Master Thesis in Geographical Information Science nr 118

Evaluating structural landscape development in the municipality Upplands-Bro, using landscape metrics indices

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2020
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Master degree thesis, 30/ credits in Master in Geographical Information Science
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Abstract

The aim of this study was to evaluate and describe the landscape development in an area located in the municipality of Upplands-Bro, Sweden. This was achieved through land use interpretation of orthophotos and implementation of different landscape indices. The study was delimited to the period 1960-2015 and mainly comprises areas in and adjacent to the town Kungsängen, north east of Stockholm.

Digital land use maps were created that show land use 1960, 1975, 1995 and 2015. The landscape development was evaluated using the landscape indices Patch density, Patch area mean, S1 and S2. S1 and S2 are two landscape indices used for detecting patch form variations The objective of implementing the landscape index, was to compare how the distribution and geometry conditions of different land use patches in the study area changed over time. The Shannon Diversity Index was implemented to measure how the landscape diversity in the study area changed over time.

The results of the evaluation showed that the landscape in the study area, has undergone structural changes under the studied period. It was concluded that there has been both a redistribution of land use and changed landscape patch composition in the study area. The thesis also showed how implementation of landscape metrics can be used when analysing landscape development and evaluating how patterns in the landscape changed over time.

Key words: *landscape development, land use, landscape indices, GIS, FRAGSTATS*

Acknowledgments

For the completion of this thesis, there are some people I would like to thank. First and foremost, I want to thank my family and friends who always support and encourage my choices and paths in life. I am extremely grateful for this support.
Also a big thanks to my supervisor Jonas Ardö at Lunds Univeristy, whose quick guidance and support has had a significant impact on my Master's degree project. All feedback and guidance have been constructive and always delivered in an understandable way. At last, thanks also to everyone who works at the GIS Center at Lund, for good and interesting course offerings and course content. The education has provided me with a great deal of new knowledge and new tools, which I definitely will get great use of in the future.

Marcus Eriksson 2020-03-09

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1. Introduction

The landscape, a defined area whose character is the result of the influence of and interaction between natural and human factors, changes over time. It is nothing new or strange according to Eriksson and Cousins (2013), that states that human culture has affected and formed the landscape for millenniums. Like many other systems and processes on earth, the landscape is affected and formed by environmental conditions, new needs and political decisions. New building establishment, expanding of agriculture land and decreasing of forest land are examples of how the landscape structure and appearance is changing.

According to Eriksson and Cousins (2013), most environments on Earth today are in some way affected or formed by human need and interactions. Development and changed landscape patterns can bring positive and beneficial effects for society and people's everyday life (Wang, Hu and Sun et al 2017). But as landscape development research has concluded, changed landscape patterns can also bring negative effects on different landscape systems (Liao, Bearup and Blasius 2017).

For example, studies have shown that patterning, fragmentation and change of landscape structures have a negative impact on the biodiversity in the landscape and challenge environmental sustainability (Wang, Hu and Sun et al 2017). Not least in Sweden and Scandinavia, where new exploitations and transportation infrastructure, like railways and roads across the region, have contribute to landscape fragmentation and isolation (Seiler and Folkesson 2006). Spatial landscape processes that can have a negative impact on the environment (Liao, Bearup and Blasius 2017).

Liao, Bearup and Blasius (2017) and Seiler and Folkesson (2006), findings illustrate that we are facing some challenges and that there is a need for studies and knowledge about structural development and changed landscape patterns. A research field that has been overlooked. The reason is primarily, that the effects of changed landscape-patterns earlier have not been considered to have significant effects on ecological processes (Liao, Bearup and Blasius 2017).

If it is possible to map and analyse how the landscape changed, it is possible to gain knowledge and create new preconditions that can protect and preserve vulnerable locations with high biodiversity and high environmental values (Wang, Hu and Sun et al 2017).

This thesis uses GIS, FRAGSTATS and suitable landscape metrics to analyse and map structural landscape development and distribution patterns in the municipality Upplands-Bro. GIS-technique and implementation of landscape metrics is a powerful tool to map and monitor spatial landscape changes (Heywood, Cornelius and Carver 2011). The tools FRAGSTATS and ArcGIS Pro, were chosen based on their opportunity to create digital land use maps and quantify and map landscape development. FRAGSTATS is an open source software program designed to compute a wide variety of landscape metrics indices for map patterns.

The study area is located in Upplands-Bro, a municipality located in Stockholm County, Sweden. The municipality has been subject to major structural changes and the population has in the last 15 years increased by over about 20 % (Upplands-Bro 2017). This growth and development make the area interesting and important to study. The results of this study could provide insights into how areas with similar development, conditions and location have been affected by landscape development. The knowledge generated can for example, be used in landscape management purposes, give information about how different specific element in the landscape have been affected and promote actions that can and preserve and protect vulnerable areas in the landscape.

1.1 Overall aim and specific research questions

The overall aim of this study is to quantify and evaluate landscape development, temporal changes of spatial arrangement of landscape patches in a near urban area in the municipality Upplands-Bro. A defined area I expect has been strongly affected by changing landscape structures, as the study area is geographical located in a region in Sweden with a high population increase and development over the last few decades.

By quantifying landscape patterns and evaluating land structural development, I investigate if it is possible to describe the land use structure and spatial configuration of different landscape patches at different times and get an understanding of how the composition and the proportions of land use and landscape patches changed. The main hypothesis is that the landscape patterns in the study area have changed, as I expect to discover that the landscape has undergone structural changes, in form of both changed land use and changed landscape patch composition. The hypothesis is based on that the general landscape trend according to previous research, is that landscapes worldwide, generally become less homogeneous and more fragmented. Not least in areas like the study area, which is located in the vicinity or in connection with already existing urban environments or developing communities. The study is limited to the time period 1960-2015.

The specific research questions the study intends to answer is,

- Where and how has the land use changed in study area between 1960-2015?
- How has the landscape structure in the study area changed in terms of patch composition between the years 1960-2015?

2 Theoretical background

2.1 Landscape theories

The landscape is defined by Forman and Godron (1986), as a heterogeneous area that is built up by integrated ecosystems and elements, which are reasonably similar throughout a delimited surface. The character and size of different landscapes differ, because there is no minimum or maximum area definition of a landscape. This allows the size of a landscape to vary from a few hectares to up to thousands of hectares (Turner, Gardner and O'neill 2015). The structure and appearance of a landscape is the result of the influence and interaction, between abiotic and biotic drivers and processes. These driving forces builds, breaks down, shapes and gives the landscape its specific arrangement of objects and elements (Turner, Gardner and O'neill 2015).
Turner, Gardner and O'neill (2015), introduce and describes four key drivers of landscape pattern, which are considered to have major impact on landscape formation and sets the specific local environmental conditions. These drivers are climate, soils, landform and land use.

- The **climate's** impact on landscape patterns can be linked primarily to that the climate on earth is dynamic. The climate in combination with other influence factors determines and sets the limits for what can live or grow in a specific location.

- The impact of **land use** on landscape patterns can according to Turner, Gardner and O'neill (2015), be linked to the fact that humanity has for millenniums influenced and formed the landscape, as we have used the landscape for example housing, agriculture, recreation and production.

- **Landform's** impact on landscape patterns can be linked to the irregular forms of different landscape. Some landforms can be very irregular and have high relief while other land shapes may be closest to flat with little relief. The form of the landscape has an impact on different systems and flows like for example water, organisms, energy and propagules. The form of a landscape can also influence the appearance and frequency of different landscape events like rain, snow and wind.

- The type of **soil** has according to Turner, Gardner and O'neill (2015), been shown to have an influence on landscape patterns. The influence can be linked to that different soil types have different ability to balance and maintain different minerals and nutrients. In general, more nutrient soils houses other types of plants and species than nutrient-poor soils.

Because of their complexity and interaction do these four key drivers have different impacts at various geographic locations, every landscape is unique according to Turner, Gardner and O'neill (2015).

2.2 Theories about landscape patterns

As this study aims to evaluate landscape development, it is important to emphasize that landscape use and landscape patterns are dynamic (Liao, Bearup and Blasius 2017). Dynamic landscapes and changed landscape patterns are not a new type of spatial event or process, according to researchers that have studied land use and landscape development in a historic context. As Eriksson and Cousins (2014), states, most landscapes in the world has in one way or another, primarily to human interactions, been subject to landscape development and changes in landscape patterns.

Human's desire to change and domesticate the landscape according to specific needs, has according to research today, been driven for different reasons. Mainly by increased human populations and an increased consumption demand for different types of landscape resources (Turner, Gardner and O'neill 2015). In order to meet this increasing demand for resources and services that the landscape potentially can provide, societies and populations both in rural and more densely populated areas have been forced to change and adapt the landscape's spatial structure. By adapting and changing different landscape patterns, it has been possible to increase the landscape's ability to produce important raw materials, improve human mobility, improve infrastructure, and increase the number of residential and industrial buildings (Xing, Qian and Yongjiu 2012).

Foley et al (2005), illustrates with the support of different defined land use transition stages, pre-settlement, frontier, subsistence, intensifying and intensive, generally how landscapes around the world develop and change, after humans are introduced and structurally influence the nature of the landscape. As the transition is affected by various locations history, social and economic conditions, and ecological contexts, different parts of the world are in different stages. Foley et al (2005), also highlights that the transition stage development is not always linear and that different phases of land use stages can be skipped. If, for example, a landscape is exposed to a very rapid development a landscape can go from a pre settlement land use transition stage direct to an intensive land use transition stage within a few weeks or months.

Land use transition stages according to Foley (2005).

- *First stage – Pre-settlement:* In a pre-settlement land use transition stage the proportion of natural ecosystem in the landscape is 100%. The landscape is unexploded with no interference or impact from human landscape activities.

- *Second stage - Frontier:* In a frontier land use transition stage, the proportion of natural ecosystem and vegetation starts to decrease as the landscape is affected primarily by limited frontier clearings. Despite the first introduction and influence of people and landscape-altered processes, the port portion of natural ecosystems in the landscape remains relatively high. Between 50-100% of the landscape still, according to Foley et al (2005), consists of natural ecosystems and vegetation in this development phase.

- *Third stage - Subsistence*: In a subsistence land use transition stage, subsistence agricultural and small-scale farms are introduced in the landscape. With the introduction of human activities that require large land areas, a large reduction of natural ecosystems occurs in the landscape. Urban environments begin to spread out in the landscape, although it is to a small and limited extent. In a subsistence land use transition stage, about <20-25% of the landscape consists of natural ecosystems and vegetation according to Foley et al (2005).

- *Fourth stage - Intensifying:* In an intensifying land use transition stage, there is a rapid development and intensification of various human landscape activities. Urban environments grow rapidly and take up larger proportion of the landscape during this development phase. Agriculture goes from small-scale to large-scale and intensified. Protected areas and places for recreation are created and protected. According to Foley et al (2005), about <15% of the landscape consists of natural ecosystems and vegetation.

- *Fifth stage – Intensive:* In an intensifying land use transition stage, which is the final land development phase, almost all small-scale and low-producing agriculture has disappeared or been transformed into an intensified and high-producing agriculture. Urban sprawl starts after a rapid increase in development phase 3 and 4, to slow down and stabilize. As large areas of natural systems have decreased, natural areas continue to be protected from exploitation. Mainly through different types of laws and regulations. Only about <10% of the landscape consists of natural ecosystems and vegetation in this development phase.

The land use transition process is not a landscape phenomenon that affects only a small number of specific societies or areas. This kind of land development trend is global according to Xing, Qian and Yongjiu (2012), who has studied landscape fragmentation and changed landscape patterns in a global context. It is important to emphasize that the shape and speed of the landscape development process can differ between different geographical locations, as local climate conditions and landscape mobility opportunities vary and can affect and limit different types of activities in the landscape. Landscape mobility opportunities refers to the ability to move easily and without restraint in the landscape. A restraint can be anything from laws and regulations to rivers, mountains and roads (Fuentes-Montemayor et al 2017).

2.2.1 Effects of landscape development and changed landscape patterns

The general landscape trend and an environmental challenge, according to researchers studying changing landscape patterns, is that landscapes around the world become less homogeneous and more heterogeneous and fragmented. Although it is possible to locate and discern opposite landscape trends locally. One example is the intensification and expansion of agricultural land that takes place in different places around the world.

Where landscapes, in contrast to the general trend, become more homogeneous as larger and larger parts of the landscape is transformed into agricultural land (Luan, and Zhou 2013). According to Jakovac et al (2017), is this landscape development particularly common in Asia and in areas of the Amazon.

Fragmentation and increased isolation in the landscape is a development, that research has shown to have negative effects on biodiversity and disturb ecological systems. The term ecological systems refer to communities of interacting organisms and their physical environment (Hulshoff 1995). Mainly because the living conditions and the environment in which different species reside change, reduces or disappear. The negative effects of changing habitat conditions can be, for example, reduced populations and genetic diversity and limited gene flow (Liao, Bearup and Blasius 2017).

Liao, Bearup and Blasius (2017), claims that habitat destruction in form of changed landscape patterns is a driving force together with habitat reduction in the extinction of species on earth and emphasizes the importance of studies that map and analyse changing landscape patterns. What often happens when the landscape's structure changes and different landscape elements become more spatial fragmented and isolated from each other, is that landscape flows and the ability of different species to integrate decrease. Landscape flows, refers to the movement of materials, energy and organisms in the landscape (Diaz and Apostol 1992). New land use types, created in conjunction with landscape development, can have some positive effects on biodiversity and some species. Turner, Gardner and O'neill (2015), state, for example, that new unique habitats can be formed through the introduction of new types of land cover. But then it is mainly other species than the native ones that are promoted.

The fragmentation which is in most cases are anthropogenic, creates landscape barriers that Liao, Bearup and Blasius (2017) states, creates un-natural habitats and affect important landscaping connectivity. Landscaping connectivity is a term, that describe the functional connections among landscape geometries (Minor and Urban 2008). Common examples of landscape barriers that can limit connectivity in the landscape and isolate populations of species and ecological systems are for example, buildings, fences, power lines and roads (Liao, Bearup and Blasius 2017).

The ecological effects and the impact of changed landscape patterns are also identified by Liu and Yang (2014), to be even higher in urban and suburban areas. Similar types of areas as this thesis study area, where cropland, meadows and forests are replaced by buildings and impermeable surfaces. Surfaces, where vegetation often has difficulty to penetrate and spread out. As a result, biodiversity and ecosystem services are often lower in these areas compared to other types of land use areas like agriculture areas, meadows and wetlands (Wästfelt and Zhang 2016). Liu and Yang (2014), lists this type of land use conversion process as a one of the environmental changes that is most important to consider and plan for. The theory is also supported by Foody (2002), who states that landscape changes have at least as much impact on the environment as global climate change.

2.2.2 Landscape ecology perspective on landscape patterns

Landscape ecology is the research field that focus on and study the relationships between ecological systems and landscape patterns at different spatial scales. The field has according to Liao, Bearup and Blasius (2017) and Turner, Gardner and O'neill

(2015), earlier been relatively overlooked and unexplored. But has since the start of the 21st century increased and gained greater space and recognition. The fact that the subject has previously been overlooked, depends largely on that it was not previously thought that landscape development and changed landscape patterns had a significant effect on different ecological processes in the landscape. This perception has, however changed with increased knowledge in landscape development and improved research on how processes in the landscape are affected by changing structures and conditions (Liao, Bearup and Blasius 2017).

Landscape ecology and landscape development studies have designed methods for measuring, analysing and determining the causes of different types of phenomena and events in the landscape. This can be complex and resource-intensive as the shape and extent of the landscape vary and can limit how it can be studied (Turner, Gardner and O'neill 2015).

2.3 Landscape metrics/ Measurement units

Researchers in landscape-related research fields like Cardille and Turner (2017), mean there are many reasons why it is important to understand different types of landscape patterns. By analysing spatial pattern changes, it is possible to retrieve information about how the landscape changed and how it has affected important ecosystems and landscape processes.

A way to understand how landscape structure change over time is to quantify and analyse landscape geometries using landscape metrics. A landscape metrics, also known as landscape-level index, is used to analyse patterns in the landscape and make it possible to quantify the structure, size, isolation and fragmentation degree of different landscapes and landscape elements (Turner, Gardner and O'neill 2015). A landscape level index can also be used to measure the diversity, the number of objects and abundance of each object for example, specie or patch that occupy a defined area in the landscape (Velázquez et al 2019). Landscape-level indices have therefore become an important tool in monitoring and evaluating spatial patterns changes in different areas and support urban and landscape planning and resources management (Turner, Gardner and O'neill 2015). Quantification of landscape structures provide measures that can be easily analysed (Cardille and Turner 2017). If it is possible to compare quantified geometric land use distribution and relationships on two different occasions, you can with greater certainty, analyse and confirm whether landscape patterns changed and how they changed over time (Turner, Gardner and O'neill 2015).

Although it is relatively easy to implement index calculations, there are some issues and questions to consider before evaluating landscape changes using geometric calculations. One is according to Cardille and Turner (2017), that there are several different diversity indices available, and they use different algorithms when quantifying spatial patterns and correlations. Which indices method, that best fits a specific analysis can vary depended on factors such as size of the sample, the study area and the number of different landscape elements in a defined area (Kumar, Denis, D and Singh et al 2018).

2.4 Spatial resolution

Spatial resolution refers to the smallest object that can be resolved by different sensors/cameras (Campbell and Wynne 2011). Spatial resolution has an impact on the detail level of an image. A relatively common spatial error that can often be encountered when trying to compare landscape analysis based on images with varied spatial resolution, is that small unusual types of surfaces that can be found in an aerial image are not included in an image with a coarser resolution. The “spatial resolution error” which can influence a landscape analysis is exemplified in Figure 1. The figure shows how the spatial resolution in each areal image becomes finer and how the color variation, the range of colors that can occur, gets higher for each image from left to right. This affects the image precision and detail quality. Which in turn increases the opportunity to more precisely interpret and classify different landscape elements in an image.

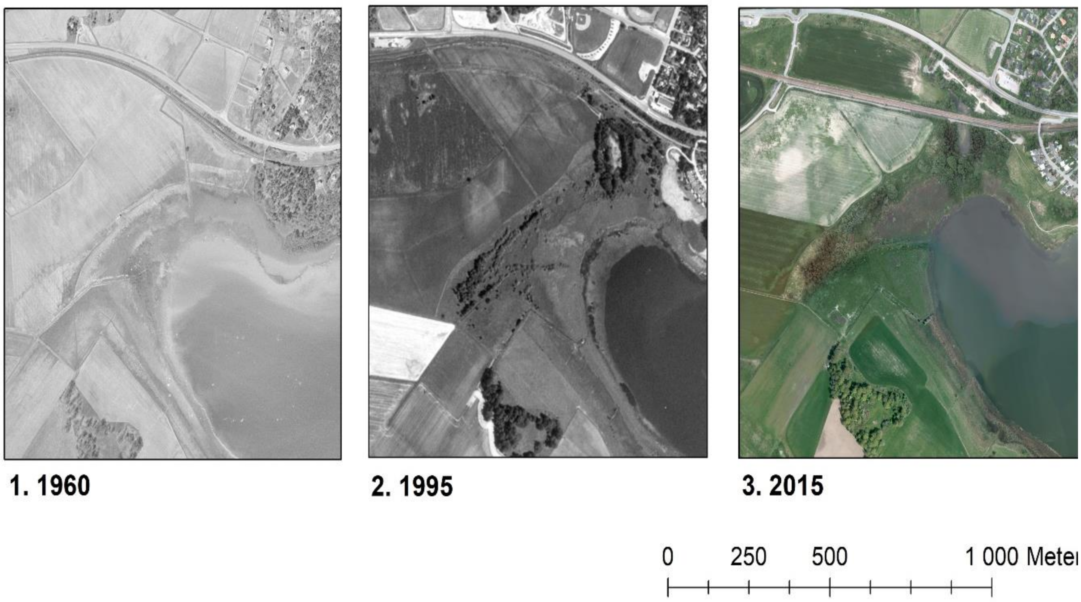

Figure 1: The images in the figure exemplify how the interpretation of land use areas in the study area is affected by the spatial resolution and colour scheme of the map image. The images cover the same area in Upplands-Bro municipality. The images are used as a basis for image interpretation in the study. Areal image 1 from 1960, has a 0.5x0.5-meter spatial resolution, image 2 from 1995, has a 0.5x0.5 meter spatial resolution and image 3 from 2015, has a 0.08x0.08 meter spatial resolution.

A basic rule that is often good to follow when conducting a spatial analysis of a landscape is, the smaller the study area, the finer resolution of the data you intend to analyse and present (Campbell and Wynne 2011). As this study in a landscape analysis context covers a relatively small area (1961 ha), I have chosen to use high resolution data (Aerial 0.2x0.2 - 1x1 meter resolution), instead of, for example, a bit coarser resolved satellite retrieved images.

2.5 Matrix and Patches

The term matrix refers to the landscapes most common element and is characterized by high connectivity and extension. To define what is the specific matrix in landscape can sometimes be difficult, mainly in landscapes where the area of different land types is relatively evenly distributed (Turner, Gardner and O'neill (2015).

Patches are defined by Turner, Gardner and O'neill (2015) as the surfaces that make up the landscape. Patches which are dynamic and varied are defined areas that can clearly be "distinguished in either shape or appearance from the surrounding areas in the landscape". A landscape is largely made up of different types of defined patches. The location and spatial form of different types of patches may vary, depending on the homogeneity or heterogeneity of the landscape.

2.6 GIS in Landscape development and Landscape ecology studies:

Progresses in GIS technology have created new big data processing opportunities (Heywood, Cornelius and Carver 2011). Not least in research fields that study and analyse spatial relationships and events in the landscape like landscape ecology and landscape development. According to Turner, Gardner and O'neill (2015), are most landscape ecology studies and projects today, supported by geographical information systems, when there is a need for handling, storage and analysis of any kind of spatial data. Much due to GIS-databases and systems today, can handle large amounts of geographic information and conduct more complex landscape analysis than earlier versions of GIS-systems. The analysis ability and data management are things Nijhuis (2015), states, that has limited GIS-implementation and affected the earlier need for GIS in the field of landscape ecology and landscape development studies.

The need and use of GIS-systems, will according to Gontier's (2013) theories, continue to increase in the future, as technology and analysis methods are constantly evolving. GIS-systems can also be even more efficient and useful in landscape development and ecological purposes if GIS-systems and technology are integrated with remote sensing and different types of landscape measurements. If you manage to combine these different means and tools, you can obtain a deeper and more precise understanding about the underlying reasons and processes of changing spatial landscape structures and patterns (Liu and Yang 2014).

2.7 Image interpretation of remote sensing data in GIS

Interpretation refers in a GIS and remote sensing context, to the process of image interpretation and marking boundaries between different categories/elements in an imagery (Campbell and Wynne 2013). Image interpretation of remote sensing data is a process that can be conducted in a numerous different ways. According to Campbell and Wynne 2013, it is largely due to the variety and complexity of different spatial data that decide interpretation method. In some cases, it may be possible to accurately, visually assess and categorize the structure of the landscape. In other cases, when the geometric or spectral landscape properties are complex, it may be more appropriate to use GIS systems or other computerized programs that has built in remote sensing interpretation tools, that can classify a landscape based on spectral properties. The size of the study area as well as the purpose of the study will also influence the interpretation approach. As there are different types of interpretation approaches, it is important that before you perform a landscape classification of remote sensed data, consider how different interpretation methods can affect the result.

3. Study area

The study area is located in the municipality of Upplands-Bro, in the north-western part of Stockholm (Figure 2). The municipality is a 23 547-hectare region in Sweden that has been inhabited for about 10 000 years (SCB 2018).
In this study, only a part of the municipality's area will be analysed and evaluated in a landscape development context. I have chosen to limit the study to a 1961 ha near urban area covering the town of Kungsängen. A near urban area includes in this study, both the built up urban area and the areas surrounding. It is often in the vicinity of these areas landscape patterns changes more dynamic with time and important agricultural and biodiversity values are affected (Matsushita, Xu, and Fukushima 2006).

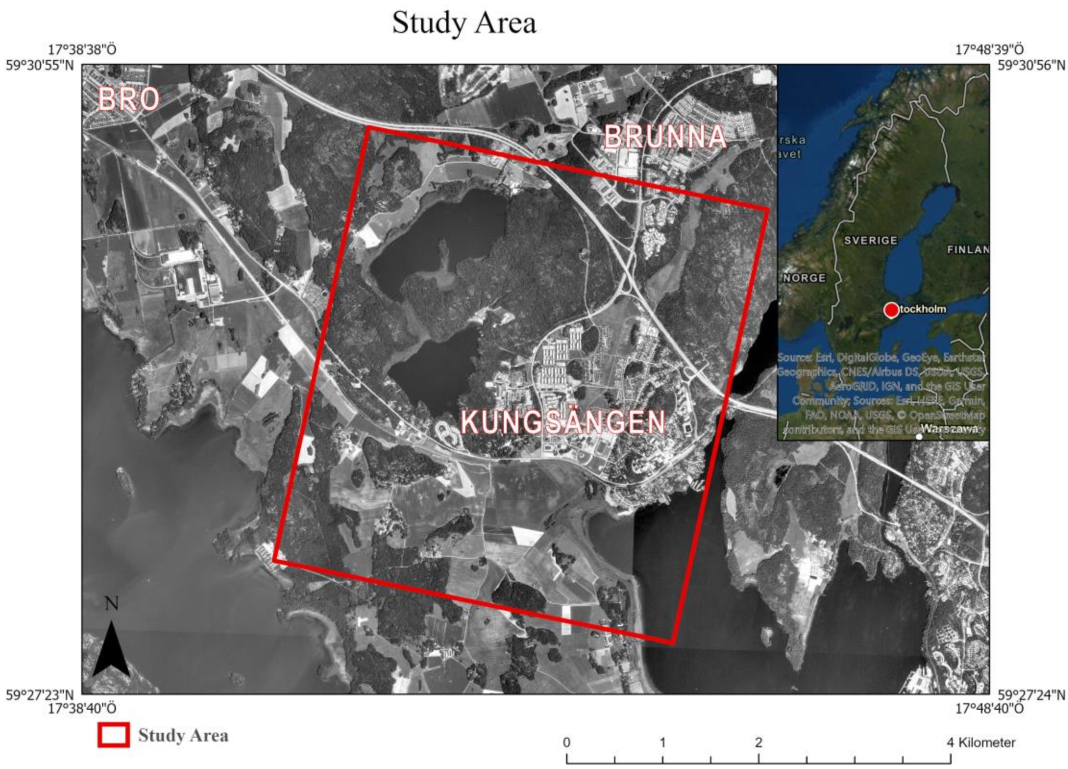

Figure 2: The study area in the municipality of Upplands-Bro. The study area mainly includes the town Kungsängen and surrounding land areas.

3.1 Landscape character and population development

The municipality Upplands-Bro located next to the northern shore of lake Mälaren, is characterized by relatively large open and cohesive arable land and pastures. Particularly in the southern and north western parts of the municipality, which both are located close to lake Mälaren. In these areas, the majority of the municipality's settled land is also located. The northern parts of the municipality, where the population density is lower, are characterized by forest land, but also with some features of arable land and pastures. Upplands-Bro, has like many other regions and areas in Sweden, been subject to major structural development and the population in the municipality has only in the last ten years (2006-2016), increased by about 20 percent (Figure 3). The increase in population in the municipality is largely linked to the Stockholm region expansion and increased occupancy. The capital area that is the centre of the country's policy and finance is according to Stockholm City (2018), one of the fastest growing regions in Europe. Which makes the study area interesting to observe in a landscape development context.

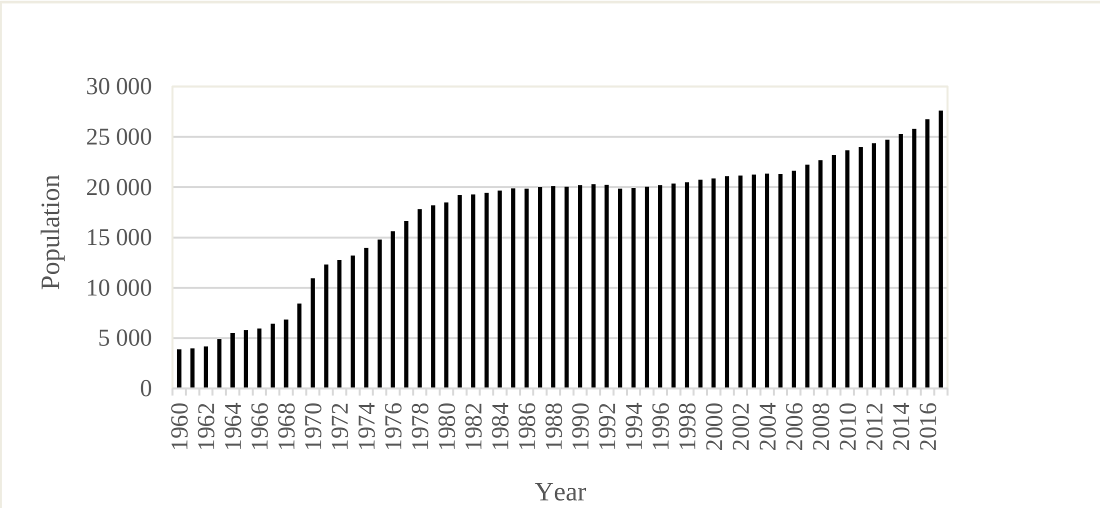

Figure 3: Population in Upplands-Bro Municipality 1960-2017 (SCB 2018).

Today (2018), 27614 people live in the municipality Upplands-Bro (SCB 2017). The majority of the municipal residents live in one of the municipality's major towns Kungsängen or Bro. The future forecast is also that the population growth will continue to increase as several new residential construction projects and exploitations are planned (Upplands-Bro 2018).

4. Methods

In order to be able to measure and analyse structural landscape development in the study area, I created digital categorical maps that describe land use conditions between 1960-2015. This was achieved through manual and visual land use interpretation, the process of retrieve data classes from a multiband raster image. I interpreted four orthophotos with guidance from Upplands-Bro ecologist Johan Björklind-Möllergård. Orthophotos are created through geometric correction of aerial images (topographic displacement and lens distortion) and has map-like properties such as scale and distance (Paine and Kiser 2012). With its properties, orthophotos are often used as a basis for map production and an important source of information concerning temporal changes in land use. Three of the orthophotos that was interpreted are in black and white and one orthophoto is in RGB color (red, green and blue). The digitization was done in vector format. After creating four vector models of the land use I also created four grid/raster representations of the land use data. The reason why I had to create raster representations of the land use data is because the software FRAGSTATS, require the format raster as input data.

GIS software:

The software's that is used in this study are ArcGIS Pro v2.1 (ESRI) and FRAGSTATS v4.2.

4.1 Land use interpretation in GIS

As the Upplands-Bro municipality's database lacks classified data that represent land use conditions in the study area, I created new categorical land use maps based on land use interpretation. Geometries where created that represent land use conditions at four different years, 1960, 1975, 1995 and 2015. The study area was divided into built up, forest, agriculture, open land and pasture and water. Built up areas includes all types of buildings and other facilities such as roads, railroad tracks and asphalted walking and cycling routes. Also facilities such as football pitches were interpreted as built up areas. Less paths crossing fields and forests and unpaved walking/cycling routes was not included in built up areas. This means they were not considered in the evaluation of landscape patterns. Agricultural land includes areas where it is clear to distinguish some form of agricultural activities or patterns. The class open land/pasture is a collection of different areas with predominantly open land. The class also includes areas with more uneven structure, where open fields can be mixed with less vegetation like bushes and small trees. The land use class includes for example, grass areas, pastures and clear cuts, open bedrock and meadows. The surfaces can and are used for many different purposes ranging from human recreation to being open for biological and ecological gains. Small groups of trees up to large cohesive forest areas were interpreted as forests.

4.1.1 Manual interpretation

The choice to use manual image interpretation instead of automated computerised interpretation was largely based on the availability of high-resolution and detailed data and that the study area is relatively small (1961 ha).

Manual interpretation is in comparison with automated landscape interpretation, a more time-consuming process but has other advantages. Mainly that the human eye/brain can interpret and distinguish areas difficult to interpret or areas with mixed land use (Campbell and Wynne 2011). The actual manual interpretation process is relatively simple and includes only that the image interpreter draws polygons around different types of land use areas, either analogously or digitally. Although the performance itself is relatively simple, one should consider that the method can have some downsides. For example, that the manual interpretation can be subjective and non-repeatable. Also that the interpretation of landscape elements can be inconsistent over the imagery can have an influence on the results and should be considered (Campbell and Wynne 2011).

The smallest polygon drawn during the interpretation of the landscape in the study area had an area of 478 m^2 and was interpreted as open land/pasture.
The reason that no area smaller than 478 m^2 was included, was because I defined a minimal polygon/landscape patch size to 450 m^2. Had I chosen to design patches below this size limit, it is possible that the accuracy and evaluation results would have been different. As the area limit and the landscape generalization degree have a major impact on the result and how you can interpret a landscape analysis (Turner, Gardner and O'neill 2015).

4.1.2 Automated interpretation

I tested to make an automated computerized interpretation of the orthophotos in ArcGIS Pro, where a built-in classification tool assigns land cover classes based on pixel reflectance. The interpretation-tool was tested on the black and white orthophotos from 1960 and 1975.

4.2.1 Landscape indices S1 and S2

The indices S1 and S2 was used to calculate how the classified vector geometries on landscape level changed over time. S1 and S2 are two relatively simple and suitable indices for comparing spatial changes i.e. one area vs another area, according to Hulshoff (1995). The S1 and S2 based on polygonal format, will produce form results based on the relationship between a specific land use patch’s area and the patch’s perimeter. The S1 index calculates the average perimeter/area for each landscape or land use class. A high S1 value indicates a landscape with relatively many patches with low area values. The S1 take no consideration to the complexity and form of the perimeter. That differ from the other geometry index S2, where larger areas and patches with complex perimeter get a higher form value. S2 is a form index based on the model that an iso diametric shape, objects or geometries that has equal diameters or axes, has the largest interior. This affects particular small spread areas that are assigned the same value as the iso shapes. Areas made up by polygons/landscape patches with isodiametric form will have low S2 values.

The form indices S1 and S2 are calculated as follow:

S1 is calculated as:

$$S1 = 1/\,Ni1 \times \sum (li \,/\, ai)$$

Where Ni1 is the number of patches/polygons i, li = the perimeter and ai = area for every patch/polygon.

S2 is calculated as:

$$S2 = 1/\ Ni1\ \times \sum (li\ /\ 4\sqrt{ai}\ )$$

Where Ni1 is the number of patches/polygons i, li = the perimeter and ai = area for every patch/polygon.

4.2.2 Interpretation of S1 and S2 calculations

S1 and S2 can give useful information about landscape development and land use changes if the indices are interpreted correctly. It is important to consider that the results of S1 and S2 calculations are often diverse, and there is no significant correlation between the different form indices S1 and S2. That is because they describe different ecological landscape terms and can sometimes show opposite trends, as the indices analyse the spatial form and extent of the geometries differently (Hulshof 1995). With different ecological terms, you refer according to Hulshoff (1995), to that S1 describe the size of the patch interior and S2 describe the form/complexity of the patch. Complexity of the patch is a measure that describes how a patch deviate from an isodiametric form. If S1 and S2 are combined, it possible to retrieve more useful information about the form and patch variation in a specific landscape, than implementing the indices separately. The information retrieved from S1 and S2 calculations can be used as an indicator and describe the nature of a landscape. A larger difference in standard deviation between the two indices indicates for example a heterogeneous landscape with both large and small patches and high variation in form.

4.3 Feature to raster conversion

The software FRAGSTATS that categorize landscape patterns and metrics requires raster data as input. The format requirement forced a data conversion. In order not to lose information about the spatial distribution of land use in the conversion from vector to raster, the new created grid's cell size was set to 0.5 m x 0.5 m.
How a cell is assigned a value when more than one vector feature falls within a cell can be controlled and depends on the data conversion method. The conversion method used in this study, is maximum area cell value assignment with no priority specified. I choose to use maximum area, as I wanted to preserve the extent and distribution of different land use areas as much as possible, in this landscape analysis, the highest overlapping land use class.

4.4 Landscape modelling in FRAGSTATS

After calculating how the landscape geometries/patches changed using S1 and S2, the next step in the evaluation was to model and analyse the land use data using the software FRAGSTATS and the programs built-in landscape evaluations tools. According to Turner, Gardner and O'neill (2015), is FRAGSTATS the most used program for measuring and analyse landscape patterns. Much due to the program's ability to calculate and retrieve useful and precise quantitative information about the form, the fragmentation and patch variation in the landscape (Liao, Bearup and Blasius 2017).

I measured the Shannon diversity index (SHDI), Mean patch area and Patch density on landscape level in FRAGSTATS. It is possible to analyse and calculate these metrics on a smaller scale (patch and class level). If the aim is specific to analyse individual landscape patches. I set the 8-neighbor rule for delineating patches. It is possible to set a 4-neighbor rule for delineating patches. The difference between the methods lies in how neighbouring cells to the focal cell, are taken into account, when the metrics determine patch membership. 4-neighbor rule only consider the 4 adjacent cells, which differ from the 8-neighbor rule that consider the 8 adjacent cells. The choice of neighbour rule will have impact on the results. Mean patch area and patch density are useful when describing the process of fragmentation and development in a landscape. Mean patch area expresses the area sum of all patches in the landscape divided by the total number of patches. Patch density express the number of landscape patches per unit, in FRAGSTATS that unit is hectare (ha). One hectare corresponds to 10,000 m^2.

Patch density is calculated as:

$$\text{Patch density} = \frac{N}{A}$$

Where N = total number of patches in the landscape and A = total landscape area (ha).

4.5 Shannon Diversity Index (SHDI)

There are different ways of calculating diversity values. Which diversity indices/metrics method, that best fits a specific landscape analysis can vary, and depend on factors such as size of the sample and number of samples. I choose to use the Shannon Diversity Index (SHDI), primarily for the reason that the metric is one of the most common used landscape metrics for the type of study I conduct. Where the objective is to describe patch evenness and richness and the spatial heterogeneity of the land use in a defined area. SHDI can according to Morris, Caruso and Buscot et al (2014), give statistical information and insights, on biological, landscape and ecological diversity. Insights that could, for example, be used and be important tools in environmental monitoring, landscape conservation and community ecology.

The quantification of form changes and diversity will be essential for an accurate analysis of structural landscape development. By only visually analysis of landscape patterns, there is a risk that the evaluation of landscape development will be incorrect as different geometries and patterns can be complex in their form and hard to interpret (Wang, Hu and Sun et al 2017).

The SHDI is calculated as:

$$\text{SHDI} = -\sum_{j=1}^{m} P_j * ln(P_j)$$

SHDI = minus the sum, across all patch categories, of the proportional abundance of each patch category multiplied by that proportion.

Small m = the number observed land use types. P_j = the proportion of the landscape (total landscape area) occupied by patch class j. *ln* represents the natural logarithm. A high SHDI indicates that the diversity in the landscape is high. A low SHDI indicates that diversity in the landscape is low, with only one or few land use classes present.

4.6 Detect and quantify temporal changes

Finally, I performed an overlay analysis because I wanted to detect and visualize where in the study area there has been a change in land use. In order to detect, where it has been a temporal change in land use, I made an overlay analysis with the land use map from 1960 with the land use from 2015. I only made a comparison of the land use maps from 1960 and 2015.

4.7 Data:

The data used and analysed in study, was collected from the Upplands-Bro municipality's internal geographical database. I used the municipality's aerial photographs (orthophotos), showing land use conditions in the years 1960, 1975, 1995 and 2015. The images have a spatial resolution between 0.08 - 1 meter. All data presented in the study has the Swedish reference system SWEREF 99 18 00, a local application of the Official Swedish geodetic reference system SWEREF 99 TM.

Table 1: The table shows the geospatial data that is used in the study.

Name	Format	Spatial Resolution	Source	Coordinate system
Historiska_orto_1960	SDE-raster	0.5, 0.5 m	Upplands-Bro Municipality	SWEREF 99 18 00
ORTO_1975_05M	Mosaic dataset	0.5, 0.5 m	Upplands-Bro Municipality	SWEREF 99 18 00
ORTO1995_1M_SV	SDE-raster	1, 1 m	Upplands-Bro Municipality	SWEREF 99 18 00
ORTO2015_008M	SDE-raster	0.08, 0.08 m	Upplands-Bro Municipality	SWEREF 99 18 00

5 Results

5.1 Land use maps:

The image interpretation (Figure 4) show the spatial distribution of different land use classes in the study area between 1960-2015.

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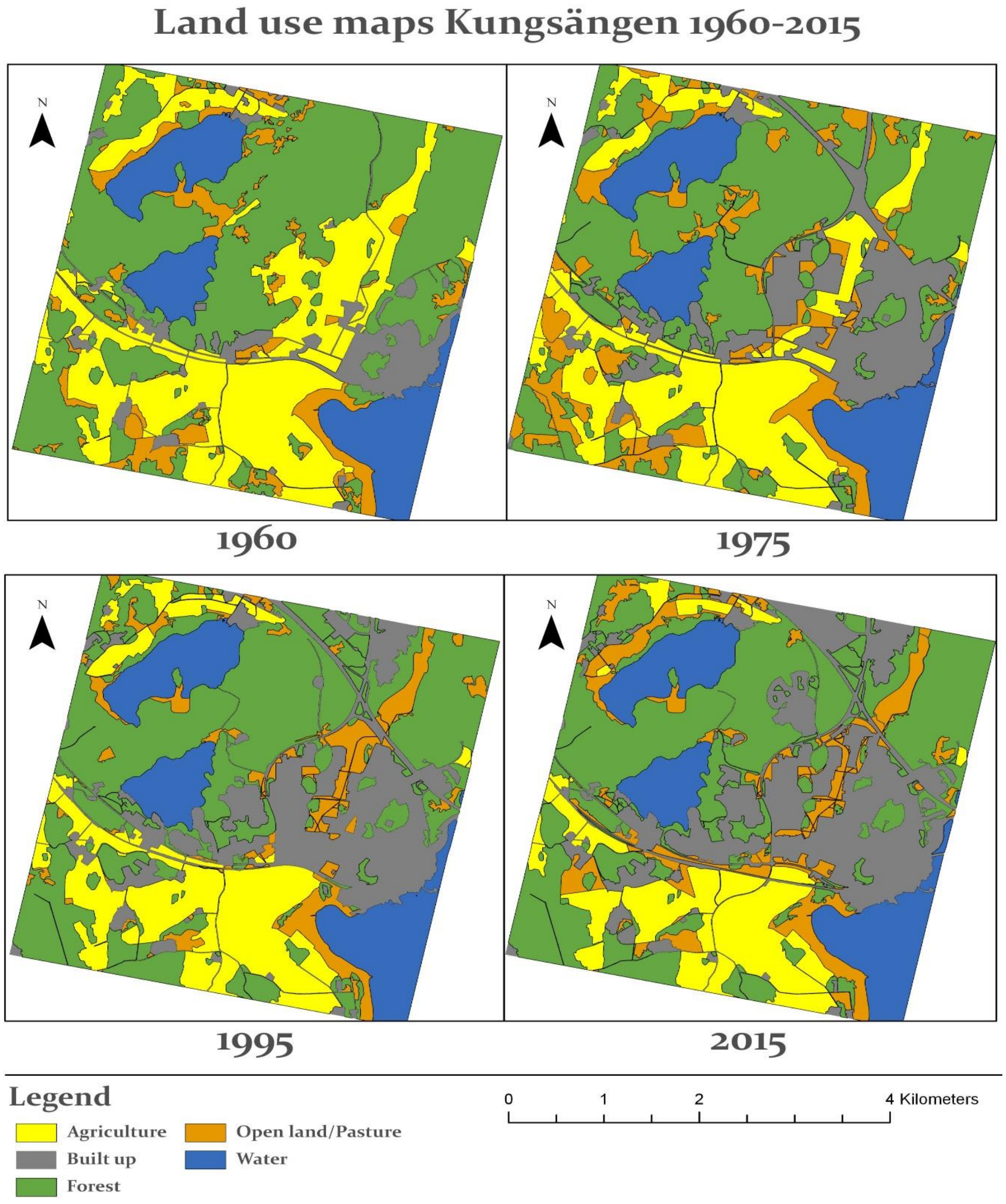

Figure 4: Land use in the study area year 1960, 1975, 1995 and 2015.

5.2 Structural landscape variations

The percentages of different land use classes for each analysed year are presented in Table 2. As the study focus on land areas, water areas was excluded from the calculations. It is possible to distinguish structural landscape variations in the study area and that the distribution of different land use classes changed over the period 1960-2015 (Table 2).

Table 2: Percentage distribution of different land use classes in the study area in Upplands-Bro for the years 1960, 1975, 1995 and 2015. The land use class water is excluded.

Year	Forest	Open land/ Pasture	Agriculture	Built up
1960	50.06	9.73	31.47	8.74
1975	41.94	14.59	24.65	18.86
1995	46.78	9.52	20.22	23.54
2015	44.24	11.93	16.20	27.71

5.3 Land use change

The spatial proportion of forest, which is the most common land use class in the study area, has decreased throughout the analysis period 1960-2015. The total decline between 1960-2015 is around 12%. However, the declining trend has not been completely downward for forests from 1960-2015. Between 1975 and 1995, the percentage of forests in the study area increased from 41.9% to 46.8% after a decline from 1960 to 1975.

The distribution of open land/pasture, has also varied over the studied period. In the year 1960, 9.7% of the study area consisted of open land/pasture. In 2015, the number was 11.9%. It is an approximately 23% percentage increase on a landscape level, from the study's starting point to the study's end point. 1975 stands out slightly from other analysis points, when open land/pasture occupied approximately 14.6 % of the entire study area. The largest area value for the land use class under the period studied. From 1975 until 2015, is open country/pasture the smallest land use class in the study area. The spatial location of open land/pasture has been dynamic and varied over time. In 1960 open land/pasture was most prevalent in the southern and north-western parts of the study area. In 1975, the prevalence of open land/pasture is relatively uniform throughout the study area. In 1995, when the proportion of open land/pasture decreased with approximately 35%. compared to 1975, the prevalence was mainly located in the eastern parts of the study area. Between 1995 and 2015, the spatial location of open land/ pasture becomes more static compared to the periods 1960-1975 and 1975-1995.

Agriculture areas is the land use class that has had the largest percentage decline in the study area in Upplands-Bro under the studied period. As table 2 shows, the trend in the study area has been downward for each specific analysed year. With a decline from 31.5% in 1960 to 16.2% in 2015, over 49% of the agricultural areas in the study area has disappeared. The decrease has resulted in that agriculture areas has gone from the second largest land use class to the third largest land use class. It is mainly in the southern parts of the study area that you in 2015, can still find large cohesive agriculture areas. The location of agriculture areas in the study area has been static in comparison with forest and open land/pasture. Only small agricultural areas, mainly in the north-western parts of the study area have been added during the analysed time frame.

Built up areas is the land use that has increased most in percentage distribution for each analysed time point and in total. In 1960, built up areas occupied 8.7 % of the area and were the smallest land use class in the study area.
In 2015, built up areas occupied 27.7 %, which means that in 2015 there were more than three times more built-up areas than in 1960. In 2015, built up areas were the second largest land-use class (Figure 6). When studying the land use maps (Figure 4), it is possible to observe that the distribution of new built up areas has largely taken place in areas connected or close to existing built up areas. Primarily in the study area's eastern and north eastern parts. It has also been added some built up areas in the study area's southwestern parts but not to the same extent as in areas adjacent to the town Kungsängen.

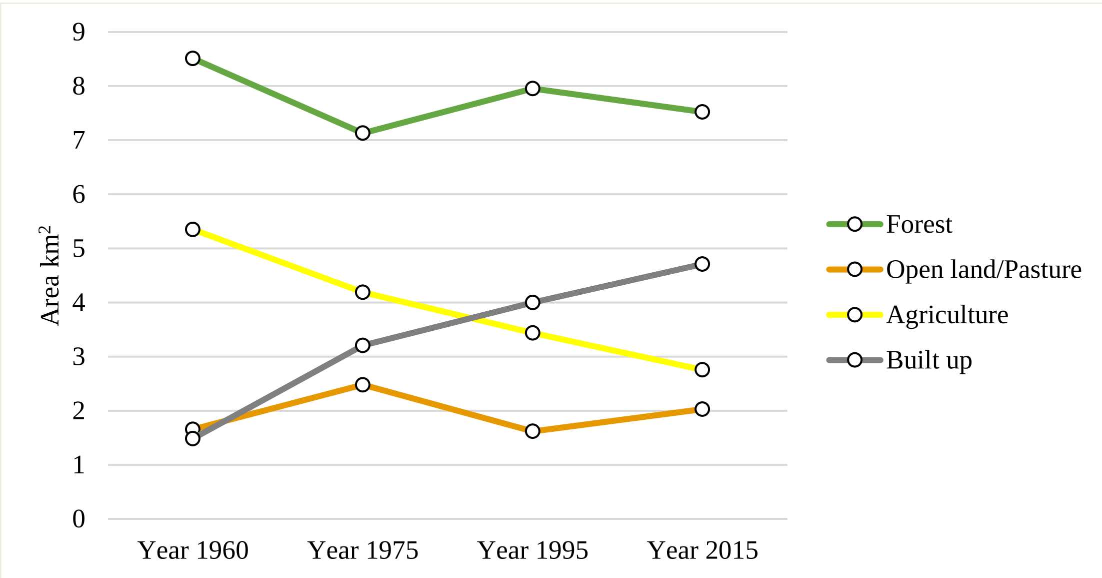

Figure 5: Land use area [km^2] 1960, 1975, 1995 and 2015, excluding water areas. The dots in the chart illustrate the four years that have been analysed in this study.

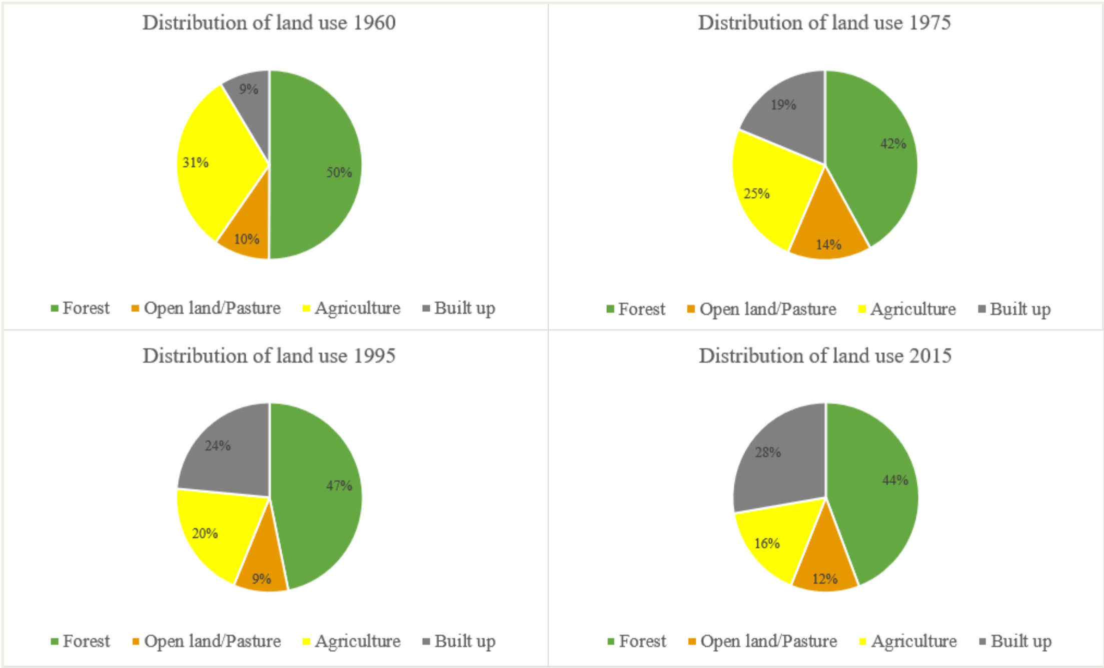

Figure 6: Percentage distribution of land use in the years 1960, 1975, 1995 and 2015. Green represents forest. Grey represents built-up areas. Yellow represents agriculture areas. And brown represents open land/pasture areas.

5.4 Detected land use change

Between the period 1960-2015, approximately 601 ha of the landscape in the study area has changed land use. 601 ha corresponds to about 31% of the study area total area of 1961 ha. The land use change is illustrated in Figure 7, which has the orthophoto from 2015 as background map. The coloured areas in the map shows the spatial location of areas where land use has changed and how areas have been converted. It is mainly possible to locate areas with changed land use in the eastern parts of the study area, where the town Kungsängen is located. The most common land use conversion, is, 1), forest to built up (200 ha), 2), agriculture to open land/pasture (124 ha) and 3), agriculture to built up (112 ha).

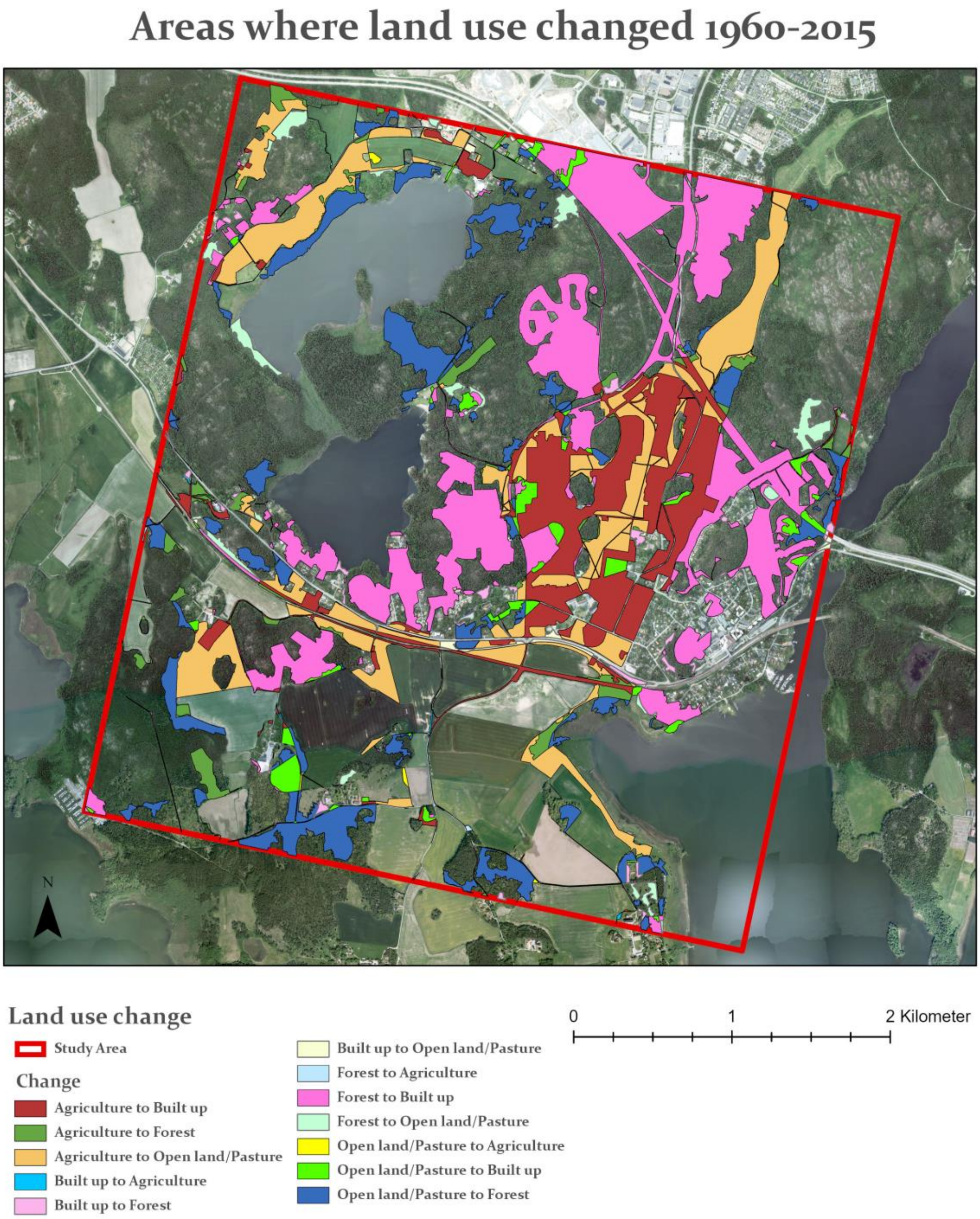

Figure 7: Areas where land use has changed in study area in Upplands-Bro between 1960-2015.

5.5 Landscape metrics

Landscape metrics were implemented to enable quantification of the form and density values for the landscape patches/geometries.
The result of the form calculations and patch structure can be studied in the Table 3. The table shows the values for the landscape indices Patch density, Patch area, mean, S1 mean, S2 mean and Shannon (SHDI), for each specific analysed year.

Table 3: The table shows the values for Patch density, Patch area mean, S1 mean, S2 mean and SHDI, for each specific analysed year in the study area.

Year	Patch Density (Patches per 100 ha)	Patch Area, Mean (ha)	S1 Mean	S2 Mean	SHDI
1960	8.82	11.33	0.06	1.64	1.39
1975	9.99	10.01	0.06	1.64	1.52
1995	11.42	8.76	0.07	1.63	1.47
2015	12.13	8.24	0.09	1.77	1.49

5.5.1 S1 and S2

Figure 9 shows how the form metrics S1 and S2, which are based on the relationship between the patch area and perimeter, varied in the study area between 1960-2015. S1 and S2 was calculated separately but are presented in the same chart with two different axes. The axis, to the left in the chart (Filled line), shows the value variation for the form index S1, which indicates changes in the landscape path's interior/area. The right-hand axis shows the value variation for the landscape patch form index S2 (Dashed line), which indicates changes in the perimeter complexity/form of the object. In this study the object corresponds to a landscape patch (Hulshoff 1995).

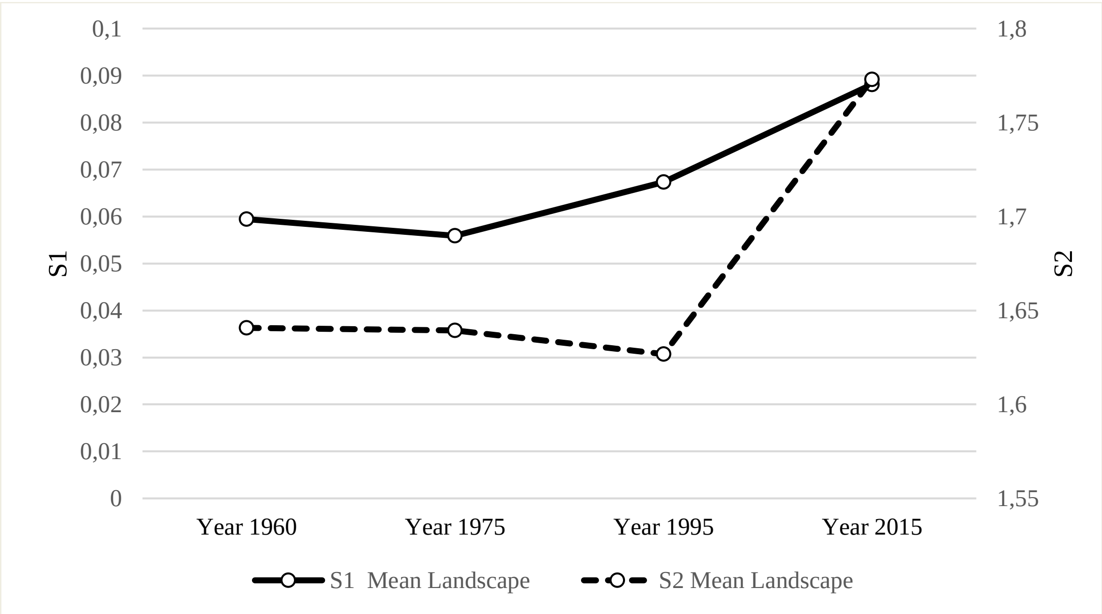

Figure 8: The chart shows S1 and S2 form indices values on landscape level in the study area in Upplands-Bro between 1960-2015. Note that the left axis illustrates the values for S1 (Filled line) and the right axis values for S2 (Dashed line).

As can be seen in the chart (Figure 8), the values of the form indices S1 and S2 have varied over the analysed time period. Looking over the entire evaluation period, both the values for S1 and S2 are higher at the end of the study in 2015, than at the study start in 1960. Although the trend for both S1 and S2 has been rising, it is possible to distinguish descending values during the analysing period. For example, is it possible to discern that the S1 decreased between 1960 and 1975. And the form index S2 decreased between 1975 and 1995. That the S1 value increase during the period 1960-2015, indicates according to Hulshoff (1995), description of the form index, that the number of patches with a small interior/low area has increased. Patches in the study area have, according to the S1 calculations become smaller for each measured time after 1975 until 2015. And that S2 increased/deviates more from 1.0, indicates that the patches perimeter has become more complex and more deviating from an isodiametric shape. The period 1995-2015 stands out from other periods, as the form and complexity increase in relation to other periods is more distinctive. Between 1960 and 1995, the value of S2 was more static in comparison to the period 1995-2015.

5.5.2 Patch density and Mean patch area:

Patch density and Patch area mean where calculated to quantify patch density and patch form in the landscape. Patch density describe the number of landscape patches per 100 ha.

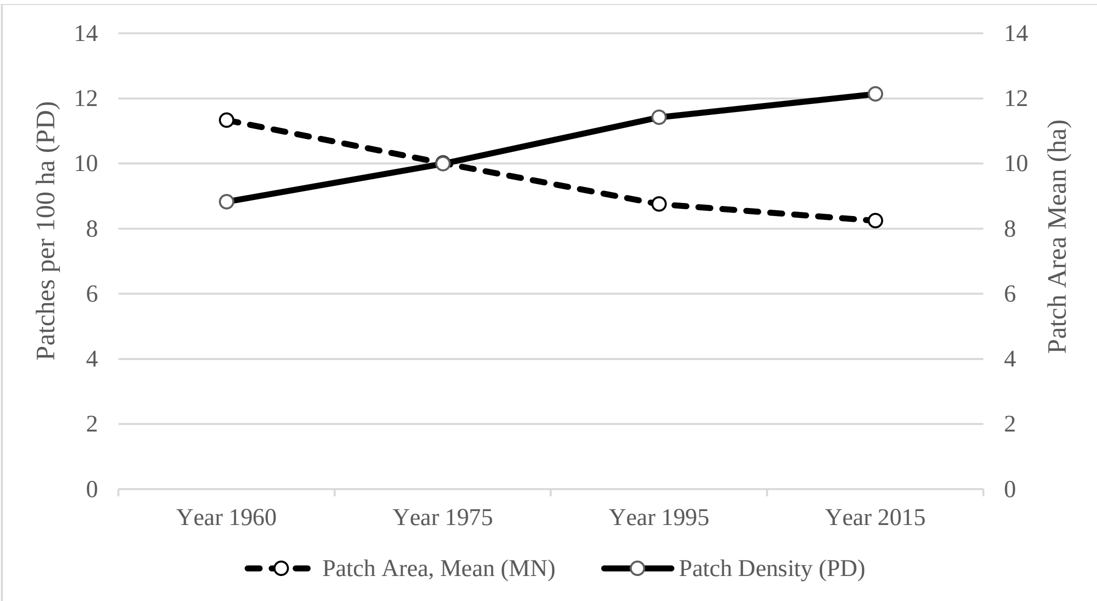

Figure 9: The chart illustrates Patch density and patch area mean values for the time period 1960-2015. The Y-axis shows the number of landscape patches per 100 hectares.

The Patch density has increased for each analysed time point. The increase in Patch density between each studied year has been relatively even over the whole analysed period. Around 1 unit of measurement for each period between 1960-1995 (Figure 9). After 1995, patch densities continued to increase, but then with a smaller increase than previous periods. Between 1995 and 2015, the increase was about 0.5 measuring unit.

Viewed over the entire measuring period 1960-2015, the value for patch density has increased from 8.8 to 12.1. This corresponds to an approximately 27% overall patch density increase. For Patch area mean, which has had a downward trend, the value has decreased from 11.3 ha in 1960 to 8.2 ha in 2015. The fact that the patches' density has increased in the study area shows that the land use patches have become smaller and more over the analysed time period. The fragmentation rate has been increasing throughout the time period as the chart illustrate (Figure 9).

5.5.3 SHDI :

SHDI was implemented and used to measure landscape diversity. SHDI which are not affected by the spatial configuration of the landscape patches becomes 0 if a dataset or layer contains only one type of object or class. If the variation of types increases or the areal proportion among the different types becomes more evenly distributed SHDI increases (Chmielewski, Chmielewski and Tompalski 2014). Figure 10 shows how SHDI, varied in the study area in Upplands-Bro between 1960-2015.

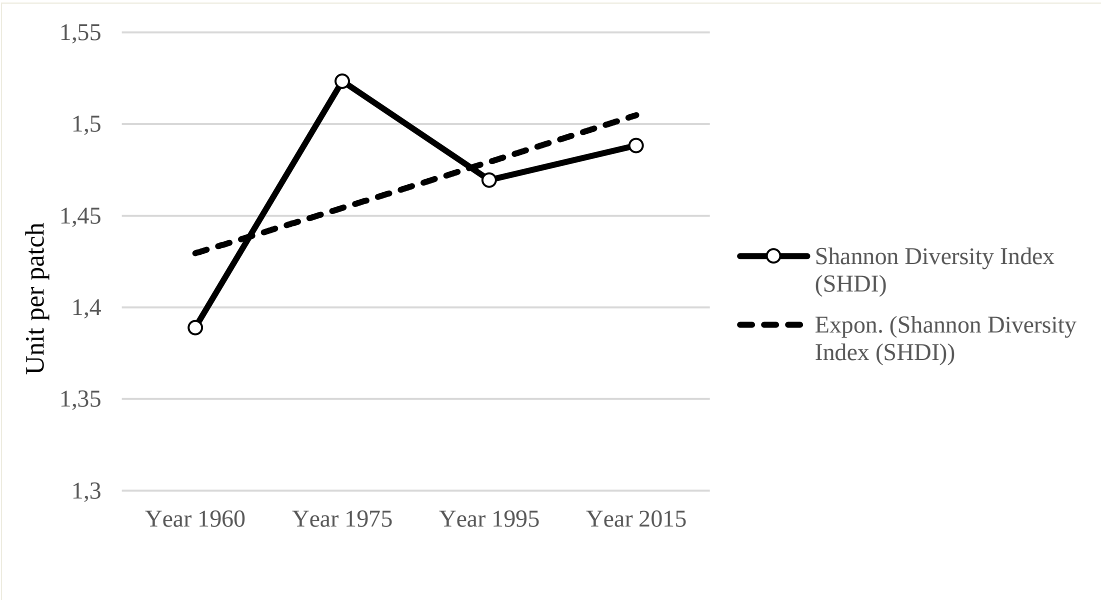

Figure 10: Shannon Diversity Index (SHDI) values for the time period 1960-2015. The Shannon diversity index (Filled line), totals minus the sum, throughout all patch categories, of the proportional abundance of each patch category multiplied by the quantity (Umass 2019).

As can be seen from figure 10, the diversity value SHDI has varied over the period studied. Between 1960 and 1975 it is possible to observe the highest rise of SHDI in the landscape. In 1960, SHDI was 1.389, the lowest measured SHDI for the analysed period. And in 1975, the value of SHDI was 1.5234, which is the highest measured value. After 1975 until 1995, diversity in the landscape decreased. However, not back down to the same level as was measured 1960. Between 1995 and 2015, the SHDI increased again, but the increase was, not as strong as the increase between 1960 and 1975 (Figure 10).

6 Discussion and conclusion

My study was motivated by an interest in applying spatial landscape metrics to a landscape in the developing and growing municipality of Upplands-Bro. The study aimed to investigate and evaluate landscape development in a study area in the munipality Upplands-Bro. Firstly by map and evaluate where and how the land use changed during the analysed time period. And secondly by implementation of different landscape metrics, analyse how the composition of landscape patches changed.

6.1 Interpretation of land use

The prerequisite for a qualitative evaluation of the landscape development in the study area, was that I managed to create land use maps that resemble the land use conditions prevailing at each analysed time point (Figure 4). Since the form indices/landscape metrics quality and use possibilities, according to Turner, Gardner and O'neill (2015), depend on how well a landscape analysis manage to interpret and map the land use. The better the interpretation and mapping of land use, with greater certainty and precision it is possible to evaluate the landscape development in a defined area. My interpretation of land use in GIS was carried out relatively smoothly without major difficulties, although the manual interpretation in ArcGIS Pro became more time-consuming than I estimated.

The advantage of a manual interpretation was, despite the scope, that I with a human eye could distinguish and interpret different landscape structures and patterns that are not considered in an automatic interpretation. An automated interpretation, according to Campbell and Wynne (2011), only considers the pixel reflectance value and may have difficulty handling surfaces with mixed land use and structures, which was an issue when I tried to make automated land use model. No observations were made in the field to assess the land use interpretations accuracy, the unit of closeness to a measured number or value. The choice to not conduct supplementary field observations, depended mainly on two reasons. 1), that the orthophoto taken in 2015, has a spatial resolution of 0.08 x 0.08 m and 2), that the landscape in the study area after 2015, has undergone further landscape development.

The image interpretation of land use in GIS (Figure 4), may have been influenced by varying scale and quality of the input data. As the interpreted orthophotos spatial resolution varied and had different colour scales. It is a spatial error that is often evident when you through remote sensing want to investigate and get an understanding of how spatial structures has changed over a long period of time. Since you are forced to handle both old and new data with varying quality.

With the technological development satellite and aerial images have become better and easier to interpret, which is illustrated in Figure 2. This was a present issue in my evaluation of landscape patterns, where I studied landscape development under a period of fifty-five years (1960-2015). As Campbell and Wynne (2011) highlights, this resolution issue has an impact on the interpretation’s quality and precision and its possibilities of being compared in different contexts. An interpretation based on better input data is more likely to resemble real conditions than an interpretation based on “poorer data” with limited resolution and colour scale (Turner, Gardner and O'neill 2015). I had, what I consider access to good and high-resolution image material, even though there was a difference in spatial resolution. The images I interpreted had, as the poorest, a geometric resolution of 1 x 1 m. Which may be considered relatively good for example, compared to Liu, and Yang's study (2015), who analysed multispectral data from satellites with a coarser geometric resolution (approx15-30 m spatial resolution).

6.2 Changed landscape patterns

My evaluation of landscape development indicates that there are good conditions for using landscape indices for quantifying the landscape in Upplands-Bro. By implementing image interpretation and landscape pattern metrics, it was possible to map and quantify the geometry and landscape patterns in the study area. By combining different types of form indices, the possibility of better evaluating the landscape development in the delimited area also increased. The more form indices implemented in an analysis of landscape development, the better the mapping and information can be obtained about the landscape's spatial structure and conditions (Turner, Gardner and O'neill 2015). As different form indices and quantifications can measure different forms of spatial parameters. The evaluation of landscape patterns shows that the landscape patterns in the study area has as I predicted, changed between 1960-2016. According to my observations, 31% of the area in the study area has changed land use under the studied period (Figure 7). That my evaluation of landscape development would show development and changed landscape patterns, was expected with social development and that the population in the municipality has increased by over 600% between 1960 and 2015 (Figure 4). The landscape development process is common in areas that have experienced rapid development.

The majority of all landscapes on earth have in some way according to landscape development science, been exposed to landscape development, not least regions with large population growth (Turner, Gardner and O'neill 2015). How specifically the landscape development has taken shape in different landscapes, can however, differ as Xing, Qian and Yongjiu (2012), highlights. Local conditions and factors be unique to each individual delimited studied area. Which means that the reasons to landscape development may vary according to Turner, Gardner and O'neill (2015), who states that the development and the structural landscape change may be due to both new societal needs and changed climate needs. In Upplands-Bro, the cause of changed landscape patterns is driven by population growth and development and not linked to changing climate conditions.

6.3 Evaluation of landscape patterns

The interpretation of land use and the landscape metrics that was implemented in the study, unveiled valuable information about landscape development and pattern changes in the study area. What I clearly can distinguish from the evaluation of landscape development, is that both the spatial distribution of different land use types and landscape patch composition has changed.

6.3.1 Land use

The evaluation of the landscape development showed changes in the distribution of land use. Throughout the analysis period, I distinguish two distinctive land use trends in the study area. A large percentage increase in built-up areas and a large percentage decline in agricultural areas. Forests and open/land pastures have also had varying distribution in the landscape during the evaluated period. But, unlike the classes built up areas and agricultural areas, the variation has, in percentage terms, not been as strong as for built up areas and agricultural areas.

Table 2 illustrates that the percentage distribution of built-up areas in the landscape has almost tripled between 1960 and 2015. As a result, built-up areas have advanced from fourth largest land use class to the second largest land use class in the study area. Most likely, if future predictions come true, the land use class will also continue to increase, as the Upplands-Bro municipality's population will continue to increase according to forecasts (Upplands-Bro 2018). For agricultural areas, the land use distribution trend has been the opposite. Over 51% of the agricultural land in the study area has according to the study's evaluation disappeared. In particular, the disappearance of agricultural land has taken place in areas connected or close to existing built-up environments. Where agriculture areas have been converted to primarily built up and open land/pasture (Figure 7).

Reduction of agricultural land in regions with high development and population growth is a spatial event that research on landscape development has shown is common. According to Turner, Gardner and O'neill (2015), it is largely due to that agricultural areas are often located in the vicinity of built-up or urban areas. This means that agriculture areas are often at risk when societies and urban areas are expanding. The land use trend in Upplands-Bro also strengthens Wästfelt, and Zhang (2016), theories that agriculture areas in near urban become more threatened on multiplied scales due to rapid urbanisation and agricultural restructuring. As the land use maps illustrates (Figure 5), the town Kungsängen has for example expanded beyond land, which in 1960 was classified as agricultural land. Area reduction of agriculture areas is a common phenomenon in Sweden, due to that agricultural land is a place-bound natural resource that takes a long time to create and manage. According to statistics from the Swedish Agriculture Department (Johansson 2019), has the proportion of agricultural area in Sweden has been declining since the 1930s.

6.3.2 Landscape patch composition

My evaluation of landscape development showed that the land use patches composition and form relationships have changed in the landscape. As table 3 illustrate, the patches have become more per ha for each analysed time point. That the patches in the landscape becomes smaller and more per landscape unit is a trend that Eriksson and Cousins (2013), mean is global, not least clear in regions with high development and population growth like Upplands-Bro.

A major reason for the increasing fragmentation, apart from increasing amounts of buildings and industries are the establishment of new roads within the area I have studied. A development that can be studied in the land-use maps (Figure 5). For example, has a motorway (E18 in the study area's northern parts), been built during the analysed period. Roads whose main purpose is to improve mobility and provide infrastructure, is a great source to new landscape barriers and increased landscape fragmentation, not least in Sweden (Karlsson and Mörtbergs 2015). This is because roads often cut through and divide the landscape as Xing, Qian and Yongjiu (2012), problematize. Establishment of buildings and roads is a process that reduce landscape connectivity and have negative ecological and diversity effects. When the landscape is fragmented, different types of species becomes isolated and the possibility of integrating decreases (Xing, Qian and Yongjiu 2012). Most species benefit according to Xing, Qian and Yongjiu (2012), from larger cohesive surfaces as isolation of different species populations can increase the risk of extinction. The future estimation is that the fragmentation and isolation values will continue to increase in the study area, as many new projections and projects have started since 2015 or are planned in the municipality.

6.3.3 Landscape diversity

Landscape diversity calculations implemented in the study showed diversity variations in the landscape during the analysed period. According to calculations of the SHDI the diversity in the landscape is higher in 2015 than in 1960. The increase in the value of SHDI is mainly due to the distribution of the four types of land use being more evenly distributed over time. As no land use class has been added or removed in the landscape during the analysis period. There has only been a redistribution of land use between agriculture, open land/pasture, forest and built up areas. One thing that needs to be considered when applying and interpreting diversity calculations, is that the calculations are dependent and sensitive to how detailed the landscape is classified. A landscape analysis impact that Turner, Gardner and O'neill (2015), discusses and problematizes. The authors highlight that the scale of the classification and the degree of generalization have a great influence on how the results of a landscaping diversity evaluation can be interpreted and used.

The lower the degree of generalization, the more detailed information can be obtained about landscape development. I merged for example different types of forest and different types of open land into two large and general land use groups. Had I included more land use types such as meadows, grassland, coniferous forest, deciduous forest in my landscape development evaluation, I would most likely retrieve a different diversity result. I had the hope of distinguishing different types of open lands and forests from each other. As research has shown that different types of open lands and forests from a diversity point of view have different ecological values and significance (Liao, Bearup and Blasius 2017). But, I could not, with enough certainty, distinguish certain types of interesting land use surfaces primarily in the older black and white orthophotos. It could have generated interesting discoveries and could provide additional useful information about landscape development and changing landscape patterns in the study area.

6.4 Conclusions

Through my study, whose purpose was to evaluate landscape development in a delimited area in the municipality of Upplands-Bro, I have come to a couple conclusions. The major conclusion is that I can confirm the thesis hypothesis, which was that landscape patterns in the study area have changed.

- On question 1, Where and how has the land use change in study area between 1960-2015? The answer is that 31% of the total study area has had changed land use between the years 1960-2015. Over the observed period, it is possible to discern that the proportions of built-up areas and open land/pasture has increased while the proportions of forest and agriculture areas has decreased.

Mainly has the land use change been concentrated to the eastern parts of the study (in the surroundings to Kungsängen), although it is possible to discern land use change in areas throughout the hole study area. The most distinctive land use development trend observed is 1), a high percentage increase in built-up areas, mainly in areas adjacent to already existing built-up areas, and 2), a large percentage decline in agricultural areas. A decrease that is largely linked to the expansion of built-up areas.

- On question 2, How has the landscape structure in the study area changed in terms of patch composition between the years 1960-2015? The answer is that the landscape becomes more fragmented. It is clear to see a trend in the study area regarding landscape homogeneity and the shape of the patches in the landscape. For each observed year has the landscape become more fragmented, in terms of patch density. The landscape patches have also become more complex in their form. The landscape development in the study area in Upplands-Bro municipality reflects, as mentioned earlier the general landscape development trend that takes place in many other areas and regions around the world. Not least in near urban areas in regions that have experienced a high development and population increase like the one studied in Upplands-Bro municipality.

7) Literature

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