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Urban expansion, land use change and development of landscape diversity in Södra Sandby, Lund municipality 1940-2019

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Abstract

Diversity is an important part of the health of our planet's ecosystems and processes. Anthropogenic factors like urbanization and agriculture have altered the landscape and in turn had a negative effect on diversity. Efforts to maintain and preserve diversity for long term ecological strength, have led to more holistic approaches by handling many types of diversity under the same field of "landscape ecology". This thesis focuses on interconnection between two types of diversity within the field of landscape ecology; landscape diversity and biodiversity. More specific, the focus is on the relationship between landscape composition, landscape structure, biodiversity and anthropogenic land use change. The study was based in and around a rural town within Lund municipality called Södra Sandby. The study area has historically been dominated by agriculture but contains multiple protected areas of high nature values. The area has previously experienced substantial urban expansion during the 20th century and is now in the plans for an expansion of 26000 residences until 2040. The municipality strives for a greener future and aims to strengthen the connection between its urban areas and the countryside. To meet the aspirations, it is important to understand how previous expansion has affected the landscape.

The aim of this study was to map the land use change between 1940-2019 in Södra Sandby, to analyze the landscape structure change over time as an effect of anthropogenic land use change and discuss what implication it could have on biodiversity. This was done by interpreting orthophotos between 1940-2019 (1940, 1973, 2004, 2010 and 2019) using a geographical information system and by quantifying landscape structure metrics for area, shape, fragmentation, diversity and evenness using FRAGSTATS. The land use interpretation resulted in five classes (agriculture, built up area, forest, water, and roads) which were then used to conduct the landscape structure analysis. From 1940-2019 the total area of agriculture decreased by 11%, built up area increased by 424%, forest increased by 80%, water increased by 35% and roads increased by 43.6%. The major changes in the landscape over the period was transitions from agriculture to built up area, and from agriculture to forest.

The structure analysis showed that the study area has become less fragmented over the period (besides the class of agriculture). There was an increase of total core area in all classes besides agriculture. All classes experienced an increase in shape complexity, indicating a more natural shape for patches of forest but a less complex shape for built up area. The results of Shannon´s diversity index and Shannon´s evenness index showed an increase in both diversity and evenness over the period.

The results point to a positive development of the landscape structure over time despite the previous urban expansion in the area. It has been heavily dominated by agriculture but over the period this class have declined. With agriculture becoming less dominant and more fragmented while built up area and forest becoming more prominent, it is highly possible that this has had a positive effect on the diversity and evenness of the landscape. The development of landscape structure over the period could also potentially indicate a positive direction for species richness and biodiversity in the area. High shape complexity, large patches, sufficient core area, low amount of isolation and increasing diversity and evenness could indicate a potentially well maintained and enhanced biodiversity. This however cannot be proven in this study as biodiversity was not quantified or tested.

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1 Introduction

Diversity is an entity that may be portrayed in many ways and on many scales. It can be seen on a global level, a national level, landscape level down to a habitat level. It may be measured in different ways depending on intention, for example biodiversity or landscape diversity (Hansen et al. 2004). Whichever way it is perceived or measured, diversity is important to our planet and its processes (Chapin Iii et al. 2000). Anthropogenic alterations to the natural landscape ranging from agriculture, urbanization or burning of fossil fuels to name a few, have negatively affected the diversity (Chapin III et al. 2011). This creates an issue not only to the ecosystem but also to humans, as the loss of diversity hinders important ecosystem services (Chapin Iii et al. 2000). In turn this weakens the resistance to environmental and climatic changes which may further add to a negative feedback loop, increasing the issues that we are already facing (Chapin Iii et al. 2000). Therefore, it is important to further understand the link and interaction between ecosystems, organisms, and human activity.

This study discusses two types of diversity: landscape diversity and biodiversity. Landscape diversity describes the variety of biotopes in the landscape, and encompasses the structure, function and spatial-temporal pattern of the landscape (Walz 2011; Biedinger 2013). Structure describes the composition and spatial arrangements of elements in the landscape (such as shape, size and diversity) (Peters and Goslee 2001; Walz 2011). Function describes the interaction of processes, phenomena and services between the elements in the landscape (such as materials, flows of energy and species) (Peters and Goslee 2001). Spatial-temporal pattern or dynamics describes how structure and function has developed over time including both natural and anthropogenic factors (Peters and Goslee 2001; Biedinger 2013). Biodiversity is defined as the variety and variability among living organisms and the ecological complexes in which they occur, and is a term collecting genetic, species and ecosystem diversity (Magurran 2013). Both landscape and bio- diversity are essential parts to the long-term health, resistance and resilience of the landscape and are important to preserve. However, the maintenance of these entities is often difficult to manage individually as they are in many ways dependent on each other (Peters and Goslee 2001; Walz 2011). To resolve this issue a more holistic approach has been used to connect landscape- and bio-diversity in the field landscape ecology (Turner et al. 2001; Biedinger 2013). Landscape ecology is a field within ecology that handles both entities by highlighting the spatial relationship between the landscape structure, ecosystem function, organism abundance/distribution, ecosystem processes and how the interaction of these elements have changed over time (McGarigal 1995; Turner et al. 2001). It is based on the understanding that to manage and maintain one part of a system, there must also be an understanding for the composition of - and relationship with, the surrounding parts of the landscape (McGarigal 1995; Turner et al. 2001; Walz 2011). The most used and well understood link between landscape and bio- diversity is the aspect of structure (McGarigal 1995; Peters and Goslee 2001; Walz 2011; Kupfer 2012). Using indices of landscape structure as proxies for measurement of biodiversity have proven to be an effective and low cost method to estimate specie abundance, presence and richness (Walz 2011; Kupfer 2012). Hence, this study focuses on the relationship between landscape composition, landscape structure and biodiversity, by studying how anthropogenic land use change have influenced the structure of the landscape and what that in turn could potentially mean for biodiversity.

The study area is situated in Lund municipality in Scania and covers 10 000 hectares. The study is focused on a rural town on the countryside within the municipality called Södra Sandby as well as the surrounding area including part of another town called Dalby. Södra Sandby is located north-east of Lund and has historically been marked mostly by agriculture and for being a tie-point for railways and trade. Södra Sandby experienced a large change during the 1900s, as agricultural land was sold to enable an expansion of the town with new residential areas in the 1950s. The expansion continued and the population increased by 75% between 1960 and 1970 (Lunds_kommun 2006). However, Södra Sanby and the surrounding area also contain areas of high nature values such as Skrylle, Dalby söderskog, Fågelsångsdalen, Kungsmarken, Flyingeslätterna and Sularpsbäcken (Lunds_kommun 2018). Many of these areas are protected by various protection programs because of their conservation value. Within the study area there are multiple nature reserves like Dalby Söderskog, Skrylle, Fågelsångsdalen and Kungsmarken. These are also protected on a European level by Natura 2000 and are labeled as particularly important areas due to their high nature values (Sundseth and Creed 2008; Lunds_kommun 2017). This means that the expansion and development that the area has undergone and will experience in the future are very much effected by the protection laws concerning these areas as it is important to the environment to enhance and maintain the these values on both a European, national and regional level (Sundseth and Creed 2008). Södra Sandby is planned to undergo urban expansion as Lund municipality wishes to build 26000 new residences until year 2040 (Lunds_kommun 2018). One third of the expansion is planned to be situated in the towns outside of Lund. Approximately 500 residences are planned to be built in Södra Sandby (Lunds_kommun 2018). Lund municipality has in publications (Lunds_kommun 2017, 2018, 2020) stated that for future planning and expansion of their municipality it is important to highlight the ecosystem and biodiversity as a way to keep the nature values high for both recreational purposes as well as for ecosystem services. Lund municipality has in publications like ”Grönprogrammet” (Lunds_kommun 2020) and ”Grön infrastruktur och ekosystemtjänster” (Lunds_kommun 2017) by Stadsbyggnadskontoret openly discussed the problem of depleting biodiversity within the municipality. They acknowledge the importance of biodiversity and the value of different types of ecosystem services that benefits both the environment as well as the human population (Lunds_kommun 2017, 2020). In the published reports (Lunds_kommun 2017, 2020) they express the need for an investigation of ecological relationships in relation to the municipality’s urban areas and the countryside. They want to map and document the supporting ecosystem services based on habitat/biotopes regarding biodiversity, to help supporting a greener and more ecofriendly residential expansion (Lunds_kommun 2017, 2020). Therefore, this study could be of high interest as it gives an overview of the current landscape structure as well as how it has evolved over time.

By using geographical information systems (GIS) as well as landscape pattern analysis it is possible to identify and quantify land use change over time. It is also possible to analyze how these changes have affected the landscape structure and the potential implications that it may have on biodiversity (Walz 2011). The results can then be used to understand the development of change into the current situation, and hence be of great interest for the municipalities current expansion goals. The softwares that were chosen for this project were Esri´s ArcMap and FRAGSTATS. ArcMap is a geographical information system that is used to handle, analyze, and present geographical information. In this study it was used to perform a land use interpretation from orthophotos. FRAGSTATS is a software that is used to compute landscape pattern and structure analysis, describing landscape ecology relationships. In this study FRAGSTATS was used to quantify size indices (total area & total core area), isolation/fragmentation indices (mean Euclidean distance index), shape indices (mean shape index) and diversity indices (Shannon´s diversity index & Shannon´s evenness index).

1.1 Delineations of study

The study area is centered on Södra Sandby. However, the actual area of the study area stretches more than the perimeter of Södra Sandby (Figure 1, map of the study area). This was decided as the study is based on a landscape scale and hence for this study to have value, an investigation of the larger areas surrounding Södra Sandby as well as the town itself was needed. Another reason for the size of the study area is that the plans of urban expansion made by Lund Municipality also include densification between Lund city and the suburbs, hence, it is interesting to cover this area. Biodiversity will not be directly measured but interpreted from landscape indices as no data covering flora or fauna were used.

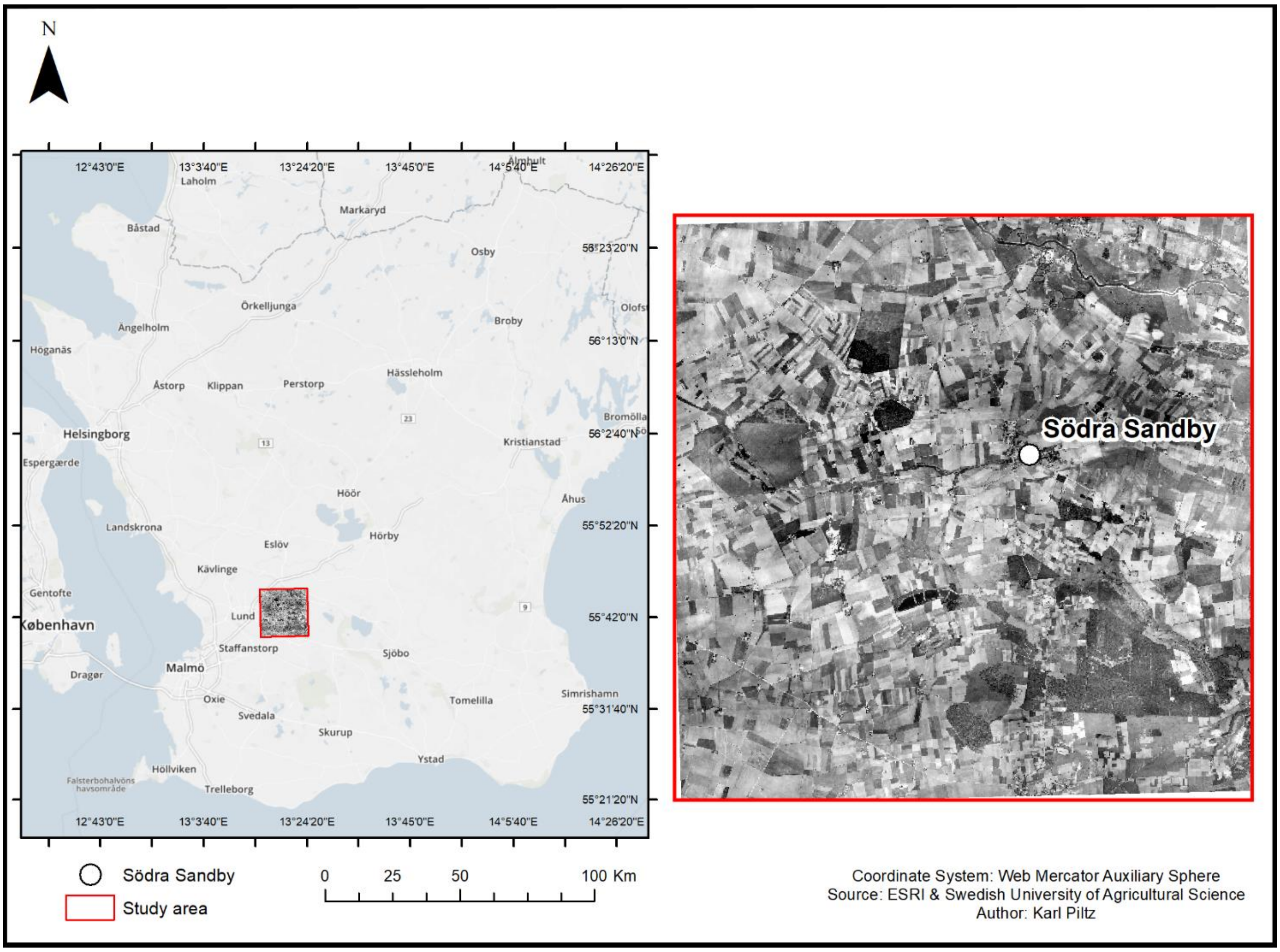

Figure 1: Location of study area in relation to Scania, Lund and Södra Sandby. Left image shows placement of study area within the region Scania, delineated by the red outline. Right image depicts the study area as in the year 1940 orthophoto. Marker shows location of Södra Sandby within the study area.

2 Aim

The aim of this study is to map the land use change between 1940-2019 in Södra Sandby, Lund municipality. This was achieved by analyzing the landscape structure change over time as an effect of anthropogenic land use change and discuss what implications it may have on biodiversity.

Research questions:

How has the landscape structure changed in the study area between the years 1940-2019?

This will be accomplished by:

1. Quantifying the total area and total core area change over time for different land-use classes.
2. Quantifying the mean Euclidean distance index i.e. class isolation.
3. Quantifying the mean shape index change over time.
4. Quantifying the Shannon´s diversity index & Shannon´s evenness index.

3 Data & Methods

3.1 Data description and sources

The 1940-2010 orthophotos were downloaded from https://zeus.slu.se/get/ (SLU) and the 2019 orthophoto was acquired from Lund municipality (Stadsbyggnadskontoret) (Table 1).

Table 1: Properties of the orthophotos used for the interpretation. Showcasing year, orthophoto type, resolution and source of orthophoto.

Year	Type (Orthophoto)	Resolution	Source
1940	black and white 1 band	0.5 m	Lantmäteriet
1973	black and white 1 band	0.5 m	Lantmäteriet
2004	black and white 1 band	1 m	Lantmäteriet
2010	RGB 3 bands	0.5 m	Lantmäteriet
2019	RGB 3 bands	0.25 m	Lunds kommun

3.2 Software

Spatial data and orthophotos were handled using ArcMap 10.5.1 (ESRI 2011). Landscape structure metrics were calculated using FRAGSTATS (McGarigal et al. 2012).

FRAGSTATS is a software used to quantify landscape metrics for analyzing landscape ecology. Its aim is to provide the user with a broad variety of landscape metrics and to effectively allow the user to choose and analyze the metrics tailored to their study. FRAGSTATS was chosen for this landscape structure analysis because it is a well-known program and user-friendly as it is almost fully automatized. It has also been widely used within landscape ecology and is very applicable with a multitude of important metrics available (McGarigal 1995).

3.3 Land use interpretation 1940–2019

The interpretation was based on Naturvårdsverkets Nationella Marktäckedata (NMD) 2018, which is a landcover interpretation of Sweden with a 10 m resolution. This layer was clipped to the study area and then used as an aid to determine the class "Built up area" (built up area inspired from NMD´s exploited area). The color key was also derived from this source. The map of Naturvårdsverket Marktäckningsdata 2018 can be found in the appendix (Figure A1).

The orthophotos were interpreted into five land use classes (Agriculture, built up area, Forest, Water, and Roads). The interpretation was done in the order of oldest to newest image, to keep the interpretation consistent as the color images of 2010 and 2019 show more contrast. This enabled an interpretation process that would apply for all years based on the land use that was identified in the oldest image (1940). "Built up area", "Forest" and "Water" were interpreted and digitized into individual polygon layers for each year. The major roads were made into its own class as roads represent boundaries between different types of land use in the area. The road layer was digitized as polylines in the mosaic. The road layer was created from the 1940 orthophoto and was continually updated for the years 1973, 2004, 2010 and 2019. The road layer was then given a buffer of six meters to represent standard road width. The digitized land use classes were added to a layer of the study area extent using a maximum overlay function. The overlay was done using the layer order (bottom-up) "Forest", "Built up area", "Water", and

"Roads". This layer was then transformed into a raster layer. The final output was done using a conditional syntax using a raster calculator where all cells that was not "Forest", "Built up area", "Water" or "Roads" was interpreted as "Agriculture".

During the interpretation multiple generalization measures had to be taken as the quality of the images varied. The classes were limited to characterizations that were applicable for all orthophotos. For example, in the 3 band RGB images of the years 2010 and 2019 it was possible to distinguish between a multitude of variations within the same type of land use for example crops or grazing and deciduous or coniferous forest. In the black and white images however, it was not possible to differentiate and interpret these different types of land use. Therefore, all types of forest (deciduous, coniferous, young, and old) were classed as "Forest". The class of "Built up area" encompassed not only buildings but also exploited areas such as building sites and quarries. The class of "Agriculture" included crops, grazing and meadows.

Land use change

After the interpretation of the orthophotos was done, the resulting layers for the different land use classes were used to produce a map showcasing the land use change/transition in the study area between year 1940 and 2019. The map was made by using the existing layers of the different classes digitized from 1940 and 2019 (Agriculture, Forest and built up area). First the areas of change within the same land use class (Ex. Forest cover 1940 and Forest cover 2019) were found by overlaying the land use from 1940 and 2019 to detect areas that had changed over the period. This was then replicated by overlaying the different land use classes (Ex. Agriculture and built up area) to find out what type of change the area had undergone over the period. The resulting map was focused on the land use classes of "Forest"," Built up area" and "Agriculture", as these where the classes that underwent the most change over the period.

3.4 Landscape structure analysis

In FRAGSTATS there are options for what level the user wants to quantify metrics on, either on a patch level, class level or a landscape level. Patches are defined as discrete areas of relatively homogeneous environmental conditions (McGarigal 2015). Class indices quantify metrics for all patches within a class and hence gives an overview of the land use class. Landscape indices quantifies metrics for the whole landscape mosaic (McGarigal 1995). For this study, the metric chosen were on class and landscape level.

3.4.1 Class metrics

For each class the total area, total core area, mean shape index distribution and mean Euclidean nearest neighbor distance were calculated. These metrics are described below.

Total area (TA) was computed to see how the different land use classes have changed in area over time. Total area for a class (i) is the sum of all patches (n) for each class Eq (1), where a_{ij} is the area for patch type ij and converted into hectare. Analyzing the total area for each class can be useful to see patterns of decline or increase of the different land use types and can thus be an indication of the overall development of the landscape (McGarigal 1995).

$$TA_i = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10{,}000}\right) \qquad \text{Eq (1)}$$

Total core area (TCA) is similar to total area but takes into consideration that not all area of a patch/habitat/ecosystem is ecologically effective or has the same function. The core areas indicate the actual effective interior part of the patch, and within a patch there can be one or multiple internal core areas. The core area metrics are based on an edge to interior ratio as the interior area and the edge area of a patch is often separated within landscape ecology due to the difference in function that they have in the landscape (McGarigal 1995; Walz 2011; McGarigal 2015). The total core area of a patch is therefore calculated as the area beyond the width of the perimeter of a patch (user specified value) i.e. it counts the edge/perimeter of a patch as an area instead of a line and is hence affected by both size and shape of the patch (McGarigal 2015). The total core area is the total area minus the width of the edge area (40 meters) Eq (2), where a_{ij}^c is the core area for patch type *ij* and converted to hectares. Total core area can be used as an indication of habitat quality for areas of high nature values or how much of a patch that is ecologically effective. For example, the total area of one or many patches could be of sufficient size to effectively support a species population or to facilitate a type of ecosystem service. However, at the same time it may not have a large enough interior of appropriate core area and can therefore not be able to provide its function to the landscape. Hence, when doing an analysis of land use change over time, it could be an interesting indication of how areas of high nature values has been maintained, enhanced, or depleted (McGarigal 1995).

$$TCA_i = \sum_{j=1}^{n} a_{ij}^c \left(\frac{1}{10{,}000}\right) \qquad \text{Eq (2)}$$

Mean shape index distribution (SHAPE) is computed to find the average shape complexity for the different land use classes. The mean shape index describes the average shape complexity for a class by calculating the patch shape using the patch perimeter and patch area and then by doing a comparison of the patch with a regular square shape of the same size as the patch Eq (3), where p_{ij} is the perimeter (m) of patch *ij* and a_{ij} is the area (m^2) of patch *ij*. The output of the calculation is a unitless value representing the average shape complexity for each class starting from 1. If the result equals 1, the average patch shape complexity is of standard square shape, and as the value exceeds 1 the average shape of the patches become more complex. The shape complexity of a patch or a class is interesting as it can indicate whether a patch or class has been naturally developed or affected by anthropogenic factors. Generally, patches that are of simpler shape (Shape≈1) have been altered or structured by humans and more complex shapes (Shape>1) are more untouched and natural (McGarigal 1995).

$$SHAPE_{ij} = \frac{.25\, p_{ij}}{\sqrt{a_{ij}}} \qquad \text{Eq (3)}$$

Euclidean nearest neighbor distance mean (ENN) is computed to quantify the average patch isolation of each of the land use classes. The mean nearest neighbor distance describes the average distance between a focal patch and the nearest neighboring patch from the same class. This is calculated using Euclidean distance i.e. the shortest straight line between the center cells of two patches Eq (4), where h_{ij} is the distance (meters) from patch *ij* to the nearest patch of the same class. The output is expressed in average distance (meters) between patches within a land use class and can be seen increasing when a patch type become more isolated and vice versa. This metric is a good indicator of how isolated a class is and can also be interesting to look at when discussing fragmentation and connectivity of the landscape mosaic (McGarigal 1995).

$$ENN = h_{ij} \quad \text{Eq (4)}$$

3.4.2 Landscape metrics

The landscape indices quantified on a landscape level were the diversity metrics Shannon´s diversity index and Shannon´s evenness index. The diversity metrics computed in FRAGSTATS are based on richness and evenness. Richness is a measure for the amount of different patch types within the landscape mosaic. Evenness is a measure for the area distribution of the different patch types within the landscape mosaic (McGarigal 1995).

Shannon´s diversity index (SHDI) was computed to quantify the landscape composition regarding diversity. It was calculated using the patch richness (number of different patch types) of the area and the proportional distribution of the different patch types Eq (5), where P_i is the proportion of the landscape occupied by patch type *i*. The output is expressed with a unitless value in the range, $SHDI \geq 0$ with no limit. When *SHDI=0*, there is no diversity. When *SHDI > 0* the landscape composition is becoming more diverse as the index value increases from 0. The metric is usually applied to estimate landscape diversity change of an area over time or to compare the diversity between different areas (McGarigal 1995, 2015). It has previously been used as an assessment of biodiversity in form of specie richness and was proven to be a good estimator especially for floristic diversity (Walz 2011). The SHDI was calculated for each year and made into a plot over time. The coefficient of determination R^2 was calculated with a linear regression line and the Pearson's correlation coefficient (R) was computed. The significance of the correlation was tested by doing a normal distributed confidence test using confidence level 0.05, standard deviation, and sample size. The confidence interval was tested against the sample population average.

$$SHDI = -\sum_{i=1}^{m}(P_i \ln P_i) \quad \text{Eq (5)}$$

Shannon´s evenness index (SHEI) quantifies landscape diversity based on how evenly distributed the landscape is. It is calculated by dividing the observed diversity with the maximum diversity for a set of patch types within the landscape mosaic Eq (6), where P_i is the proportion of the landscape occupied by patch type *i* and *m* is the number of patch types present in the landscape. The output is expressed with a unitless value between 0 and 1. When the index is equal to 0 there is no evenness and as the value rise towards 1 the landscape become increasingly evenly distributed. The index is applied the same way as Shannon´s diversity index (McGarigal 1995, 2015). The SHEI was calculated for each year and made into a plot over time. The coefficient of determination R^2 was calculated with a linear regression line. Also Computed was Pearson's correlation coefficient (R). The significance of the correlation was tested by doing a normal distributed confidence test using confidence level 0.05, standard deviation, and sample size. The confidence interval was tested against the sample population average.

$$SHEI = \frac{-\sum_{i=1}^{m}(P_i \ln P_i)}{\ln m} \quad \text{Eq (6)}$$

Before choosing metrics to analyze and running FRAGSTATS, some initial settings were applied. FRAGSTATS was run with the no sampling method and was enabled to calculate patch, class, and landscape level metrics. For total core area a user specified edge depth of 40 meters was applied for all land use classes. The edge depth was based on previous studies that used core metrics. The studies calculated core area for different types of land use classes (mostly forest) and used a value between 25-100 meter edge depth depending on type and age of the forest (Aune et al. 2005; Harper et al. 2005; Ribeiro et al. 2009). The 40-meter fixed value was chosen as most of the important protected areas within the study area was forest. Since the interpretation was generalized with no consideration to age or type of forest, an intermediate value was set. On class level the model ran the metrics total area, total core area, mean shape index and mean Euclidean nearest neighbor distance. On landscape level the model ran the metrics total area, Shannon´s diversity index and Shannon´s evenness index

4 Results

4.1 Land use interpretation 1940-2019

The land use in 1940 was dominated by “Agriculture” (89%, Figure 2a), whereas “Forest” was only covering 8% of the study area mostly concentrated in the south-east with some sporadic patches spread out over the area. “Built up area” was covering 1% of the area located in the center of the map (Södra Sandby) as well as in the south (Dalby). “Water” was represented by dams, a river, and many mash pits within the agricultural patches and was together with “Roads” covering about 2% of the total area.

In 1973, “Agriculture” covered 84% of the total land use, whereas “Forest” covered 11% of the total study area with the majority situated in the south east (Figure 2b). Substantial areas of “Built up area” can be found in the center and south of the map. “Built up area” covered approximately 3% of the study area.

In 2004 the major classes covering the area were “Agriculture” with 82% and “Forest” with 11% of the total landscape (Figure 2c). “Built up area” covered circa 4% of the total cover and “Water”/ “Roads” classes 3%.

In 2010, “Agriculture” covered 78% of the total area whilst “Forest” covered 14% and “Built up area” about 5% (Figure 2d). “Water” and “Roads” covered approximately 2% of the study area.

In 2019, the land use distribution was near identical to year 2010 with “Agriculture” covering approximately 78% of the total area. “Forest” covered 14%, “Built up area” covered 5% and “Roads” and “Water” covered 2% (Figure 2e).

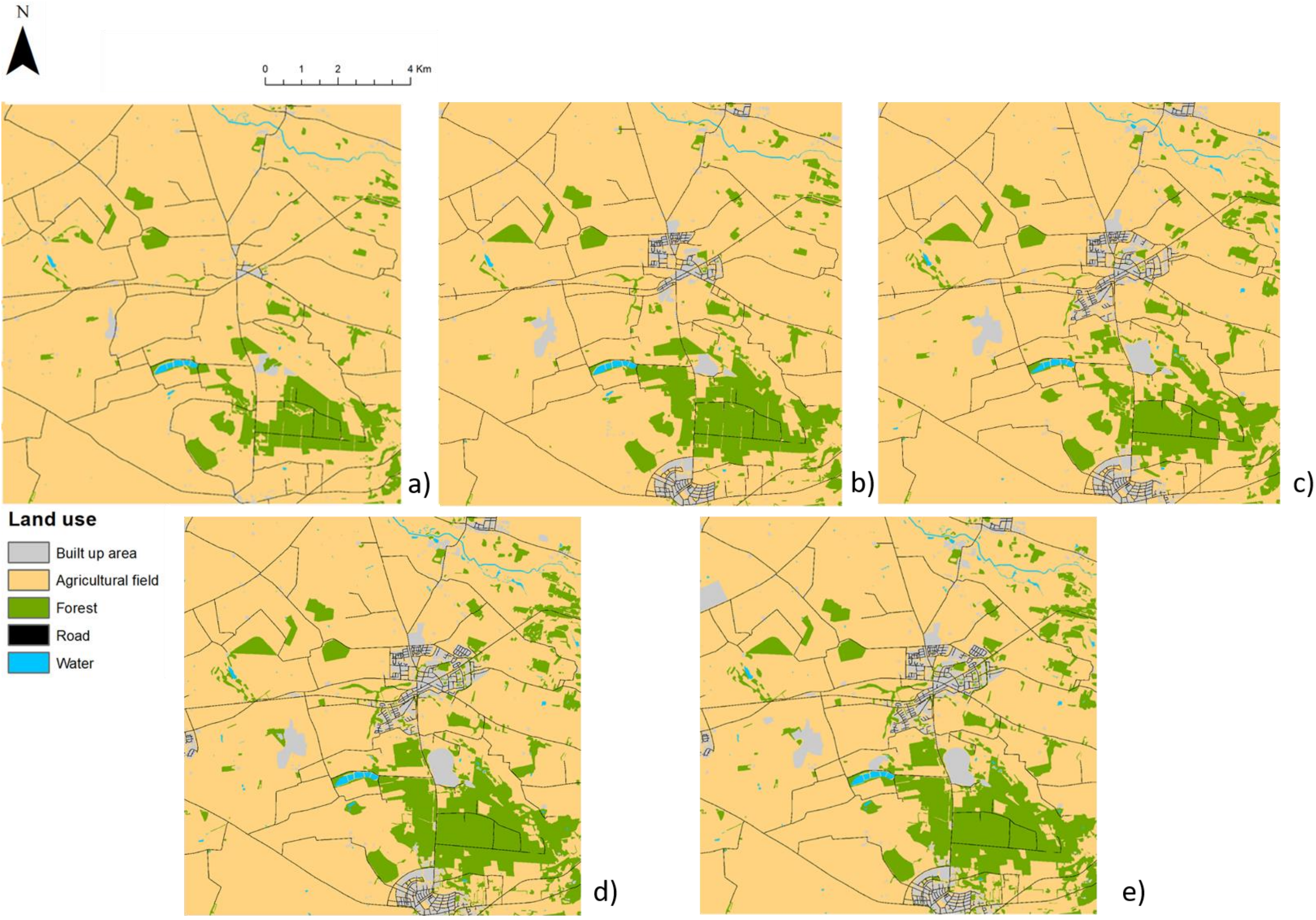

Figure 2: Land use in Södra Sandby year a) 1940 b) 1973 c) 2004 d) 2010 e) 2019; where Gray="Built up area", Light yellow=Agriculture, Green=Forest, Black=Road, and Blue=Water. Based on land use interpretation of orthophotos. Full size images found in appendix (Figure A2-A6).

Land use change 1940-2019

Between year 1940 and 2019, "Built up area" increased from 100 to 524 hectares i.e. by 424%, with the largest increase in 1940-1973 (Table 2). "Agriculture" remained the dominant land use over the whole period, although it experienced a decrease in area of 11% (from 8914 ha in 1940 to 7780 ha in 2019, Table 2). "Forest" increased by 628 hectares i.e. 80% over the period (from 785 ha in 1940 to 1413 ha in 2019, Table 2). "Water" area increased by 35% over the period. The development of "Water" was mostly found from smaller streams or ponds/pits in the landscape as the greater water courses have undergone little to no change over the period. "Roads" increased by 43.6% over the period. The major alterations to the land use from 1940 to 2019 was transitions from "Agriculture" to either "Built up area" or "Forest" (Figure 3). All growth of "Forest" cover from 1940 was derived from a conversion of "Agriculture" (light green, Figure 3). Almost all expansion of "Built up area" since 1940 was constructed on prior "Agriculture" (light red, Figure 3), with a couple instances of "Forest" turned into "Built up area" (lime green, Figure 3).

Table 2: Total area for each individual land use class 1940-2019. Area is given in units hectares.

Total area (Ha)					
Year	Agriculture	Forest	Built up area	water	road
1940	8914	785	100	37	164
1973	8387	1098	279	34	202
2004	8223	1093	418	43	223
2010	7841	1399	473	52	235
2019	7780	1413	524	50	233

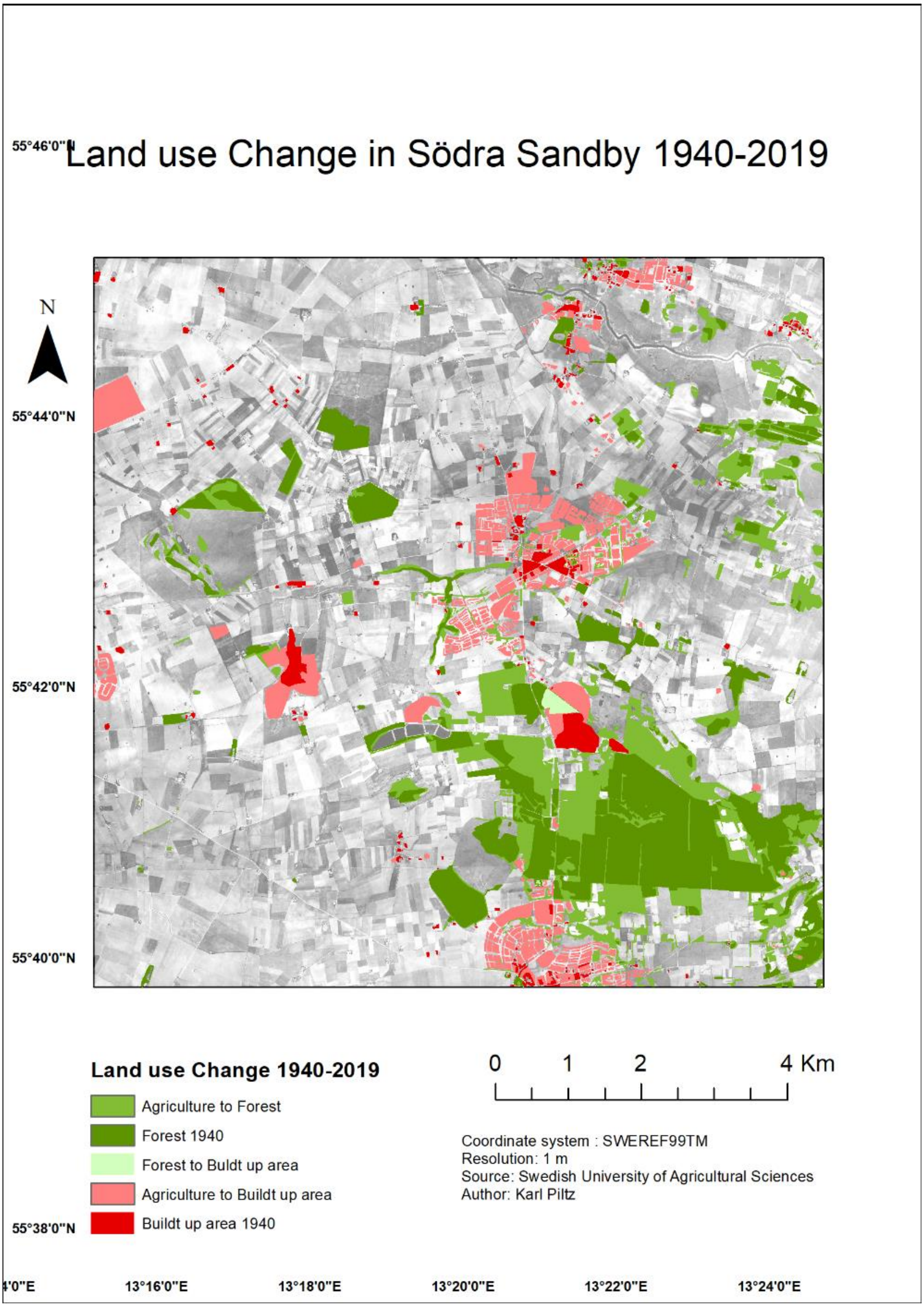

Figure 3: Land use change in Södra Sandby since 1940-2019; where Light green=Agriculture to Forest, Dark green=Forest cover 1940, Lime Green=Forest to Built up area, Light red=Agriculture to "Built up area", and Red="Built up area" 1940.

4.2 Landscape structure analysis

The total core area of “Agriculture” has decreased by 1403 hectares since year 1940, i.e. by 16%. “Forest” has since 1940 increased in core area by 364 hectares; an increase of 101% (Table 3). “Built up area” has increased with 117 hectares, an increase of 780%, and “Water” with 8.7%. There was a decrease of total core area within the agricultural class, however a positive pattern of increased total core area of the other land use classes. Core area is connected to the total area of the same patch and will increase together; however, it can be limited by the patch shape as a higher complexity influences the edges of a habitat and thus also the core area.

Table 3: Total core area for each individual class 1940-2019. Area shown in the unit hectares.

Total core area (Ha)					
Year	Agricultural field	Forest	Built up area	Water	Road
1940	7178	359	15	4.1	0
1973	6592	589	54	4.1	0
2004	6231	528	90	3.3	0
2010	5818	707	99	4.4	0
2019	5775	723	132	4.5	0

The mean shape index of “Agriculture” has increased over time from 1.45 in year 1940 to 1.61 in 2019 (Table 4). “Forest” mean shape index has increased from 1.74 to 1.84. “Built up area” has increased from 1.33 to 1.44. “Water” has increased from 1.49 to 1.65 in 2019. The shape of the different types of patches over time has shown an increase in shape complexity in all land use classes, except “Roads”. “Built up area” is over the period consistently represented by an intermediate shape complexity which is what is expected, as urban areas often have simpler rectangular shapes for effective planning and fitting. The mean shape complexity of “Forest” has been consistently intermediate-high over the period.

Table 4: Mean shape index for each individual class 1940-2019. The mean shape index describes the average shape complexity for a class with a unitless value representing the average shape complexity for each class starting from 1 (i.e. shape complexity is of standard square shape). As the index value exceeds 1 the average patch shape of the class become complex.

Mean Shape index					
Year	Agriculture	Forest	Built up area	Water	Road
1940	1.45	1.74	1.33	1.49	15.63
1973	1.58	1.71	1.37	1.78	25.95
2004	1.57	1.75	1.41	1.74	27.18
2010	1.59	1.86	1.45	1.61	17.29
2019	1.61	1.84	1.44	1.65	14.57

The Euclidean nearest neighbor distance mean_for “Agriculture” increased from 4.6 meters in 1940 to 5.5 meters in 2019 (Table 5). “Forest” has decreased mean distance over time from 93.5 meters to 52.3 meters in 2019. The distance for “Built up area” has decreased from 105 meters to 37.2 meters. “Water” has decreased from 276.5 meters to 237.4 meters. “Roads” has increased from 83 meters to 92.4 meters in 2019. “Agriculture” has become more isolated or fragmented i.e. the nearest distance between neighboring patches have increased over time with a change of a mean distance of 0.9 meters between patches. This is a very low number, and hence the connectivity of this landscape class is very high and has been continuously over the monitored period. However, it is shown that even though the connectivity is high, it is becoming more fragmented, as “Built up area” and “Forest” has become less isolated and fragmented.

Table 5: Mean Euclidean nearest neighbor distance for each individual class 1940-2019. Units shown is meters.

Euclidean Nearest Neighbor Distance mean (m)					
Year	Agriculture	Forest	Built up area	Water	Road
1940	4.6	93.5	105	276.5	83
1973	5.3	88	57.5	420.8	208
2004	4.9	91.9	38.6	276.8	208
2010	5.5	55.4	36.4	257.1	117
2019	5.5	52.3	37.2	237.4	92.4

The Shannon´s diversity index increased from 0.44 in 1940 to 0.74 in 2019 (Figure 4). A pattern of increased diversity can be seen in the index over the period, with the greatest increase in diversity is found between the year of 1940 and 1973. The diversity index has changed over the period from 0.44 in 1940 to 0.74 in 2019. The trendline have an R^2 of 0.95 showing a high positive correlation (Figure 4) (Table 6). After testing the confidence level, the correlation was found to be statistically significant (Table 6).

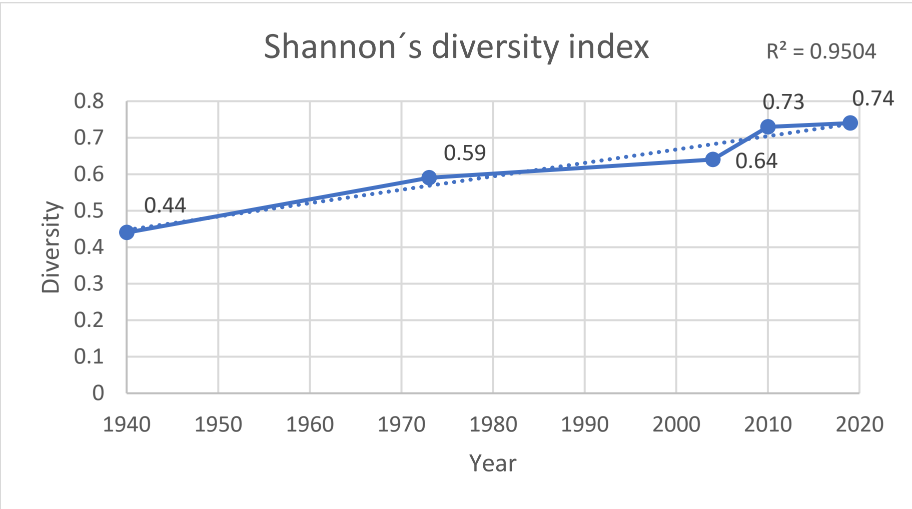

Figure 4: Shannon’s diversity index values plotted for years 1940-2019. Years displayed along x-axis; Diversity expressed as a unit of information along the y-axis. Linear regression line represented by checkered line with the coefficient of determination R^2 in the top right corner.

The Shannon´s evenness index showed an increase between 1940-2019, from 0.27 in year 1940 to 0.46 in year 2019 (Figure 5). The index shows a slight increase in evenness in the landscape distribution over the period, with the largest increase observed between year 1940 and year 1973. In year 2019 the index has reached 0.46, indicating a low-intermediate evenness, with a continuous pattern of higher evenness at every year since 1940. The trendline have an R^2 of 0.95 showing a high positive correlation (Figure 5) (Table 6). After testing the confidence level, the correlation was found to be statistically significant (Table 6).

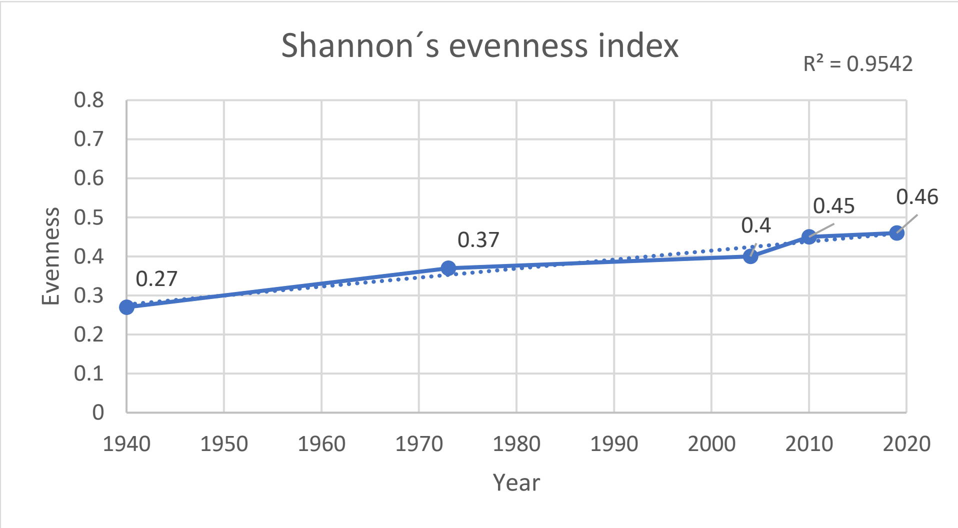

Figure 5: Shannon´s evenness index values plotted for the years 1940-2019. Years displayed along x-axis; Evenness displayed along y-axis. Linear regression line represented by checkered line with the coefficient of determination R^2in the top right corner.

Table 6: Values and results from testing of correlation and significance of the trends of Shannon´s diversity index over time and Shannon´s evenness index over time. Computed was Pearson's correlation coefficient (R) and the coefficient of determination (R^2). The significance of the correlation was tested by doing a normal distributed confidence test using confidence level α 0.05, standard deviation, and sample size. The confidence interval was tested against the sample population average.

SHDI		SHEI	
Pearson´s correlation coefficient R	0.97	Pearson´s correlation coefficient R	0.98
Coefficient of determination R^2	0.95	Coefficient of determination R^2	0.95
Standard deviation	0.11	Standard deviation	0.07
Sample population average	0.628	Sample population average	0.39
Confidence level α	0.05	Confidence level α	0.05
Sample size	5	Sample size	5
Confidence interval +-	0.096	Confidence interval +-	0.06

5 Discussion

5.1 Land use change, structure & diversity

The results of the spatial-temporal analysis of the study area show that the land use has changed between 1940 and 2019 (Figure 2, Table 2). In the land use maps (Figure 2) over the whole period the largest area development is the increase and expansion of built up areas. This expansion can be linked to the development of Södra Sandby (and Dalby), as the largest increase of ”Built up area” was found between 1940-1973 (Table 2), the same period as Södra Sandby was integrated into Lund municipality and experienced a population increase of 75% (Lunds_kommun 2006). Furthermore, the decrease of agriculture over the period could also be explained by the urban expansion of the area (Figure 3). As the population increased, the need for residences also grew, therefore, agricultural land was sold during the 1940-1973 period to make way for more built up areas (Lunds_kommun 2006). This is reflected in the results as there was a decrease in “Agriculture” area but a large increase of “Built up area” during this period (Table 2). Additionally, most of the expansion of Södra Sandby was found to be a transition from agriculture to build up (Figure 3). In spite the urbanization of the area, forest has been maintained and has increased over the period. This could possibly be linked to the efforts of Lund Municipality to incorporate green area/structure in and around the towns when expanding, with more wooded areas outside the town perimeter as well as corridors and parks that have been integrated as a part of the urban areas (Lunds_kommun 2017, 2018, 2020). Another explanation for the development of forest could be that the area contains multiple protected areas that have protection on both a national level and by the European Natura2000 protection and have hence been undisturbed during expansions (Sundseth and Creed 2008; Lunds_kommun 2017, 2018).

The total core area of the different patches shows the same patterns and development as the total area over the period. Core area is a metric very similar to the total area calculation, however, is limited by edge-core ratio of the patch (McGarigal 1995). Hence, the increase or decrease of total core area is connected to the total area of the same patch and will develop together (McGarigal 1995). It is therefore affected in the same way by land use change as total area, however can sometimes be limited due to shape complexity (McGarigal 1995). A higher shape complexity can influence the edges increasing the edge effect (i.e. edge depth) of a habitat and thus also the core area (McGarigal 1995). Another thing to note is that shape complexity is often influenced by fragmentation or isolation in the landscape (Aune et al. 2005). As the landscape or a land use type gets more fragmented this usually leads to a higher shape complexity with more irregularity (Aune et al. 2005). The higher irregularity of the shape in turn often leads to more edge area/effect and hence also a decline in core area (Aune et al. 2005). This could potentially have been a factor for the core area development of the study area, as ”Agriculture” is the only class appearing more fragmented over the period as well as experiencing decline in core area and the other classes less fragmented with an increased core area. The increase of core area indicates that the inner part of a patch that is often associated with the ecologically effective area of a patch have increased (McGarigal 1995; Walz 2011). What ecologically effective means is however difficult to define as it is dependent on what you are relating it to (Kupfer 2012). In previous studies the core area measurement has been successfully used as a proxy to predict specie abundance, climate variables and species richness (Aune et al. 2005; Harper et al. 2005; Ribeiro et al. 2009; Walz 2011). For the purpose of this study ecologically effective is defined as the area suitable to facilitate flora, fauna and processes that are only acclimated to interior patch conditions (Walz 2011).

The changes in the land use can possibly be seen in the Shannon´s evenness index (Figure 5). As ”Agriculture” has been replaced by “Built up area” and “Forest” (Lunds_kommun 2006) (Figure 3), this is somewhat reflected in the index. As the largest increase of evenness is seen between year 1940 and year 1973, the same period as the major urbanization was experienced together with the turnover of agricultural land (Lunds_kommun 2006). The continuous positive pattern indicates that the land use change over the period has made the landscape more evenly distributed.

Similarly, a pattern of increased landscape diversity can be seen in the Shannon diversity index (Figure 4). As Shannon´s diversity index is based on both richness i.e. number of different types of land use and evenness i.e. how evenly distributed different land use types are, the positive pattern of landscape diversity could be linked to the evenness index of the landscape and hence also the land use change over the period (McGarigal 1995). As the landscape has become more evenly distributed since 1940 (Figure 5) due to agriculture becoming “less” dominant as well as the increase of built up and forested areas (Table 2), this has most likely also led to a more diverse landscape and has played a significant factor for the positive pattern in the diversity index (McGarigal 1995, 2015).

The results of the mean Euclidean nearest neighbor distance show that the isolation of the different patch types in the landscape have changed over the period. This result could be traced to the land use change over the period, as the pattern of fragmentation in most cases is reflected in the change of total area of the same land use types. The decline of “Agriculture” as an effect of urban expansion has made “Agriculture” more fragmented whilst built up areas can be seen becoming more connected over the period. Similarly, the increase of total area of “Forest” has resulted in a higher connectivity in 2019 (Table 2, Table 5). That fragmentation is affected by land use change is a known feature, and is seen on a global level from the effects of anthropogenic development in the landscape (Estreguil et al. 2013). However, as anthropogenic development like urbanization often leads to a more fragmented landscape with more isolated land use classes (Estreguil et al. 2013). This opposes the results of this study, which point to a more connected landscape over time. This could be explained by multiple factors. Similarly, to the evenness of the landscape, ”Agriculture” has been the dominant class over the period, hence the decline in area and increase of fragmentation of this class could benefit the connectivity of other classes (Lunds_kommun 2006). As much of the forested areas lies within protected parts of the landscape, this land use class could have been left mostly untouched by urban expansion over the period as well as Lund municipality’s effort to implement green corridors and parks in urban planning could have benefited the connectivity of forest in the area (Sundseth and Creed 2008; Lunds_kommun 2017, 2018). A similar study was handed out by Hjertkvist and Persson (2020), where they analyzed the development of green structure, connectivity, and land use change between year 1940-2018 in Dalby, Lund municipality (Persson and Hjertkvist 2020). They found similar results, where through major expansion of urban areas, the landscape had become more connected over time (Persson and Hjertkvist 2020).

The shape complexity of the landscape follows the same pattern as the other parameters and reflects a development that could be expected when looking at the land use change over time. Anthropogenic alteration of the landscape is often marked by more simple shapes like rectangles or quadrants for the purpose of effective planning and structure for management (McGarigal 1995). This is reflected in the landscape as “Built up area” continuously over the period is marked by a lower shape complexity. The increase in shape complexity of the "Agriculture" could be an effect of the fragmentation and areal decrease due to the land use change from "Agriculture" to "Built up area" over the period (McGarigal 1995; Lunds_kommun 2006). The increase of shape complexity of "Forest" indicates a more natural development of this land use class. This follows the same pattern as for total area and fragmentation, which could again be explained as most forested areas are protected and the urban development have been planned around these areas (Sundseth and Creed 2008; Lunds_kommun 2017, 2018).

5.2 Biodiversity

The different results of the landscape indices have shown positive development regarding landscape structure and composition (Table 2-5 and Figure 4 & 5). This could in theory have an indirect influence on the biodiversity of the area (Walz 2011; Magurran 2013). It is of course impossible to accurately represent biodiversity without a thorough knowledge of the flora, fauna, and specie distribution of the area. However, the landscape diversity and structure can potentially give an indication and overview of an expected species richness and diversity based on patterns from landscape diversity and evenness indexes as well landscape structure parameters that positively benefits specie richness and hence potential biodiversity (Magurran 2013).

The positive pattern of increased area and core area (besides agriculture) (Table 2 & 3) could also potentially indicate a positive tendency in species richness. With increased total area there is a possibility for a higher richness and distribution of species as it creates more opportunity for movement, reproduction/pollination, and more protection (Aune et al. 2005; Walz 2011). Total core area which gives an indication of the size of the ecologically effective area of a patch has been seen to increase for most classes over the period. This is positive for areas of high nature values and thus means that especially protected areas have possibly been well-maintained (Walz 2011). For species richness and distribution this is of course positive. The positive patterns shown from the area indices could also indicate a higher biodiversity as there is a difference between species thriving at the edge of a patch and in the core of a patch. As the ratio of edge to core of a patch become more distinct, together with increased area, this would potentially indicate a greater potential specie distribution/richness due to the distinct separation of patch core, patch edge and transitional zones i.e. ecotones between patches (Walz 2011). Edges and transitional zones can be very beneficial for biodiversity, in fact for floristic studies it has been found that highest biodiversity can be found along habitat edges as well as ditches along roads (Walz 2011). Moreover it would be important for future studies using actual empirical data to not only look at edges as buffers for core area metrics but calculating edge metrics as well (McGarigal 1995; Walz 2011). When only using edges as the edge effect of core area it only estimates it as boundaries in the landscape when they in fact are very important parts of the overall biodiversity (Walz 2011).

The positive pattern in isolation/fragmentation of the landscape (besides agriculture) (Table 5) could also be positive for species richness, evenness, and diversity. This is because as isolation of landscape patch types would cause specie population isolation as well, by inhibiting movement and distribution (Walz 2011). As the overall pattern shows a more connected landscape over time this could indicate a positive and beneficial pattern for specie richness and biodiversity (Walz 2011). "Agriculture" has over the period continuously been the dominant land use class of the area (Figure 2, Table 2). Isolation or fragmentation of agriculture could hence be a positive change for the area regarding specie distribution and biodiversity, as it would allow more variation of the landscape (Fahrig 2003). However, the increased isolation of agriculture has been small. The impact that it could have on the whole landscape mosaic could therefore be questioned. The class of "Forest" has become less isolated over the period. This is important to this area since most of the protected areas with high conservation values are mainly forest. A higher continuity of the "Forest" class could hence be very important for the specie richness overall as well as for the support of important species within the Natura 2000 and nature reserves of the area.

Shape complexity of the land use classes has shown to increase over the period (Table 4). This could have a positive effect on specie richness and biodiversity as higher shape complexity of a patch and transitional zones between patches enhance richness and diversity and has been shown to be especially potent for plant species richness (Walz 2011).

The Shannon's diversity and evenness indexes both show positive patterns of a more diverse and evenly distributed landscape over time (Figure 4 & 5). The increase of landscape diversity could of course in theory be reflected in biodiversity as the structure of the landscape is an important part of ecological diversity and biodiversity (Walz 2011). Hence, the increased overall diversity and evenness of the landscape could also indicate an increase of biodiversity because of this (Walz 2011). However, it is important to note that the positive trend in Shannon´s diversity index does not necessarily have to equal a higher biodiversity. The area has been and is still dominated by "Agriculture". The decline in area of "Agriculture" has been a factor to a more evenly distributed landscape, though richness i.e. number of patch types in the area has not changed. Two of the classes that have increased in the landscape are "Built up area" and "Roads". These are not patch types that are natural and does not function as normal ecosystems and could instead be boundaries or disturbances to biodiversity. Hence the increase of these urban patch types and moreover the increase of SHDI does not automatically mean higher biodiversity (McGarigal 1995). Also SHDI is sensitive and heavily influenced by rare patch types and due to the dominance of "Agriculture" the index value could have been overestimated by the less occurring classes in the landscape (McGarigal 2015).

5.3 Discussion summary

For the landscape metrics that have been quantified to monitor the response of land use change over time to have any value, it is important to understand what has been quantified. One could and should question the ecological relevance that the indices have to the landscape (Kupfer 2012). Many of the metrics are inherently based on a species or process specific level, which requires a thorough knowledge of the relationship between phenomena and landscape (Aune et al. 2005; Kupfer 2012). In this study there were no consideration for any specific phenomena or process, hence, the understanding of the limitations to the ecologic relevance of the results is key (Kupfer 2012). The results do not evaluate function of the landscape, but instead gives an overview of the structure of the landscape. This is an entity that is integral when trying to understand landscape functioning and how anthropogenic changes have affected the landscape over time (Walz 2011; Kupfer 2012; Biedinger 2013). There has been a shift towards a more holistic approach when evaluating a landscape for management and conservation purposes (Section 1) (Turner et al. 2001; Biedinger 2013). Hence, for the purpose of evaluating the landscape in regards to Lund municipality´s and Södra Sandby´s expansion plan

(Lunds_kommun 2018), structure is only one piece of the puzzle. This study has given an overview of the landscape structure and how previous land use change has affected said structure. There is however much more to be explored about how the structure affects function. To do a full constructive evaluation of the area, more research must be done, testing the landscape indices against important process and/or species-specific attributes in the study area. Moreover, a larger documentation on a landscape ecology level would be needed for Lund municipality to meet and fulfill their vision of a greener future and expansion that they strive to achieve from 2040 and forward (Biedinger 2013; Lunds_kommun 2017, 2018, 2020).

5.3.1 Sources of error

When conducting this study, there where multiple issues met along the way that could potentially affect the results. The interpretation was done by handling a mixture of historical orthophotos, where some of the photos were monochrome (1940, 1973 and 2004) and some were of color (2010 and 2019). This complicated the interpretation of the area as there was more land use types identifiable in 2010 and 2019 than in the monochrome photos. For the interpretation to apply for all years the interpretation had to be generalized into few and broad classes. This could potentially affect the structure analysis, as some of the indices are based on patch richness (number of different land use types).

Another important discussion point is the validity of the results/method of the study. Even though there was a high significant correlation for SHDI over time and SHEI over time there are questions that could be asked about the validity of the results of these indexes. SHDI is a metric that is based on patch richness i.e. number of land use types present in the landscape as well as evenness i.e. distribution of area among the different patch types (McGarigal 2015). Due to the generalization this could potentially have underestimated the diversity index value of the study areas as a greater patch richness leads to a higher landscape diversity. On the contrary, the SHDI computation is also more sensitive to richness and is heavily influenced by scarce patch types in the landscape (McGarigal 1995). In this study area there is few land use classes (5) with a dominance of one class (“Agriculture”). Hence, when calculating SHDI in this area it is possible that the index value has become overestimated as “Agriculture” have become “less” dominant over time. One could also question usage of both SHDI and SHEI in this study. Since the number of patch types i.e. patch richness is constant over the period the only difference between the two is the factor of $\frac{1}{(\ln m)}$. They are very similar, and a simple interpretation of SHEI is that the higher evenness index value the higher the diversity is (McGarigal 2015). However, SHEI focus on the evenness aspect of landscape diversity while suppressing the influence of richness which offers a somewhat different interpretation of landscape diversity. Also, the SHEI output is the proportion of maximum evenness in the range 0-1 which makes interpretation of the results more straight forward than SHDI (McGarigal 2015).

6 Conclusion

The aim of this study was to map the land use change between 1940-2019 in Södra Sandby, Lund municipality. To analyze the landscape structure change over time as an effect of anthropogenic land use change and discuss what implication it may have on biodiversity. The study shows that there have been considerable changes in the landscape over the period. Agriculture has become less dominant because of urban expansion and growing forest.

The study also shows that the landscape structure has changed because of the land use development in the area. The landscape structure analysis point to that despite previous urbanization, there has been a positive development for the indices of structure that was analyzed. It shows a potentially more diverse and evenly distributed landscape that has become less isolated over the period. Also, important protected areas of forest have increased in core area and got more natural patch shapes and edges. Although not quantifiable the development of structure for some of the computed indices could potentially indicate that the landscape facilitates opportunity for enhanced specie richness.

The research question *"How has the landscape structure changed in the study area between 1940-2019?"* is answered below:

- The total area and total core area of land use classes have increased (except for agriculture) over the period 1940-2019.

- The landscape has become less isolated/fragmented (except for agriculture) over the period 1940-2019.

- The patch shape (for agriculture, forest, and water) has become more complex over the period 1940-2019 with more irregular and natural shapes.

- The landscape has become more diverse and evenly distributed over the period 1940-2019.

7 References

Aune, K., B. G. Jonsson, and J. Moen. 2005. Isolation and edge effects among woodland key habitats in Sweden: is forest policy promoting fragmentation? *Biological conservation,* 124**:** 89-95.

Biedinger, N. 2013. *Biodiversity: a challenge for development research and policy*. Springer Science & Business Media.

Chapin III, F. S., P. A. Matson, and P. Vitousek. 2011. *Principles of terrestrial ecosystem ecology*. Springer Science & Business Media.

Chapin Iii, F. S., E. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. Reynolds, D. U. Hooper, S. Lavorel, et al. 2000. Consequences of changing biodiversity. *Nature,* 405**:** 234-242.

ArcGis Desktop. ArcMap 10.5.1, ESRI.

Estreguil, C., G. Caudullo, D. de Rigo, and J. San-Miguel-Ayanz. 2013. Forest landscape in Europe: pattern, fragmentation and connectivity. *EUR Scientific and Technical Research,* 25717.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. *Annual review of ecology, evolution, and systematics,* 34**:** 487-515.

Hansen, A. J., R. S. DeFries, and W. Turner. 2004. Land Use Change and Biodiversity. In *Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface,* eds. G. Gutman, A. C. Janetos, C. O. Justice, E. F. Moran, J. F. Mustard, R. R. Rindfuss, D. Skole, B. L. Turner, and M. A. Cochrane, 277-299. Dordrecht: Springer Netherlands.

Harper, K. A., S. E. Macdonald, P. J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Euskirchen, D. Roberts, et al. 2005. Edge influence on forest structure and composition in fragmented landscapes. *Conservation biology,* 19**:** 768-782.

Kupfer, J. A. 2012. Landscape ecology and biogeography: rethinking landscape metrics in a post-FRAGSTATS landscape. *Progress in physical geography,* 36**:** 400-420.

Lunds_kommun. 2006. Tätortsprogram för Södra Sandby.

Lunds_kommun. 2017. Grön infrastruktur och ekosystemtjänster.

Lunds_kommun. 2018. Översiktsplan för Lunds kommun, Del 2 Markanvändning och Hänsyn.

Lunds_kommun. 2020. Grönprogram för Lunds kommun.

Magurran, A. E. 2013. *Measuring biological diversity*. John Wiley & Sons.

McGarigal, K. 1995. *FRAGSTATS: spatial pattern analysis program for quantifying landscape structure*. US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McGarigal, K. 2015. FRAGSTATS help. *University of Massachusetts: Amherst, MA, USA*.

FRAGSTATS 4, University of Massachusetts.

Persson, S., and L. Hjertkvist. 2020. Ett sekel av grönstruktur: grönstrukturens förändringar i Dalby från 1940 till idag.

Peters, D. P., and S. C. Goslee. 2001. Landscape diversity. *Encyclopedia of biodiversity,* 3**:** 645-658.

Ribeiro, M. C., J. P. Metzger, A. C. Martensen, F. J. Ponzoni, and M. M. Hirota. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological conservation,* 142**:** 1141-1153.

SLU. GET (Geographic Extraction Tool) Retrieved 17/04 2020, from https://zeus.slu.se/get/.

Sundseth, K., and P. Creed. 2008. *Natura 2000: protecting Europe's biodiversity*. European Commission Luxembourg.

Turner, M. G., R. H. Gardner, R. V. O'neill, and R. V. O'Neill. 2001. *Landscape ecology in theory and practice*. Springer.

Walz, U. 2011. Landscape structure, landscape metrics and biodiversity. *Living reviews in landscape research,* 5**:** 1-35.

8 Appendix

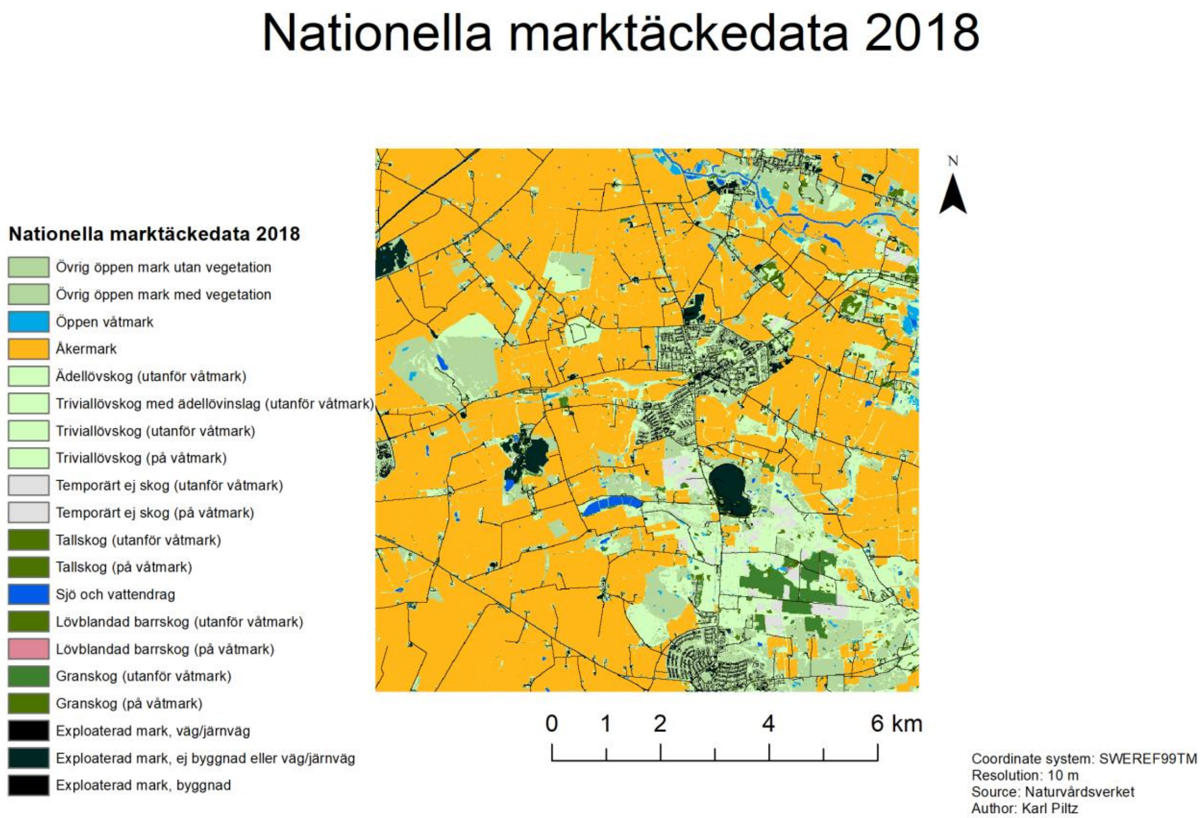

Figure A1: Map showcasing the Land cover of the study area using Naturvårdsverkets "Nationella marktäckesdata 2018.

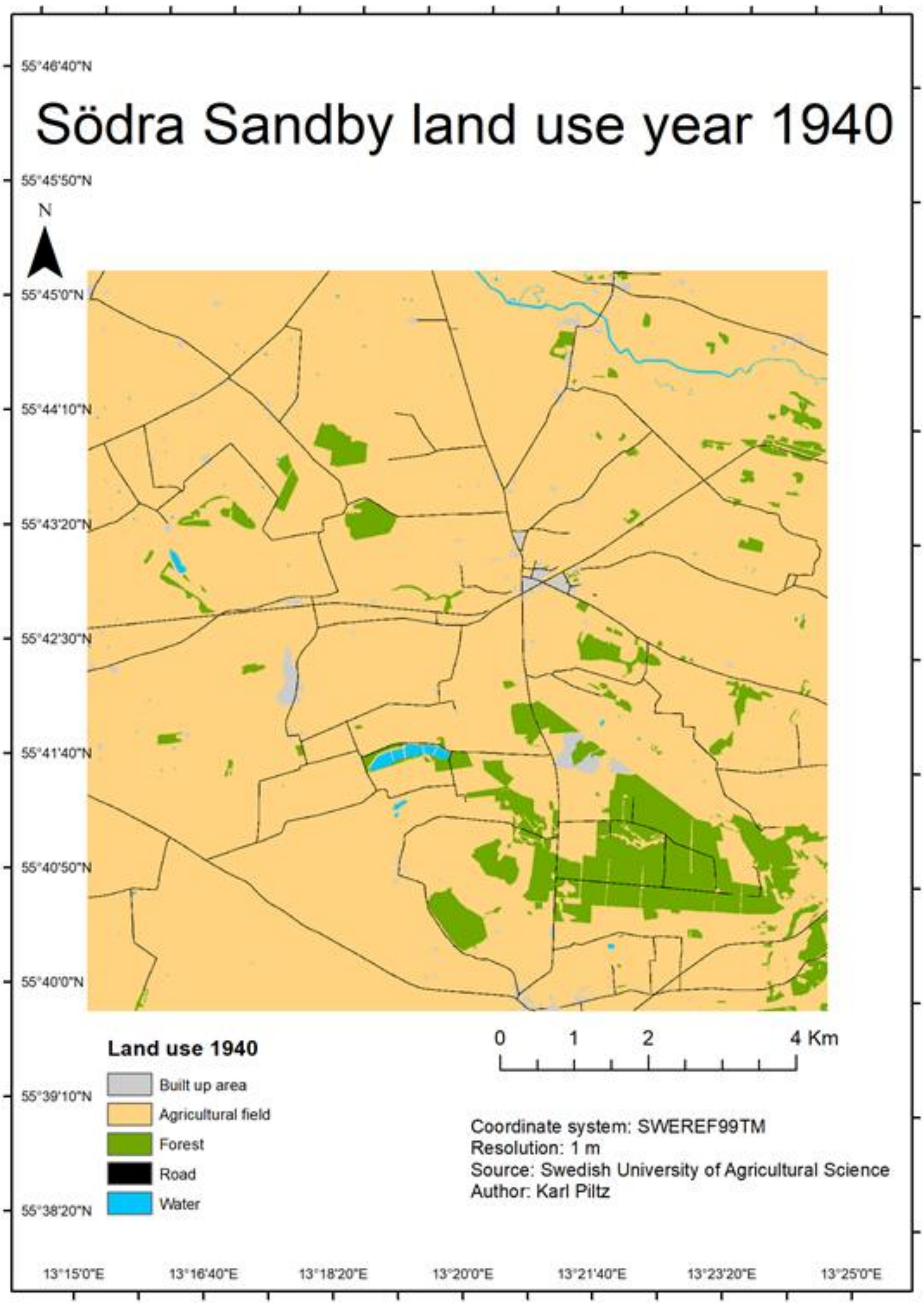

Figure A2: Map displaying the land use in Södra Sandby year 1940.

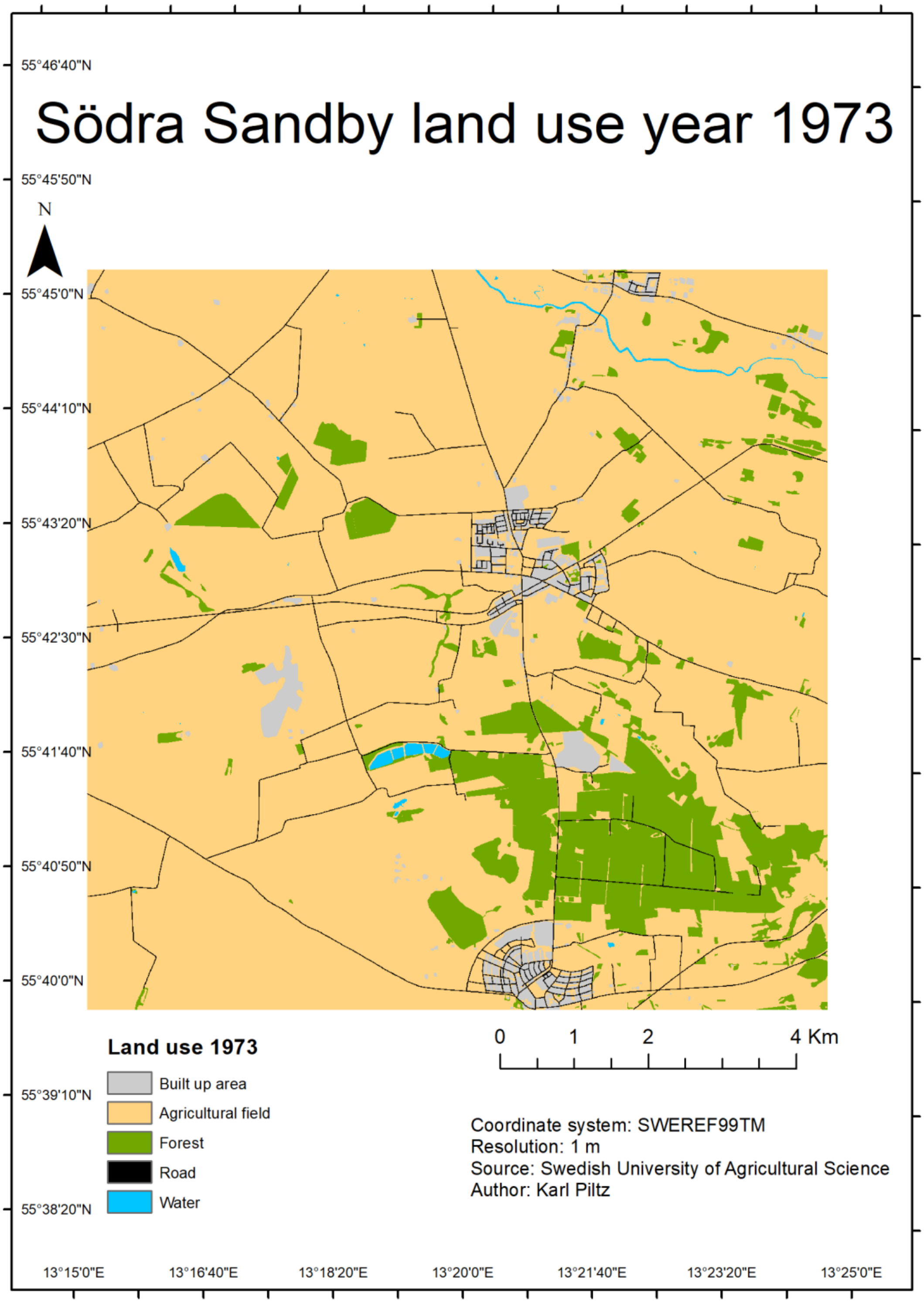

Figure A3: Map displaying the land use in Södra Sandby year 1973.

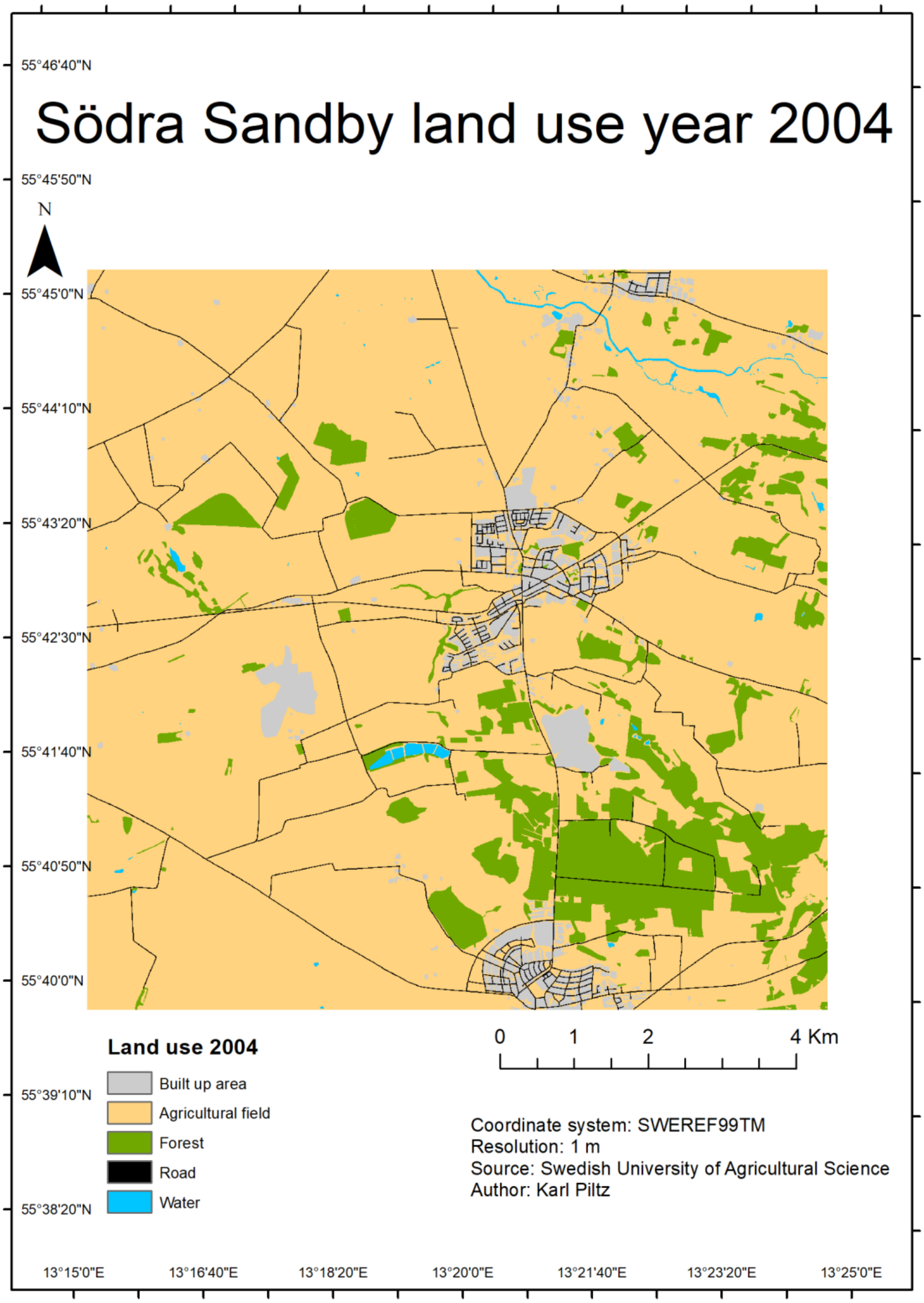

Figure A4: Map displaying the land use in Södra Sandby year 2004.

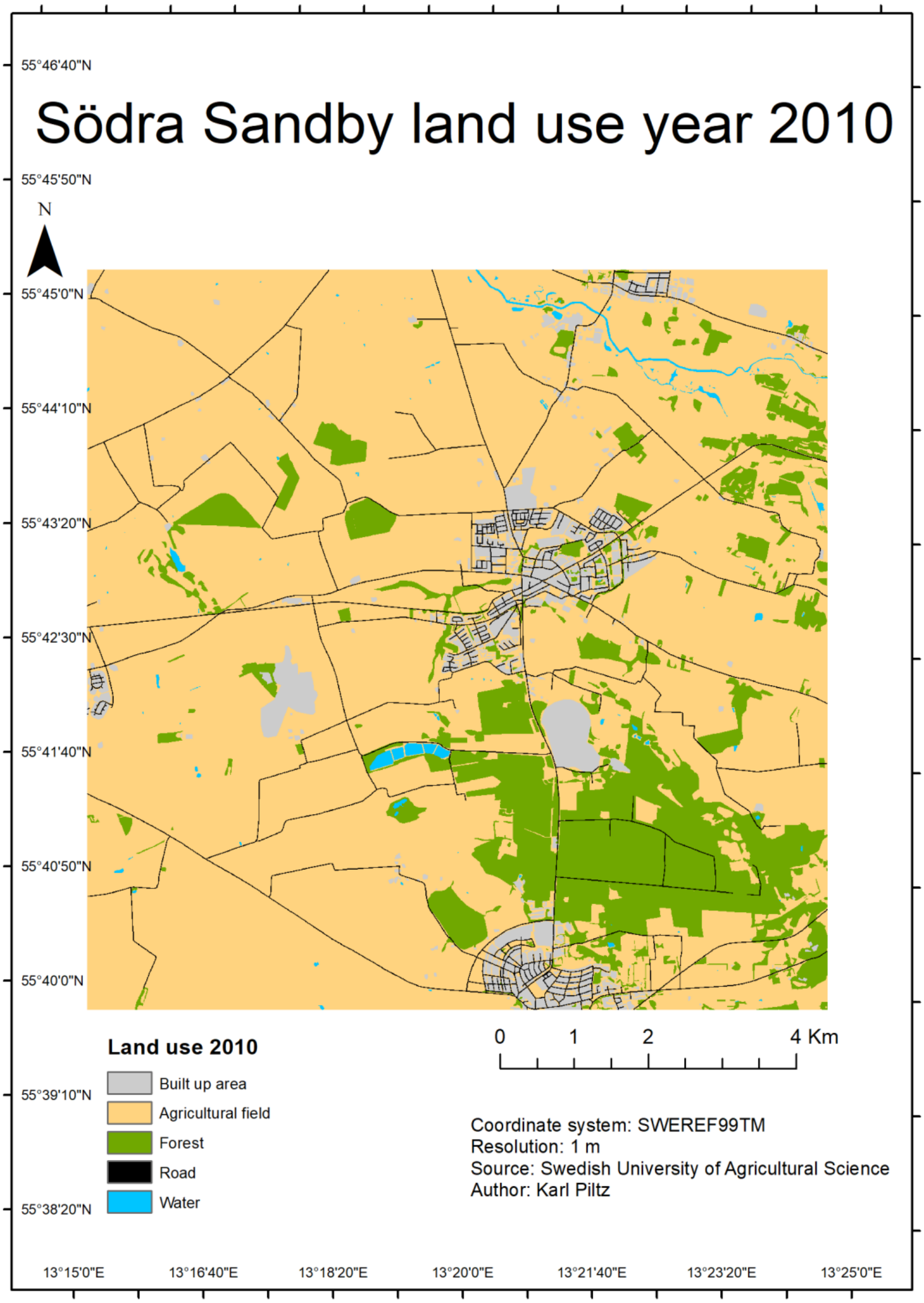

Figure A5: Map displaying the land use in Södra Sandby year 2010.

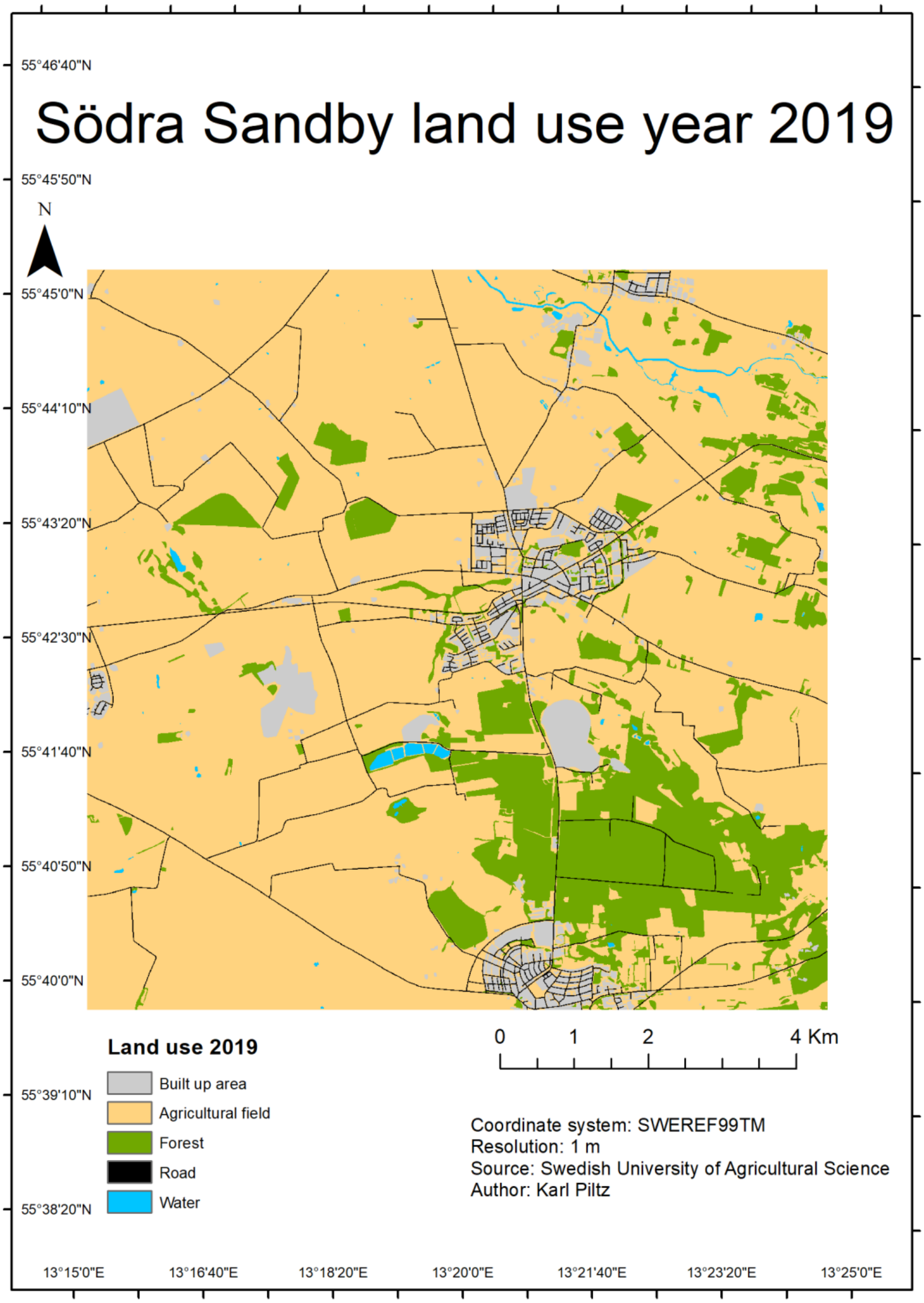

Figure A6: Map displaying the land use in Södra Sandby year 2019.