Student thesis series INES nr 479

Remote sensing based analysis of linkages between urban green space dynamics and social-economic factors: A case study in Malmö, Sweden

Yixin Zhang

2019
Department of
Physical Geography and Ecosystem Science
Lund University
Sölvegatan 12
S-223 62 Lund
Sweden

Yixin Zhang

Remote sensing based analysis of linkages between urban green space dynamics and social-economic factors: A case study in Malmö, Sweden

Fjärranalysbaserad analys av kopplingar mellan urbana grönytor och socioekonomiska faktorer: En fallstudie i Malmö

Bachelor degree thesis, 15 credits *in Physical Geography and Ecosystem Science*

Department of Physical Geography and Ecosystem Science, Lund University

Level: Bachelor of Science (BSc)

Course duration: *March* 2019 until *June* 2019

Disclaimer

Remote sensing based analysis of linkages between urban green space dynamics and social-economic factors: A case study in Malmö, Sweden

---

Yixin Zhang

Bachelor thesis, 15 credits, in *Physical Geography and Ecosystem Science*

Supervisor:

Marko Scholze, Lund University

Department of Physical Geography and Ecosystem Science

Exam committee:

Janne Rinne, Lund University

Vaughan Phillips, Lund University

Abstract

The global rapid growing urban inhabitants and urbanization promotes a conflict with natural resources conservation, sustainable urban structure establishment, and urban expansion. Urban green space (UGS) plays an essential role in sustainable communities, human health promotion, and economic development, however, is gradually replaced by the basic infrastructures in the context of densification strategy for urban expansion. UGS that has multiple functions might be unequally distributed as social and economic discrepancy varies from different communities in cities.

This thesis aims to evaluate the historical variation and distribution of large-scale UGS from 1960 to 2016 with the growth of population and Commercial/ Industrial/ Residential area (CIR area) in Malmö municipality, Sweden. It further aims to analyse the area of the UGS in each district with considering the social-economic factors in order to identify, which zone in the city lacks of UGS and if the UGS are evenly distributed. Part of this thesis is also to create a regression model with the variables for predicting future the UGS and generating suggestion adapted to the densified urban structure and future planning.

The study found a downward trend of the UGS during the 50 years associated with the variation of policies and urban plan, which, however, did not correlate significantly with the population growth and CIR area development. The UGS was found to be unevenly distributed in the west and east, potentially related to the population density, CIR area, and income level. The models for predicting future UGS, however, are not accurate due to the limitation of explanatory power of the chosen variables (such as walking distance to park, waterbodies and public transport infrastructure).

Keywords: *UGS, population, CIR area, Urban expansion, sustainable, social-economic factors*

Abbreviation

CIR area: Commercial/ Industrial/ Residential area

UGS: Urban green space

SCB: Statistics Sweden

WHO: World Health Organization

Content

List of Figures:

List of Tables:

1. Introduction

The urban area throughout the world rapidly has increased in size over the last century. The urban population accounts for 50 percent of the total world inhabitant. (The World bank 2018). The global population who will live in urban areas are expected to increase by 20% in 2030. (Demuzere et al. 2014). The rapid growth of the global population and urbanization changes the urban landscape patterns and process significantly, promoting conflict between natural resources, sustainable environment, and urban expansion. (Lahoti et al. 2019; Rees 1997). The demand for necessary infrastructures such as residential areas, water, energy supply, and sanitation, that are prioritized has increased in the context of urban expansion. A solution to urban expansion is urban compaction without affecting economic development and population growth, which however reduces the existing area of green spaces, replacing them with the required infrastructure and buildings. (Joaquín et al. 2018; Sanström, 2002). Urban green space, though as a second priority, plays an essential role in sustainable communities, human health promotion, and well-being. (Jennings 2019).

Urban green space (UGS) is urban vegetated area that provides ecosystem services can benefit the quality of human life and sustain the environment. (Jennings 2019). Previous studies show that UGS can reduce the risk of cardiovascular-related deaths and obesity, improving mental health, and promoting outdoor activity. (Gascon et al. 2016; Fong et al. 2018). Other examples for the environment are: promoting visual aesthetic values such as parks and gardens, biodiversity conservation such as providing different habitats. (Sanström 2002); moderating urban island heat through evapotranspiration. (Razzaghmanesh et al. 2016); and reducing urban flood risk as increasing precipitation by climate change. (Kim et al. 2016). Green spaces are an essential infrastructure to achieve the goal of sustainable development in cities. (Chiesura 2004).

As UGS can provide a wide range of benefits, the accessibility and distribution of UGS in different communities in some cities are associated with socio-economic factors e.g. income, education and health. A previous study by Jennings (2019) shows social inequality such as income inequality commonly related to the distribution of injustice. Other studies demonstrate that the inequitable accessibility of urban green spaces has a linkage with people has been in low socioeconomic status. (James et al. 2015). Moreover, research from Casey at al. (2017) indicates the coverage of UGS within metropolitan areas in the U.S are associated with the level of education, class and wealth. Due to the discrepancy between economic developments in different districts, UGS distribution might have different priorities. (Kabisch and Haase 2014; Sathyakumar et al. 2018).

In Sweden, open green space is under threat from urban expansion and rapid population growth. (European Commission 1996; The World bank 2019). The country is currently implementing compact city policies and co-existing green urban structure. (OECD Publications Centre 2012). The Swedish legislation was modified in 1992 and took a special consideration into the importance of developing green space in urban areas. (Johansson 1993/1994). Developing green spaces is regarded as one of the mandatory structure plans in Swedish cities and towns based on the revised legislation. (Statens Offentliga Utredningar 1994; Lönn 1999).

Malmö municipality has transformed from an industrial to a post-industrial society in the last century and targeted be a sustainable city since 2009 as well as a becoming climate neutral (in terms of greenhouse gas emissions) city in 2020. According to the green plan in Malmö (2018), the city will continue to establish functional blue spaces such as waterfront parks, lakes and harbours; and green spaces, meanwhile, protect the existing green and blue areas. However, raising continuous immigration and fast-growing population in the past 15 years has resulted in wealthy discrepancy and home segregation. (Grander and Alwall 2014). Equally distributing and accessing UGS has become a challenge for public policymakers and planners. Evaluating the historical variation and distribution of UGS with the population growth and social-economic development can help to identify, which zones in the city lacks of UGS and if the spaces are evenly distributed. Further, such an analysis is able to generate a suggestion for future planning.

Aim

This study aims to analyse and predict the change of UGS with social and economic factors by using aerial photos from Lantmäteriet in selected districts in Malmö city, Sweden. The aim is divided into four objectives:

- Identify the historical and current distribution of the UGS from 1960 to 2016.
- Analyse the relationship between the variation of UGS, population and commercial/industrial/residential area (CIR area).
- Measure and analysis the area of the UGS in each district with the social-economic factors.
- Create a simple model based on the social-economic factors and predict future UGS.

2. Background

This section describes the definition and classification of urban green space (UGS) and the benefits of UGS in the environment, human life as well as economic development. The social equality and distribution of UGS is presented in this section and exemplified. The legislation, plan and society development behind the planning of UGS are indicated in section 2.7 for Malmö municipality. Moreover, this part presents and discusses the existing methodology to calculate UGS from remote sensing data.

2.1 What is Urban green space?

The most common definition to describe green space is a surface area that can has the ability to support vegetation and contains the vegetation being supported. (Jo 2002). Examples of the green space that refer to a surface of vegetation are forests, street trees, parks, gardens, and backyards, farmland, and food crops. (Taylor and Hochuli 2017). The conceptualization of green space has two subsets, including green spaces that as nature and green spaces as urban vegetated spaces. Green spaces as nature can be defined as natural vegetation that can be assessed in public, such as parks, gardens and less managed areas involving woodland and nature reserves. (Lachowycz and Jones 2013). The difference between the first concept and urban green space is that UGS refers to any vegetated area adjoining an urban environment.

UGS varies from shapes, purposes, property, and quality, providing different functions and benefits. To fulfil a range of different role, UGS is arranged for recreation and cultural purposes, as well as economic and environmental purposes. (Lee et al. 2015). UGS can therefore be divided into eight groups according to the green space typology developed by Hansen(2017) :agricultural land; allotments and community gardens; blue spaces; building greens; natural, semi-natural and feral areas; parks and recreation; private, commercial, industrial and institutional green space connected to grey infrastructure; and riverbank green.

2.2 Urban green space and urban ecology system

Urban green space contributes to the urban ecology system in terms of regulating biogeochemical cycling, mitigating local climate change such as warming and changes in precipitation, reducing air pollution and noise, and biodiversity conservation. Previous studies show that urban vegetation plays a vital role in regulating biogeochemical cycling by CO_2 sequestration and evapotranspiration. (Grimm et al. 2008; Alberti and Hutyra, 2009; Hutyra et al. 2011; Lin et al. 2011; Yu and Hien, 2006). Vegetation in a city such as trees, shrubs, and grass accumulate and sequester CO_2 from the atmosphere by the process of photosynthesis. Moreover, urban vegetation can reduce the urban heat effect from buildings by absorbing solar radiation, and by the process of evapotranspiration leading to local cooling. (Omer 2011). Also, the speed of wind can be reduced by urban vegetation, thereby decreasing the wind tunnel effect in urban environment.

Furthermore, UGS can mitigate the increasing precipitation and reduce a risk of urban flooding. (Bai 2018). As the growing residential area replacing UGS, such impermeable cover increases the volume of surface runoff, and thus raise the risk of urban flooding. UGS can delay the time of the peak runoff by increasing infiltration, then change the cycling of groundwater and surface water and reduce a pressure of urban drainage. (Bonan 2002). However, the appropriate size of UGS required to mitigate the flooding needs further discussion.

UGS that can contribute to noise-reduction depending on the type of UGS. Research by Dunnett and Kingsbury (2008) shows that green roofs can absorb outdoor sound waves, and thus further reducing indoor noise. Moreover, UGS such as tree cover can remove a variety of air pollutants by uptake through leaf stomata and interception of airborne particles. (Nowak 2002). Tree covers in New York City, for example, reduced 0.47% of particulate matters, 0.45% of ozone and 0.43% of SO_2 on average during the daytime in the growing (leaf-on) season. (Nowak 2002). The emission of volatile organic compounds (VOC) by trees, though, contributes to the formation of ozone and CO, varies from different tree types. Additionally, previous research has shown that increasing tree cover can reduce VOC emissions further with decreasing ozone levels because VOC emissions depend on temperature and tree cover can mitigate the heat and reduce local temperatures. (Nowak 2002).

Increasing urban expansion results in biodiversity diminishing and habitat loss. UGS can provide habitats and corridors for biodiversity conservation. (Kong 2010). A study by Sandström (2004) indicates that avian species have an inclined trend as the green space increases from the centre to the suburbs in Sweden. The study also emphasizes the importance of UGS in contributing to maintaining ecological diversity. Moreover, research about forest ecosystems by Tewksbury et al. (2002) shows that increasing green corridors, e.g., trees and shrublands, can improve plant and animal biodiversity through enhancing connectivity among species. For example, the gene flow between the white-footed mouse population is found to increase with developing green corridors, thereby promoting the biodiversity in New York City. (Munshi-South 2012).

2.3 Urban green space and human life

Urban green space provides several benefits to human health and the quality of human life. UGS with recreation values promotes outdoor physical activities, such as in the form of walking and reduces mental illness. (Jackson 2003; Giles-Corti et al. 2005). It has previously been observed that people who live in an urban area that can access more green spaces are healthier than in rural areas. (de Vries et al. 2003). UGS that provides natural elements from a window can reduce blood pressure and stress. (Hartig, et al. 2003). Moreover, UGS plays a major role, especially for elders and children. Regular physical activity promotes walking by the elderly and decrease the risk of dying from several diseases. (Zoeller 2009; Orsini et al. 2009). An urban area with a public playground surrounded by vegetation increases children's physical activities and diminishes unhealthy amounts of solar radiation. (Timpiero et al. 2008; Boldemann et al. 2006).

UGS increase the quality of human life, such as increasing security, social interaction, and ideal living and working environments. Previous research by Kuo 2001 and 2003 demonstrates communities with more UGS have less violence crime and better security and social interaction than others. Furthermore, UGS such as trees and shrubs impact on driver behavior and increases traffic safety. (Rosenblatt et al. 2008). UGS development, such as community gardening, creates social interaction between different ethnic groups and promotes social inclusion. (Waliczekz et al. 1996; Saldivar-Tanaka et al. 2004). Research shows that working environment with more green space is more attractive and increases working satisfaction at the same time. (Dravigne et al. 2008) The green work and living environment, also, reduces working stress. (Stigsdotter 2004).

2.4 Urban green space and economic benefit

Urban green space plays an essential role in the economy and generates more direct economic values and benefit such as property values, urban city branding, and initiatives to pay for goods. (Berg et al. 2012). High quality urban green space increases the value of property in both residential or commercial area and promotes the economic development in surrounding areas. (Luttik 2000). One outcome of developing the urban green space to promote the economy is tax increasing due to the property value growth, which then returns to the local government. (McCord 2014). They have shown that apartments in Finland, that are located close green spaces area such as water and forested recreation area, have seen increasing prices. Additionally, a study shows the willingness to pay for products increases with areas located to UGS with large canopy covers and other vegetation in the USA. (Wolf 2009). Another example in Sweden is increasing urban gardening that benefits biodiversity, and urban agricultural products and contribute to a high economic value, around 2.7 billion SEK in 2001. (Björkman 2001). Finally, the area with economic growth helps to attract tourism and more investment, consequently, promote labor market and enhances city branding. (Björkman 2001).

2.5 Urban green space and socio-economic inequalities

Socio-economic inequality is related to differences in social and economic factors. (Perrons and Plomien 2010). Economic inequalities are associated with discrepancies in income. Social inequality is linked to disparities in accessing social commodities, such as education and healthcare or to social infrastructures and institutions. Social inequality is related to economic inequalities when obtaining social commodities depends on income. (Perrons and Plomien 2010).

As urban green space can provide a wide range of benefits, including mental, social and physical advantages for human life, the accessibility, and distribution of urban green space for different communities in a city were captured more attention by the increasing number of scholars followed by publishing the policies of environmental justice. (Watkins and Gerrish 2018; Li et al. 2015). Research shows that the distribution of injustice commonly related to the income inequalities for example. (Jennings 2019). Also, other studies demonstrate that the inequitable accessibility of urban green spaces has a linkage with people has been in low socioeconomic status. (James et al. 2015). For example, Casey et al. (2017) have research in 2017 about analyzing the change in vegetation within metropolitan areas in the U.S over for ten years and related this to demographic characteristics and wealth gaps. They have shown that the coverage of urban green space is associated with the level of education, class and wealth. (Casey et al. 2017). However, the distribution of environmental amenities for all the people, should not consider the national origin, income, Color or race. (U.S. EPA 2018).

2.6 Existing methodology for measuring Urban Green Space (UGS)

Several studies have used different methods to evaluate the area and distribution of UGS in cities. Gupta et al. (2012) have analysed UGS using an urban neighbourhood green index model. The model calculates a percentage area of green in remote sensing images based on distinguishing similar characteristics, namely measuring neighbourhood greenness. The amount of green in percentage termed as Green Index (GI) is used to access the spatial distribution of UGS. Another approach by Beiranvand et al. (2013) is to calculate the area of UGS with visual interpretation through provided orthophotos and dot grid. The green space ratio in this study is measured by using the number of points captured and located in UGS divided by the total number of points in the whole city. In this thesis, the area and distribution of UGS due to the low quality of historical aerial images is analysed by using visual interpretation with remote sensing data. Social-economic and demographic variation were used as indicators in the evaluation of the change of UGS from 1960 to 2016.

2.7 Study area

The municipality of Malmö is located at the southwestern of Sweden in the province of Scania on the border to Denmark, as showed in Figure 1. Malmö is the third largest city in Sweden with a population of 316,588 in 2018. (Statistics Sweden SCB 2018). The Municipality was divided into ten main areas before a reform in July 2013; now it consists of five areas, including Väster, Innerstaden, Norr, Söder and Öster (Malmö Municipality 2013). The study focused on the districts close to the center, that belong to Norr and Innerstaden. These areas have a rapid economic and population growth. The two areas are divided into six districts, consisting of Möllevången, Sankt Johannes, Sankt Petri, Sankt Pauli, Slottsstaden, and Sofielund. The study area was selected based on comparing the population density in 2015 from SCB and geographic location in each district.

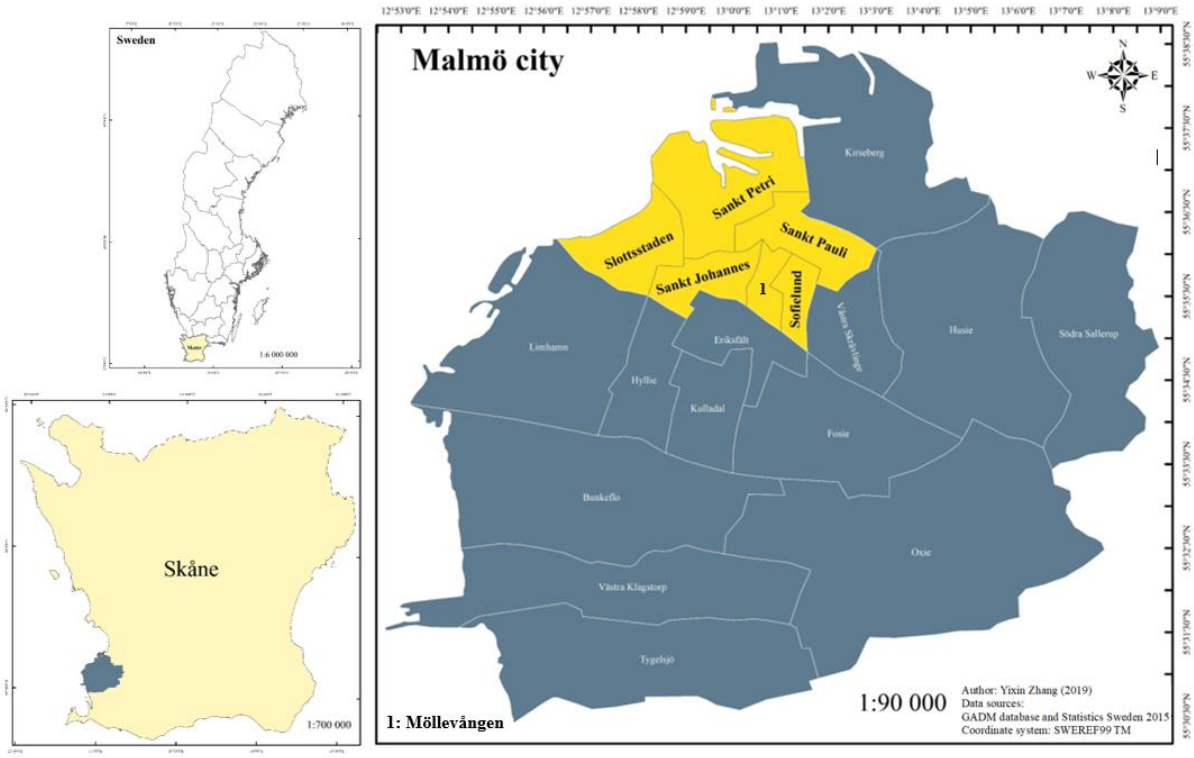

Figure 1 Malmö city. The study area is coloured in yellow in Malmö City

Malmö is one of the important cities in the Öresund region since the Öresund Bridge was inaugurated and connecting the city with the capital city in Denmark in 2000. The city has transformed from an industrial society to a post-industrial society in the last century. Since the late 18th century, the population in the city increased slightly. (Grander and Alwall 2014). During 1970s and 1980s, the inhabitants decreased markedly due to the industrial crisis. After the 1990s, population and economic growth have been part of the transformation. Continuous immigrants, mostly refugees were an essential factor affecting the population growth and wealth discrepancy. The city becomes a multi-culture city which contains 170 nationalities. (Jansson 2014). The city's changes in character during the last decades have resulted in the inequality of distributed infrastructures. UGS as one of the public infrastructures may be unevenly distributed in some areas caused by social segregation, however, there is a lack of research to prove this hypothesis.

With the increase in population, the strategy of a compact city was implemented in Malmö in 2014 (Malmö stad. 2014). Formulating guidelines and targets for developing functional green space plan under pressure is essential (Green plan Malmö 2003). According to the plan for green and blue environments in Malmö in 2019, the city aims to become a social-economic, environmental and sustainable city, meanwhile, an attractive place for inhabitants to live and work. Currently, the city covers over 50% green space which includes private parks and gardens in the residential area (Hansen et al. 2015).

The city should adapt to climate change according to the target from the Action Plan in Malmö (2012). Climate change affects the city with the following main three consequences: increasing precipitation with the risk of flooding, sea level rising, and increasing urban temperature. Currently, the actions that have been implemented to achieve the goals of a sustainable city and including adaption to climate change, involves developing green roofs in Augustenborg and the western harbour for multiple functions. (Delshammar 2015)

3. Materials and Methodology

The section introduces the data sources that have been mainly used for the methodology framework and the limitation of the data. It also includes the methodology for the four objectives, including aerial photos interpretation, followed with area distribution analysis and models prediction.

3.1 Data acquisition

The UGS area calculation mainly depended on digitized aerial images. The historical aerial images were acquired from Lantmäteriet, and their resolution varied from 0.5 to 2m (see Appendix I). The recent aerial photos in Colour had a resolution of 0.5m, taken in 2007 and 2016 during the growing season. The aerial photos from the years 1960 and 1973 were in black and white had as the resolution of 0.5m. The images from 1991 had a lower quality, a resolution of 2m, and contain geometric distortion. Vegetation was less easily identifiable on black and white images in the year 1960, 1973 and 1991. Satellite images from Google earth, starting from 2002, were used to assess the accuracy of the interpretation. The historical data of municipality population were obtained from Statistics Sweden (SCB), but these data lack information of the historical population density and population in each district.

3.2 Methodological Framework

The method used for the four objectives, included image interpretation, the UGS variation analysis based on space and time, and future UGS prediction. The procedures were divided into two parts, including land use analysis with ArcGIS 10.5.1 and statistical tests with R 3.5.3 and Microsoft Excel 2016. For this study, the aerial photos of the years 1960, 1973, 1991, 2007 and 2016 were digitized to calculate the area of the UGS in the selected districts in Malmö. The land use which corresponded to commercial, industrial and residential (CIR area) were extracted as a potential factor affecting the UGS. Another factor potential factor affecting UGS was population. For both factors, CIR area and population the correlation with UGS was calculated. Finally, a regression model to predict future UGS was developed based on these two (population/population density and CIR area) predictors.

3.2.1 Image interpretation

The image interpretation for the five aerial photos involved three steps: digitization, map accuracy calculation, and land use classification correction.

The image digitization was based on the interpretation key, as shown in Figure 2. According to the guideline in the Green plan for Malmö (2003), the scale of greenery for the city was between 2000 m^2 to 10,000 m^2. This study focused on large-scale UGS, assuming the minimum size of the GS for each digitized polygon of 1000 m^2 according to the above-mentioned guideline as the reductive study area.

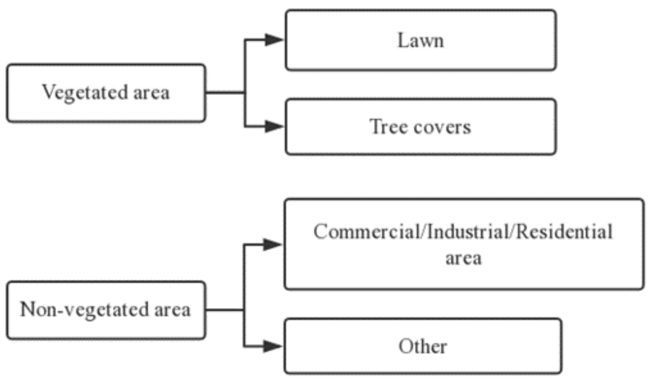

Figure 2. Interpretation key for land use/land cover classes

Lawn and tree cover in the city was considered to be the total UGS because of the limitation of distinguishing lawn and tree cover in historical images. Because the area of waterbodies in the city constant remained constant, waterbodies as part of the green elements were not considered as UGS in this study here. Areas such as bare soil and undeveloped fields were classified as others. Green roofs in the western harbour in the Sankt Petri district have been analysed in a previous study by Rosenström(2017). Their maximum size was less than 1000 m^2, and therefore not included in the classification here. The tree corridors along the streets were digitized continuously along the streets to meet the limitation of the area size. Because parts of residential and industrial buildings were mixed with the commercial area in the centre of the city and harbour, the three areas were assumed to be in one class. The shapefile of the commercial area in 2015 from SCB was used to improve the accuracy of digitization. Example of digitizing vegetated area and non-vegetated area can be visualized in Figure 3 below.

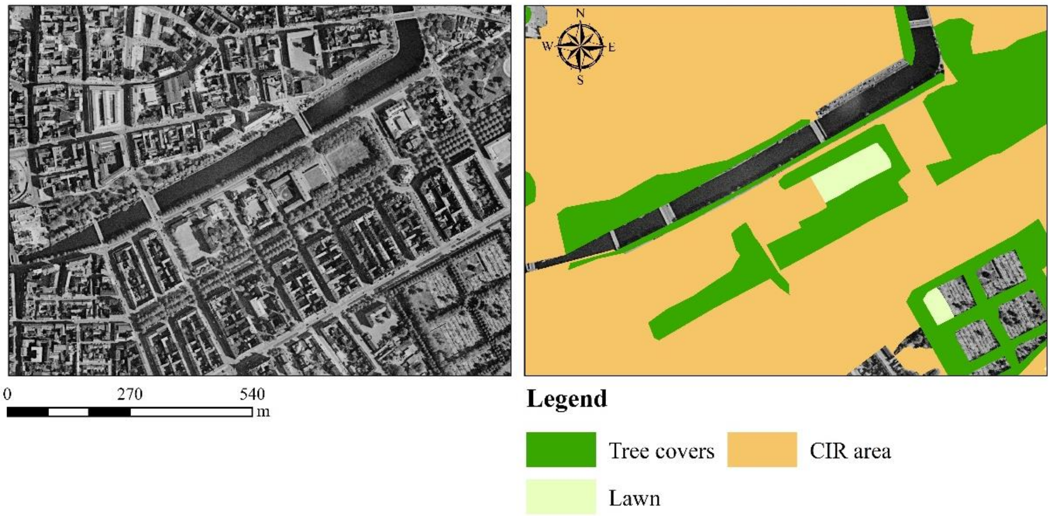

Figure 3. Example of interpreting tree covers, lawns and CIR area in the historical aerial photo 1960. (Aerial photo to the left, Orthophoto raster, 0.5 m Black and White © Lantmäteriet 1960)

The tool of *Iso Cluster Unsupervised Classification* was first used to help to classify the land use in the five yearly images in order to minimize operator-induced errors. The tool, as one of the unsupervised classification methods, was used to create a map with user-defined number of classes based on the pixels that are comprised of similar pixel values. Next, the images were digitized manually by using visual clues such as pattern, shapes and textures, and the unsupervised classification.

3.3.2 Image accuracy and correction

The thesis adopted the image accuracy assessment methods from Du and Weng's study (2007). To determine the accuracy of each image, the stratified sampling method was used to ensure numbers of random samples were generated within each class. Around 200 sampling points from the classified data were created in ArcGIS using *create accuracy assessment points*. The tool was used to create sampled points based on the user's defined sampling method and labelled their classification types by referring the digitized maps. Then, compared the classification types of the sampled points with the ground truth data from the satellite images in Google Earth. The satellite images with 3D buildings in 2016 and 2007 were compared with the classified images to update the accuracy assessment points. The samples in the classified images of the years 1991, 1973 and 1960 were revised based on the same imagery that was used to create the classification. The confusion matrix was created for each map to compare the user's and producer's accuracy within each class and to calculate the corresponding overall accuracy and Kappa coefficient of agreement. The producer's accuracy in the matrix indicated the frequency of a land use class on the ground that has been correctly classified. The user's accuracy, similarly, demonstrated the probability of the class on the map has been present on the ground. The coefficient was used to estimate the agreement between the classified and truth values. A value of 1 indicated the classification is accordant with the referenced map. The maps with an accuracy or an agreement above 0.8 indicated a strong accuracy or agreement between the classified maps and the referenced map. Last, the land use classification of each map was updated based on the referenced images.

3.3.3 The UGS change analysis and Pearson correlation coefficient

The total area of UGS and CIR area was calculated based on the classified maps. Also, the area of the UGS was calculated within different districts and for the different five years according to the images. The distribution of UGS in each district was analysed by comparing the proportion of UGS in each district as well as associating it to changes in CIR area and population or population density.

The Pearson correlation coefficient is used to analyse the relationship between the total area of UGS and CIRS; the area of UGS and the total population in the city. The correlation coefficient (r) is a statistical method to test the relationship between two variables. The value of the coefficient ranges from -1 to +1, which indicates if the correlation is negative or positive to a certain extent. A coefficient of ≥ ± 0.5 indicates a strong correlation, a value between 0.3 and 0.5 indicates a weak correlation. A p value is used to test the significance level of the correlation. If the p value is less than the alpha level (0.05), it means the correlation is statistically significant.

3.3.4 Multiple linear regression model

Multiple linear regression tests the relationship between one response variable *y* and two or more predictor variables *x* by the following equation (1).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (1)$$

The model was applied to measure how the area of UGS as the dependent variable changed with changes in the independent variables, here CIR area and either population for the city area analysis or population density for the district analysis. The population density in the five districts was assumed to be even-distributed due to the lack of historical data from Statistics Sweden (SCB). The model was used to predict future UGS with only considering these two factors.

The regression model indicates the direction and significance of the relationship, assuming the residuals (the difference between the actual y and the predicted $\hat{y}$) are normally distributed. The coefficients (β), is also called slope coefficient, represents the average change in the dependent variable (y) for a unit change in the independent variable (x).

ANOVA test is a statistical test that used to estimate differences of variances among groups of samples. It was used to assess a significance of the overall linear regression model. A null hypothesis in this test assumes the model cannot be explained by all independent variables. (H_0: $\beta_1 = \beta_2 = 0$). The statistical significance of the differences is tested using a F value. Its p value is used to test a probability that the result happened by chance. The F value along with its p value decides if the result is significant or not with a degree of freedom at a 95% confidence level. If the F value is greater than Fa (k, n-k-1) in the F-distribution table and the p value is lower than the alpha level (0.05), the null hypothesis can be rejected. (k is the number of independent variables; n =samples size; n-k-1 means a degree of freedom). These indicate the overall result is statistically significant and at least one predictor variable is significantly associated with the dependent variable. (Kassambara 2018).

Two-sided T test is used to compare a difference between the means among two samples. The test in the linear regression model is used to assess which independent variable is significantly associated with a dependent variable. A null hypothesis for this test states a predictor variable is not significantly related to the dependent variable. (H0: $\beta 1 = 0$). The statistically significant of the difference in the t test is tested using a t value. If the t value is larger than $T_{\alpha/2}(n-2)$ in the T-distribution table and p value is greater than the alpha level 0.05, it means the variable is significantly associated with the dependent variable. (α = significant level 0.05; n =samples size). The p value in the test determines whether a probability of the null hypothesis is true or not. A standard error in the t test represents a variance of a coefficient. A small value of the standard error indicates the set of observed values are well fitted with the model.

R^2 and Residual standard error (RSE) is used to assess the quality of the model. R^2 varies between 0 and 1. If the r^2 is close to 1, the model represents a large percentage of the variation in the dependent variable can be predicted by the independent variables. (Kassambara 2018). Because r^2 will increase when more independent variables added to the model, it is adjusted with R 3.5.3 to ensure the proportion of variation is explained by only predictor variables that have an impact on the outcome of the variables. (James et al. 2013). The adjusted r^2 that is less than the original r^2, can be negative. The RSE tests the error of the prediction. If the RSE is close to 0, it indicates an accurate mode.

The overall model is assumed to be insignificant if one of the independent variables is insignificantly associated with the dependent variable; even the overall model is significant with a p-value less than 0.05.

4. Result

The results based on the area calculations in five digitized maps include three main sections: the trend analysis of UGS, CIR area and the population at the city level; the variation analysis of these three variables at the district level; and derived regression models.

The average accuracy of these maps was 84%, and the kappa coefficient was 81%, indicating a strong accuracy and agreement between the classified maps and the referenced maps. (see Table 1). It is obvious to see the maps in 1960 and 1973 that were digitized with black and white aerial photos had a lower accuracy than others in recent years. The performance of the classification indicated a low user's accuracy in 1960 and 1973 for tree covers and CIR area. This means a number of polygons that were classified as tree covers or CIR area were not actually present on the ground. (see Table 2). Tree covers and CIR area category in 1960 and lawn category in 1973 also had a low producer' accuracy. It means the categories referred to the ground truth data were classified incorrectly. It is notable that the classification for lawns and tree covers in 1991, 2007, and 2016 performed a high user's and producer's accuracy. The result indicated the large-scale vegetated area can only be distinguished precisely with the images in recent years.

Table 1. Result from confusion matrix showed the overall accuracy and agreement of the maps.

	1960	**1973**	**1991**	**2007**	**2016**
Overall accuracy (%)	80	76	87	92	88
Kappa coefficient (%)	74	70	84	89	85
Average accuracy (%): 84					
Average agreement (%): 81					

Table 2. result from map accuracy assessment showed summary of user's and producer's accuracy as percentage for each Land use Land cover (LULC) category in these five years. The significant results are underlined.

LULC category	**1960 Accuracy**		**1973 Accuracy**		**1991 Accuracy**		**2007 Accuracy**		**2016 Accuracy**	
	Producer's	User's	Producer's	User's	Producer's	User's	Producer's	User's	Producer's	User's
CIR area	65	74	70	77	97	88	91	90	89	86
Lawn	76	95	68	76	73	83	<u>**100**</u>	<u>**100**</u>	74	<u>**100**</u>
Tree covers	63	17	85	76	89	<u>**100**</u>	<u>**100**</u>	<u>**100**</u>	85	89
Other	86	97	68	95	77	80	82	86	93	73

4.1 Total UGS, CIR area and Population at the city level

The result from the area calculation (see Table 3 and Table 8 in Appendix II) showed that the total UGS declined by nearly 15% in the 50 years from 1960 to 2016. The total UGS had an increasing trend after the year 2007. (see Figure 4) Conversely, the total area of CIR has grown by around 20% in the 50 years, however the increase was less after 2007, as showed in Figure 5. The population has increased by approximately 30% during the 50 years.

Table 3. Result for the ratio of change for the total UGS, population/population density and CIR area in five years.

Year	UGS (%)	Population (%)	CIR area (%)	Population density (%)
1960 - 1973	**-11.62**	-14.52	3.61	8.94
1973 - 1991	-2.13	-16.38	6.74	-6.62
1991 - 2007	-3.01	7.08	5.89	19.59
2007 - 2016	**1.65**	-8.21	1.32	16.98
1960 - 2016	-14.72	-29.74	18.64	42.33

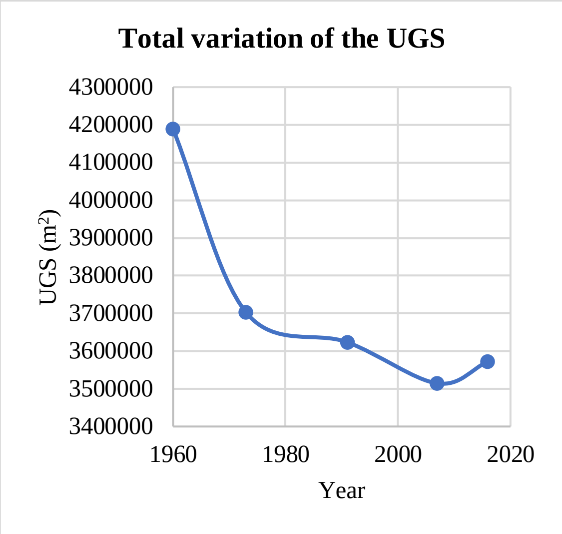

Figure 4 the result from the total UGS area calculation in the five years

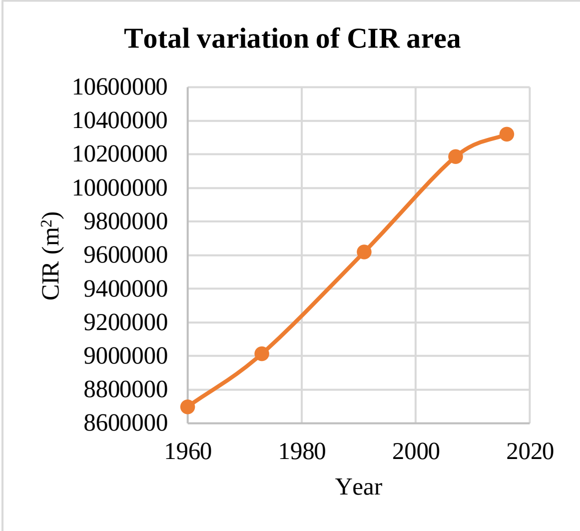

Figure 5 the result from the total CIR area calculation in the five years

4.1.1 Correlation matrix

The correlations between the three variables were found to be insignificant with the p-values being higher than the alpha level 0.05. (see Table 4).

Table 4. The result from correlation test with 0.05 significant level between the area of UGS, and CIR and Population density.

	r	**p value**
UGS vs Population density	-0.58	0.30
UGS vs CIR area	-0.83	0.24
CIR area vs Population density	0.81	0.24

4.2 UGS and CIR area at the district level

The results from the area calculation on the district level showed that there was a discrepancy in the proportion of UGS. A large proportion of UGS was located in the western part of the study area in Slottstaden district, which had the lowest proportion of CIR area (see Figure 6, 7 and 8). Conversely, Sofielund district, which was located in the east had the second lowest proportion of UGS and the highest proportion of CIR area. The proportion of UGS in the city center, Sankt Petri district, had the lowest proportion of UGS, despite it had a lower proportion of CIR. Other districts had around 20% of UGS and 60% of CIR area. It is worth noting that Möllevången district, though had 20% of UGS, had a high proportion of CIR area. (The proportion of UGS and CIR area in each district in other four years remained relatively constant, see Table 9 in Appendix III).

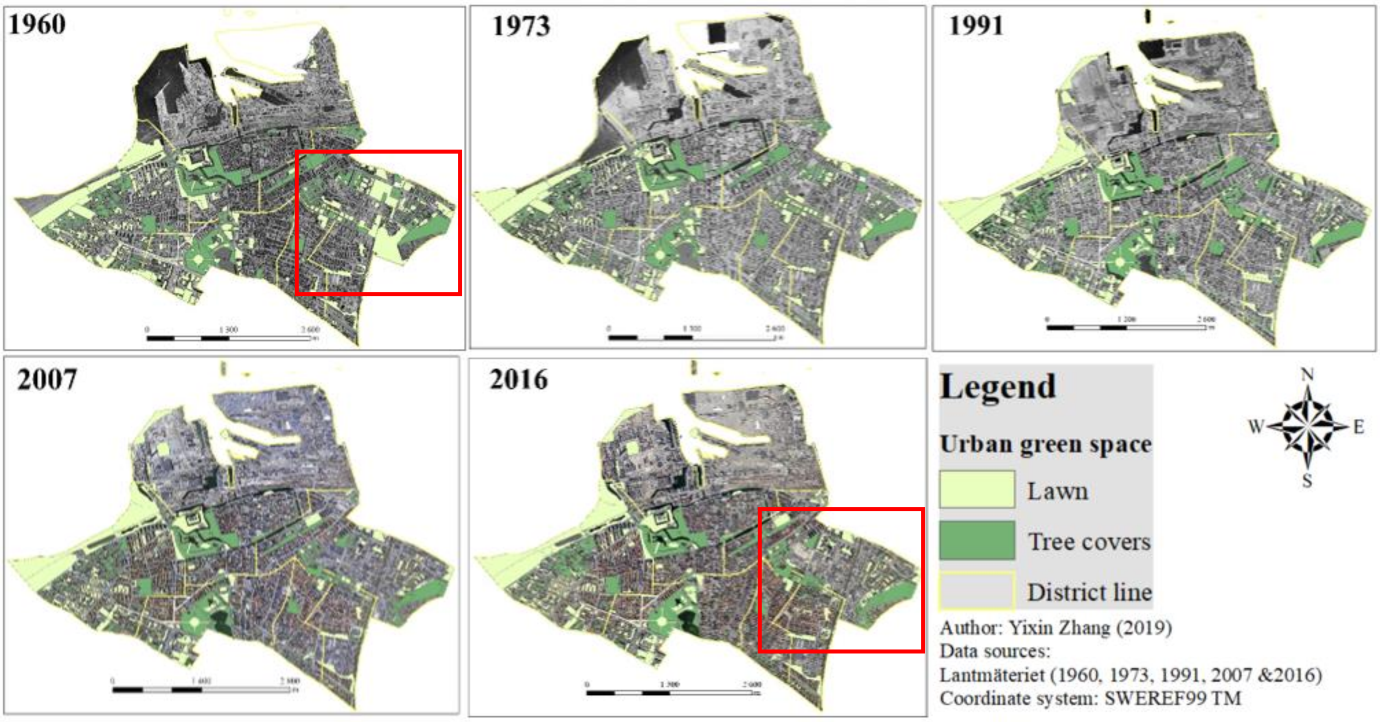

Figure 6. The UGS area change over time from the five selected years, the area with the largest change in UGS area was indicated with the red rectangle. (Aerial photos 1960, 1973& 1991 Black and White; Aerial photos 2007 and 2016 Raster RGB © Lantmäteriet).

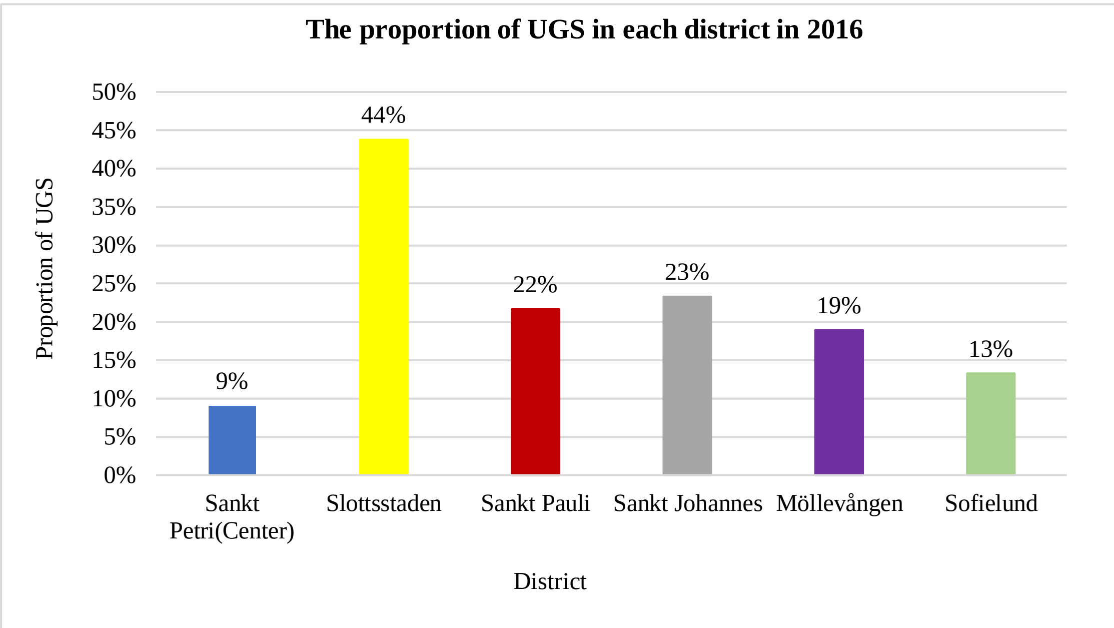

Figure 7. The proportion of UGS in each district in 2016.

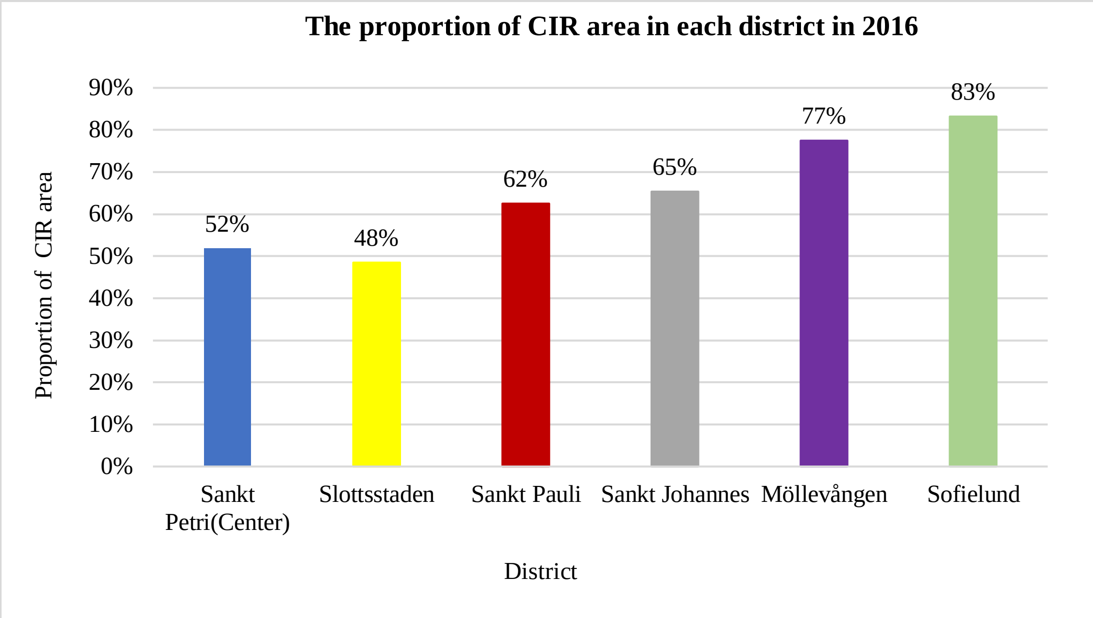

Figure 8. The proportion of CIR area in each district in 2016

The most substantial variation of UGS was concentrated in Sofielund and Sankt Pauli in the eastern part of the city, where the UGS dropped by around 60% and 50% respectively in the 50 years (see Table 5). Similarly, the UGS in Sankt Johannes had a significant decline with a reduction in area by 30% in the 50 years. The UGS in Slottsstaden showed the least change in UGS from 1960 to 2016. It is noted that there was a slight increase in the UGS except in Sankt Pauli and Möllevången from 1973 to 1991. (see Figure 9)

The variations of UGS for the six districts are interpreted in detail as follow (see Figure 9 and Table 5):

- Sankt Petri (Center): The area decreased by around 10% in the 50 years. It had a marked increase from 1973 to 1991 and further had a sharp drop from 2007 to 2016.
- Slottsstaden: The area had a small variation in the 50 years, which declined by around 6% in total. Similarly, the area rose by around 7% from 1973 to 1991 and started to decrease afterwards.
- Sankt Pauli: The area reduced slightly after 1991 but dropped by half during the 50 years.
- Sankt Johannes: The UGS declined by around 30% in the 50 years, which, though, had a slight increase in 1991.
- Möllevången: The area remained steady from 1960 to 1973, and then reduced by around 10% afterwards.
- Sofielund: The area dropped by 50% from 1960 to 1973 but had a marked increase in 1991.

Table 5. the result from the area calculation of UGS shown as the percentage change for the given time periods. The significant variations were highlighted.

District	1960 - 1973	1973 - 1991	1991 - 2007	2007 - 2016	1960 - 2016
Sankt Petri (Center)	-0.17	**15.32**	-2.69	**-20.23**	-10.63
Slottsstaden	-5.38	**6.71**	-1.61	-5.76	-6.38
Sankt Pauli	**-25.22**	**-26.06**	-0.60	-6.73	**-48.74**
Sankt Johannes	-14.71	**0.83**	-7.62	-13.49	**-31.27**
Möllevången	0	-5.43	-7.38	-1.25	-13.50
Sofielund	**-55.34**	**28.10**	-11.46	-19.44	**-59.19**

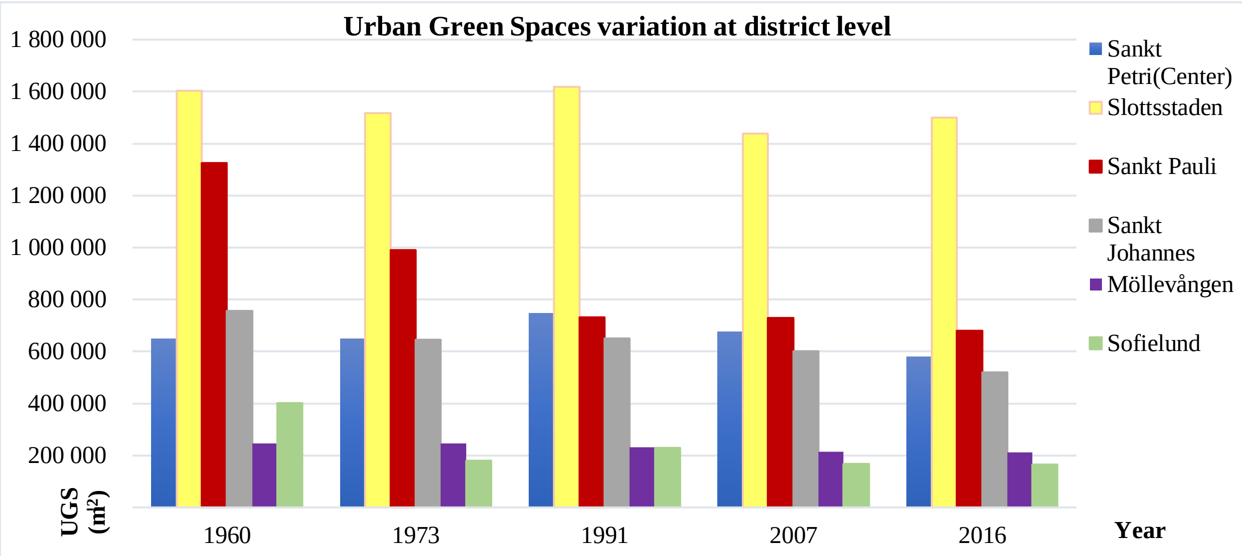

Figure 9. the result from zonal area calculation indicating the trend of UGS change in six districts.

The result for CIR area showed a marked increase in the area from 1960 to 2016, specifically in Slottsstaden, Sank Pauli, and Sankt Petri. (see Table 6 and Figure 10). It is notable that the area in Sankt Petri and Sankt Pauli had a gradual increase in 1973. Conversely, the area in Sofielund had a slight drop in 1973. From 1973 to 2016, the total area in each district fluctuated slightly, except in Sankt Petri. A substantial change in CIR area can be found in Sankt Petri, especially from 1960 to 2007.

Table 6. The result from the area calculation of CIR shown as the percentage change for the given time periods per district. The significant variations were marked in bold.

District	1960 - 1973	1973 - 1991	1991 - 2007	2007 - 2016	1960 - 2016
Sankt Petri (Center)	15.83	**-10.53**	16.80	0.93	**22.16**
Slottsstaden	3.57	11.76	4.45	6.81	**29.12**
Sankt Pauli	29.70	2.64	-1.53	-0.37	**30.60**
Sankt Johannes	7.49	-0.82	2.90	0.44	10.18
Möllevången	0.20	4.29	-1.80	-0.54	2.07
Sofielund	-6.54	7.99	2.38	0.33	3.66

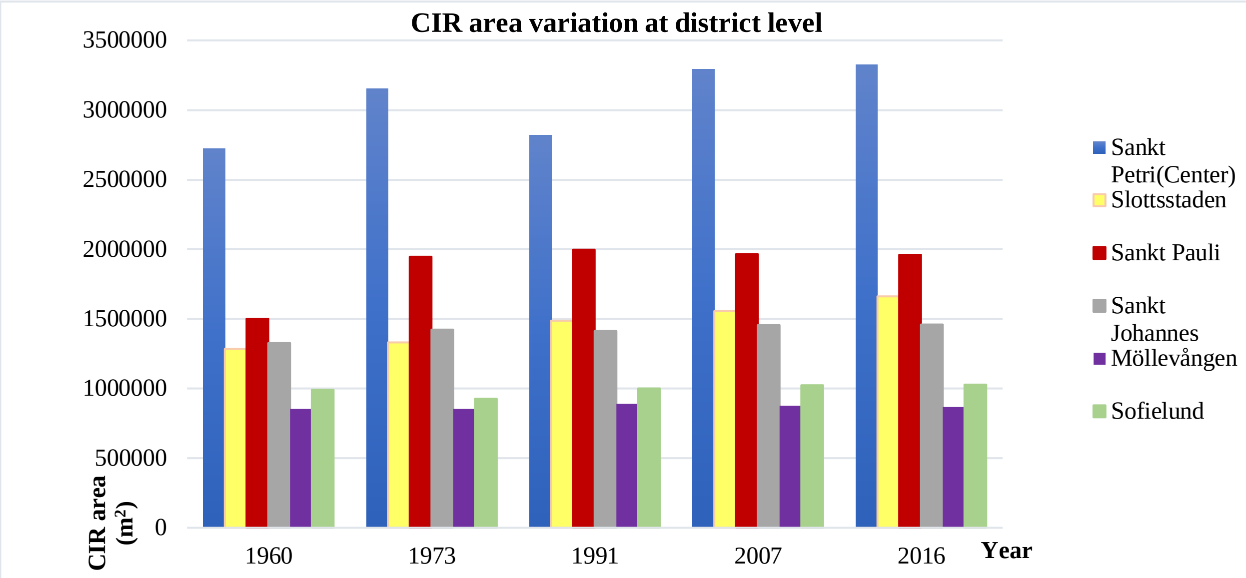

Figure 10. the result from the area calculation indicated the trend of CIR change in six districts.

4.3 Multiple Linear Regression

The result for the study area indicated the relationship between each variable and UGS were not significant. (the model for the study area: p values >0.05, see Table 7). The overall model was not accurate to predict the UGS in the study area. ($r^2 < 0.5$ and RSE >>0). It is notable that the overall model for predicting the UGS in Sankt Johannes district was significant. (overall p value < 0.05). However, each independent variable was not associated with the UGS with its p value being greater than 0.05, as showed in Figure 11 and 12. The model was also not accurate to predict the UGS. (RSE >>0). Models for predicting the UGS in other five districts were not significant or accurate with p values being greater than 0.05 and RSE being larger than 0.

Table 7. The result from the linear regression models and three indicators for the whole study area and each district. The significant results were marked in bold.

District	r^2	p value	RSE	Model
The study area	0.44	0.28	149,200	UGS= 7,094,324.40 -0.40 CIR area+1.86 Pop
Sankt Petri (Centre)	-0.19	0.60	73,830	UGS = 706,994.65 + 0.14 CIR area -518.89 PD
Slottsstaden	0.50	0.25	37,820	UGS = 1,599,058.79 +0.33 CIR area -662.27PD
Sankt Pauli	0.79	0.11	125,300	UGS = 3,298,727.74- 1.023 CIR area -615.33 PD
Sankt Johannes	**0.95**	**0.025**	19,140	UGS = 2,212,089.80 -0.92 CIR area -336.45 PD
Möllevången	0.077	0.12	7,735	UGS = 373,496.49 - 0.077 CIR area -99.17 PD
Sofielund	0.18	0.41	87,170	UGS = 422,641.68 + 0.31 CIR area -601.74 PD

**CIR area: Commercial/industrial/residential area; Pop: population; PD: population density.*

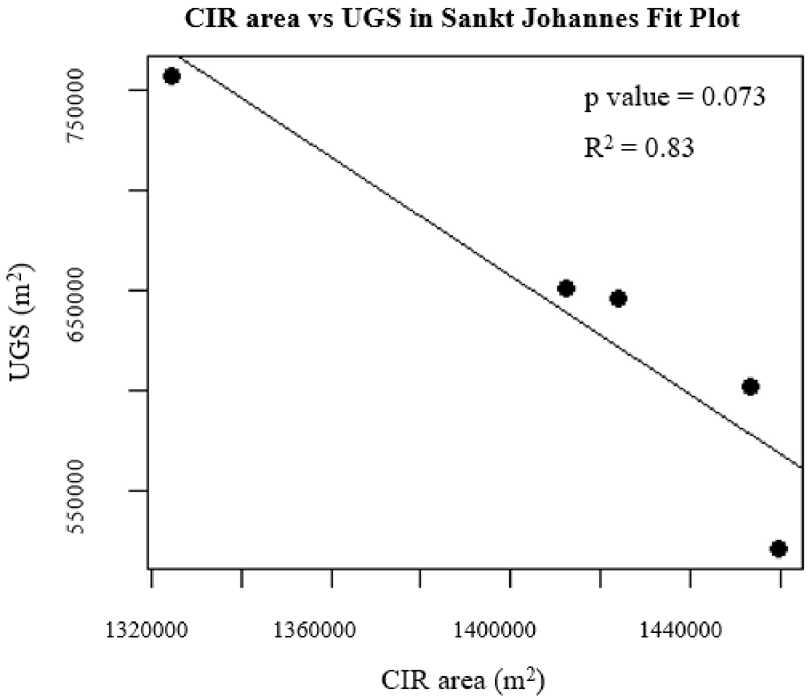

Figure 11. the result from the linear regression showed the predictor variable, CIR area related to the UGS in Sankt Johannes, however insignificant. The black dots were the predicted UGS in m^2 and the straight line was the linear regression line.

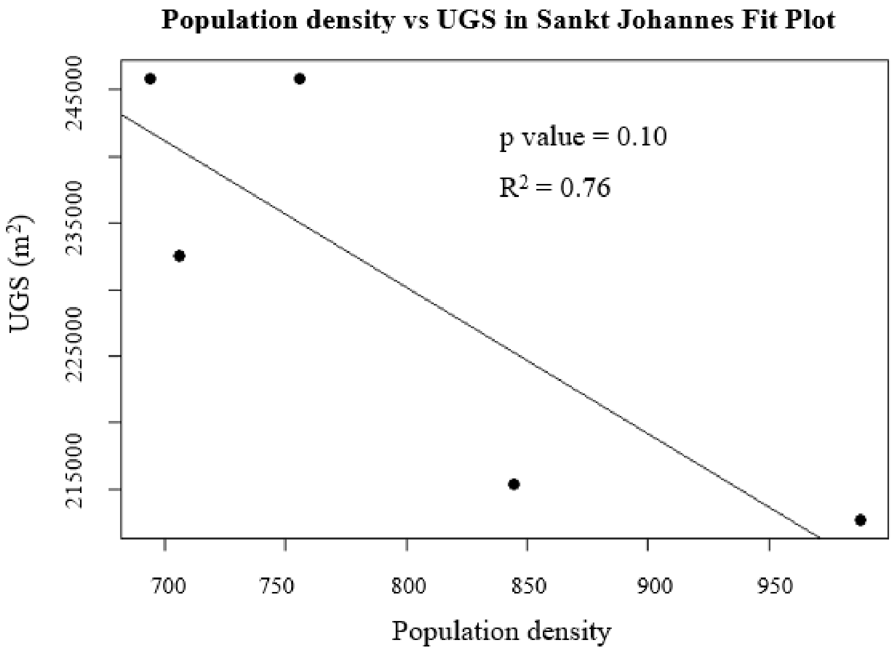

Figure 12. the result from the linear regression showed the predictor variable, population density related to the UGS, however insignificant in Sankt Johannes. The black dots were the predicted UGS in m^2 and the straight line was the linear regression line.

5. Discussion

The study suggested that the reduction in the total UGS over the past 57 years was associated with the growth of population and CIR area during the same time period, however, the correlation analysis resulted in only a weak correlation essentially due to the lack of sample data (only five maps were obtained over the 57 years period). It is notable that total UGS increased slightly from 2007 to 2016. The trend of the UGS could also be related to variations in urban policy, economy and social development; a detailed analysis with these factors was not performed.

Most of the UGS was concentrated in the western part of the study area, in Slottsstaden and Sankt Petri. Sofielund, as one of the industrial areas, had the least UGS distributed. The social inequality and changing regional green plan could be two of the factors behind the development of UGS and CIR area, and which affected the UGS distribution and variation in different districts, which is discussed in the following section 5.2.

The derived regression models for the total study area and for each district with the historical population density and CIR area turned out to be inaccurate for predicting the future UGS area. Due to time limitations and a lack of available historical data in the present study, future studies in Sweden should consider more affected variables. An example of such a study is Joaquín et al.'s 2018 of UGS in Bogotá. The errors and the revised method are mentioned in section 5.3.

5.1 The historical total public UGS variation at the city level

The dramatic growth of CIR area and population during the last decades is the result of social developments. From 1960 to 1970, Malmö was a rapidly growing industrial city undergoing fast economic and population growth. However, the regional policies in the 1960s put the city at a disadvantage. The number of industrial factories in the western part of the city increased to offer greater employment opportunities. (Anderberg 2015).

From 1965 to 1975, the government decided that one million residential buildings would be constructed to meet the needs of a growing population and increasing housing requirements. (Grander and Alwall 2014). Two-thirds of the new buildings were built in the unexploited area outside the city centre in Sweden. (Grander and Alwall 2014). The decline in UGS was related to the changes in CIR area and population. But due to a lack of data samples the correlation between UGS, CIR area and population was insignificant in this study. However, the change in UGS was likely the result of social developments.

Furthermore, by 1985 the urban population had declined by 35,000 due to the bankruptcy of local industries. This was accompanied by the growth of high-income residences which immigrated to suburbs, promoting residential segregation. (Holgersen, 2014; Grander and Alwall 2014). In the 1990s, Malmö began to transform into a post-industrial city. For example, formerly industrial areas in the western part of the harbour were transformed into environmentally-friendly commercial and residential areas. In accordance with these social transformations during the post-industrial period, UGS decreased slightly. The increase in UGS from 2007 to 2016 could be explained by the implementation of the Green Plan in 2003, which suggested that the existing urban green space should be protected and secured.

5.2 The distribution of public UGS with socio-economic factors at the district level

The study by Hoffimann et. al. (2017) showed that UGS distribution is geographically biased in the USA, the UK, and part of the European countries. In Malmö municipality, a severe economic recession and the growth of foreign immigration in the early 1990s strengthened income inequality as well as the housing segregation in Malmö, despite the development promoted a renewed growth of education and economy. (Grander and Alwall 2014). A study from Nilsson (2017) demonstrated the distribution of the public UGS in Malmö was significantly associated with population density and levels of income.

The result in this thesis suggested that the UGS was unevenly distributed between the east and the west in the study area, that was related to the social inequality, population density, and urban development, though it cannot be inferred directly from the study. The area in the east of the study area, Sofielund district, had the second lowest UGS area. According to statistical data from SCB in 2014, more than 50% of the inhabitants in this district were low-income earners. Also, the population density in 2014 was higher in Sofielund than in the other districts. A report from Malmö Stad (2011) specified that a significant number of industrial areas was developed in Sofielund since the early 1930s and continued to expand from 1975 to 1980. The urban development can explain a substantial growth of CIR area and correspond with the drop of the UGS during that time in the district.

Furthermore, the Green Plan (2003) in Malmö indicated that there was relatively little UGS area in Möllevången and the harbour area close to Sankt Petri, which was consistent with the result in this thesis. The inhabitants of Möllevången district, similar to Sofielund, had relatively low income. As one of the industrial areas developed from the early 20th century, Möllevången district was also the region with the highest population density based on the statistical data in 2014 compared to other districts.

Conversely, a large proportion of the UGS was concentrated in the western part of the city in Slottsstaden district which has medium population density and the highest income level of the five regions. This region also had the lowest CIR area. The post-industrial transformations during the 90s in Malmö affected the variation of CIR area in Slottsstaden. The change potentially associated with the variation of UGS. For example, Slottsträdgården as UGS in the district was developed in 1994. (Hansen et al. 2017)

Similar patterns associated with income level and the proportion of CIR area can be observed in Sankt Johannes and Sankt Pauli. Medium income earners were concentrated in these districts, where population density and CIR area was relatively in the middle level. The UGS distribution in the harbour area, Sankt Petri, however, cannot be related to the inhabitants' income level, population density or CIR area. Sankt Petri in the centre of the city was one of the economically fastest-growing regions, in which the UGS can also be affected by the development of transportation and different strategies of urban planning. Green roofs and walls that started to develop in 2001 in the western harbour in Sankt Petri districts, were not considered as part of UGS here in this study. But obviously, this could affect the analysis of UGS variation in the district.

Therefore, higher income earners had more UGS available in the areas with low population density in most of the study area. The variation of UGS was potentially affected by urban developments such as the establishment of CIR area. The achievement of revised Swedish legislation (1992) that announced the importance of developing and protecting the UGS could be observed in the reduced rate of change in UGS. (Johansson 1993/1994)

5.3 Limitation, errors and future research

Uncertainties and errors were generated at different stages of an image classification in remote sensing. It essentially affected both an accuracy of the classifications and area calculation. (Lu and Weng 2007). The limitation of sources e.g. images with low spatial resolution and geometric distortion, resulted in uncertainties when different classes of land use/cover were mixed in the images. (Lu and Weng 2007; Chen et al. 2004). Sources of errors included classification errors, position errors, and omitted errors resulting from interpretation errors, training data and the quality of the base and referenced aerial photos/satellite images.

In this study, large-scale UGS and CIR area was digitized manually based on the visual clues and the unsupervised classification depending on the personal sensitivity of the operator. When the aerial photos in black-and-white with the low resolution was used for the interpretation, shadows of trees and buildings were mistakenly classified as lawns or others due to the mixtures among these classes. (Lu and Weng 2007; Nath et al. 2014). It is obvious that this approach cannot avoid uncertainties and errors in the classified land use/cover. Moreover, the distorted historical map in 1991 can result in inaccurate polygon shapes and further affecting the area calculation. (Lu and Weng 2007). The unprecise ground-truth data limited the accuracy assessment of digitizing historical images due to the lack of other historical images being compared in the same years. It is notable that such classification error had a great impact on the image-processing chain including unprecise classification, inaccurate image correction, area calculation and the trend analysis at both the city level and the district level. The impact of the mixed pixel due to the low spatial resolution of the images can be reduced by modelling the uncertainties. Researches by Yocky (1996) and Shaban and Dikshit (2002) described implementing data fusion with using higher spatial resolution and multispectral data can reduce such uncertainties and improve the classification.

Because of the limitation of the historical images, UGS beyond 1,000 meter-square was not taken into account. This certainly led to omitted errors in the analysis of changes in UGS in recent years, especially considering the development of green roofs, facades, and small front gardens during the last decade, which were usually of smaller size than the chosen minimum detection size for UGS. The effect of the omitted UGS on the trend analysis was not essential because the results were mostly depended on the sample size. Because UGS below 1,000 meter-square were mainly private gardens or yards before the 90s, the omitted errors only had an impact on the analysis of the accessibility to UGS, which, however, did not consider into this study. The error also had an impact on the analysis the UGS variations in each district in recent years, e.g. the urban policies change, and social and economic development cannot explain the UGS reductions in area in Slottsstaden and Sankt Petri from 1997 to 2007. The omitted UGS for future research can be identified by measuring neighbourhood green index with a high-resolution image, that was adopted in a study for the city of Delhi by Gupta et al. (2012).

Additionally, it was not possible to calculate UGS per capita due to the lack of data for the population in each district. Therefore, the results obtained here could not be evaluated in terms of the amount of UGS per capita in the city and not be compared with the recommended standard UGS per capita (4 m^2 of green space per capita) from the World Health Organization (WHO).

Comparing the accessibility of UGS in a residential area and UGS per capita with more social-economic factors such as education levels, ages and cultural background can be further analysed to identify the socio-economical inequalities.

The regression models with the two variables were not accurate to predict the future UGS. Inadequate sample data result in non-parametric distribution of residuals in the model and an insignificant relationship between the predictors and the area of UGS. Further research can be improved by adopting more variables as has been done in a study for Bogotá by Joaquín et al. (2018). A strong relationship between the distribution of public UGS and independent variables such as public transport infrastructure, distance to a commercial or industrial area, walking distance to park, distance to water bodies has been reported in this paper.

6. Conclusion

The study showed that there was a marked decline in the amount of UGS area in the selected districts in Malmo. Being limited to historical images and data samples, the reduction in UGS at the city level was insignificantly correlated with the growth of population and CIR area. However, the reduction in UGS area as well as the increase in CIR area were potentially associated with changes in urban policies and social development over the analysed time period from 1960 to 2017. Similarly, the UGS in each district was insignificantly related to the variation in population density and CIR area due to the lack of information on the historical population.

The result showed UGS distribution was geographically biased in the study area. There were more proportion of UGS distributed in western study area Slottsstaden. In comparison, Sofielund district in the east of the study area had lower proportion of UGS. Income level and population density in recent years had an impact on the distribution of UGS in four of the analysed districts, except for the Sankt Petri district in the city centre. The findings are consistent with prior studies, particularly with the conclusion derived for Berlin, Germany by Kabisch et al. (2013) who found that UGS in some of the inner-city areas was unequal distributed. In future studies the accessibility of UGS as well as UGS per capita should be taken into account when analysing the social-environment justices of UGS.

Last, the main weakness of this study was the paucity of different predictor variables to affect the UGS for the linear regression models. The regression models based only on the two variables chosen here (population/population density and CIR area) were not accurate to predict future UGS.

7. Acknowledgement

First, I would like to thank my supervisor Marko Scholze at Lund University. I really appreciate his guidance, patience and useful advice! I would like to thank Marko's group, Hongxiao jin, Micael Runnström and Charlotte Hansson Webb at Lund University for their insights. Secondly, I would also like to thank Thomas Holgersson from Geodatasupport, Lantmäteriet for supporting the historical aerial photos and Statistics Service from Statistics Sweden (SCB) for supporting the historical data of population. I also want to thank my evaluators Janne Rinne and Vaughan Phillips for their comments. Thirdly, I would like to thank my classmates and my friends at Lund University during these three years for supporting me and helping me. Last, I would like to thank my family for supporting my study and their understanding.

8. Reference

Alberti, M., and L. Hutyra. 2009. Detecting carbon signatures of development patterns across a gradient of urbanization: Linking observations, models, and scenarios. In Fifth urban research symposium.

Anderberg, S. 2015. Western harbour in Malmö. red. L. u. I. f. e. o. i. u. I. m. Originator, and L. u. T. f. Originator, Rotterdam, Nederländerna: International Society of City and Regional Planners, 210.

Bai, T., A. L. Mayer, W. D. Shuster, and G. Tian. 2018. The Hydrologic Role of Urban Green Space in Mitigating Flooding (Luohe, China). Sustainability, 10. DOI: 10.3390/su10103584

Bastian, O., D. Haase, and K. Grunewald. 2012. Ecosystem properties, potentials and services – The EPPS conceptual framework and an urban application example. Ecological Indicators, 21: 7-16. DOI: https://doi.org/10.1016/j.ecolind.2011.03.014

Beiranvand, A., A. E. Bonyad, and J. Sousani. 2013. Evaluation of Changes in Per Capita Green Space through Remote Sensing Data. International Journal of Advanced Biological and Biomedical Research, 1: 321-330.

Berg, P. G., M. Granvik, and P. Hedfors. 2012. Functional density: a conceptual framework in a townscape areas context. Nordisk arkitkturforskning: Nordic journal of architectural research, 24: 29-46.

Boldemann, C., M. Blennow, H. Dal, F. Mårtensson, A. Raustorp, K. Yuen, and U. Wester. 2006. Impact of preschool environment upon children's physical activity and sun exposure. Preventive medicine: 301. DOI: 10.1016/j.ypmed.2005.12.006

Bonan, G. B. 2008. Ecological climatology: concepts and applications. Cambridge University Press.

Björkman, L.-L., 2012. Fritidsodlingens omfattning och betydelse. Försöksresultat för fritidsodlare(The scope and importance of leisure culture. Experimental results for recreational growers). Swedish University of Agricultural Sciences, Report. [in Swedish, English summary]

Casey, J. A., P. James, L. Cushing, B. M. Jesdale, and R. Morello-Frosch. 2017. Race, Ethnicity, Income Concentration and 10-Year Change in Urban Greenness in the United States. Int J Environ Res Public Health, 14. DOI: 10.3390/ijerph14121546

Chen, D., D. A. Stow, and P. Gong. 2004. Examining the effect of spatial resolution and texture window size on classification accuracy: an urban environment case. 2177-2192.

Chiesura, A. 2004. The role of urban parks for the sustainable city. Landscape and Urban Planning, 68: 129-138.

de Vries, S., R. A. Verheij, P. P. Groenewegen, and P. Spreeuwenberg. 2003. Natural environments…healthy environments? An exploratory analysis of the relationship between greenspace and health. Environment & Planning A, 35: 1717-1731. DOI: 10.1068/a35111

Delshammar, T., 2015. Report of case study city portraits: Malmö Sweden. City of Malmö, Report 13 pp. [in Swedish, English summary]

Demuzere, M., K. Orru, O. Heidrich, E. Olazabal, D. Geneletti, H. Orru, A. G. Bhave, N. Mittal, et al. 2014. Mitigating and adapting to climate change: multi-functional and multi-scale assessment of green urban infrastructure. J Environ Manage, 146: 107-115. DOI: 10.1016/j.jenvman.2014.07.025

DigitalGlobe. 2007. Satellite image. Retrieved 6 May 2019, from https://www.google.se/maps/@55.5755886,13.0065208,16025m/data=!3m1!1e3?hl=en&authuser=0

DigitalGlobe. 2016. Satellite image. Retrieved 6 May 2019, from https://www.google.se/maps/@55.5755886,13.0065208,16025m/data=!3m1!1e3?hl=en&authuser=0

Dunnett, N., and N. Kingsbury. 2008. Planting green roofs and living walls. Timber Press.

Dravigne, A., T. M. Waliczek, R. D. Lineberger, and J. M. Zajicek. 2008. The effect of live plants and window views of green spaces on employee perceptions of job satisfaction. Journal of the American Society for Horticultural Science, 43: 183-187.

ERRI. 2019. Accuracy Assessment for Image Classification. Retrieved 17 May 2019, from

http://desktop.arcgis.com/en/arcmap/latest/manage-data/raster-and-images/accuracy-assessment-for-image-classification.html .
ERRI. 2019. Iso Cluster Unsupervised Classification. Retrieved 17 May 2019, from http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/iso-cluster-unsupervised-classification.htm.
European Communities. 1996. European sustainable cities: report. Office for Official Publications of the European Communities.
European Commission, 2012. Science for Environment Policy In-depth Report: The Multifunctionality of Green Infrastructure. The University of the West of England (UWE), Report. [in Swedish, English summary]
Fong, K., J. E. Hart, and P. James. 2018. A Review of Epidemiologic Studies on Greenness and Health: Updated Literature Through 2017. Curr Environ Health Rep, 5: 77-87. DOI: 10.1007/s40572-018-0179-y
GADM database. 2015. Sweden Administrative areas. Retrieved 2 April 2019, from http://www.diva-gis.org/gdata
Gascon, M., M. Triguero-Mas, D. Martinez, P. Dadvand, J. Forns, A. Plasencia, and M. J. Nieuwenhuijsen. 2015. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. Int J Environ Res Public Health, 12: 4354-4379. DOI: 10.3390/ijerph120404354
Casey, J. A., P. James, L. Cushing, B. M. Jesdale, and R. Morello-Frosch. 2017. Race, ethnicity, income concentration and 10-year change in urban greenness in the United States. DOI: 10.3390/ijerph14121546.10.3390/ijerph14121546. UC Berkeley: Retrieved 2 April 2019, from: http://www.escholarship.org/uc/item/8304q46r
Gascon, M., M. Triguero-Mas, D. Martinez, P. Dadvand, D. Rojas-Rueda, A. Plasencia, and M. J. Nieuwenhuijsen. 2016. Residential green spaces and mortality: A systematic review. Environ Int, 86: 60-67. DOI: 10.1016/j.envint.2015.10.013
Giles-Corti, B., M. H. Broomhall, M. Knuiman, C. Collins, K. Douglas, K. Ng, A. Lange, and R. J. Donovan. 2005. Increasing walking: How important is distance to, attractiveness, and size of public open space? American Journal of Preventive Medicine, 28: 169-176. DOI: 10.1016/j.amepre.2004.10.018
Grander, M., and J. Alwall, 2014. Combating Inequalities through Innovative Social Practices of and for Young People in Cities across Europe: WP4 Malmö. Malmö University, Report, Malmö Sweden, 36 pp. [in Swedish, English summary]
Gupta, K., P. Kumar, K. P. Sharma, and S. K. Pathan. 2012. Urban Neighborhood Green Index - A measure of green spaces in urban areas. Landscape and Urban Planning, 105: 325-335. DOI: 10.1016/j.landurbplan.2012.01.003
Grimm, N. B., S. H. Faeth, N. Golubiewski, E., C. Redman, L., J. Wu, X. Bai, and J. Briggs, M.. 2008. Global Change and the Ecology of Cities. Science, 319: 756. DOI: 10.1126/science.1150195
Hansen, R., M. Buizer, E. Rall, Y. DeBellis, C. Davies, B. Elands, F. Wiersum, and S. Pauleit, 2017. Urban Green Infrastructure Planning: A Guide for Practitioners. Report 105 pp. [in Swedish, English summary]
Hartig, T., G. W. Evans, L. D. Jamner, D. S. Davis, and T. Gärling. 2003. Tracking restoration in natural and urban field settings. Journal of Environmental Psychology, 23: 109-123. DOI: https://doi.org/10.1016/S0272-4944(02)00109-3
Hutyra, L. R., B. Yoon, and M. Alberti. 2011. Terrestrial carbon stocks across a gradient of urbanization: a study of the Seattle, WA region. Global Change Biology, 17: 783-797. DOI: 10.1111/j.1365-2486.2010. 02238.x
Holgersen, S. 2014. The Rise (and Fall?) of Post-Industrial Malmö. Investigations of city-crisis dialectics. PhD Thesis. Lund, Sweden: Lund University
Hoffimann, E., H. Barros, and A. I. Ribeiro. 2017. Socioeconomic Inequalities in Green Space Quality and Accessibility-Evidence from a Southern European City. Int J Environ Res Public Health, 14. DOI: 10.3390/ijerph14080916
James, G., D. Witten, T. Hastie, and R. Tibshirani. 2013. An introduction to statistical learning: with applications in R. Springer.
Jackson, L. E. 2003. The relationship of urban design to human health and condition. Landscape and Urban Planning, 64: 191-200. DOI: 10.1016/S0169-2046(02)00230-X
Jansson, M. 2014. Green space in compact cities: the benefits and values of urban ecosystem

services in planning. Nordisk arkitkturforskning: Nordic journal of architectural research, 26: 139-160.
James, P., R. F. Banay, J. E. Hart, and F. Laden. 2015. A Review of the Health Benefits of Greenness. Current Epidemiology Reports, 2: 131-142.
Jennings, V., M. H. E. M. Browning, and A. Rigolon. 2019. Urban Green Spaces: Public Health and Sustainability in the United States. Springer International Publishing.
Jo, H.-k. 2002. Impacts of urban greenspace on offsetting carbon emissions for middle Korea. Journal of Environmental Management, 64: 115-126. DOI: 10.1006/jema.2001.0491
Joaquín, A. F. G., P. Daniel, and R. Abbas. 2018. Methodological proposal for measuring and predicting Urban Green Space per capita in a Land-Use Cover Change model: Case Study in Bogota. In Commission 7 Annual Meeting. Bogota Colombia: Civil and Environmental Engineering, Faculty of Engineering, Los Andes University, Bogotá, Colombia. Center of Spatial Data Infrastructure and Land Administration, Faculty of Infrastructure, the University of Melbourne, Melbourne, Australia. .
Johansson, O. 1993/1994. Strategi för biologisk ma˚mångfald (Strategy for Biodiversity). ed. S. Riksdag, 84. Sveriges Riksdag.
Kabisch, N., and D. Haase. 2014. Green justice or just green? Provision of urban green spaces in Berlin, Germany. Landscape and Urban Planning, 122: 129-139. DOI: https://doi.org/10.1016/j.landurbplan.2013.11.016
Kim, H., D.-K. Lee, and S. Sung. 2016. Effect of Urban Green Spaces and Flooded Area Type on Flooding Probability. Sustainability: 134. DOI: 10.3390/su8020134
Kong, F., H. Yin, N. Nakagoshi, and Y. Zong. 2010. Urban green space network development for biodiversity conservation: Identification based on graph theory and gravity modeling. Landscape and Urban Planning, 95: 16-27. DOI: 10.1016/j.landurbplan.2009.11.001
Kuo, F. E., and W. C. Sullivan. 2001. Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue. Environment and Behavior, 33: 543-571. DOI: 10.1177/00139160121973124
Kuo, F. E., and A. F. Taylor. 2004. A potential natural treatment for attention-deficit/hyperactivity disorder: evidence from a national study. American Journal of Public Health, 94: 1580-1586. DOI: 10.2105/AJPH.94.9.1580
Lachowycz, K., and A. P. Jones. 2013. Towards A Better Understanding Of The Relationship Between Greenspace And Health: Development Of A Theoretical Framework. Landscape and Urban Planning, 118: 62-69. DOI: 10.1016/j.landurbplan.2012.10.012
Lahoti, S., M. Kefi, A. Lahoti, and O. Saito. 2019. Mapping Methodology of Public Urban Green Spaces Using GIS: An Example of Nagpur City, India. Sustainability, 11: 2166.
Lantmäteriet. 2016. Orthophoto raster RGB 0.5m. Retrieved on 2 April 2019.
Lantmäteriet. 2007. Orthophoto raster RGB 0.5m mosaic. Retrieved on 2 April 2019.
Lantmäteriet. 1991. Scanned aerial photos Black and White 2m. Retrieved on 2 April 2019.
Lantmäteriet. 1973. Orthophoto historical raster Black and White 0.5m. Retrieved on 2 April 2019.
Lantmäteriet. 1960. Orthophoto historical raster Black and White 0.5m. Retrieved on 2 April 2019.
Lee, A. C. K., H. C. Jordan, and J. Horsley. 2015. Value of urban green spaces in promoting healthy living and wellbeing: prospects for planning. Risk Management and Healthcare Policy, 8: 131-137. DOI: 10.2147/RMHP.S61654
Lin, W., T. Wu, C. Zhang, and T. Yu. 2011. Carbon savings resulting from the cooling effect of green areas: a case study in Beijing. Environmental Pollution, 159: 2148-2154. DOI: 10.1016/j.envpol.2011.02.035
Lossau, J., and K. Winter. 2011. The Social Construction of City Nature: Exploring Temporary Uses of Open Green Space in Berlin In: Endlicher W. (eds) Perspectives in Urban Ecology. Springer, Berlin, Heidelberg.
Lu, D., and Q. Weng. 2007. A survey of image classification methods and techniques for improving classification performance. 823-870.
Luttik, J. 2000. The value of trees, water and open space as reflected by house prices in the Netherlands. Landscape and Urban Planning, 48: 161-167. DOI: 10.1016/S0169-2046(00)00039-6
Malmö stad. 2003. A Green Plan for Malmö. Sweden, Malmö stad.

Malmö stad. 2009. Environmental Programme for the City of Malmö 2009 – 2020. Sweden, Malmö stad.
Malmö stad 2011. Sofielund. Retrieved May 18 2019, from https://malmo.se/Uppleva-och-gora/Arkitektur-och-kulturarv/Kulturarv-Malmo/P-S/Sofielund.html
Malmö stad. 2012. Handlingsplan för klimatanpassning Malmö 2012-2014 [Action plan for climate adaptation Malmö. In Swedish]. Sweden, Malmö stad.
Malmö Municipality. 2013. Malmö in brief. ed. Malmö Municipality.
Malmö stad. 2014. Översiktsplan för Malmö - ÖP2014 : planstrategi : utställningsförslag [Overview plan for Malmö. In Swedish]. Sweden, Malmö stad.
Malmö stad. 2018. Plan för Malmös gröna och blå miljöer. [Plan for Malmö's green and blue environments. In Swedish]. Sweden, Malmö stad.
McCord, J., M. McCord, W. McCluskey, P. T. Davis, D. McIlhatton, and M. Haran. 2014. Effect of public green space on residential property values in Belfast metropolitan area. Journal of Financial Management of Property and Construction: 117. DOI: 10.1108/JFMPC-04-2013-0008
Munshi-South, J. 2012. Urban landscape genetics: canopy cover predicts gene flow between white-footed mouse (Peromyscus leucopus) populations in New York City. Molecular Ecology, 21(6): 1360-1378. DOI: 10.1111/j.1365-294X.2012. 05476.x
Nath, S. S., J. Kar, G. Mishra, S. Chakraborty, and N. Dey. 2014. A survey of image classification methods and techniques. In International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), Control, Instrumentation, Communication and Computational Technologies (ICCICCT), 554. IEEE.
Newman, M. 2005. The compact city fallacy. Journal of planning education & research, 25: 11-26.
Nilsson, J. 2018. Perspectives on urban justice: is sustainable Malmö reality or utopia? A spatial analysis of socio-economic inequalities in availability of urban green spaces in Malmö, Sweden. PhD Thesis Lund University
Norton, B. A., A. M. Coutts, S. J. Livesley, R. J. Harris, A. M. Hunter, and N. S. G. Williams. 2015. Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning, 134: 127-138. DOI: 10.1016/j.landurbplan.2014.10.018
Nowak, D. J. 2002. The effect of urban trees on air quality. USDA Forest Service: 1-5.
OECD Publications Centre. 2012. Compact City Policies: A Comparative Assessment. OECD Publications Centre.
Omer, A. 2011. Energy, environment, and sustainable development in Sudan. The IIOAB Journal, 2: 31-44.
Orsini, N., R. Bellocco, M. Bottai, M. Pagano, S.-O. Andersson, J.-E. Johansson, E. Giovannucci, A. Wolk, et al. 2009. A prospective study of lifetime physical activity and prostate cancer incidence and mortality. British Journal of Cancer: 1932. DOI: 10.1038/sj.bjc.6605404
Perrons, D., and A. Plomien. 2010. Why socio-economic inequalities increase? : facts and policy responses in Europe. Publications Office of the European Union.
Pataki, D., E., M. Carreiro, M., J. Cherrier, N. Grulke, E., V. Jenning, S. Pincetl, R. Pouyat, V., T. Whitlow, H., et al. 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. Frontiers in Ecology and the Environment, 9: 27.
Razzaghmanesh, M., S. Beecham, and T. Salemi. 2016. The role of green roofs in mitigating Urban Heat Island effects in the metropolitan area of Adelaide, South Australia. Urban Forestry & Urban Greening, 15: 89-102. DOI: 10.1016/j.ufug.2015.11.013
Rees, W. E. 1997. Urban ecosystems: the human dimension. Urban Ecosystems, 1: 63-75. DOI: 10.1023/a:1014380105620
Rosenblatt, N. J., B.-S. Kweon, and P. Maghelal. 2008. The street tree effect and driver safety. ITE Journal on the web: 69-73.
Rosenström, N. 2018. Quantification of the effect that Green Roofs have on ambient CO_2 concentrations: Västra Hamnen, Malmö. PhD Thesis. Lund, Sweden: Lund University
Saldivar-Tanaka, L., and M. E. Krasny. 2004. Culturing community development, neighborhood open space, and civic agriculture: The case of Latino community

gardens in New York City. Agriculture and Human Values, 21: 399-412.
Sandström, U. G. 2002. Green Infrastructure Planning in Urban Sweden. Planning Practice & Research, 17: 373. DOI: 10.1080/02697450216356
Sandström, U. G. 2004. Biodiversity and green infrastructure in urban landscapes. Örebro universitetsbibliotek.
Sathyakumar, V., R. A. A. J. Ramsankaran, and R. Bardhan. 2018. Linking remotely sensed Urban Green Space (UGS) distribution patterns and Socio-Economic Status (SES) - A multi-scale probabilistic analysis based in Mumbai, India. GIScience and Remote Sensing. DOI: 10.1080/15481603.2018.1549819
Shaban, M. A. and O. Dikshit. 2002. Evaluation of the merging of SPOT multispectral and panchromatic data for classification of an urban environment. International Journal of Remote Sensing, 23: 249-262.
Shafique, M., R. Kim, and K. Kyung-Ho. 2018. Green Roof for Stormwater Management in a Highly Urbanized Area: The Case of Seoul, Korea. Sustainability: 584. DOI: 10.3390/su10030584
Shishegar, N. 2015. The Impact of Green Areas on Mitigating Urban Heat Island Effect: A Review The International Journal of Environmental Sustainability, 9: 119-150. DOI: 10.6084/m9.figshare.1493013.v2
Statens Offentliga Utredningar 1994. Miljö och fysisk planering : delbetänkande [Environment and Physical Planning. In Swedish]. Fritze.
Statistics Sweden (SCB). 2015. Befolkningstäthet (Population density). Retrieved on 2 April 2019.
Statistics Sweden (SCB). 2019. Folkmängd och landareal i tätorter, per tätort. Vart femte år 1960 - 2018 (Population and land area in urban areas, per urban area. Every fifth year 1960 - 2018). SCB. Retrieved 2 April 2019 from http://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BE__BE0101__BE0101A/BefolkningNy/?rxid=51656e46-3fe5-4e0e-a287-cb5e0b24e7c4.
Statistics Sweden (SCB). 2015. Handelsområden (Commercial Areas). Retrieved 2 April 2019 from https://www.scb.se/hitta-statistik/regional-statistik-och-kartor/geodata/oppna-geodata/Handelsomraden/
Statistikdatabasen(SCB). 2019. Tätorter vektor (Urban areas vector). Retrieved 2 April 2019.
Stigsdotter, U. K. 2004. A garden at your workplace may reduce stress. Design & Health: 147-157.
Lönn, T. I. 1999. Grönare områden i planeringen [More Green Areas in the Planning Process. In Swedish]. Karlskrona, The National Board of Housing, Building and Planning.
Taylor, L., and D. F. Hochuli. 2017. Defining greenspace: Multiple uses across multiple disciplines. Landscape and Urban Planning, 158: 25-38. DOI: https://doi.org/10.1016/j.landurbplan.2016.09.024
Tewksbury, J. J., D. J. Levey, N. M. Haddad, S. Sargent, J. L. Orrock, A. Weldon, B. J. Danielson, J. Brinkerhoff, et al. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. 12923-12926.
The World Bank 2018. Urban population (% of total). The World Bank.
Timperio, A., D. Crawford, N. Andrianopoulos, K. Ball, J. Salmon, C. Hume, and B. Giles-Corti. 2008. Features of public open spaces and physical activity among children: Findings from the CLAN study. Preventive Medicine, 47: 514-518. DOI: 10.1016/j.ypmed.2008.07.015
Useuelli, M. 2014. Machine Learning Essentials Practical Guide in R Birmingham, UK: Packt Publishing Ltd.
U. S. EPA, 2018. Environmental justice. ed. United States Environmental Protection Agency
Waliczek, T. M., R. H. Mattson, and J. M. Zajicek. 1996. Benefits of Community Gardening on Quality-of-Life Issues. Journal of Environmental Horticulture, 14: 204-209. DOI: 10.24266/0738-2898-14.4.204
Watkins, S. L., and E. Gerrish. 2018. The relationship between urban forests and race: A meta-analysis. Journal of Environmental Management, 209: 152-168. DOI: 10.1016/j.jenvman.2017.12.021
World Health Organization (WHO). Urban green spaces and health: A review of the evidence. Copenhagen: WHO Regional Office for Europe, 2016.
Wolf, K. L. 2009. Strip Malls, City Trees, and Community Values. Arboriculture & Urban

Forestry, 35: 33-40.
Yocky, D. A. 1996. Multiresolution wavelet decomposition image merger of Landsat Thematic Mapper and SPOT panchromatic data. Photogrammetric Engineering and Remote Sensing, 62: 1067-1074.
Yu, C., and W. N. Hien. 2006. Thermal benefits of city parks. Energy & Buildings, 38(2): 105-120. DOI: 10.1016/j.enbuild.2005.04.003
Zhang, Y., A. E. Van den Berg, T. Van Dijk, and G. Weitkamp. 2017. Quality over Quantity: Contribution of Urban Green Space to Neighborhood Satisfaction. International Journal of Environmental Research and Public Health, 14. DOI: 10.3390/ijerph14050535
Zoeller, R. F. 2009. Lifestyle in the Prevention and Management of Cancer: Physical Activity. American Journal of Lifestyle Medicine, 3: 353-361. DOI: 10.1177/1559827609338680

9. Appendix

Appendix I. Data description

Table 8 data sources and description.

Dataset	Spatial resolution	Reflectance properties	Data sources	Reference system
Urban area vector 2015			Statistics Sweden	SWEREF99TM
Orthophoto 1960	0.5m	Black and White	Lantmäteriet	SWEREF99TM
Orthophoto 1973	0.5m	Black and White	Lantmäteriet	SWEREF99TM
Scanned aerial photo 1991	2m	Black and White	Lantmäteriet	
Orthophoto 2007 mosaic	0.5m	Colour	Lantmäteriet	SWEREF99TM
Orthophoto 2016	0.5m	Colour	Lantmäteriet	SWEREF99TM
Population (1960-2016)			Statistics Sweden	SWEREF99TM
Population density in each district 2015			Statistics Sweden	
Commercial area 2015			Statistics Sweden	SWEREF99TM
Sweden municipality border 2015			GADM database	SWEREF99TM
Google earth 3D 2007&2016	0.5m		DigitalGlobe	

Appendix II. the result from the area calculation at district level.

Table 9 result from area calculation showed total UGS, population, population density and total CIR area

Year	Total UGS(m^2)	Population	Population density	Total CIR area (m^2)
2016	3,572,375	328,494	693.91	1,032,117
2007	3,514,451	280,801	755.96	10,187,045
1991	3,623,404	234,796	705.94	962,073
1973	3,702,216	251,431	844.26	901,360
1960	4,188,934	230,795	987.65	869,922

Table 10 result from zonal area calculation showed the variation of UGS in six districts

	1960	1973	1991	2007	2016
Sankt Petri (Center)	649,774	648,696	748,074	727,982	580,696
Slottsstaden	1,603,219	1,517,019	1,618,775	1,592,673	1,500,962
Sankt Pauli	**1,324,605**	**990,570**	**732,391**	**727,982**	**678,996**
Sankt Johannes	757,242	645,885	651,225	601,576	520,446
Möllevången	*245,874*	*245,873*	*232,530*	*215,369*	*212,673*
Sofielund	**401,551**	**179,341**	**229,733**	**203,403**	**163,854**
Total	4,227,384	4,227,384	4,212,728	4,068,985	3,657,627

Appendix III. The result of regression models.

Table 11 Result from the regression model for the total UGS with the total CIR area and population.

Model	Unstandardized Coefficients		T value	p value
	β	Std Error		
Urban Green Space (Response variable)	7,094,324.40	1,564,250.50	4.54	0.0453
Commercial/Industrial/Residential area	-0.404	0.244	-1.66	0.240
Population	1.863	4.283	0.44	0.706
R^2	0.44			
F value on 2 DF	2.58			
p value	0.28			
RSE	149,200			
Error Rate	0.04			

** DF = a degree of freedom*

Sankt Petri

Table 12 Result from the regression model for the UGS with the CIR area and population in Sankt Petri.

Model	Unstandardized Coefficients		T value (T score= 3.18)	p value
	β	Std Error		
Urban Green Space (Response variable)	706,994.65	457,792.74	1.54	0.26
Commercial/Industrial/Residential area	0.14	0.25	0.55	0.64
Population density	-581.89	578.51	-1.01	0.42

Adjusted R^2	-0.19
F value on 2 DF	0.98
p value	0.60
RSE	73830

** DF = a degree of freedom*

Slottstanden

Table 13 Result from the regression model for the UGS with the CIR area and population in Slottstanden.

Model	**Unstandardized Coefficients**		**T value**	**p value**
	β	Std Error		
UGS (Response variable)	1,599,058.79	184,813.2	8.66	0.01
CIR area	0.33	0.2239	1.52	0.27
Population density	-662.27	284.15	-2.33	0.15

Adjusted R^2	0.50
F value on 2 DF	3.02
P value	0.25
RSE	37,820

** DF = a degree of freedom*

Sankt Pauli

Table 14 Result from the regression model for the UGS with the CIR area and population in Sankt Pauli.

Model	**Unstandardized Coefficients**		**T value**	**p value**
	β	Std Error		
UGS (Response variable)	3,298,727.74	591,719.74	5.58	0.03
CIR area	-1.023	0,33	-3.07	0.09
Population	-615.33	574.14	-1.07	0.40

R^2	0.79
F value on 2 DF	8.38
p value	0.11
RSE	125,300

** DF = a degree of freedom*

Sankt Johannes

Table 15 Result from the regression model for the UGS with the CIR area and population in Sankt Johannes.

Model	**Unstandardized Coefficients**		**T value**	**p value**
	β	Std Error		
UGS (Response variable)	2,212,089.80	310,408.97	7.13	0.019
CIR area	-0.92	0.26	-3.51	0.073
Population	-336.45	117.22	-2.87	0.10
R^2	0.95			
F value on 2 DF	39.36			
p value	**0.025**			
RSE	19,140			

** DF = a degree of freedom*

Möllevången

Table 16 Result from the regression model for the UGS with the CIR area and population in Möllevången.

Model	**Unstandardized Coefficients**		**T value**	**p-value**
	β	Std Error		
UGS (Response variable)	373,496.49	40,404.30	9.24	0.011
CIR area	-0.077	0.044	-1.77	0.22
Population	-99.17	32.34	-3.06	0.092
R^2	0.077			
F value on 2 DF	7.55			
p value	0.12			
RSE	7735			

** DF = a degree of freedom*

Sofielund

Table 17 Result from the regression model for the UGS with the CIR area and population in Sofielund.

Model	**Unstandardized Coefficients**		**T value**	**p value**
	β	Std Error		
UGS (Response variable)	422,641.68	361,503.80	1.17	0.36
CIR area	0.31	0.32	0.96	0.44
Population	-601.74	374.20	-1.61	0.25
R^2	0.18			
F-statistic on 2 DF	1.43			
p value	0.41			
RSE	87,170			

** DF = a degree of freedom*