals and will be necessary in order to decide whether 3-30-300 or 2-20-200 is the best guideline in a Swedish context. The difference in providable ecosystem services between 30% and 20% tree canopy cover is crucial and needs to be further investigated.

Further research should also focus on improving the viewshed-based method for estimating visible trees. To analyze visible trees from different observer heights and include tree permeability could for instance be interesting improvements. The possibility to conduct viewshed analyses in 3D representations should also be furthered investigated as this potentially can enable analyses from windows and visibility under tree canopies.

6 Conclusion

This study shows that it is difficult to fulfill the 3-30-300 rule in the central and industrial areas of the city of Gothenburg. The criteria 3 visible trees and 300 meters to a green space is assessed as feasible to fulfill by both the GIS-analyses and the city planners while 30% tree canopy cover is assessed as difficult. The suggested viewshed-based method to estimate visible trees showed good overall accuracy (85%) and can suitably be used to investigate the criterion of 3 visible trees. The method should however be seen as an indicator of access to visible trees rather than an exact estimation of number of visible trees.

The city planners are primarily positive to 3-30-300 and highlights that it is comprehensive, concrete, and easy to remember, which in turn can strengthen the role of urban greening. There are however some challenges connected to 3-30-300 from a planning perspective and competition both below and above the ground is one of the main challenges. There are also some juridical challenges such as limited legislation about urban greening and private properties you do not have authority over that can make it difficult to work towards goals like 3-30-300. The high tree canopy cover goal is also a challenge and to lower this goal to 25% or 20% seems more reasonable. This would however not fit in with the stickiness of 3-30-300 and has led to the suggestion of 2-20-200 which the findings from this study indicate is more realistic in a Swedish context. It is however important to recognize that local considerations always will be necessary and that the rule should be perceived as a guideline rather than a strict policy. The scale for analyzing the rule should be different for different purposes and grids of 250x250 meters is assessed as suitable for larger scales while grids of 100x100 or 50x50 meters is assessed as suitable for smaller scales.

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Appendix 1 – Interview guide

1. How do you work with urban greening today? Which quantitative measures/policies are you using?

2. What do you think 3-30-300 can provide compared to the current measures/policies?

3. What is your impression of the results in Gothenburg?

    -Something you think stands out?

4. Do you think 3-30-300 are reasonable goals in a Swedish context or are they too high/low?

    -Obstacles?

    -Possibilities?

5. Do you see any potential challenges with 3-30-300 from a planning perspective?

6. What would be required for 3-30-300 to become policy in Swedish cities?

    -Should it become policy?

7. At what scale would you like to work with 3-30-300?