Student thesis

Distribution and Accessibility of Green Spaces and Urban Vegetation across Malmö's Regional Statistical Areas

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Abstract

Green spaces are important parts of our cities supporting both public health and providing ecosystem services such as lowering air temperature and providing stress relief. The study area, Malmö is a city in southern Sweden with a high population density. The city is largely built on and surrounded by agricultural land resulting in few naturally occurring green spaces and only planted trees. Despite this, there are currently no detailed spatial analyses of canopy coverage or green space accessibility in the city. This makes it important to analyse Malmö's canopy coverage and the green space accessibility.

This study assessed the accessibility and canopy coverage in Malmö through GIS analysis. Accessibility and canopy coverage thresholds were based on the 3-30-300 guideline, which recommends a minimum canopy coverage of 30% across neighborhoods and that all residents should live within 300 meters of a green space. The results showed that a majority of Malmö adheres to the 300-meter threshold with the city-wide mean green space distance of 297 meters. There were exceptions; parts of the north and the southeast were located significantly further away from green spaces, upwards of 2000 meters. The canopy coverage was substantially lower than recommended, with a mean canopy coverage of 2.8%, and with lower coverage observed in the outskirts of the city. The coverage and accessibility were also analysed in relation to socioeconomic status showing that more deprived areas generally had higher canopy coverage and were located at shorter distances from green spaces. The findings suggest that the city should primarily focus on improving canopy coverage, by both increasing overall canopy coverage and protecting existing trees.

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1 Introduction

Green spaces and urban vegetation are important components of our cityscapes. They are vital components of urban ecosystems and important to protect public health by providing cooling, noise reduction and can lead to certain improvements in air quality (Hartig et al., 2014). They also have important social functions by providing spaces for social interactions, stress reduction and promoting physical activity (Konijnendijk, 2023; Hartig et al., 2014). Mapping these features' spatial distribution is therefore crucial to understand potential vulnerabilities of people living and working in different parts of cities.

The recognition of green spaces' importance has led to the development of frameworks in recent years regarding urban greenery, most notably the 3-30-300 recommendation presented in a Journal article by Konijnendijk (2023). The recommendation states that everyone should be able to see 3 trees from their place of work or residence, that there should be a minimum canopy cover of 30% in each neighbourhood, and everyone should have access to a park within 300 meters from where they live (Konijnendijk 2023). This recommendation has been adopted widely and is used in both Sweden and other European countries (Browning et al., 2024).

Malmö, Sweden's third largest city, is located in the far south of the country (N 55°36, E 13°00) (OpenStreetMap contributors, 2020). The city has the fastest population growth in the country (2.3%) and is projected to increase to 395 000 by 2035 (Malmö stad, 2026). Malmö municipality highlights the population growth as the reason for the observed decrease in green spaces since 2005 and emphasizes that this trend is likely to continue under the high population growth rate (b. Malmö stad, 2026). As a result, there is a particular need to analyse and map Malmö's green space accessibility and canopy. Despite this, there are few publicly available maps showcasing Malmö's greenspace accessibility and canopy coverage distribution in detailed resolution, thereby limiting identification of areas which are particularly underserved.

The aim of this report is therefore to fill this gap by analysing and mapping the spatial distribution of green spaces and canopy cover in Malmö and if they differ between Regional statistical areas (RegSos) with different socioeconomic status. The analysis is performed using the thresholds described in 3-30-300 recommendation. The aim is addressed through the following research questions:

1. How do the distances to green spaces vary within Malmö?
2. What is the pattern of canopy cover distribution in Malmö?
3. Does the distribution and extent of these measures differ across areas with different levels of socioeconomic vulnerability?

2 Background

2.1 Impacts of urban green spaces on the environment

Urban green spaces and urban vegetation impact the local environment primarily by cooling that occurs through evapotranspiration and shading.

Evapotranspiration (ET) transfers solar energy as latent heat instead of sensible heat due to the evaporation of water, thereby decreasing the surrounding air temperature (Chen et al., 2026; Winbourne et al., 2020). The degree of the effect differs based on vegetation type and density, with higher and denser vegetation, such as forests, generally being more effective at producing latent heat fluxes than grasslands (Winbourne et al., 2020). ET is dependent on local environmental factors such as temperature and how processes such as stomatal conductance react to them (Winbourne et al., 2020). Factors that support evapotranspiration rates include solar radiation, high temperatures, and high irrigation (Winbourne et al., 2020). Conversely, high temperatures can lead to water scarcity and thereby lower stomatal conductance, negatively impacting the ET rate. A reduction in cooling effectiveness has been observed in southern Europe during summers and is likely to become more common at higher latitudes as climate change progresses (Schwaab et al., 2021).

Evapotranspiration and shading are closely linked. A larger canopy cover will provide more shade and is more likely to provide evapotranspiration-related cooling. One study found that urban trees are particularly effective at mitigating urban heat extremes at northern latitudes. They additionally found that trees in Scandinavia can provide greater heat mitigation during extreme heat events compared to normal summer temperatures (Schwaab et al., 2021). The shading effect is particularly influenced by plants with extensive canopy coverage, as they are able to intercept and absorb solar radiation effectively over a larger area, reducing the amount of shortwave radiation which reaches the ground (Schwaab et al., 2021). Shading by urban trees occurs through the interception of shortwave radiation by tree canopies, leading to larger quantities of shortwave radiation being absorbed by the shading canopy instead of hitting the ground surface (Schwaab et al., 2021; Chen et al., 2026). It is linked to a daytime reduction in LST, particularly for artificial surfaces such as asphalt and in less built-up urban areas (Speak et al., 2020; Schwaab et al., 2021).

The importance of tree distribution and density depends on the climatic region. For example, canopy density had a greater impact on lowering surface temperature across Baltimore, a hot and humid city, compared to Sacramento, a hot and dry city, which was more impacted by the spatial configuration of the tree canopy coverage (Zhou et al., 2017).

The cooling effects of urban green spaces on the surroundings are localized and determined by the type of green space, its spatial configuration and location in an urban area (Vallivattam et al., 2025). For example, parks located in the centre of Sheffield showed higher cooling intensity compared to parks located further away from the city center (Vallivattam et al., 2025). They also found that urban forests had the highest cooling intensity, whilst the cooling effects of urban grassland extended longer distance, had a longer cooling extent (Vallivattam et al., 2025). Another example is the complex relationship between landscape irregularity and cooling extent. Smaller green areas in Copenhagen, 0.5 to 1 ha in size, showed an inverse relationship between high spatial irregularity, large edge-to-area ratio, and cooling extent. For larger green spaces (>1 ha), an inverse relationship was found; areas with high spatial irregularity had a larger cooling extent (Yang et al., 2020).

The lowering of surface temperatures in built-up areas surrounding a green space is facilitated by park breezes (Vallivattam et al., 2025). These slow outflowing winds, often averaging at speeds below 1 m/s, flow from the cooler green spaces primarily during the night and the early morning (Vallivattam et al., 2025). This is caused by thermally induced pressure gradients between the greenspace and the built-up area surrounding it, similar to a sea breeze (Vallivattam et al., 2025).

The position of the green space in relation to other components of the urban area is an important determinant of the extent of the cooling effect of the green space. For example, if a green space is located uphill, upwind, and away from potential barriers, such as large buildings, the cooling impact will likely extend to a larger area (Vallivattam et al., 2025). Cooling effects on urban areas are not limited to green spaces located within the urban boundaries. Large-scale blue spaces, such as ocean fronts and natural areas surrounding a city, have a noticeable effect on urban temperatures primarily through different breezes impacted by pressure deficits (Yang et al., 2020; Schwaab et al., 2021).

2.2 Impacts of urban greenness on public health

The temperature reduction linked to urban vegetation is an important tool to help safeguard public health by lowering the impact of the urban heat island (UHI) effect. UHI causes urban temperatures to be approximately 2 to 4°C higher than the rural surroundings (Aghamohammadi & Santamouris, 2022). UHI is particularly linked to increased nighttime temperatures, reducing the respite for people living in urban areas. This is linked to higher rates of heat-related hospitalizations and deaths during the year's warmer months, especially during extreme heat events. Heat-related hospitalization and mortality rates are therefore dependent on place and time of the year. They occur most often in vulnerable populations, such as elderly people and people with preexisting conditions such as cardiovascular illnesses or mental illnesses (Aghamohammadi & Santamouris, 2022). The threshold for extreme temperatures is lower during earlier parts of the summer and in areas with lower annual temperatures (Aghamohammadi & Santamouris, 2022).

Cold-related deaths still surpass heat-related deaths in Sweden. However, one study found that heat-related deaths amongst the elderly could surpass cold-related deaths in the same cohort, for urban areas such as Stockholm by the end of the century (Fonseca-Rodríguez et al., 2023).

Overall, urban green spaces can be beneficial for people's physical and mental health, through their size and accessibility, providing space for activities including exercise and rest, as well as the different ecosystem services, including improving air quality. (Hartig et al., 2014).

2.3 3-30-300

The 3-30-300 urban greenness recommendation, presented by Konijnendijk (2023), has been embraced by international organisations like the Nordic Council and adopted by municipalities like Malmö. It is a framework that delineates urban green space accessibility and distribution thresholds (a.Malmö stad, 2026; Nordiskt samarbete, 2025). The recommendation states that: *i)* everyone should have 3 trees visible where they live, go to school, and work; *ii)* every neighbourhood should have a 30% canopy cover; and *iii)* the entire population should have access to a park within 300 meters of their place of residence (Konijnendijk, 2023).

The recommendation about 3 visible trees from places of residence and work is grounded in empirical studies, regarding the positive mental health impacts of visible vegetation (Konijnendijk, 2022). However, the value “3” was picked to allow for continuity with other values of the recommendation (“30” and “300”). Due to the limited scientific evidence

supporting the “3” parameter, as well as the difficulties in accurate assessment of the green view, this parameter was omitted from the analysis.
The recommendation “30” refers to a study which found 30% canopy cover to be a threshold above which noticeable health benefits could be observed (Holtan et al. 2014; Konijnendijk, 2022). The parameter “300” comes from the WHO recommendation stating that everyone should have a park above the size of one hectare within a 300-meter linear distance from their residence (World Health Organization Regional Office for Europe, 2017). The specified size is due to larger parks generally offering more opportunities for recreation (Konijnendijk 2022). The recommendation emphasizes the need for cities to modify it to take local contexts into account; cities will have widely different starting points. For example, some cities might be surrounded by a forest, while others are surrounded by fields or have parts of the city that are very dense, making certain greenery thresholds impossible to reach (Konijnendijk, 2022).

2.4 Greenspace equity

Greenspace equity is defined as fair and equal access to greenspaces of sufficient size and quality, across different income levels and for different vulnerable populations, recognizing that the need for these features is not equal across society (Elderbrock et al., 2024). Socioeconomically vulnerable communities see greater benefits to their physical and mental well-being from having close access to high quality green spaces and green vegetation (Newton et al., 2026). These communities generally have higher rates of chronic illnesses, such as cardiovascular disease, and often have worse health outcomes (Weiers et al., 2008; Newton et al., 2026). These vulnerabilities, combined with often being less able to change their surroundings by moving or travelling, or making alterations to their place of residence, as they are more likely to rent and less likely to own a car (Aghamohammadi & Santamouris, 2022), are all factors increasing the need to have good access to urban green spaces (Newton et al., 2026).

3 Study area

3.1 Malmö

Malmö is a city located in the far south of Sweden (55.36°N, 13°E) in the region of Scania (OpenStreetMap contributors, 2020; Britannica, 2026). Malmö has a history that stretches back to the 1200s, when it was under Danish rule, and is now Sweden's third largest city (Britannica, 2026). In December 2025 the municipality had a population of 367 924, while the central administrative area had a population of 339 316 in 2024 (h.Malmö stad, 2026; Hugsi, 2026). The population density of the central administrative area is 3880 pp/km² and is classified as dense (Hugsi, 2026).

The city is located by the Öresund and has an area of 100.26 km² (Hugsi, 2026). Malmö has a mild temperate oceanic climate, and it has an annual average rainfall of 658 mm and an annual average temperature of 9.1°C (Chen & Weiteng Chen, 2013; d.Malmö stad, 2026; e.Malmö stad, 2026). The city is characterized by a relatively flat topography with important coastal meadow ecosystems in the western part of the city. The area has limestone bedrock and soil rich in lime and other nutrients, which has contributed to it being an historically heavily farmed area (Skånes

Länstyrelse, 2026). The area is marked by anthropogenic influence, with multiple previously present gravel hills having disappeared due to gravel extraction (Skånes Länstyrelse, 2026).

The study area will be narrowed down to Malmö central administrative region due to it being the closest geographical extent to what OpenStreetMap (OSM) retrieves when querying for "Malmö" (*Figure 1*).

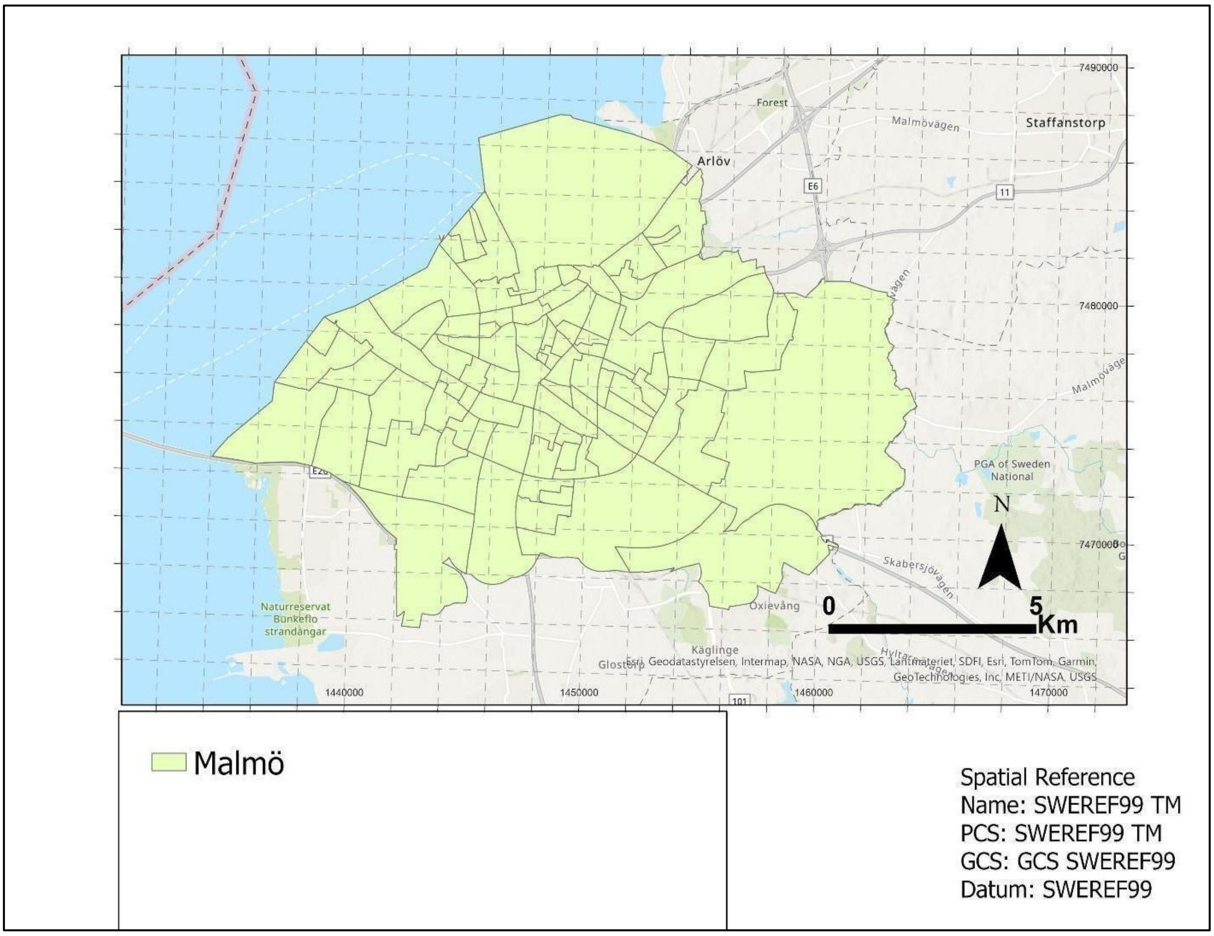

Figure 1. The study area, Malmö.

3.2 Greenspace policy in Malmö

Malmö is known internationally for having successfully implemented green policies in urban planning, having developed a 'Green point system' and a 'Greenspace Factor' during the early periods of the construction in Västra Hamnen in the 1990s (Kruuse et al., 2011).

The aim of the 'Greenspace Factor' is to ensure a certain level of greenness and minimize the sealed surfaces in newly developed areas. The 'factor' is a weighted index where different surface types are assigned weights, which are then multiplied by their extent within the designated area and lastly divided again by the total area of the feature. It can be applied to both private places, such as courtyards, and public areas like parks. The weights range from 1, which is given to vegetation that reaches ground water level, to 0, which is given to sealed surfaces.
The green factor value of a new development must meet a specific target of 0.5 (Kruuse et al., 2011; c.Malmö stad, 2023).

'Green points' are used as a metric to evaluate and ensure that the greenery in a development meets a certain level of quality. This has been done by providing a list of features that provide some form of feature associated with high-quality green spaces, such as aiding biodiversity. During the construction of Västra Hamnen, developers were given a list of 35 of these features and had to pick 10 of them for each courtyard (Kruuse et al., 2011; c.Malmö stad, 2023).

The municipality adopted the 3-30-300 model by Konijnendijk (2023) as thresholds for tree and green space coverage distribution in the city in their planning policy document that came into effect in 2023 (b.Malmö stad, 2023). The municipality highlights that low canopy coverage is the biggest obstacle to meeting the 3-30-300 recommendation. They state that the ability to ensure high canopy coverage around new developments is great whilst it is significantly harder to increase the canopy coverage in already built areas such as Möllan (a.Malmö stad, 2026). There are a few publicly available maps of tree cover or accessibility over the city, based on the recommendation of which one is published by the Region of Scania in 2023 (Region Skåne, 2023). However, the report uses buffering distance from green spaces, limiting the analysis to comparing areas of the municipality located within 300 meters from a green space with areas that fall outside the threshold (Region Skåne, 2023). The report also solely relies on a zonal statistics raster for tree canopy coverage (Region Skåne, 2023). SLU published another relevant article which mapped the degree of canopy coverage, distance to greenspace and for each demographic statistical area from an equity perspective (Randrup et al., 2025). However, with the maps provide by Region Skåne (2023), the maps are at a coarse spatial resolution. The report also does not highlight areas that are underserved at a consistent spatial scale as the demographical statistical areas vary in size.

4 Data description

4.1 Parks and Squares

Data on parks were obtained from a GeoJSON file called Parks and Squares (g.Malmö stad, 2026). The dataset is provided by Malmö municipality and updated weekly ensuring that it has up to date information about the green space configuration in the city. The data layer contains information about place names, ground cover type (natural or artificial), as well as name and aerial extent.

4.2 Canopy cover (trädteckning)

Canopy cover data (trädteckningdata) in the format of raster displaying trees with canopy height of above 3 m, was obtained from Swedish National Board of Housing, Building and Planning (Boverket). This dataset was used as it is a comprehensive raster dataset of tree cover over Malmö with clear documentation regarding method and validation processes. Another clear advantage with using the Boverket dataset compared to a global canopy coverage dataset it uses data from Lantmäteriet which is specifically suited to mapping Sweden. The dataset was developed by using a combination of Normalized Difference Vegetation Index NDVI and surface height models to identify canopy extent and tree height (Boverket, 2023).

4.3 Area types (Områdetyper)

The area division used for the analysis are regional statistical areas (RegSos) (Regionala statistikområden). In 2023, the Malmö urban area comprised 86 such areas. A common metric used to indicate these areas' socioeconomic conditions is a metric from Boverket called area types. Area types are graded using the Socioeconomic index (Socioekonomiskt index), which is based on three equally weighted indices of socioeconomic standard (Segregationsbarometern, 2026). These variables concern financial status, education levels, and long-term reliance on financial aid (Table 1). Socioeconomic data over RegSos and their subsequent area types were retrieved from an Excel sheet (xlsx) from Boverket Segregationsbarometer called Områdestyper (Segregationsbarometern, 2026). It included yearly data from the years 2011 to 2023.

Table 1. Variables used for the socioeconomic index.

Variable	**Meaning**
V1	Low financial status
V2	Highest form of education below high school level
V3	Have received financial aid in the last 6 months for 10 months or more

The areas are graded from 1 to 5 based on their value relative to the standard deviation from the national mean. A grade of one indicates that an area faces major socioeconomic issues, while five indicates that the area is socioeconomically well-off (Segregationsbarometern, 2026).

Table 2. Area types and their socioeconomic index scores.

Area type	**Standard deviation from national mean**	**Socioeconomic conditions**
1	≥ 2	Areas with major socioeconomic challenges
2	between ≥ 1 and < 2	Areas with socioeconomic challenges
3	between ≥ 0 and <1	Socioeconomically mixed areas

4	between ≥ –1 and <0	Areas with good socioeconomic conditions
5	< –1	Areas with very good socioeconomic conditions

Out of Malmö's 86 RegSos, 30 are considered socioeconomically vulnerable. These areas were home to 31% of the population in 2023. The most common area type was area type 3, with 37% of the population living in areas with that classification (Segregationsbarometern, 2026; see Figure 2 for spatial distribution of area types).

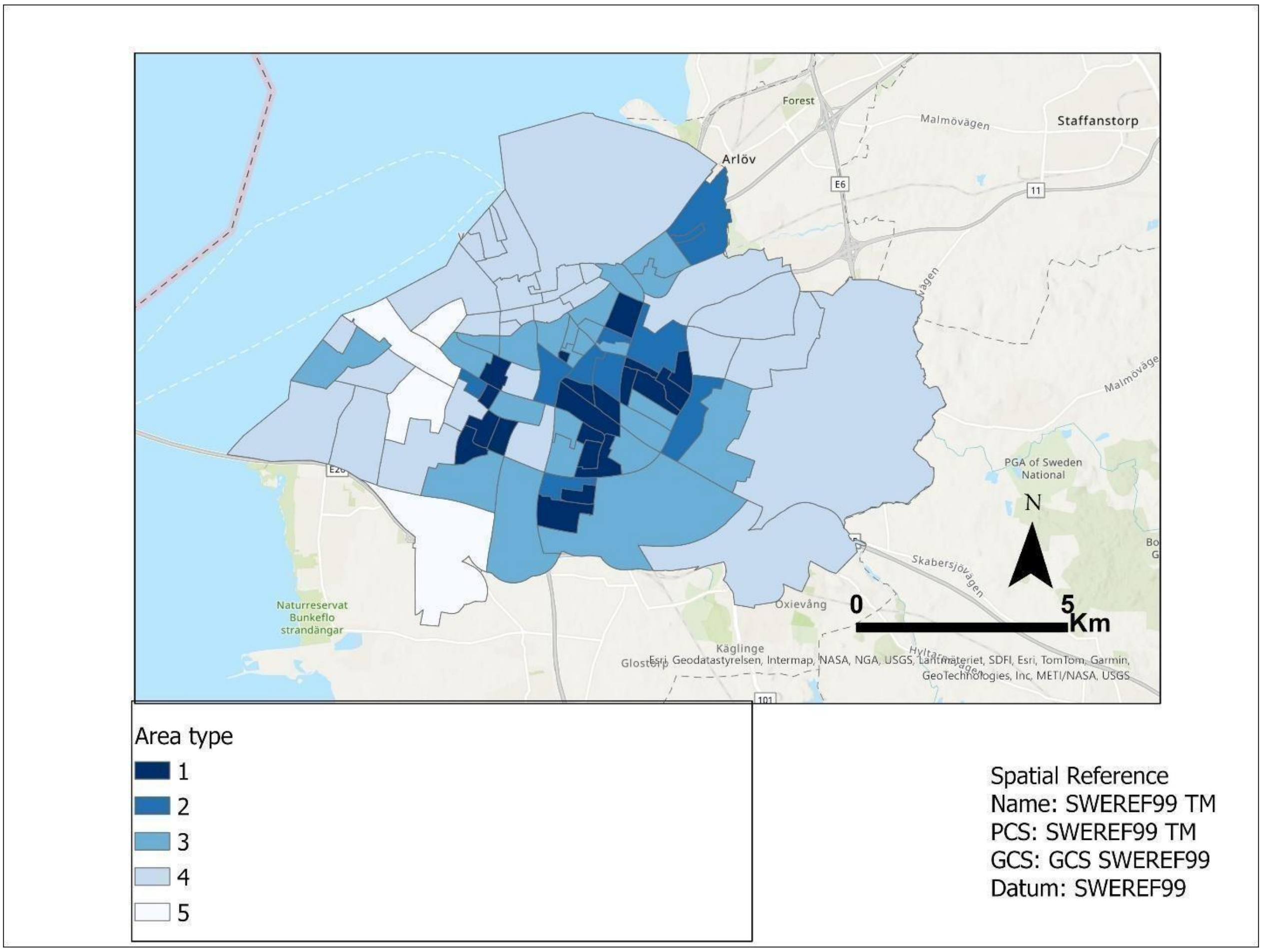

Figure 2: Area types of the Regional statistical areas (RegSOs) belonging to Malmö Urban area.

4.4 RegSos 2020

RegSos 2020 (Rgeso_2020) is a vector layer provided by SCB (Statistics Sweden) from 2020 containing all Sweden's regional statistical areas as well as information about names, area, the municipality and region they belong to (SCB, 2020). The extent of the RegSos was altered slightly in 2025 (SCB, 2026). Considering that the area types of data from Boverket spans until 2023, the dataset from 2020 was used instead to ensure compatibility.

4.5 City districts (Tätorter_2023)

Tätorter_2023 is a vector layer from SCB (2023) containing boundaries for central administrative areas, urban areas in Sweden (SCB, 2026).

4.6 Population (GHS-POP_GLOBE_R2023A)

GHS_POP_GLOBE_R2023A, (GHS-POP) is a population layer provided by Copernicus (Schiavina M. et al., 2023). The layer uses population data and long-term administrative-level population growth rates and disaggregates the data to the desired resolution, for this analysis, the resolution of 100x100 m was chosen. The dataset was chosen as it can provide high resolution population estimates and has previously been used for similar analyses.

All datasets used in the analysis are provided in Table 3.

Table 3. Datasets used for the analysis.

Dataset name	Type	Source	Format	Description
Area types (Områdetyper)	Table	Boverket	Xlsx	Socioeconomic indices for RegSos 2011–2023
Trädteckning	Raster	Boverket	GeoTiff	Tree cover over Tätorter 2023, resolution: 1x1 m
RegSos2020	Polygon	SCB	Geopackage	Boundaries of RegSos in Sweden from 2020
Parks and squares	Polygon	Malmö stad	GeoJSON	Green spaces and squares in Malmö
GHS-POP_GLOBE_R2023A	Raster	Copernicus	GeoTiff	Population density estimates for

				2025, 100x100 m resolution
Tätorter_2023	Polygon	SCB	Geopackage	Central administrative area boundaries from 2023

4.7 Data processing

The Tätort layer was filtered to only include Malmö tätort. The layers RegSos_2020 and Trädteckning were filtered in ArcGIS Pro 2.7 (Esri Inc., 2020) to only include data over RegSos within Malmö tätort.

The Områdestyper's Excel sheet was filtered to Malmö for the year 2023, then uploaded to ArcGIS Pro and joined to the RegSos2020 layer. The layer Parks and Squares was filtered to only include areas which had a natural ground cover, then exported as a GeoJSON file to R version 4.5.3 (R Core Team, 2026) and converted to a format compatible with greenR (Mahajan, 2024).

5 Methods

5.1 Accessibility Analysis (RQ1)

5.1.1 Computing distances to the green spaces

The 'Analyze Green Space Accessibility Using Street Network' function in the greenR package was used to compute the distance to the nearest green area from grid centroids by both network distance (along the roads) and Euclidean distance (Mahajan, 2024).

The network distance analysis retrieves road features from OSM, (OpenStreetMap contributors, 2026) for the selected mode "walking". The tool retrieves roads classified as footway, path and pedestrian (Mahajan, 2024). The grid cell size was set to 300x300 meters for the analysis in line with the 300-meter parameter in the 3-30-300 recommendation (Konijnendijk, 2023). The tool also computes population count per grid cell by incorporating GHS_POP data. Due to the incomplete OSM pedestrian road network. The resulting network distance analysis output therefore only covered approximately 20% of the study area. Hence, the remainder of the analysis steps used the results from Euclidean distance instead. ArcGIS Pro's "Summarize within" tool was used to summarize the average distance to Greenspaces across the 300x300 m grid cells and within the RegSos.

5.1.2 Hotspot analysis (Getis-Ord Gi*)

Hotspot analysis (Getis-Ord Gi*) was used to identify areas with a long distance to a green space. The Getis-Ord Gi* statistic identifies spatial clustering by comparing a cell's value and its neighbors' values to what would be an expected sum for the entire dataset, its output includes a zscores and a p-value. In this analysis a high z-score and a low p-value indicated a longer distance to a greenspace, while a negative z-score indicated a shorter distance to greenspaces than is possible to explain by random chance. The threshold distance was set to 300 meters to ensure that neighboring cells would be considered when computing the significance. A statistically significant hotspot is indicated by Gi_bin being ≥1 (a.ArcGIS Pro, 2026).

5.2 Canopy coverage analysis (RQ 2)

5.2.1 Canopy Coverage percentages

The Canopy coverage percentages were calculated within the 300x300 m grid cells as canopy pixel area inside the cell divided by the grid cell area. As one pixel in the Boverket Trädteckning corresponds to 1 m² of canopy coverage due to its resolution of 1x1 m.

ArcGIS Pro's "Summarize within" tool was used to summarize the canopy coverage across the RegSos.

5.2.2 Kernel Density

A kernel density analysis was used to interpolate the tree cover density across the study area. It calculated the point density per unit area in a neighbourhood using a defined search radius, here set to 169 meters. The radius was set to 169 meters to obtain a search area similar to the 300x300 m grid cells (90 000 m²), allowing for comparisons between the kernel density and the gridbased results.

5.2.3 Optimized Hotspot analysis (Getis-Ord Gi*)

Getis-Ord Gi* in ArcGIS Pro was used to calculate clusters of high canopy coverage in the tree coverage data set. "Optimized hotspot analysis" function was used due to the significant number of features (589 000) within Malmö Urban area to ensure that the output only consists of the most significant clusters. The function takes the coverage of individual features together with the values of their neighbors to calculate hotspots. "Optimized hotspot analysis" function is similar to "hotspot analysis" with the main difference being that it aggregates the input features, creating weighted points resulting in a more conservative output (b.ArcGIS Pro, 2026).

5.3 Analysis of Distribution Across Area Types (RQ 3)

5.3.1 Summary Statistic

ArcGIS Pro summary statistics were used to calculate mean value of canopy coverage and Euclidean distance to green spaces for each area type. The summary was based on the mean canopy coverage and mean distance to green spaces derived for each individual RegSO.

5.4 Use of AI

AI, specifically Claude Sonnet 4.6, was used to generate some of the code used to transform the Trad_data GeoJSON layer to a polygon layer compatible with ArcGIS Pro, as well as the commands to download the accessibility analysis into an ArcGIS Pro-compatible format. For the exact lines of code generated by AI see Appendix.

6 Results

6.1 Green space accessibility analysis (RQ 1)

Green space accessibility varied considerably across Malmö with areas with low accessibility mostly located in the outskirts of the city. The Euclidean distance from the grid cell centroid to the nearest green space ranged between 0 and 2361 meters across the study area (*Figure 3*). Grid cells with shorter distances to green spaces are more evenly spread throughout the study area, whilst cells located further away from green spaces cluster in the north and in the southeast.

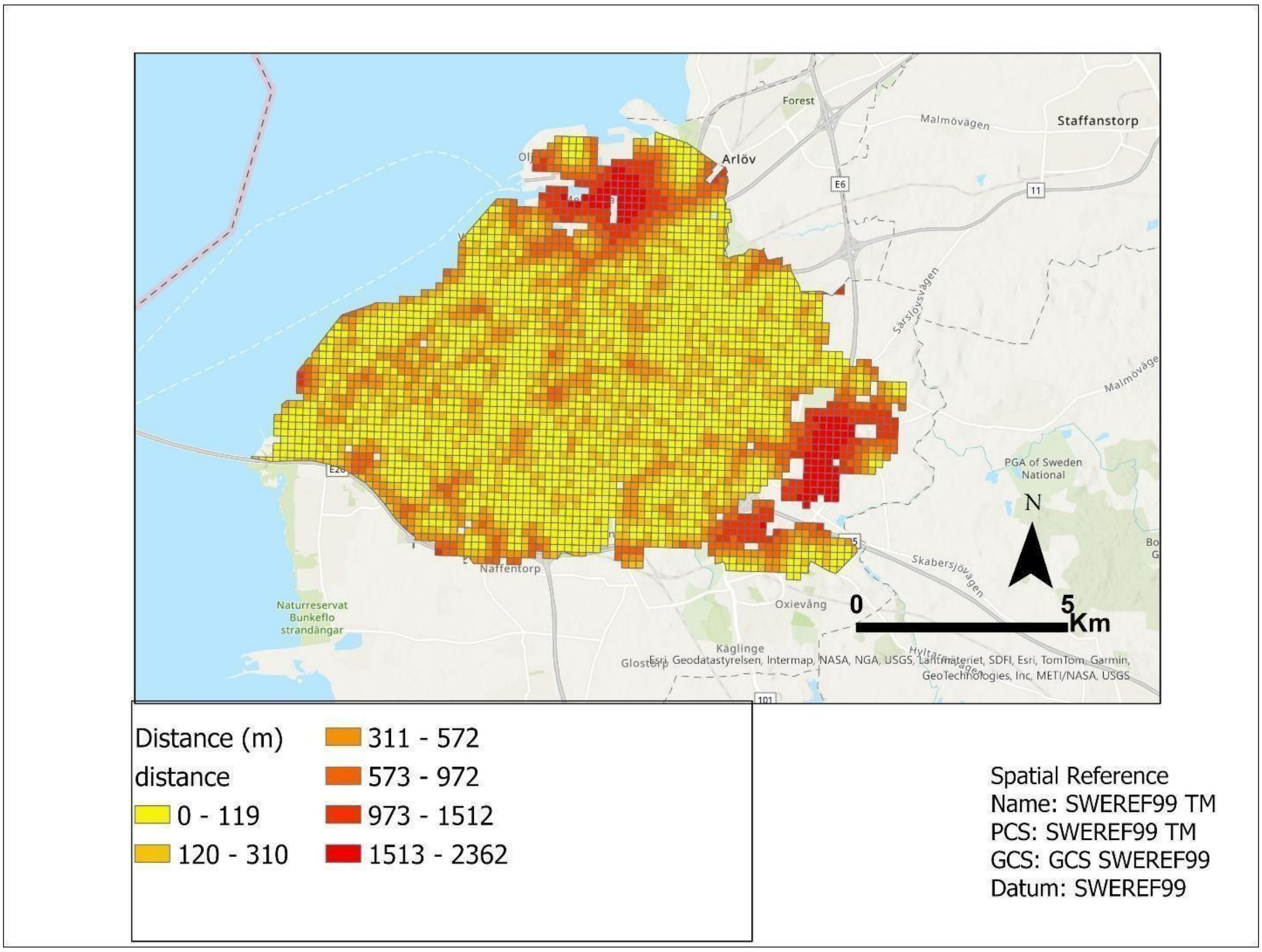

Figure 3: Euclidean distance in meters from grid cell centroid to green spaces. The grid cells resolution is 300 x 300 m.

On a RegSO-level a similar pattern is found areas that were closer to the centre have a lower mean distance to green spaces compared to areas in the outskirts. Mean values of Euclidean distance to green spaces across Malmö Urban areas RegSOs range from 56.9 to 736.5 meters (*Figure 4*). Figure 4 illustrates that the mean distance is particularly low in parts of the southwest falling well below the 300-meter threshold, indicating generally satisfactory access to greenspace in these areas. Conversely the average distance to green spaces is significantly higher, in the southeast and in the north of the city, with the average distance to green spaces failing to meet the 300-meter threshold.

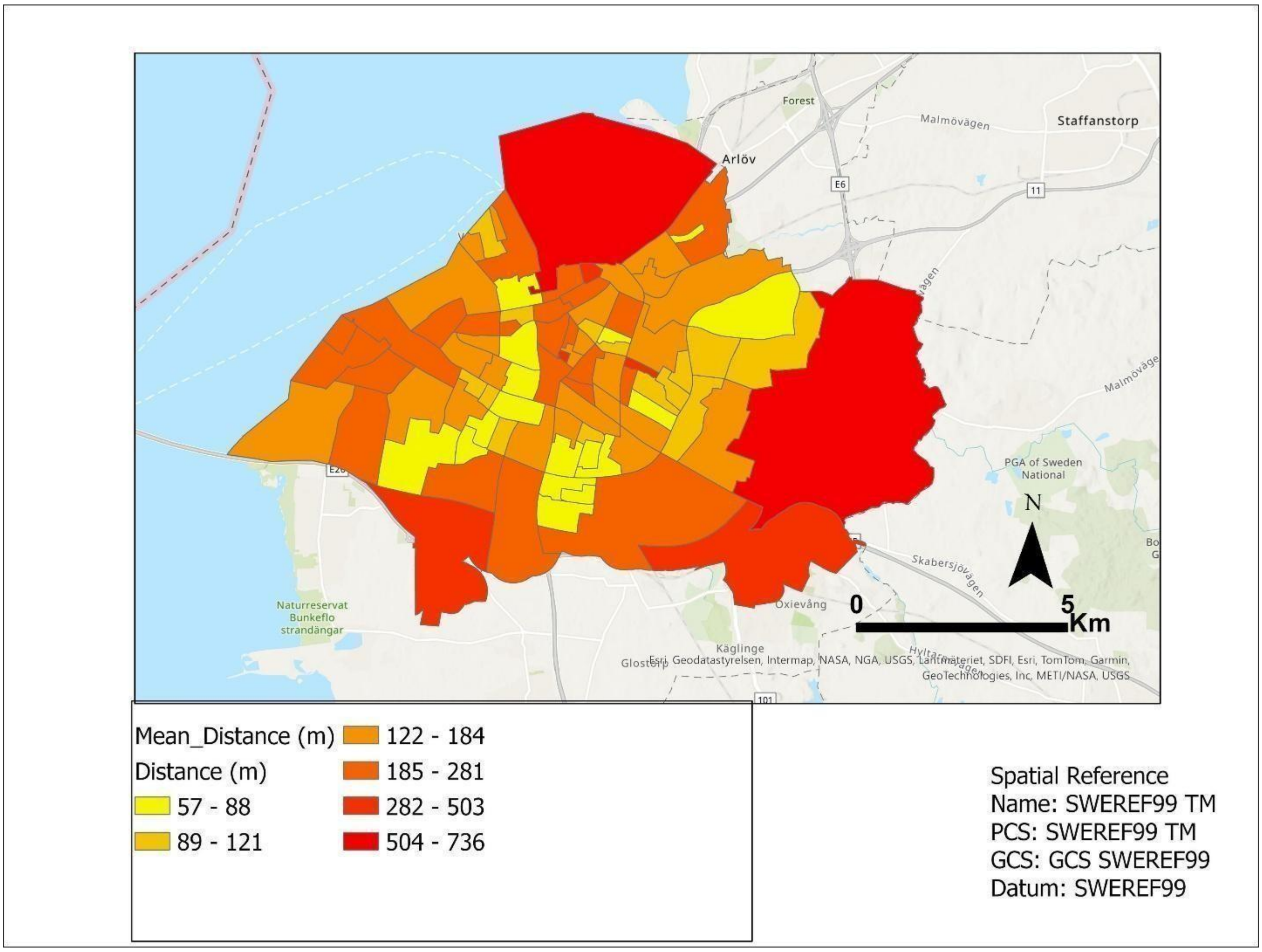

Figure 4: Mean distance to green spaces across the Malmö Urban area RegSos, in meters.

Access to green spaces in Malmö is generally good, with most of the city falling within the 300meter threshold, however accessibility varies considerably across the city. The distance to green spaces shows a clear right-skewed distribution, with a mean of 297.7 meters and a median of 158 meters, with some grid cells located at significantly greater distances from green spaces (*Figure 5*).

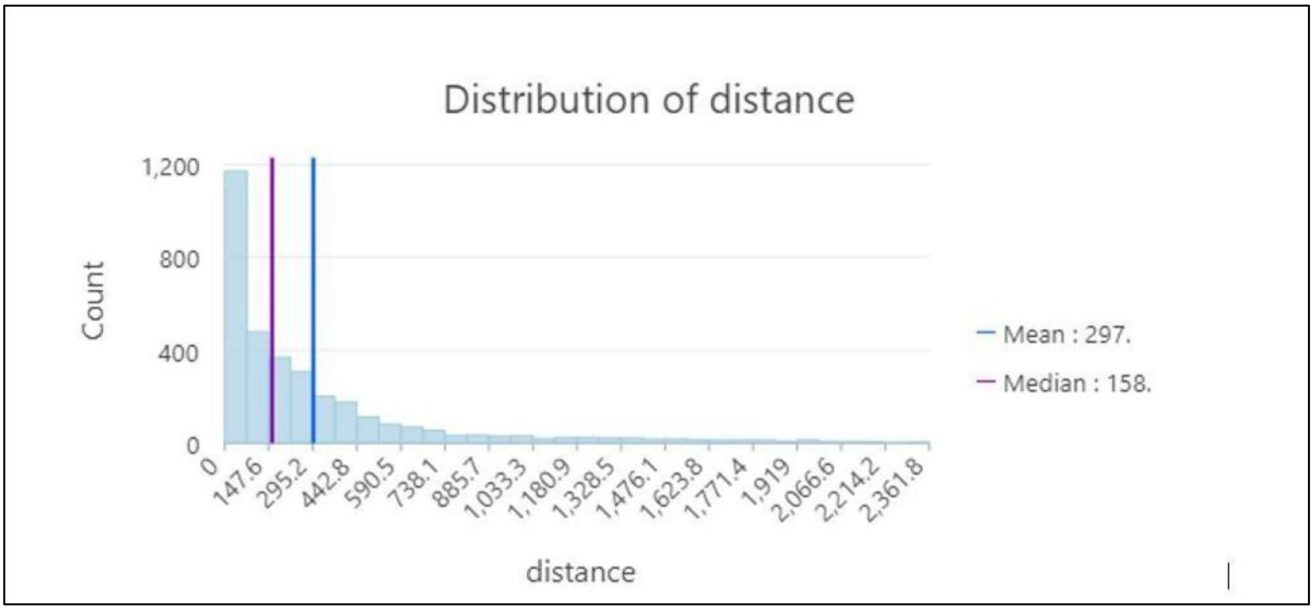

Figure 5: Distribution of grid cell distances in meters.

The results from the Getis-Ord Gi* hotspot analysis confirm these patterns of uneven green space accessibility. The analysis highlights the part of the north and the southeast mentioned earlier, as areas located at a significant distance to green spaces, compared to the rest of the study area. As seen in Figure 6 is the analysis also able to highlight the long distances to green spaces in some areas near the coast and in the south that the general accessibility analysis was unable to highlight further nuance the picture of green space accessibility in the city (*Figure 6)*.

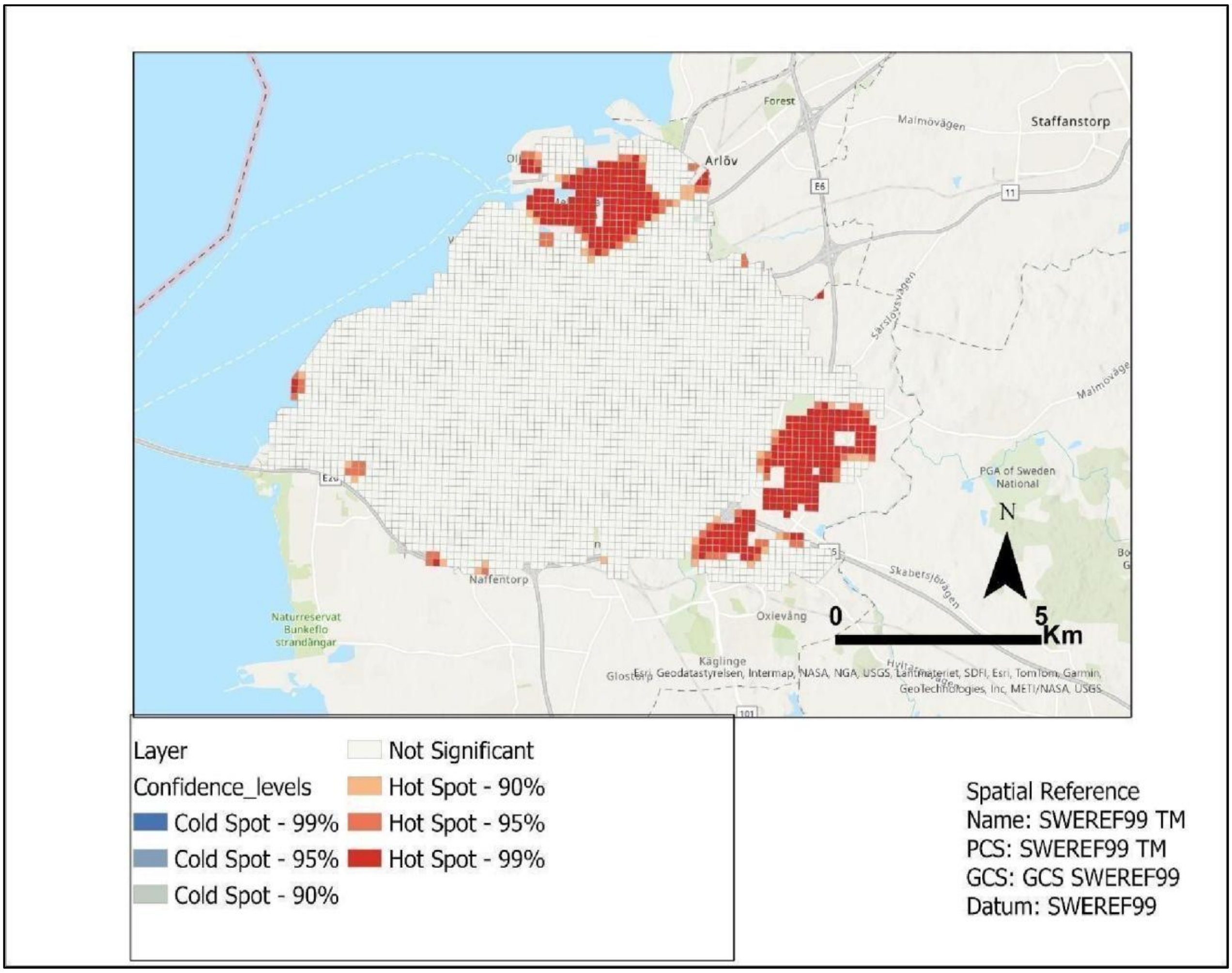

Figure 6: Hotspot analysis showing areas where the green space access is significantly lower than expected.

Areas with higher population density often have shorter distances to green spaces and areas with lower population density are positioned at longer distances to green spaces. The bivariate visualization (*Figure 7)* shows that most areas with a high population also have good access to green spaces. However, there are outliers some areas with high population counts that are located far from green spaces are scattered throughout the city, but cluster in the north and the west.

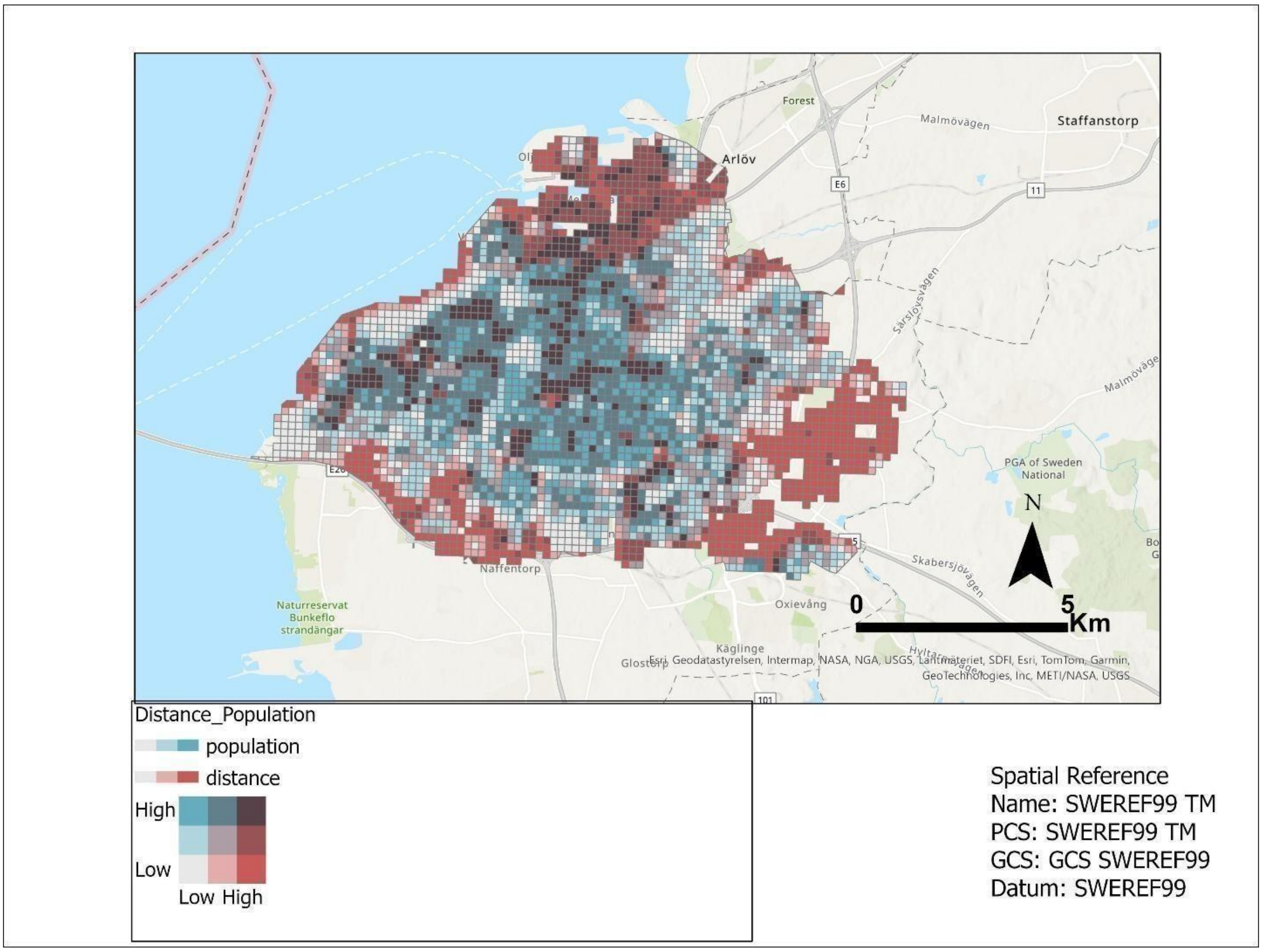

Figure 7: Distance to green spaces overlaid with GHS_POP population density.

6.2 Canopy coverage (RQ 2)

The canopy coverage across the city generally did not meet the 30% canopy coverage threshold with only small sections of the city showing high canopy coverage. This is illustrated by Figure 8 showing that the canopy coverage ranged from 0 to 30% with most areas having values below 10%. There are generally higher values closer to the centre of the city and lower values near the edges of the urban area, except for parts of the northeast where the canopy coverage is high (*Figure 8)*.

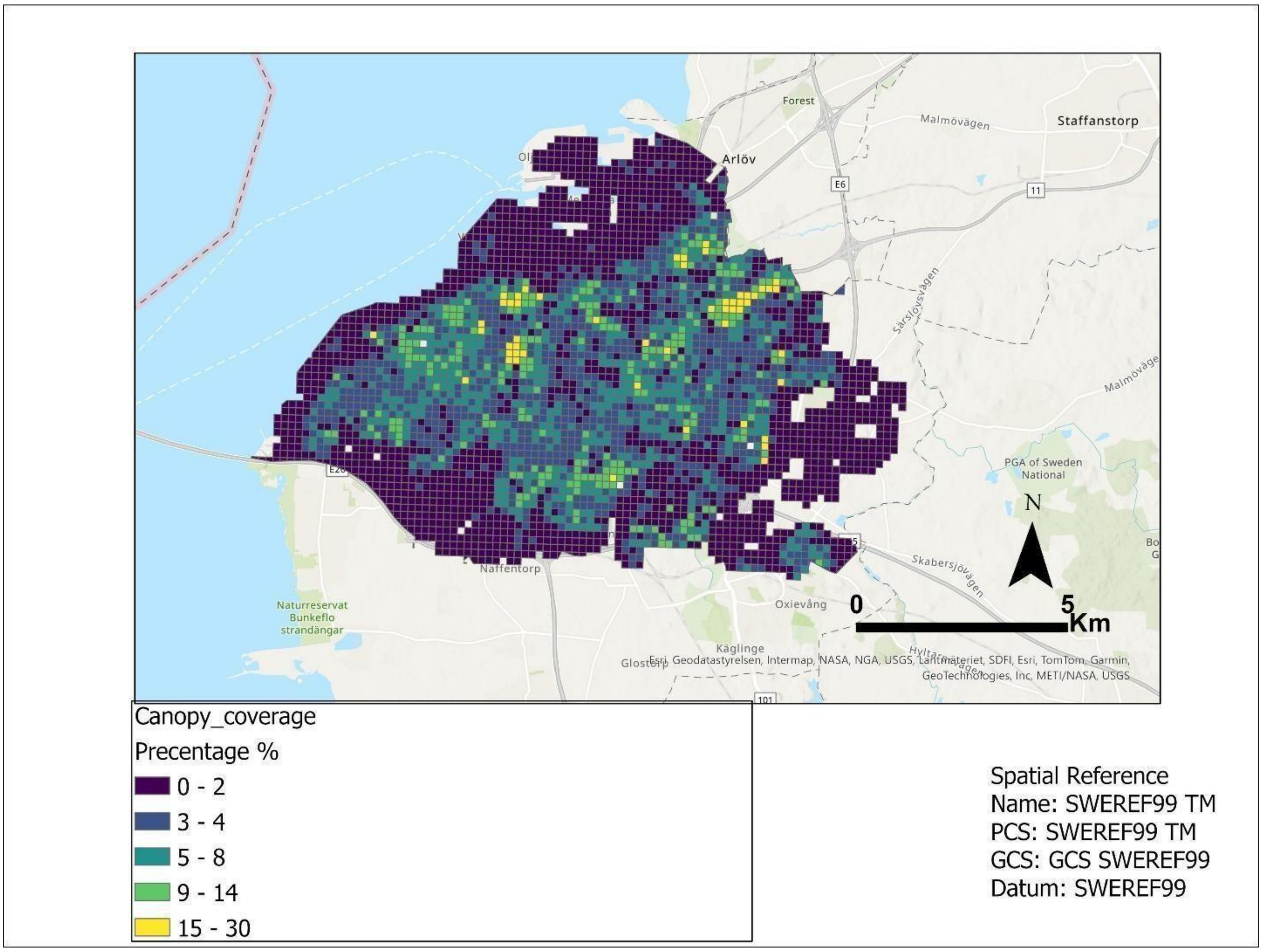

Figure 8: Canopy coverage in percent within the 300 x 300 m grid cells.

The low canopy coverage shown in the canopy coverage analysis, is confirmed statistically. The coverage has a clear right-skewed distribution with a mean coverage of 2.8% and a median coverage of 1.8 % however unlike the distance to green spaces distribution, this skewness reflects that most of the study area is far from reaching the 30% canopy threshold (*Figure 9)*.

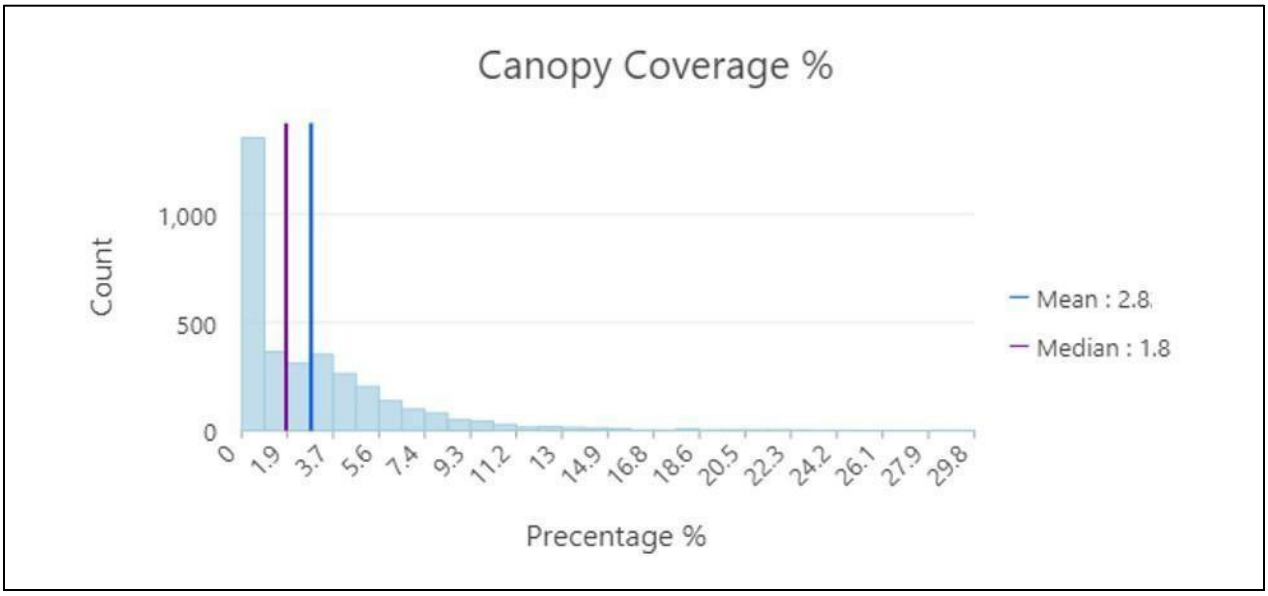

Figure 9: Distribution of canopy coverage percentages across the study area.

This low canopy coverage is also reflected on a RegSOs-level with mean canopy coverage being well below 30% across the entire study area. The mean canopy coverage ranged from 0 to 9%, with lowest values, coloured white and green, located in the outskirts of the city particularly in the south, and the north. The areas with the highest canopy coverage are located mainly in central parts of the city, coloured blue *(Figure 10*).

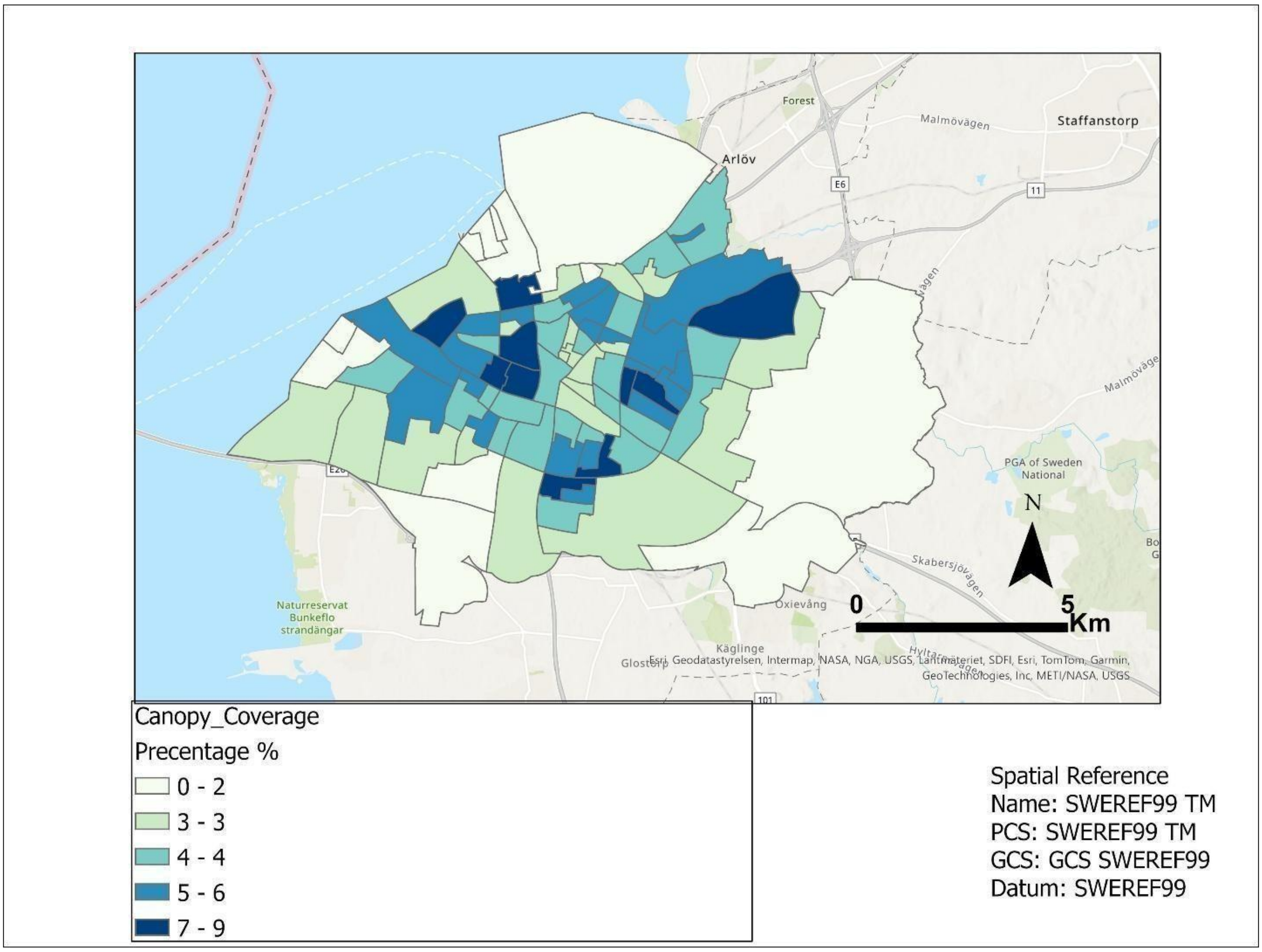

Figure 10: The mean canopy coverage in percentages across the 86 RegSos completely or partially belonging to Malmö urban area.

Tree density follows a similar pattern as the canopy coverage. There is a higher density in the centre of the city extending towards the northeast to the edge of the study area, while the tree density in the outskirts of the city is generally low (*Figure 11*). The tree density ranges from 0 to 3 and is displayed using 10 x 10 m cells, derived using kernel density interpolation.

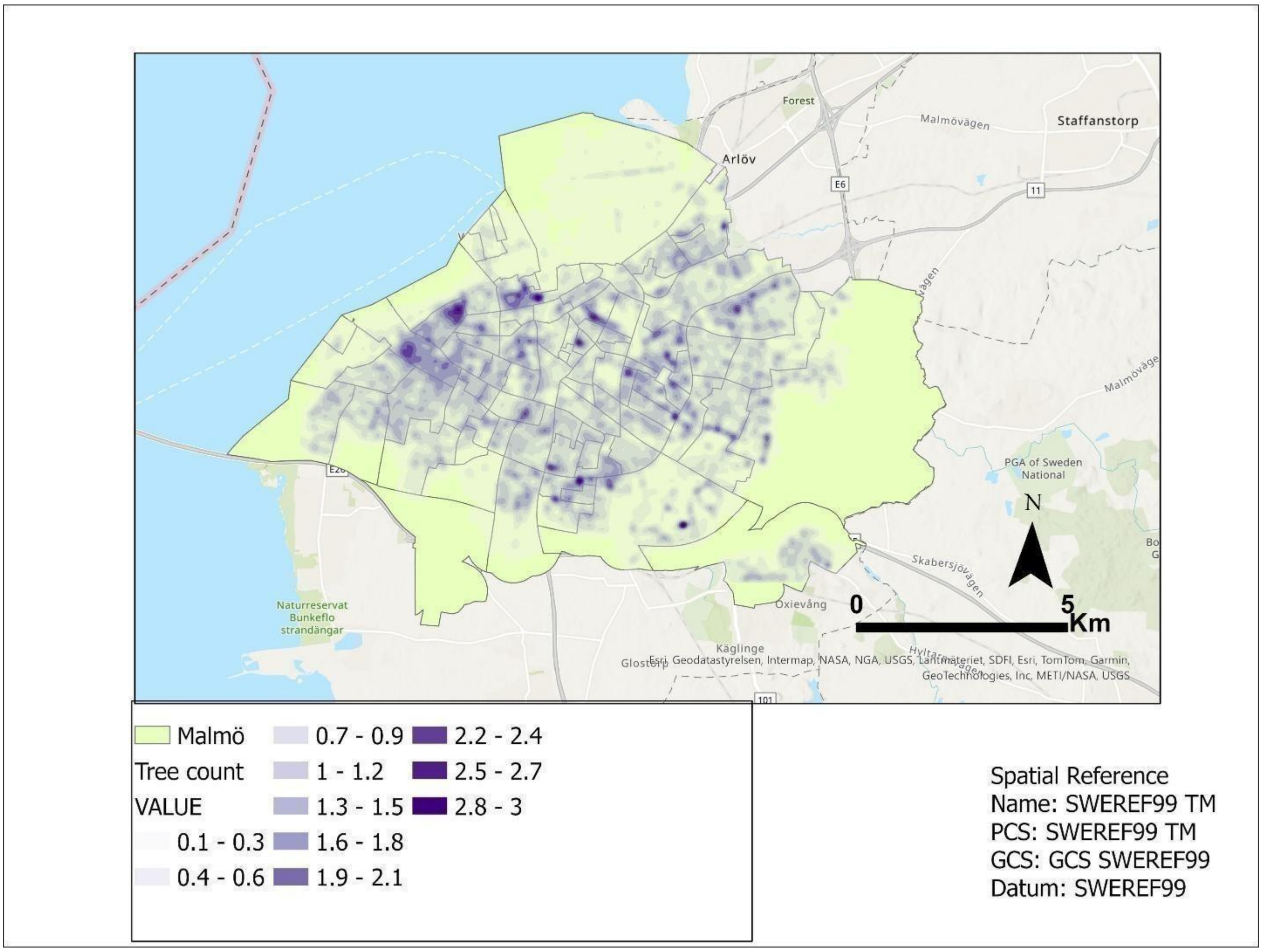

Figure 11: Figure showing expected tree counts in Malmö.

There are few areas in the city with very high canopy coverage. Figure 12 showcases the results from the optimized hotspot analysis, highlights smaller areas particularly in the north and the northeast as areas with high coverage. This includes some well-known parks such as Slottsparken and Bulltoftarekreationsområde (*Figure 12*). However, it is worth noting that many of these areas appear patchy, especially areas in the south, indicating that the city has very few larger areas with full canopy coverage.

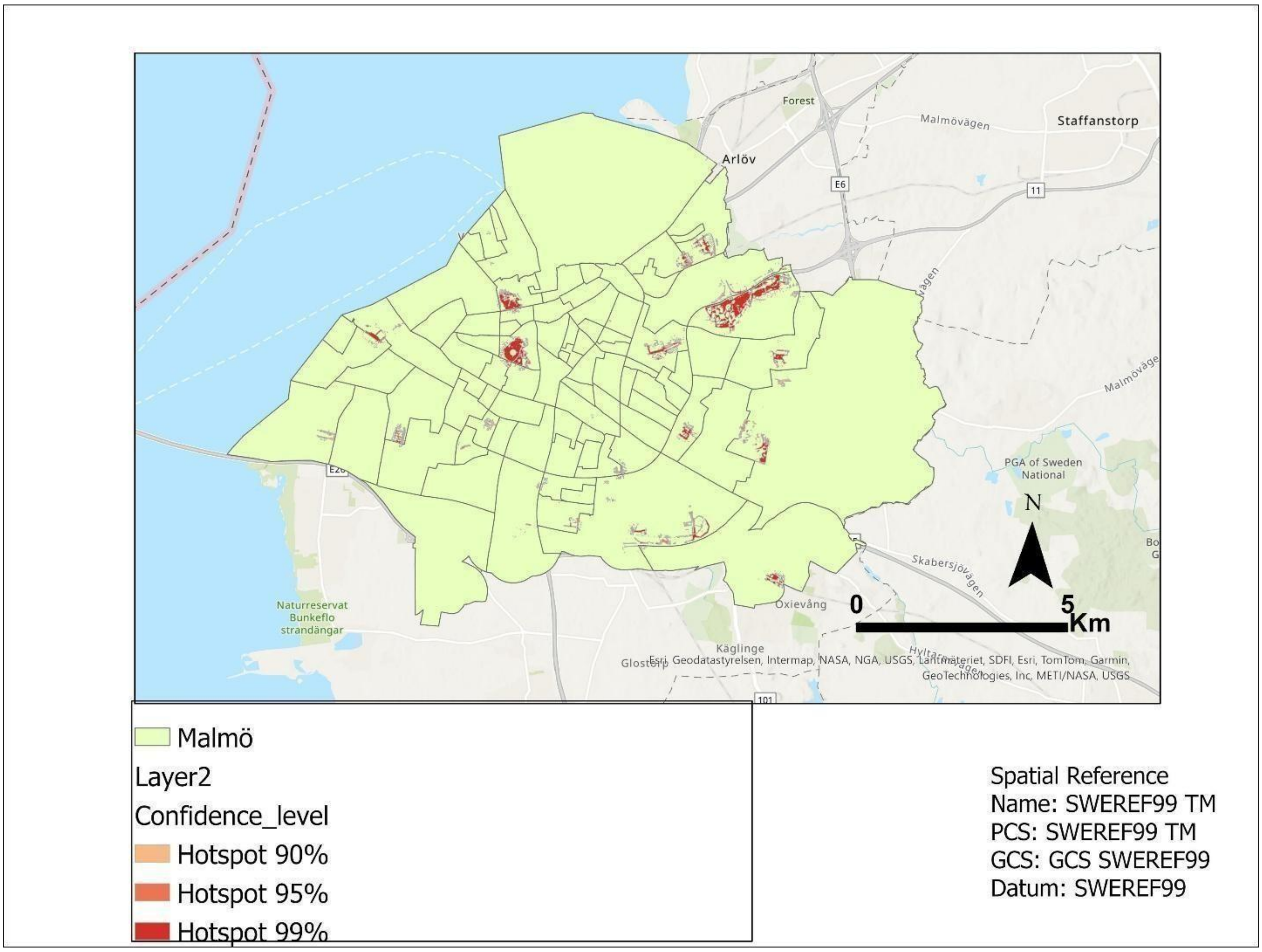

Figure 12: Figure showing significant canopy hotspots in Malmö.

The areas with high canopy coverage and high population density (dark blue) are located primarily near the centre of the city. Areas with low canopy coverage and high population coverage (light blue) are mostly located at the outskirts of the city and in some small parts of the centre (*Figure 13*).

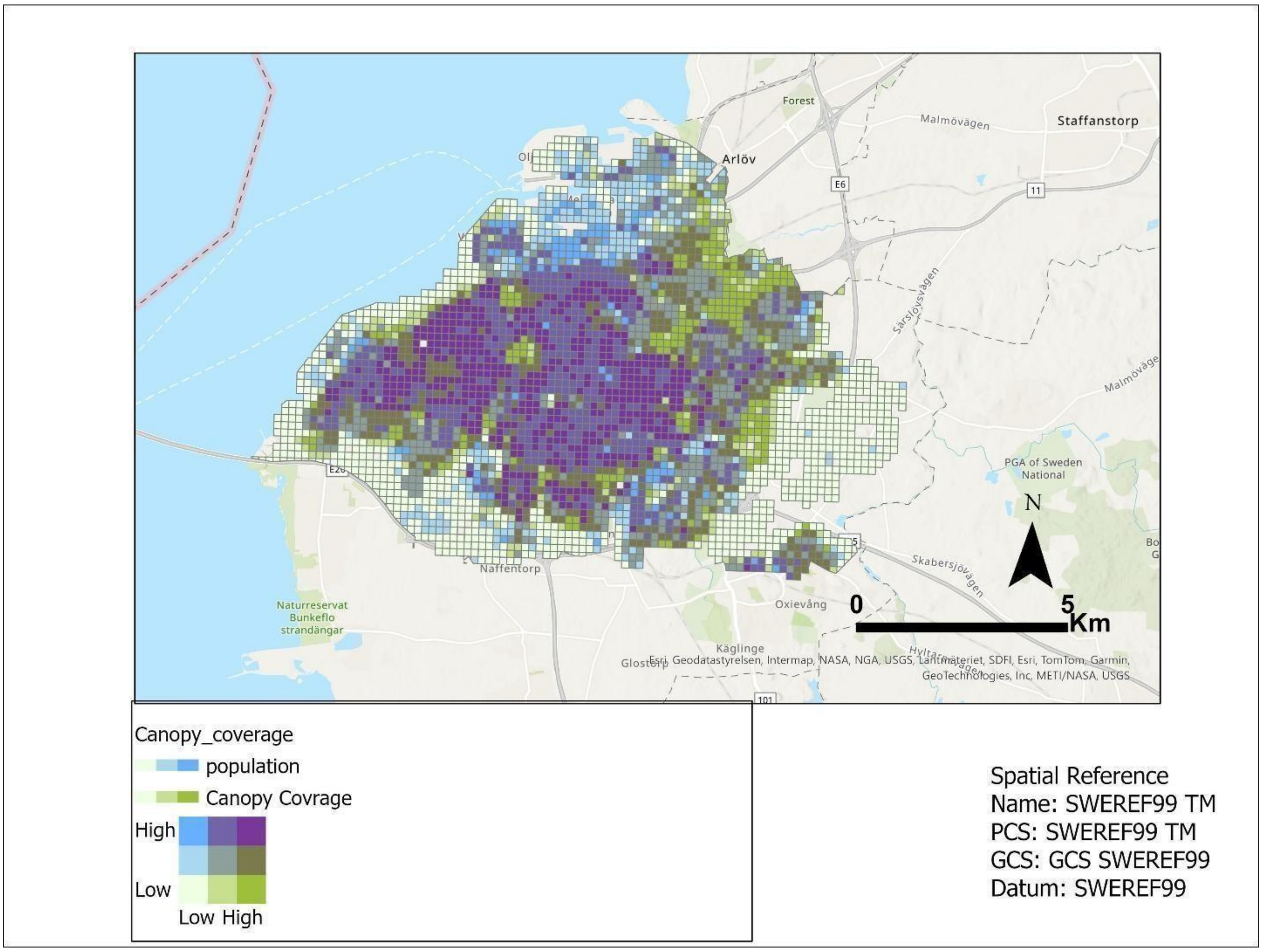

Figure 13: Figure showing GHS_POP population density combined with the canopy coverage percentage.

6.3 Analysis of Distribution Across Area Types (RQ 3)

Across Malmö the distance to greenspaces is similar between different area types, the Euclidean distance to green spaces ranges from 146.8 to 221.3 m. Notably socio-economically deprived areas, area type 1 and 2 have slightly shorter distances to green spaces compared to areas classified as 4 and 5 which are socio-economically well off. (*Table* 4).

Table 4: Mean Distance to Green spaces for each Area type.

Area Type	Mean Distance (m)
1	147
2	151

3	146
4	221
5	209

Mean canopy coverage ranges from 4.3 to 3.0% across the different area types (*Table* 5). Similarly to the mean distance to green spaces, socioeconomically vulnerable, area types 1 and 2, have slightly higher canopy coverage compared to socioeconomically well-off area types 4 and 5, although all areas fall short of the 30% canopy coverage threshold.

Table 5: Mean Canopy coverage percentage within different area types in Malmö.

Area Type	Canopy Coverage %
1	4.3
2	4.6
3	3.8
4	3.0
5	3.8

7 Discussion

7.1 Accessibility Analysis (RQ 1)

The Euclidean distance to green spaces varies considerably across Malmö ranging between 0 and 2631 meters Both the mean and the median distances to green spaces fall within the

300meter recommendation for maximum distance to green space, meaning that a majority of Malmö would likely be considered to be within the 300-meter threshold. This is supported by previous literature (Region Skåne, 2023), which found that 92% of Malmö was located within 300 meters of a green space. The results also highlight cells and clusters mostly in the north and the southeast that are located particularly far away from green spaces, this pattern is mirrored on a RegSo level. The 3-30-300 rule explicitly states that people should live 300 meters from green spaces; areas with a high population located far from green spaces should be prioritized for a more in-depth greenspace access analysis since they could be particularly underserved.

The Greenspace accessibility analysis interpolates the distance from the grid cell centroid to the whole pixel and is therefore not necessarily representative for the whole grid cell. It does not guarantee that there are no boundaries which would prevent crossing on foot, and the Euclidean distance to a green space will differ at the edges compared to the center of the cell. The network distance output was only 1/5 of the Euclidean distance analysis due to an incomplete pedestrian road network in OSM and did not provide enough coverage to conduct a city-wide analysis. A complete network distance analysis would likely have generated longer mean distances to green spaces as the routes generated would account for barriers such as highways and buildings. This suggests that some areas that appear to have good accessibility to green spaces in the Euclidean distance analysis may in fact be underserved in terms of green space access when real walking routes are considered, revealing a more complex picture of green space access across the city.

The result of an analysis attempting to quantify the distance to a Greenspace will be dependent on what features are of a relevant size and have the necessary characteristics. In this report, the definition of green spaces has been set to areas which are publicly owned and have a green surface cover, including parks, sports areas, allotments and cemeteries. This means that a certain priority has been given to the aforementioned ecosystem and climate benefits over the degree of usage. This definition contrasts with the region of Scania's definition, which includes cemeteries but excludes allotments (Region Skåne, 2023). The region's definition prioritizes openness and accessibility, spaces that are open for different uses. However, this definition can become difficult as the degree of access that someone has to a space will vary. It might therefore not be appropriate to include cemeteries when filtering green spaces based on size to allow for different types of activities, as done by Randrup et al. (2025).

7.2 Canopy Coverage Analysis (RQ 2)

The analysis of the canopy coverage percentage using the same 300 x 300-meter grid as in the accessibility analysis showed a fairly low degree of coverage, ranging between 0 and 30 %. Very few of the grid cells therefore met the 30% canopy coverage threshold set by the 3-30-300 rule (Konijnendijk, 2023) and many parts of the city, particularly areas in the outskirts of the city, primarily the north and the south parts, are far away from meeting the limit. Due to the large variation in neighborhood configuration across cities, there is no universal size definition for a neighborhood. The 300 x 300-meter grid cells generated from the accessibility analysis therefore were used as a proxy for a neighborhood since it would allow for continuity in the geographical divisions used for the analysis. This choice is further justified by Malmö municipality's definition of the 30% canopy coverage target at the neighborhood block level, making the 300 x 300-meter grid a reasonable spatial unit for this analysis (a.Malmö stad, 2026).

This is further confirmed by the analysis, which show that the mean canopy coverage is 2.8% while the median canopy coverage is 1.8%. The canopy cover between different area types ranges from 3 to 4.6%, and, like the mean distance to green spaces, areas with lower socioeconomic standards tend to have higher canopy cover.

Areas that have a high population density also have a higher canopy coverage and are located closer to green spaces. This could likely be explained by the recognized need for greenery in urban planning both during modern times, such as by Malmö's usage of the greenness factor and the green point system, as well as historically. Some of the parks highlighted by the hotspot analysis for their high canopy coverage include Pildamsparken, which was established as a park in preparation of the Baltic exhibition in 1914, and Slottsparken, which was opened in 1900 (c.Malmö stad, 2026; a.Malmö stad, 2023). Areas in and around today's Malmö are heavily influenced by anthropogenic influence, particularly farming (Region Skåne, 2023). Planting trees and establishing new parks has therefore had to be a conscious decision.

Areas showcased by the Hotspot analysis that can be deemed to provide particularly impactful ecosystem services such as shading and noise reduction, due to their cooling properties they are also likely more drought resistant.

The kernel density results showed the spatial distribution of the city's trees (*Figure 11*). It also provided a good indicator of canopy coverage: if the expected tree count was less than one, the likelihood of a high canopy coverage was low, such as in the southeast of the city. The results from the kernel density analysis (*Figure 11*) can be used to cross-reference with the figure from the canopy coverage analysis (*Figure 8*) to show areas with a high canopy coverage and a low tree count. These areas are parts of the city that risks a drastic decrease in canopy coverage if at least some of the trees for any reason are cut down.

7.3 Distribution Across Area Types (RQ 3)

The relationship between level of socioeconomic vulnerability and green space access in Malmö contrasts with patterns typically observed in other contexts, with more socioeconomically vulnerable areas showing both higher canopy coverage and better access to green spaces. The higher canopy cover and better access to green spaces in more socioeconomically vulnerable areas is likely due to planning practices in the 1970s, as many of the more vulnerable areas are part of Miljonprogrammet (Randrup et al., 2025). Areas in Malmö with lower socioeconomic status having higher canopy coverage and higher green area accessibility were also recognized in other studies (Randrup et al., 2025). This contrasts with findings from primarily the US, which found lower access to green spaces and lower canopy coverage in areas that are socio economically vulnerable (Locke et al., 2021; Nesbitt et al., 2019). However, just because there is more coverage and better access does not mean that access is equitable, as the need for green spaces in these communities is greater.

When assessing the equitability of green spaces access you look at multiple different factors including, the quality of the green space Randrup et al (2025) used maintenance budget as a proxy for this. Other factors used when indicating green space equity include Urban density, population density in the area of interest, green space context which is defined as the presence of private gardens (Rega et al., 2026). Consequently, athe need for green spaces in an area determined by other factors as well and therefore differs between areas of a similar level of socioeconomic vulnerability. Due to these complexities associated with assessing green space equity, it was deemed to be outside the scope of this study. The analysis therefore took a more large-scale qualitative approach, highlighting overarching accessibility patterns between different area types.

7.4 Implications of Results

The study has investigated a general pattern of green spaces accessibility canopy coverage in Malmö. To meet the 3-30-300 recommendations, a substantial area of the city needs to establish new parks and plant new trees. Findings from this report highlight parts of the city centre, that have low canopy coverage or low accessibility to green spaces whilst having a high population density. These areas would ideally be prioritized for a more detailed future accessibility and canopy coverage analysis as they are the areas in particular need of further greening measures.

The municipality has multiple programs assessing the low canopy coverage. They prioritize the areas with lower average incomes and areas with many children (a.Malmö stad, 2026), which shows a clear awareness of the issue and a clear idea of which vulnerable groups to prioritize. An example of these programs was one called Grönare Möllan which added 150 trees to Möllevången in 2020, increasing the canopy coverage from 8 to 12% (Malmö stad, 2025).

The kernel density analysis suggests that the municipality should plant trees to increase the general canopy coverage in the city to come closer to meeting the 30% canopy threshold. To ensure an increase in canopy coverage and that existing trees remain healthy, it is important to look at how the trees have been planted. An appropriate tree pit size is crucial to lower the risk of water stress on the trees planted in impervious environments (Rosenberger et al., 2024). Older trees, which provide larger canopy cover, are more sensitive to pit sizes as they are more likely to experience water stress (Rosenberger et al., 2024). This could become a bigger problem in the future as Malmö is expected to see drier summers by the end of the century. It might therefore be necessary to make changes to the existing trees' pits to lower the risk of water stress.

Due to the Kernel density figure’s higher resolution is it possible to effectively highlight areas with a high tree coverage. This makes it possible to pinpoint areas where the tree coverage primarily consists of privately owned trees. Privately owned trees are important when increasing the canopy coverage. The city could therefore look into whether soft measures, such as ad campaigns, could be appropriate to spread awareness of the importance of an extensive canopy coverage, thereby encouraging private companies or citizens to maintain these trees. This could potentially be a low-cost supplement to tree plantations on municipal land. It could be particularly beneficial for areas in stronger socioeconomic communities, as they are more likely to own a home.

The city should also prioritize increasing the areas with particularly high canopy coverage, as such areas are particularly beneficial during heat waves and drought events. When comparing two intercity parks in Leipzig during the summer period, the park dominated by trees could maintain cooler temperatures than the surroundings throughout the day, while the park dominated by grass heated up during the day and cooled down significantly during the night (Kraemer & Kabisch, 2022).

In line with the need for more detailed equity analysis of green spaces accessibility, future research could look at combining GIS-based analysis with communal dialogue to get a more comprehensive view of a community's perceived access to green spaces. Malmö's need for greenspaces and vegetation together with its increasing population creates a need to optimize the positioning and configuration of existing greenspaces. It might therefore be interesting to look at where and how the greenspaces in the city would be positioned to ensure that they remain accessible and that neighborhoods are provided by the necessary ecosystem services.

7.5 Data Accuracy

The data set used for green spaces, *Parks and squares* provided by Malmö municipality has local perspective, which is important since the Konijnendijk (2023) states that cities should adapt the rule to local conditions. This need is further amplified by the discrepancy between the Region Skåne and Statistics Sweden's (SCB) definition of a green space were SCB includes a lower size limit of 0.5 ha that is not included in the definition by Region Skåne (Region Skåne, 2023). However, the dataset is rather small scale, and the only available documentation of the dataset is the attribute table, which includes general information about the area states what an area is labeled as under current zoning plans. The lack of clear documentation regarding definitions makes the dataset more difficult to validate.

The GHS_POP population data estimates have a very high resolution of 100x100 meters; however, it is important to note that these estimates are the product of disaggregation of administrative boundaries and interpolated between years and can therefore not be considered as reliable as the SCB population data layer, which has a resolution of 1x1 km.

Boverket mentions that their tree cover data set risks overestimating the coverage in areas such as forests while missing smaller trees due to the insufficient resolution. They therefore recommend using it to analyze single pixels but to look at larger areas. It is therefore likely that the actual canopy coverage, especially in central parts of Malmö, might be slightly higher, considering that singular trees are more likely to be left out of the data set. It simultaneously means that the data set might overestimate the coverage of the areas highlighted in the hotspot analysis due to their high canopy coverage.

8 Conclusion

This study showcases the distance to green spaces and canopy coverage across Malmö Urban area. The study investigates the 30 and 300 components of the 3-30-300 urban greenness recommendations, using a 300 meters distance threshold as an indicator of accessible green spaces and 30% as a benchmark for adequate canopy cover. The following research questions were answered:

1 How do the distances to green spaces vary within Malmö?
2 What is the pattern of canopy cover distribution in Malmö?
3 Does the distribution and extent of these parameters differ across areas with differences in socioeconomic vulnerability?

The first research question was answered through a combination of an R and GIS-based analysis and found that the Euclidean distance ranges between 0 to 2310 meters with a mean distance of 297 meters. The analysis revealed that areas in the northern and eastern parts of Malmö had significantly low accessibility to green spaces. Also, parts near the city center could be considered to have low access to green spaces when the population density is taken into account.

The second research question was answered through a GIS-based analysis, which found that the canopy coverage ranges between 0 and 30 % with a mean coverage of 2.8% across the study area. It also found that the canopy coverage was relatively high near the center of the city, while lower in the outskirts. The analysis highlights similar areas as the accessibility analysis for having low canopy coverage and a high population density.

The final research question was answered by summarizing the features analyzed for the research questions one and two. The conclusion is in line with previous literature that areas with lower socioeconomic status generally have slightly better access to green spaces and a higher canopy coverage, reflecting planning decisions from the 1970s. However, considering these areas have a greater need for greenspace access and extensive canopy coverage, the analysis is unable to draw conclusions regarding the equity of the distribution.

The analysis revealed that the distance to green spaces across Malmö is closer to meeting the 300-meter accessibility threshold, while the canopy coverage falls significantly short, and should be addressed through targeted tree planting measures. The results frequently highlight parts near the center of the city as having relatively low access to green spaces and a relatively low canopy coverage relative to population count. Areas with lower socioeconomic status show higher canopy coverage and better access to green spaces. However, further research combining GIS analysis with communal mapping would be needed to help gauge if the greenness needs are met in these communities.

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10 Appendix

10.1 Supplementary Figures

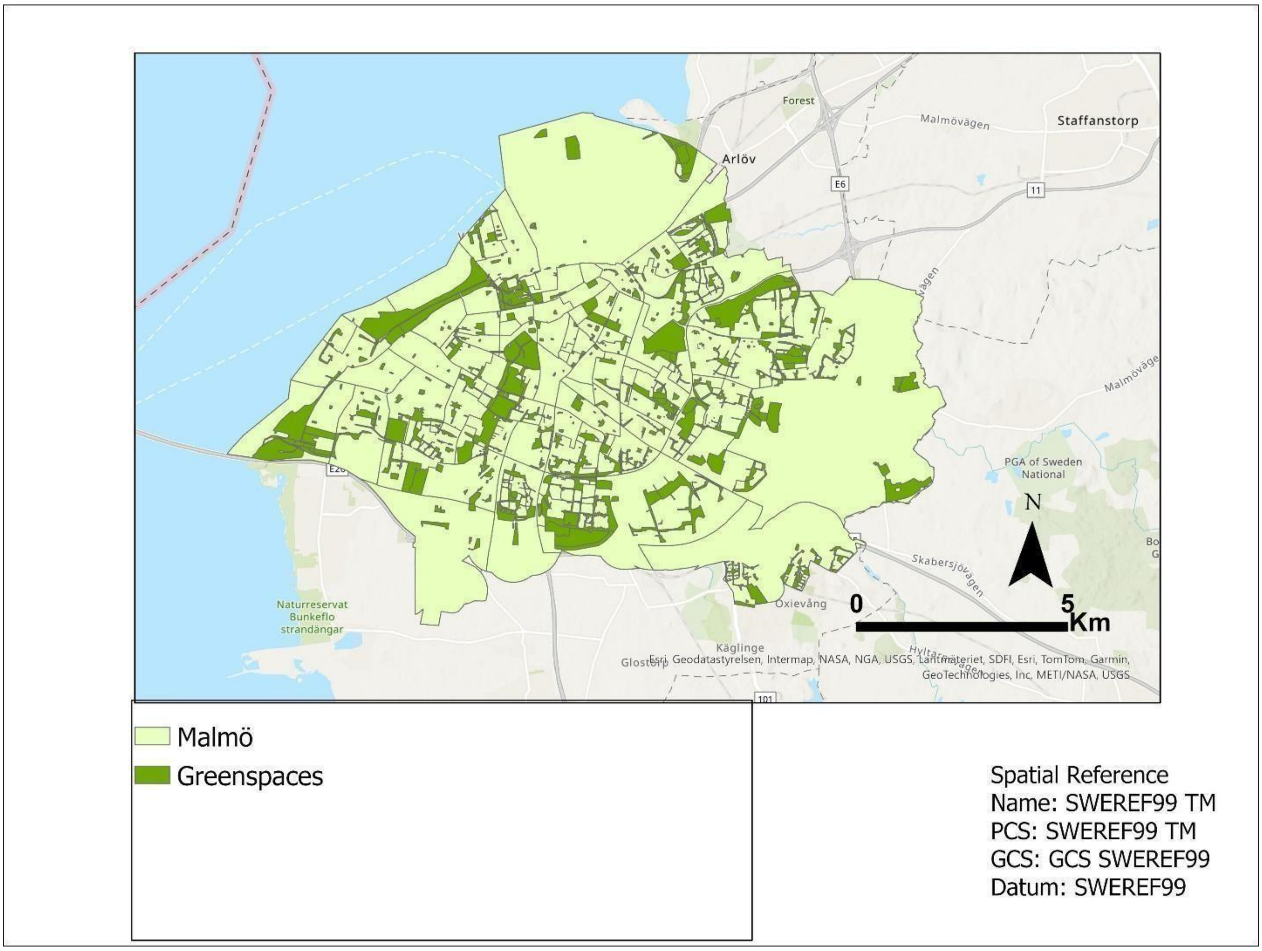

Figure 14 Green spaces form the Malmö parks and squares layer that were used for the accessibility analysis.

10.2 Ai generated code

The following code was generated using Claude Sonnet 4.6:

1. library(sf)

library(greenR)

Load your own green areas file ("C:/THIS/parkonly_grid.gpkg".) my_green_areas <-

st_read("C:/THIS/parkonly_grid.gpkg)

2.
Make sure CRS matches (WGS84 is typical) my_green_areas

<- st_transform(my_green_areas, crs = 4326)

Save the grid result as a shapefile sf::st_write(result$grid,

"green_accessibility.shp")

Or as GeoJSON (also opens fine in ArcGIS) sf::st_write(result$grid,

"green_accessibility.geojson")