Chapter 5

Urban Expansion and Public Transport: Implications for Inclusive Development

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Abstract

This project aims to create a better understanding of how different areas of the local economy and the inclusive growth pattern are influenced by the development of public transport, using urbanization process in Southern part of Sweden as an example.

Keywords: Urbanization, Transportation, Inclusive Development, Sweden

1. Introduction

Accelerated population growth puts pressure on land use and increases the risk of urban expansion inadequately connected to public transport capacity. Urban expansion without inclusive policies can put societies in risk where new residential expansion areas become the scene of new phenomena of social exclusion and mobility poverty. Guaranteeing sustainable and inclusive urban development implies, among other things, fair access to the public transport network - and to the main opportunities/activities being reached through it - for all individuals/groups in the whole society.

The present research project, taking advantage of the complementary data and methods involved, suggests a novel approach to incorporate inclusive development and social and spatial equity as core elements while designing accessible public transport networks. Usually, planning practices are based on utility maximization. Hence, policymakers have to make rather ad hoc decisions in order to address obvious equity issues and the social impact related to land-use and housing development; the current project´s approach facilitates this decision-making process in a more integrated manner. Eventually, this approach embraces many aspects of place-based as well as individual-based accessibility - containing housing-land-use planning and the public transport network - that allows for thinking of the public transport system as a social investment, creating a supportive environment in expanding urban areas.

The context of this study is Sweden, a country with a rapidly ageing and shrinking population in rural areas that poses developmental impediments to make it difficult to sustain/develop existing and /new public transport services, especially those having a fixed infrastructure. Losing/lacking public mobility exacerbates the dependence on personal automobiles in rural areas that hinders the promotion of more sustainable modes of transport and exacerbates transport safety for the older segment of the population. Given increased rise in economic disparity, owning and maintaining a personal automobile become, if not always, an unaffordable option for those who are economically unstable. The lack of car mobility deprives them of opportunities to commute to the labour market in a city where public transport is not well operated, and thus limits their job opportunities. Within constrained transport budgets, the efficient development of public transit is inevitable, but it is not easy to eliminate some "voids" in public mobility within urban/rural areas where shared public transport is the solution to fill such voids and enhance mobility equity and efficiency.

Objective of the research

The purpose of the project is to study the impact of public transport on regional and local development using spatial analysis based on three different types of spatial information from Skåne, the most southern region in Sweden. The analysis is based on:

1) Regional travel statistics as well as geographical information describing the public commuter train network expansion,

2) Sales statistics of small houses,

3) Remotely sensed information describing the change of land use. Furthermore, the project has compiled and made available statistical data that contributes to providing improved estimates of the changes in regional growth in relation to the expansion of public transport, with the focus on Skåne.

The project gives an idea of how the expansion of public transport and changing commuting habits affect the region's development over time.

The work is based on spatial quantitative information using the Geographic Information Systems (GIS) to compile this information in a geocoded database that enables statistical calculations, time series analyses, and visualization in a map format of the information and spatial analysis. The strength of using a geocoded databases is that they are relatively easy to update and make available to other researchers. The study uses spatial analysis by analyzing local spatial conditions. An accessibility analysis has been developed to calculate how accessibility in Skåne has changed through expansion of the commuter train network. The time period studied,1995 to 2015, is limited by the availability of the different data sets. From the mid-1990s, Sweden has experienced an exceptional growth rate with growth doubling, which indicates that Sweden had experienced the rationalisation phase during the last fifteen years when the economy was evolving into a more services based economic structure.

This project aims to create a better understanding of how different areas of the local economy and the inclusive growth pattern are influenced by the development of public transport.

Structure of the report

The structure of the report is divided into four main parts; i) a review the literature regarding sustainability from the policy perspective, ii) data and analysis providing visualization of the data used in order to offer a learning opportunity outcome from the interlinkage between the change in land use patterns and public transport development, and lastly, iii) conclusions.

2. Literature review

The starting point for the literature review is the study of how geographic space has been applied in a variety of studies, including economics, urban planning, and economic history (Keola et al. 2015; Bustos et al., 2015; Potter, 2004). An important aspect of the study of geographic space is the scaling property indicating that small objects are far more numerous than large ones, i.e., the size of the objects being studied is extremely diverse. The concept of scaling resembles a fractal in geometric terms and power law distribution from the perspective of statistical physics. In the study of geographic space, the most important concept is geographic representation, which represents or partitions a large-scale geographic space into numerous small pieces, e.g., vector and raster data in conventional spatial analysis (Haggett 1965). Geographical representation can be seen as a type of ontology, by which we can specify and conceptualize the real world (Hägerstrand 1970). How we represent the real world fundamentally affects the way we perform the corresponding interpretation and analysis. These efforts contribute significantly to the extension of geographic representation. For instance, the concept of time-geography developed by Hägerstrand (1970).

Scale can be viewed as a continuum between micro (very small) and macro (very large) (Meyer et al., 1992), but in practice the processes that drive and shape sustainability tend to organize themselves more characteristically at some scale more than others, giving the sustainability scale continuum a kind of lumpiness (Wilbanks, 2003). Geographical scale is a factor in the interaction between, for example, transport planning and sustainable urban development, because of varying spatial dynamics of key processes, and because of the varying scale at which decision-making is focused. In a world where the meaning of 'global' and 'local' is being reshaped by technological and social change, a challenge to sustainable urban development is realizing the impressive, but often elusive, potential for public transport related investment at different geographic scales to be complementary and reinforcing. The context of scale should always be specified according to whether it pertains to (1) a process (or phenomenon), (2) observation (or measurement), or (3) analysis. The present report, not for the first time and certainly not for the last time, points out that scale has numerous meanings, some of which are unrelated and some of which are similar, or maybe even contradictory. It is important to avoid in favor of more specific terms (such as cartographic ratio, resolution, extent, support, range, grain, etc.) in order to reduce ambiguity. As previously discussed, scale is defined as "the spatial, temporal, quantitative, or analytical dimension used by scientists to measure and study objects and processes" (Gibson et al., 2000, p. 219). However, scale can be more technically defined depending on the academic discipline (Purvis & Granger, 2004; Sayre, 2005). A geographical scale of nested hierarchies is a common approach to measurement (Gibson et al., 2000; Parris & Kates, 2003; Purvis & Granger, 2004) with the delimited areas at one level containing others at subordinate levels (Gibson et al., 2000; Purvis & Granger, 2004).

Figure 1. Upscaling and downscaling and aggregation of observations

Figure 1, illustrate the interlinkage between different scales and the process of downscaling respective to upscaling. Each division, and subsequent divisions, provides a different understanding of what is happening throughout the scale (Dovers, 1995; Gibson et al., 2000; Purvis & Granger, 2004). The choice of scale can be tailored to the needs of the researchers, and may include such things as the units of analysis, academic fields, and the areas for investigation (Gibson et al., 2000; Parris & Kates, 2003; Purvis & Granger, 2004).

A common approach to choosing a scale for sustainable development is the ecological scale (Norgaard, 2010; Purvis & Granger, 2004). The main benefit of using the ecological scale is that it has the potential to aid researchers to monitor the level of critical natural capital per major biome-types (Norgaard, 2010; Purvis & Granger, 2004; Sayre, 2005). The disadvantages with this scale include limitations in available data, particularly due to the fact that most data is generally collected and organized within social limits versus the environmental limits (Norgaard, 2010; Purvis & Granger, 2004). Further, the discontinuity between the social and environmental scales of data and actions poses multiple problems in evaluating patterns of resource depletion, development, and socio-economic systems (Turner et al., 1989; Norgaard, 2010; Purvis & Granger, 2004; Sayer, 2005). The most popular alternative to the ecological scale is the scale used by social scientists (Purvis & Granger, 2004; Sayer, 2005). With this scale, a global area is divided into a hierarchy of political territories. The ecological scale was organized by natural capital, the social scale is not, although it is able to take natural capital into consideration (Purvis & Granger, 2004; Sayer, 2005; Wilbanks, 2003). The largest advantage of using the social scale is the amount of data that has already been generated and collected according to the political delineation, data that includes environmental, economic, and social aspects (Dovers, 1995; Purvis & Granger, 2004; Blöschl and Sivapalan, 1995). Systems for organizing and collecting this data are well established, providing historical data and trends, and continued methods for its collection and organization (Dovers, 1995; Purvis & Granger, 2004; Sayer, 2005). The fact that this scale takes into account all three pillars of sustainable development allows for integrated monitoring and analysis of the data within a practical scope (Purvis & Granger, 2004; Sayer, 2005). The availability of data within this scale tends to make the social scale the most practical choice (Dovers, 1995; Purvis & Granger, 2004). Added to this is the fact that the causes of environmental degradation and natural resource depletion usually begin outside a particular biome that is being affected, and provide a picture of only 'what' is happening and not 'why' it is happening (Purvis & Granger, 2004). However, the generation of data in line with the ecological scale can be conducted using remote sensing data, for example, in the form of the vegetation index or night time light emission, and then utilize it within the context of the social science scale.

However, these representations depend upon the aggregation level and can create a biased named modifiable areal unit problem (MAUP) and, most importantly, they do not consider geography in the sense that the variation of the sites does not affect the measure (Arbia 2001). A relevant vein of this literature considers the treatment of micro-geographic data (Bonneu & Thomas-Agnan 2015). Geographical space can be considered as continuous geographical space, projected onto a map, with activities potentially taking place everywhere, and flows being continuous vector fields (Quattrochi and Goodchild, 1997). Here, we are dependent on micro-geographical data. This type of data usually consists of the precise location of the studied object together with information of the attributes of the studied object, for example the location of a sold property and its price, and other attributes such as its size and standard.

Understanding inclusive urban expansion in the era of cities depends on a complex set of theoretical concepts as Figure 2 describes. The present research is divided into four concepts forming the basis for empirical analysis modelling. Smart inclusive urban growth depends on changing land use development, public transport development, changing travel patterns, and lastly social and spatial equity.

Figure 2. Theoretical concepts

Land use development

The real estate market represents a channel estimating the willingness to pay to own a house at a specific location, thus influencing the land use development. This information can be used to address the issues related to socially sustainable urban development: in particular, it could help with understanding the economic outcome of promoting a greater transit accessibility in urban expansion areas (Li and Joh, 2016). Indeed, looking at the longitudinal sale transactions, it may be possible to understand if positive synergistic effects how and to what extent property values can be generated (Bartholomew and Ewing, 2011). A further consideration needs to be done about the linkage between *affordable housing* and *public transport development*: as *sustainable transport policies* carried out in urban expansion districts could bridge housing and transportation costs and lower them altogether, making the urban expansion areas more affordable for all (Baum-Snow and Kahn, 2000).

Downstream of this first theoretical concept, we expect to analyze and overlap - for the identified expansion districts- the characteristics of the resident population with the reconstruction of the urban development during the selected period, both in terms of the public transport system and real estate prices. Our goal consists in building a *longitudinal map* of the Skåne region and detecting its main peculiarities, and *selecting those areas that require a more extensive investigation* (we can refer to them as the 'significative districts').

Social and spatial equity

Equity is a complex and multiform subject whose definition is not straightforward due to the existence of diverse social norms and moral judgments (van Wee and Geurs, 2011), but the aspects that matter will depend on the particular context and circumstances (Sen, 1992 and 1997). Two main types of equity are generally evaluated in transportation planning: *horizontal and vertical equity*. The former refers to the uniform distribution of benefits and costs among individuals within a group with the same needs. Based on egalitarian theories, horizontal equity opposes unjustifiable preferences of one individual or group over another (Meadows et al. 1972). Most studies related to this aspect of equity deal with the spatial distribution of transportation impacts. Vertical equity concerns the distribution of benefits among groups with different needs necessities. In this case, a distribution is considered fair if it provides larger/better resources to the most disadvantaged individuals or groups (Krumholz and Forester, 1990). These two types of equity often overlap or conflict. A particular decision might seem fair according to one criterion but inequitable according to another. An immediate example could be the following: horizontal equity requires users to bear the cost of their transport facilities and services, but vertical equity often requires subsidies for disadvantaged people. As a result, the evaluation of transport equity impacts can lead to outcomes that are conflicting (depending on the type of equity evaluated), or simply dismissed as 'intangible', with the implication that they are considered immeasurable and can be ignored (Litman, 2014).

For the purpose of this project, equity refers the distribution of transportation impacts (benefits and costs) throughout all sectors of society (Martens, 2011) and investigates the fairness and appropriateness of this distribution (Litman, 2014). Individuals, groups of people, and regions inevitably have different levels of access to destinations such as shops, job locations, or medical services. This unequal access is not necessarily problematic, but clearly, some distributions can be considered 'unfair'. The lack of fairness is less acceptable when the level of provision to the disadvantaged categories is below the subsistence threshold (Ye and Wei, 2005).

The equity issue can be related to the spatial/horizontal aspect (Repetti and McDaniel, 1992) when individuals and groups are considered equal in ability and needs necessities (thus, they should be treated the same way, receiving an equal share of the resources and bearing the same costs). Alternatively, a vertical equity should be considered in situations with different levels of need (gender, income, social class, or mobility ability): this promotes social justice and social inclusion, by considering policies that are equitable if they favor economically and/or socially disadvantaged groups, compensating for any overall inequities.

Although the relevance of transportation equity has been clearly highlighted in previous studies, it happens that most of the traditional approaches that it is possible to find in the pertinent literature reviews often neglect the equity goals at the network planning stage (Camporeale et al., 2017). Transit network design problems have predominantly focused on minimizing user and operator cost without considering equity or access for the disadvantaged population (Kepaptsoglou, and Karlaftis, 2009). Considering the societal function of transportation systems, however, it is crucial that the planning stage of networks, even at the operational level, is addressed to the research of solutions in which the outcomes of the design (costs and/or benefit) are distributed as much as possible among the potential users or classes of users.

Among the efforts that have already been done in this direction, it is worthy to mention that in 2011 (Fan and Machemehl, 2011), for the first time, the spatial equity issue was explicitly considered to find the solution to a public transportation redesign problem.

This implies a preliminary deeper investigation about the horizontal and vertical equity indicators that have already been used in similar contexts, and an accurate study about the different methods/strategies that have to be pursued in order to develop a composite index.

At this stage of the project, more than one indicator may be formulated: in the following steps, we aim at selecting the one that is better able to reflect the network users' equity of accessibility.

Public transport investments and polices

Public transport is a strategic means of achieving a sustainable transport system, hence other important social goals for employment, education, and regional development. The main task of public transport is to provide basic accessibility for everyone to access work, education, care, culture and leisure activities. It therefore contributes to regional development and growth. Statistics on socio-economic development with a focus on regional growth and travel patterns have been collected at various administrative levels in Sweden. Actors such as the municipalities, county and state authorities, as well as the private sector work differently in collecting and analyzing quantitative information within their areas of activity.

At the same time, the scope and breadth of the different types of statistics drastically increases as a result of the continual digitization by society. This is especially true of public transport operators through digitization of ticket sales and travel statistics. Much of the newly generated data contains large amounts of geographical data, which allows for new types of analyses. Planning public transport expansion includes a number of complex issues, including financing, increased accessibility, and any social impact. Active use of the data generated is therefore central in order to continuously develop and improve the analysis of public transport and its social impact (van Wee, 2016).

As we have previously discussed, the concept of equitable access to the transport network, and for the purposes of this research we need to clarify which meaning we are attributing to the word *accessibility*. Accessibility can be defined as *the extent to which land-use and transport systems enable individuals to reach activities or destinations by means of a combination of transport modes* (Geurs et al., 2016; Geurs and van Wee, 2004), with improving access being put forward as the goal of transportation policies, different accessibility measures have been developed to support the planning and evaluation of transport interventions. Despite the plethora of these measures, it is not clear which one can provide more realistic results: in general, they incorporate a number of pre-determined components of generalized travel costs - such as travel time, distance, monetary costs, etc. -, in order to calculate the range of opportunities within the reach for any individual/population group following methods used by Hess and Tangerine (2007) and Gibbons and Machin (2015).

Conclusions

Importantly, achieving inclusive urban expansion together with providing sustainable economic growth are linked, and if properly coordinated, can lead to strengthened synergy and stronger overall progress. Sustainable urban development indictors derived from a set of agreed international goals or commitments, and a composite indicator, which is the compilation of individual indicators into a single index, are considered to be a good vehicle to help measure and monitor sustainable urban development and the progress achieved in such areas. Indicators corresponding to the SDGs are most important in monitoring future progress, but they need to be complemented by composite indices of sustainable urban development progress.

These indicators are meant to present complex data and trends in a simplified format for the policy makers. They can support policy formulation on the basis of information which is transparent and evidence-based. The challenges, among others, are to develop and agree upon the fully integrated framework of measurement at the global level, which includes both goals and a set of indicators for assessing the needs and tracking the progress of sustainable development. Remote sensing and other "big data" approaches have great potential for assessing long-term sustainable urban development and complement and improve the official statistics. This would allow estimating the proposed aggregate SD index at various spatial and temporal scales. The leading research questions are: which could be the best/most suitable way to evaluate the distributional effects of urban development among the involved individuals? How can the outcomes be measured? This project aims at selecting, among the pool of composite indicators formulated at the end of the second module of our research, the specific index that can better quantitatively assess the equity of accessibility to the public transport nodes (stops, stations, hubs) within the regional area being studied.

3. Data and Analysis

This section sets out the data together with an analysis mainly using visualizations to indicate changes in the studied region. Investments have primarily influenced those areas that previously had no track-bound public transport. The map in Figure 3, shows a geographical availability analysis and the change of travel in Skåne divided into SAMS areas.

Figure 3. Expansion of the passenger railway network (Median distance (m) within each SAMS, from a transacted property to the nearest station)

SAMS areas have been used because the common level is considered too large for this analysis. A change at the municipal level is considered not to capture the variety of accessibility available within the different parts of the municipalities. SAMS areas are smaller; therefore, a more detailed analysis of the variation within a municipality can be studied.

Figure 4. Expansion of the passenger railway network (Median distance (m) within each SAMS, from a transacted property to the nearest station

Figure 4, provides an overview of how the increase in travel (light blue circles whereby the size illustrates an increase) is dominated by Skåne's major cities. The trains that link the region's labor market centers of Malmö / Lund, Helsingborg and Kristianstad can be clearly identified by the increased journeys travel at the stations along the route. New stations in the period 2006-2015 are marked with a yellow star, and show relatively small increases in the number of journeys.

The second dimension in Figure 4 is the accessibility analysis based on the location of the sold houses located within a SAMS area during the period 1996 to 2015, where dark orange areas show a decrease in media distance from all sold properties to the nearest regional train station. Here, a clear geographical pattern can be observed following the pattern observed in Figure 2's last map, with expansion of stations in the southwest, northwest, and north east of Skåne with a total of nine new stations.

Figure 5. Average Population Density Change 2005 to 2015 (Weighted by Urban Footprint from MODIS LAND COVER)

Source: Statistics Sweden and GeoSweden

In order to account for the changing population in the region at the local level, two types of data have been used to scale down the municipality level data to the finer SAMS area data. Figure 5, shows the average population density change from 2005 to 2015. The analysis applies the population data at the municipality level weighted by urban footprint from MODIS LAND COVER products. This give us an understanding of the population dynamics at a lower geographical scale.

Figure 6. Small House Transaction Data 2002 -2004 (Spatial distribution and the transaction volume change)

The market for small houses in Skåne has undergone three phases according to Figure 6, during the study period (2002-2015). At the beginning of the period, the number of transactions increased from 7,000 units sold to 8,500 in 2007, after which the market decreased to the lowest observed level over the years 2012 and 2013 with 5,000 houses sold each year. Since 2013, the market has recovered, and nearly 7000 items were sold. However, this is not a complete recovery, but the number of items sold is still lower than 2002. The geographical pattern of the change is the median price in SEK per square meter during the period 2002-2015 in Skåne.

Figure 7. Small House Transaction Data (Median price change SEK/m2)

Figure 7, shows that detached houses located in SAMS areas near the coast at the major cities in western Skåne have increased significantly more in price than houses in central and eastern parts of the region. There are large areas in mainly the northern and eastern parts of Skåne where prices have not changed, or have even decreased, during the period being studied.

Figure 8. Small House Transaction (Market Segmentation)

Figure 8, shows how the change in the median price and the number of transactions are distributed over time. Where the study period is divided into 3 periods of time; Period 1 through 2005, Period 2 is 2006-2010, and Period 3 is 2011-2015. The maps show two variables; the number of houses sold in light blue that changes to dark blue indicates an increase in price, and the number of transactions where light blue changes to grey indicates an increase in the number of transactions. Observe the increase in both variables giving this a dark purple / blue color. Observe nil or minor changes in both variables, giving this a light blue color. The stations in 2005 are shown in light green color, the new stations opened in Periods 2 and 3 are shown with a red mark. In Studder's market for single-family homes over all three periods, only very small changes can be observed.

Figure 9. Remote Sensing Analysis (NOAA DMSP-OLS Night Time Light Images)

Night time light has more specifically been used as a proxy for the socio-economic variables, most frequently population and income (Levin and Duke, 2012). The use of night time light data is especially popular in estimating such variables in countries and regions where traditional economic and demographic data is not available, or where it is thought to be inaccurate. Generally, studies employing night time light as a proxy for economic development and population are undertaken for one study year. A good body of knowledge exists regarding the effectiveness of night time light as a proxy for economic and demographic data at a snapshot in time. However, very few studies take advantage of the full temporal extent of the data available. Therefore, a clear research gap exists in the findings regarding the change in night time light over time, and how this may or may not be linked with economic development and population.

Currently OLS Stable Lights products from 1992 to 2012 are distributed on the website of NGDC. DMSP-OLS is an oscillating scan device with two bands (visible (VIS) and thermal-infrared (TIR)) designed to map clouds during both day and night. The visible band uses a photomultiplier tube (PMT) to collect photons. The result has 6-bit quantization, with digital numbers (DN) ranging from 0–63 and a limited dynamic range. For night time overpasses, the gain setting is usually set to the highest level to enable observation of moonlit clouds. Therefore, pixels in bright areas such as city centers often reach a DN of 63, leaving no further details to be recognized. Such pixels are termed as “saturated”.

The generation of radiance calibrated night time light products can be divided into three steps. Firstly, fixed-gain data needs to be collected and processed into global fixed-gain cloud-free composite data for three gain settings (low, medium, and high). Secondly, cloud-free composite data from the three gain settings are merged. Lastly, the stable light product is blended in with the merged global fixed-gain composite data.

Another application of night time light in the social sciences has been in determining or validating urban extent. This is relevant for two reasons. Firstly, administrative boundaries in cities do not accurately depict the built up urban area, and having more accurate information regarding the actual shape and size of cities is beneficial in many applications. Secondly, night time light data often overestimates the spatial extent of development due to a phenomenon known as blooming. The studies that have been undertaken on urban extent aim to reduce this overestimation of the illuminated lighted area in order to provide more accurate estimates of urban boundaries. Imhoff, et al. (1997) produced one of the first studies dealing with urban extent. They used the 1994/1995 night time light dataset for the percentage of illuminated observations to accurately map the urban areas in the United States by finding the optimal threshold at which contiguous polygons shrank in area but before which they started to fragment. The result eliminated small and poorly lit inhabited areas and showed no statistically significant difference to census generated results of urban areas. A similar study was undertaken by Henderson, et al. (2003) for three economically diverse cities: Lhasa, Tibet; Beijing, China, and San Francisco, the United States. They compared two night time light datasets (percent lighted illuminated observations from 1994/1995 and radiance calibrated during 1996/1997) with Landsat land cover imagery to find the thresholds which most accurately approximated the urban extent as determined from the Landsat imagery. They found that there is no universal threshold which can be applied to identify urban boundaries; very different thresholds are required for cities with different levels of development. Small, Pozzi and Elvidge (2005) also examined differing thresholds by evaluating the results of changing the thresholds in three different years (1992/1993, 1994/1995 and 2000). They confirmed that increasing the thresholds leads to fragmentation and reduction of the contiguous illuminated areas. They also found that smaller illuminated areas are detected less frequently than larger areas, and that larger areas have more convoluted shapes than smaller areas. They concluded that thresholds above 90 percent lead to the closest matches in urban area between night time light and the Landsat data sets; however, just as Henderson, et al. (2003), they found that there is no single threshold. Elvidge, et al. (2007) took a different approach to determining urban extent, by producing the first global grid of impervious surface area (ISA) density. They used night time light and gridded population data combined with an existing U.S. Geological Survey (USGS) ISA data set as the reference data set to develop a linear regression model to estimate the density of ISA in the United States, which was then applied to generate the global gridded ISA density map. They found that their calculations were slightly higher than the USGS calculations for ISA in the United States. In summary, the night time light data set has been used to develop estimates of global and local urban extent. Both light intensity and percent illuminated observations have been used to develop thresholds at which urban areas are best represented; however, most studies are clear that a universal threshold is not appropriate. Studies related to urban extent have focused exclusively on single year analyses. From the publications analysed, no work has been done on examining the urban extent over a time series.

The third dimension of this study is an analysis of land use change and urban expansion in Skåne. Skåne is a densely populated county with a growing population. The need for new housing is high and the pressure on undeveloped land is significant. The region has some of the best agricultural land in Sweden, and the region as a whole consists of almost half of fields and pastures. Skåne together with the county of Halland and Uppsala make up the counties where the highest proportion of agricultural land is being exploited. The most common reasons are the construction of small houses, multi-family houses, industrial and business establishments, and infrastructure. An analysis of the change of land use shows the type of land used when urban areas expand. This analysis is of particular importance in a region like Skåne, where there is agricultural land with high productivity.

The need for information on land use and crops is particularly important in the context of urban expansion. An analysis of a sustainable interaction between urban expansion, agriculture, the environment, and rural areas is one of today's major societal challenges. In order to analyze land use and soil coverage, comprehensive information about how the land is used is required. Remote analysis by satellites is mainly used to monitor global resources. Common applications are studies of land use and changes in vegetation. A key concept when registering with remote sensing methods is the ground resolution, that is, the size of the ground and the smallest image element that can be registered. Low-resolution remote lane satellites (approximately 1km) are used for applications involving entire countries or continents. The higher-resolution satellites have a ground resolution from one to a few meters, and medium-resolution satellites of 30 to 500 meters and can be used to analyze land use and soil analysis.

MODIS Land Cover Data

Over the past several years, researchers have increasingly turned to remotely sensed data to improve the accuracy of the data sets that describe the geographical distribution of land cover at the regional and global scale. *Land cover* is the physical material on the surface of the Earth. *Land use* is a description of how people utilize the land. Urban and agricultural land uses are two of the most commonly known land use classes. There are two primary methods to capture land cover information: field surveys and analysis of remotely sensed imagery.

Land cover can be determined based on physically derived spectral and spatial properties of, for example, maize, asphalt, and water. Land uses are more difficult to determine as they are established based on the human use of land. As an example, while land cover may be identified remotely as "asphalt" based on spectral characteristics, the land use could be anything from a road to a playground. Many remote sensing classification systems mix land cover types with land use.

There exist several global land cover data sets. Some are based on spatial and temporal heterogeneous maps and atlas data. Since the early 1990s, global remotely sensed land cover data sets derived from the low-resolution NOAA-AVHRR sensor were produced. The current generation of global land cover datasets includes the GLC2000, a detailed data set produced from a data set of fourteen months of pre-processed daily global data acquired by the vegetation instrument onboard SPOT 4. The project is a European Commission initiative in collaboration with a network of partners around the world. GlobCover is an ESA initiative that began in 2005. The aim of this project was to develop global land cover maps using input observations from the 300m MERIS sensor on board the ENVISAT satellite mission. ESA makes available the land cover maps for two periods: December 2004 - June 2006 and January - December 2009.

The Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Terra and Aqua spacecraft are producing several interesting suites of imagery with global coverage and high spatial and temporal resolution. Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, and observations are averaged over 8 or 16 days. The MODIS instrument provides high radiometric sensitivity (12 bit) across 36 spectral bands ranging in wavelength from 0.4 μm to 14.4 μm. Two bands are imaged at a nominal resolution of 250m, five bands at 500m, and the remaining 29 bands at 1km. MODIS land products are received, distributed, and archived at the Land Processes Distributed Active Archive Center (LP DAAC), a component of NASAs Earth Observing System (EOS) Data and Information System (EOSDIS).

MODIS land cover products are produced from supervised classifications, unlike GlobCover and GLC2000, which are produced from mainly unsupervised classifications. MDC12Q1 is the MODIS yearly land cover product existing in two versions, the older version (V005, 2001—2007) and the more recent version (V051, 2001—2010). Data is presented in tiles of approximately ~1200 x 1200km (~10° x 10° at the Equator) with a 500m nominal spatial resolution.

MDC12Q1 includes five layers based on different classification systems:

17-class International Geosphere-Biosphere Program classifications

14-class University of Maryland classifications

10-class system for the MODIS LAI/FPAR algorithm

8-biome classifications by Running

12-class plant functional type classifications by Bonan

Data is produced on a calendar year basis, and the inputs to the classification algorithm are no fewer than 135 different features, for example, spectral and temporal information from MODIS bands 1-7, Enhanced Vegetation Index and Land Surface Temperatures. Approximately 1,860 sites around the world are used as training data for the classification algorithm. Sites are selected to ensure geographic and ecological variation. They are manually delineated in the Landsat imagery and are generally between 0.2km^2 to 80km^2, as our aim is to capture any change and urban expansion where agricultural land is transformed into urban land. Figure 10, illustrates the first and last year of the analysis using Land Cover images from MODIS.

Figure 10. Remote Sensing Analysis NASA MCD12Q1 Land Cover Images in 2001 and 2013

Figure 11, illustrates an analysis of the change in Skåne during the period 2001-2013. This analysis is based on remote sensing information where satellite products from NASA MCD12Q1 Land Cover Images with a resolution of 250m have been used. If the resolution is classified as medium, it is difficult to see the changes on small surfaces; therefore, the analysis has been done at the municipal level. The upper map in color scale blue to gray in Figure 11 shows municipalities with a low intensity of vegetation during the start in 2001. Most western Skåne with Malmö and nearby municipalities have low levels of vegetation. We can also observe the change analysis in the maps that follow. There may be an increase in this type of land use in the previously mentioned areas. An interpretation of this observation is that land use is in a transitional phase where the expansion of a city, especially the expansion and the building sites close to the major city Malmö, is sufficiently extensive for capturing by satellite imagery.

Figure 11. Land Cover Analysis (NASA MCD12Q1 Land Cover Images: Change at the Municipality UNCIP Level)

The lower charts in Figure 11 show an analysis of the agricultural land category. In the first map the brown color illustrates a large proportion of agricultural land and western Skåne's agriculture can be observed. In the north and northeast of Skåne, the category of agricultural land is not observed to the same extent. In the change analysis that follows, the same pattern as in the maps above can be observed whereby Malmö loses farmland.

Figure 12. Spatial-Analysis: Visualization of the spatial model-building process

4. Conclusions

Skåne is a metropolitan region with seven identified regional cores - Malmö, Lund, Helsingborg, Landskrona, Kristianstad, Hässleholm, and Ystad - of which the first three meet the criteria for being a labor market center. The fact that Skåne has several major cities that can take development is a strength, compared to more monumental metropolitan areas, such as Stockholm and Gothenburg. Skåne does not, like classical metropolitan areas, have suburbs that provide a large city, but comprises several independent resorts. Different places have different roles, as well as regional cores and other towns and the surrounding areas, which contribute valuable functions in Skåne. It is therefore central to focus on the qualities available at the specific locations.

For example, public transport in Skåne enables specialization and profit for business, reduced congestion and environmental problems, as well as choice and diversity for residents, businesses, and visitors. At the same time, the majority of the population demand a well-developed public transport system that enables time and cost effective commuting. The growing population poses special requirements for the region, and cross-border development can provide new opportunities. Better transport links and measures to facilitate commuting are central to an efficient labor market, but southwest Skåne is characterized by capacity problems, while the needs in the northeast include, in particular, the quality of the transport system (1).

The County Administrative Board of Skåne has identified five three strategically important measures to achieve sustainable transport in the county. (1) An increased number of public transport passengers, an enhanced public transport system through developed overview planning, and an increased share of fossil fuel-free heating, electricity, and transport. (2) There is a connection between the structure of buildings and the choice of the means of transport. Higher housing density, but also higher self-sufficiency and greater service offerings can reduce car journeys. (3) In a dense city, a larger proportion of the journeys are made by walking, cycling, or public transport rather than by car. A greater density also produces a higher share of public transport trips. In order to maintain and strengthen the travel base, new buildings should be concentrated on good existing public transport modes. (4) Public transport is an investment-intensive activity, and major public transport initiatives require large travel budgets. . Insulating and developing buildings along existing pathways is central to both climate and energy considerations, as it is not resource efficient that public transport provides dispersed housing.

(5) It is important that existing public transport modes are exploited primarily with a high degree of exploitation. Areas closest to the train stations in Skåne have a large densification potential. Only about 20 percent of the land within a radius of one kilometer around the stations is developed. The County Administrative Board in Skåne sees great potential in these areas, or the corresponding strong public transport modes.

References

Arbia, G. (2001). Modelling the geography of economic activities on a continuous space. *Papers in Regional Science*, 80(4), 411-424.

Bartholomew, K., & Ewing, R. (2011). Hedonic price effects of pedestrian-and transit-oriented development. *Journal of Planning Literature,* 26.1: 18-34.

Baum-Snow, N., & Kahn, M. E. (2000). The effects of new public projects to expand urban rail transit. Journal of Public Economics, 77(2), 241-263.

Blöschl, G., and M. Sivapalan., (1995). Scale issues in hydrological modelling: A review. *Hydrological Processes*, 9:251–90.

Bonneu, F., & Thomas-Agnan, C. (2015). Measuring and testing spatial mass concentration with micro-geographic data. *Spatial Economic Analysis*, 10(3), 289-316.

Bustos, M. F. A., Hall, O., & Andersson, M. (2015). Night time light and population changes in Europe 1992–2012. *Ambio*, 44(7), 653-665.

Camporeale, R., Caggiani, L., Fonzone, A., & Ottomanelli, M. (2017). Quantifying the impact of horizontal and vertical equity in transit route planning. *Transportation Planning and Technology*, 40(1), 28-44.

Cervero, Robert, and John Landis. (1997). Twenty Years of the Bay Area Rapid Transit System: Land Use and Development Impacts. *Transportation Research Part A: Policy and Practice,* 31 (4): 309–33.

Chalermpong, Saksith. (2007). Rail Transit and Residential Land Use in Developing Countries: Hedonic Study of Residential Property Prices in Bangkok, Thailand. *Transportation Research Record*, 2038 (1): 111–19.

Dovers, S. R. (1995). A framework for scaling and framing policy problems in sustainability. *Ecological Economics*, *12*, 93-106.

Dungan, J. L., Perry, J. N., Dale, M. R. T., Legendre, P., Citron-Pousty, S., Fortin, M. J., & Rosenberg, M. (2002). A balanced view of scale in spatial statistical analysis. *Ecography*, 25(5), 626-640.

Elvidge, C. D., et al., (2007). Global distribution of density constructed impervious surfaces. *Sensors*, 7, pp. 1962-1979.

Ewing and Robert Cervero (2010). “Travel and the Built Environment: A Meta-Analysis,” Journal of the American Planning Association, Vol. 76, No. 3, Summer, pp. 265-294.

Fan, W., & Machemehl, R.B. (2011). Bi-level Optimization Model for Public Transportation Network Redesign Problem Accounting for Equity Issues. *Transportation Research Record - Journal of the Transportation Research Board*, 2263, 151-162.

Geurs, K.T., Patuelli, R., & Dentinho, T.P. (Eds.). (2016). *Accessibility, Equity and Efficiency: Challenges for Transport and Public Services*. Edward Elgar Publishing.

Geurs, K. T., & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport geography*, 12(2), 127-140.

Gibbons, Stephen and Stephen Machin. (2005). Valuing rail access using transport innovations. *Journal of Urban Economics,* 57(1): 148–169.

Gibson, Clark C., Ostrom, E., & Ahn, T. K. (2000). The concept of scale and the human dimensions of global change: A survey. *Ecological Economics*, 32, 217-239.

Haggett P. (1965). *Locational analysis in human geography*, London: Edward Arnold.

Henderson, M., et al., (2003). Validation of urban boundaries derived from global night time satellite imagery. *International Journal of Remote Sensing*, 24(3), pp. 595-609.

Hess, Daniel Baldwin, and Tangerine Maria Almeida. (2007). Impact of Proximity to Light Rail Rapid Transit on Station-Area Property Values in Buffalo, New York. *Urban Studies* 44 (5–6): 1041–68.

Hägerstrand T. (1970). What about people in regional science? *Papers of the Regional Science Association*, 24, 1-12.

Hägerstrand, T., (1975). ‘Space, time and human conditions’, in: A. Karlqvist, L. Lundqvist, F. Snickars (eds), *Dynamic Allocation of Urban Space*, Saxon House, Farnborough, UK, 3–12.

Imhoff, M. L., Lawrence, W. T., Stutzer, D. C. and Elvidge, C. D., (1997). A technique for using composite DMSP/OLS “City light” satellite data to map urban areas. *Remote Sensing of the Environment*, 61, pp. 361-370.

Keola, S., Andersson, M., & Hall, O., (2015). Monitoring economic development from space: using night time light and land cover data to measure economic growth. *World Development*, 66, 322-334.

Kepaptsoglou, K., & Karlaftis, M. (2009). Transit route network design problem. *Journal of transportation engineering*, 135(8), 491-505.

Krumholz, N., & Forester, J. (1990). Making Equity Planning Work: Leadership in the Public Sector. Philadelphia, PA: Temple University Press.

Li, W., & Joh, K. (2016). Exploring the synergistic economic benefit of enhancing neighborhood bikeability and public transit accessibility based on real estate sale transactions. *Urban Studies*, 0042098016680147.

Litman, T. (2014). Evaluating Transportation Equity - Guidance for Incorporating Distributional Impacts in Transportation Planning. *World Transport Policy & Practice*, 8,1-153.

Martens, K., (2011). Substance Precedes Methodology: On Cost-Benefit Analysis and Equity. *Transportation*, 38(6), 959-974.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth*. New York, 102.

Norgaard, R. B. (2010). Ecosystem services: From eye-opening metaphor to complexity blinder. *Ecological Economics*, 69, 1219-1227.

Parris, T. M., & Kates, R. W. (2003). Characterizing and measuring sustainable development. *Annual Review of the environment and resources*, 28(1), 559-586.

Phillips, J.D., (1988). The role of spatial scale in geomorphic systems. *Geographical Analysis*, 20:308–17.

Potter, R. B. (2004). *Geographies of development*. Pearson Education.

Purvis, M., Grainger, A., (2004). *Exploring Sustainable Development: Geographical Perspectives*, Earthscan, London.

Quattrochi, D.A., and M.F. Goodchild, eds., 1997. *Scale in Remote Sensing and GIS*. New York: CRC Press.

Repetti, J.R., & McDaniel P.R., (1992). Horizontal and Vertical Equity: the Musgrave /Kaplow Exchange. *Florida Tax Review*, 1, 607-622.

Sen, A. (1992). *Inequality reexamined*. Clarendon Press.

Sen, A. (1997). *Choice, welfare and measurement*. Harvard University Press.

Sayre, N. F. (2005). Ecological and geographical scale: Parallels and potential for integration. *Progress in Human Geography, 29*(3), 276-290.

Turner, M.G., R.V. O'Neill, R.H. Gardner, and B.T. Milne., (1989). Effects of changing spatial scale on the analysis of landscape pattern. *Landscape Ecology* 3:153–62.

van Wee, B. (2016). Accessible accessibility research challenges. *Journal of Transport Geography*, 51, 9–16.

van Wee, B., & Geurs, K. (2011). Discussing Equity and Social Exclusion in Accessibility Evaluations. *European Journal of Transport and Infrastructure Research,* 11 (4): 350–367.

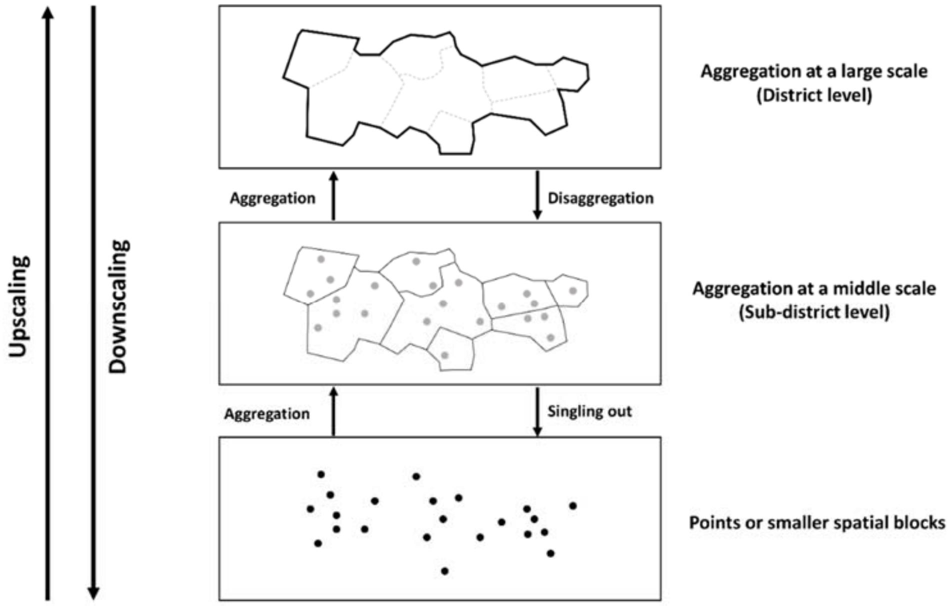
Wilbanks, T., (2003), 'Geographic scaling issues in integrated assessments of climate change'.

J. Rotmans, D. Rothman (eds), *Scaling Issues in Integrated Assessment*, Swets and Zeitlinger, Lisse, The Netherlands, 5–34.

Wilbanks, T. J. (2007). Scale and sustainability. *Climate Policy*, *7*(4), 278-287.

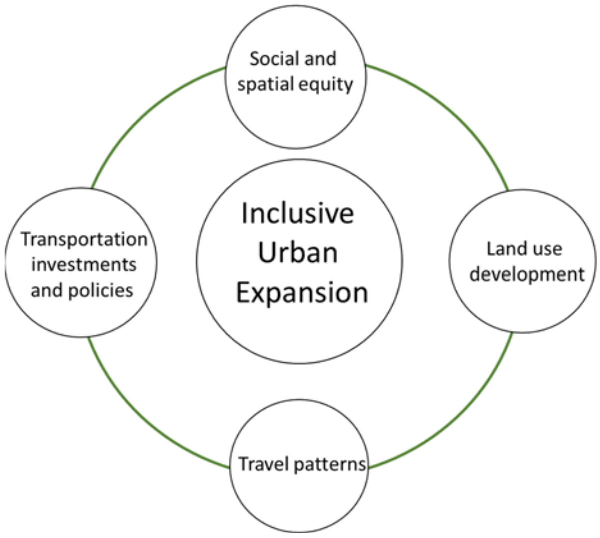
Ye, X., & Wei, Y. D., (2005). Geospatial analysis of regional development in China: the case of Zhejiang Province and the Wenzhou model. *Eurasian Geography and Economics*, *46*(6), 445-464.

Figure 1. Upscaling and downscaling and aggregation of observations



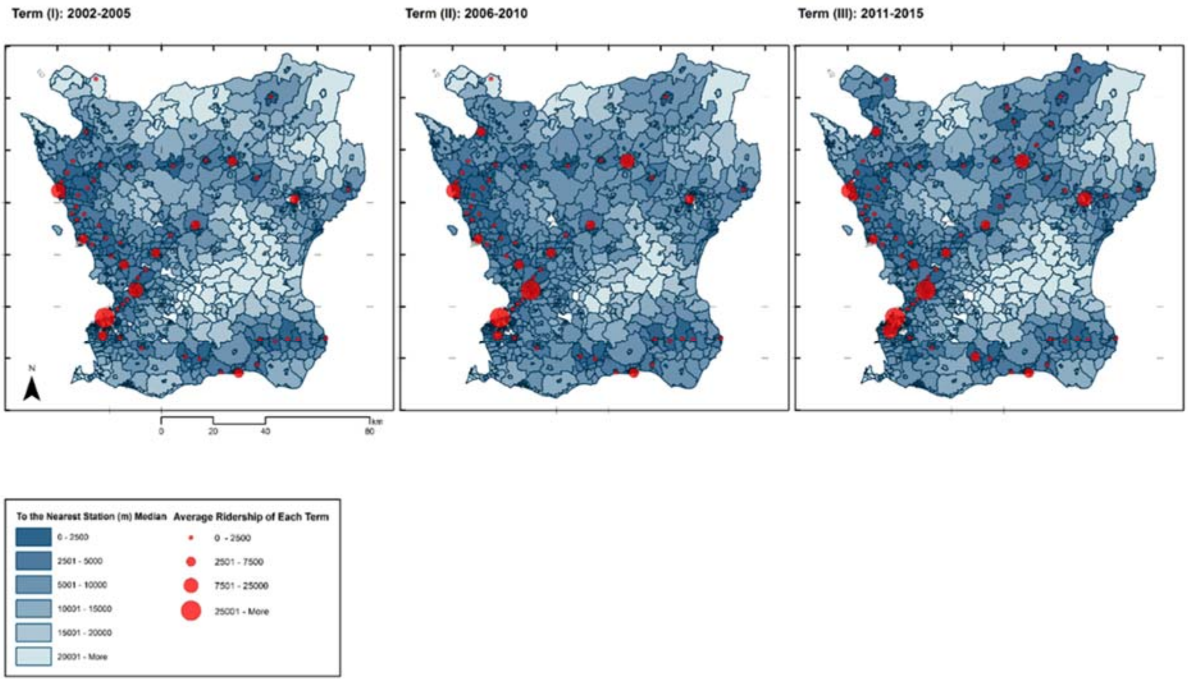
Source: Author's elaboration

Figure 2. Theoretical concepts



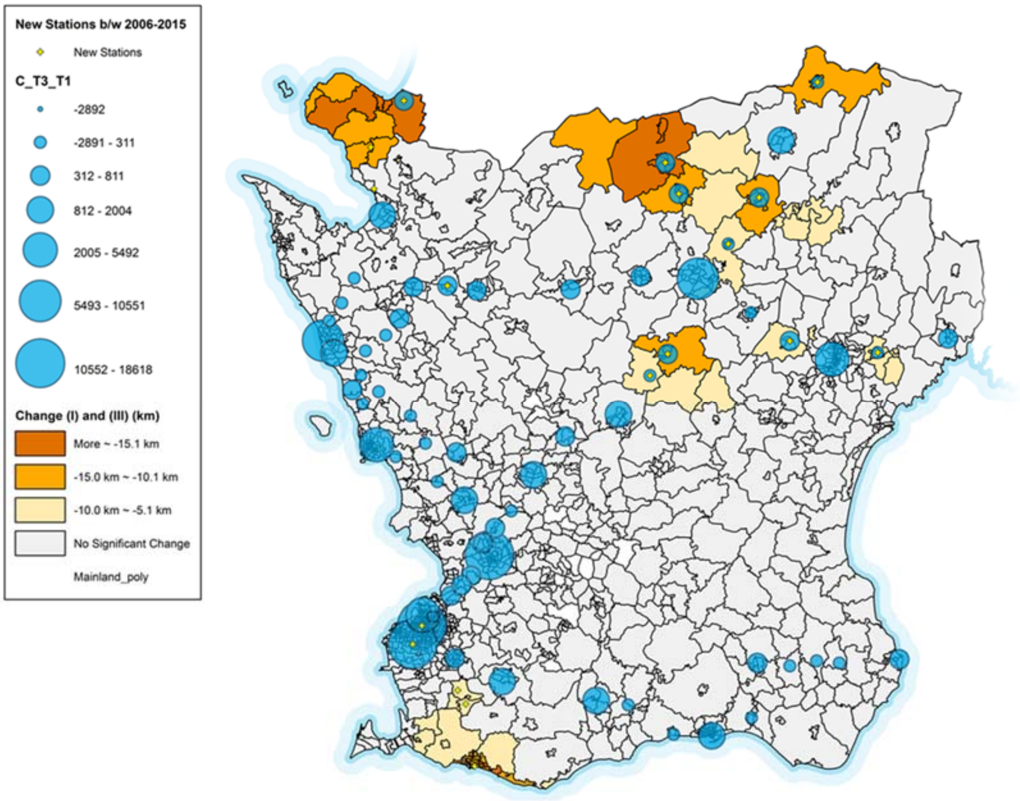
Source: Author´s elaboration

Figure 3. Expansion of the passenger railway network (Median distance (m) within each SAMS, from a transacted property to the nearest station)



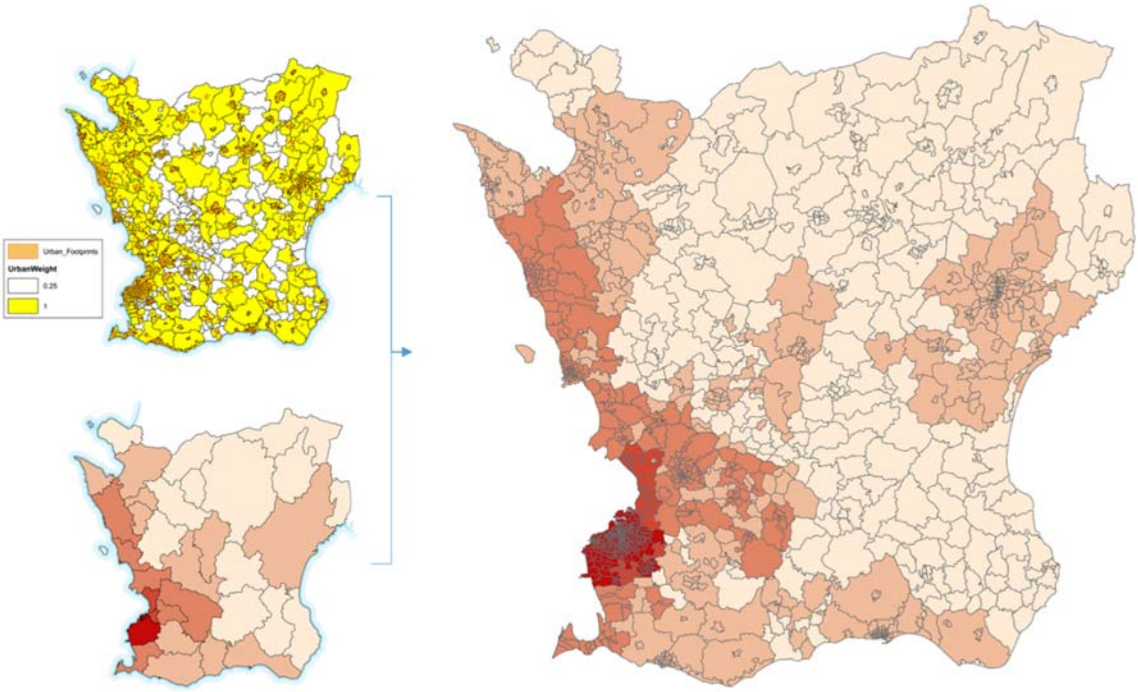
Source: Trivector

Figure 4. Expansion of the passenger railway network (Median distance (m) within each SAMS, from a transacted property to the nearest station



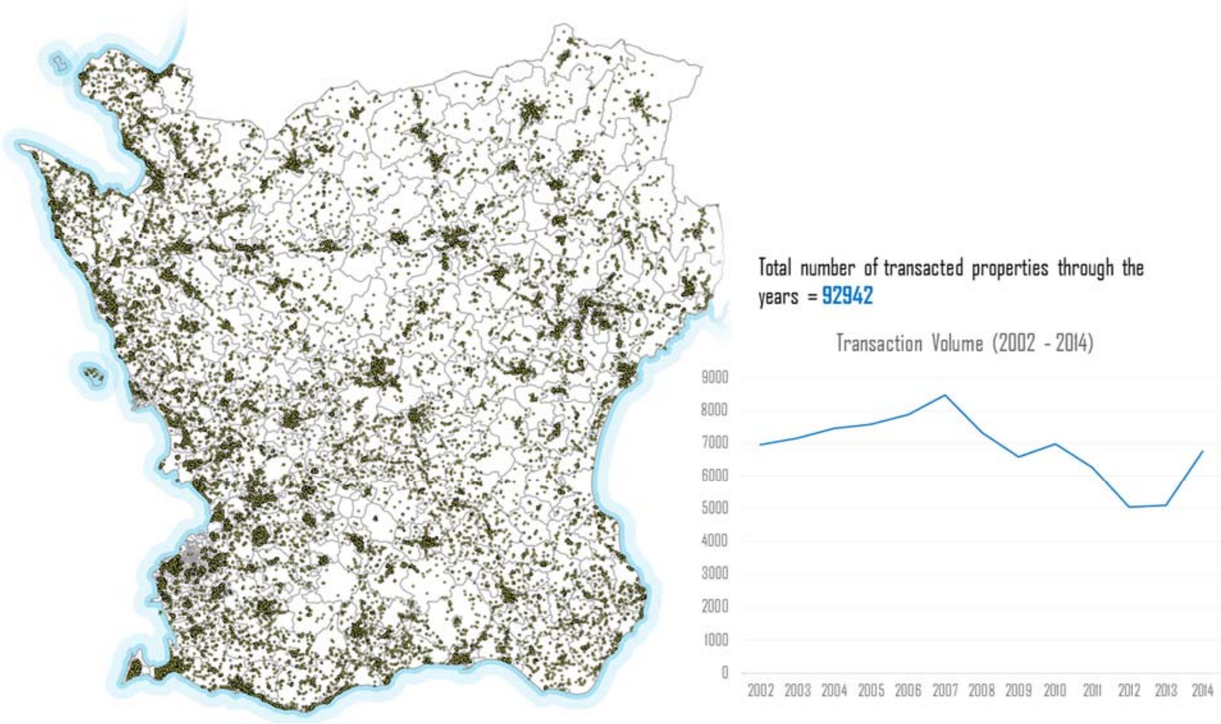
Source: Region Skåne

Figure 5. Average Population Density Change 2005 to 2015 (Weighted by Urban Footprint from MODIS LAND COVER)



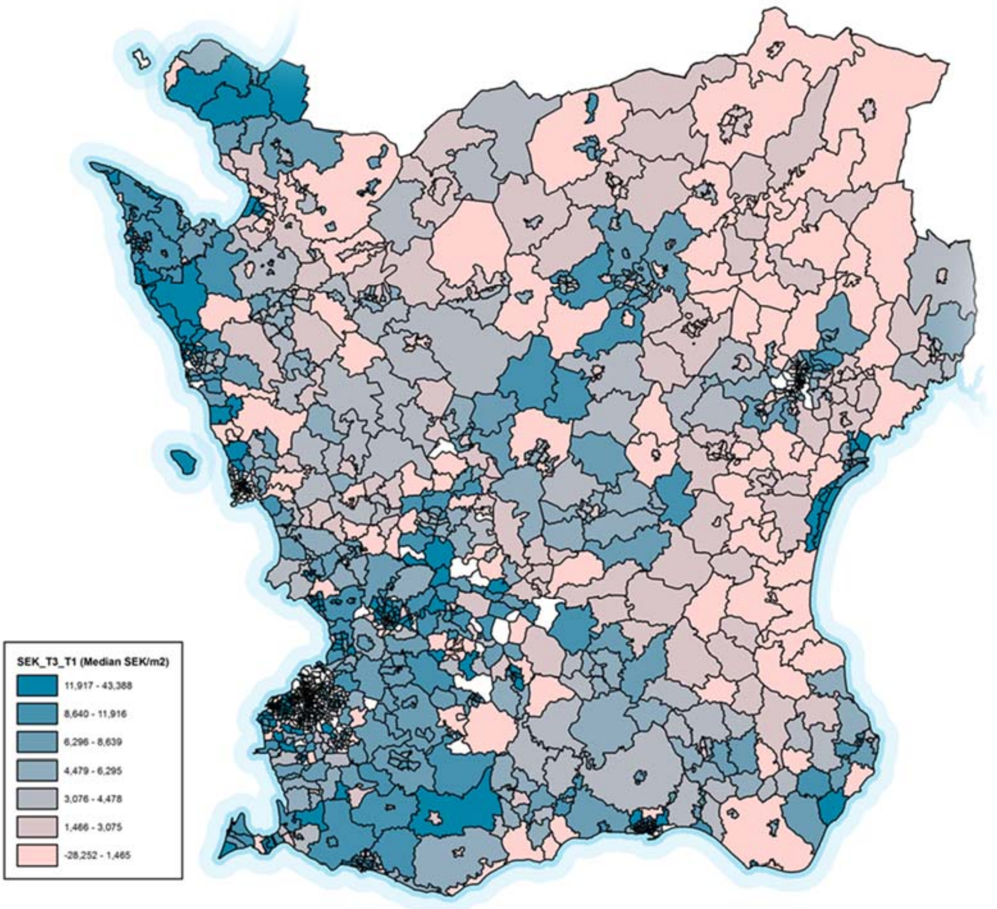
Source: Statistics Sweden and GeoSweden

Figure 6. Small House Transaction Data 2002 -2004 (Spatial distribution and the transaction volume change)



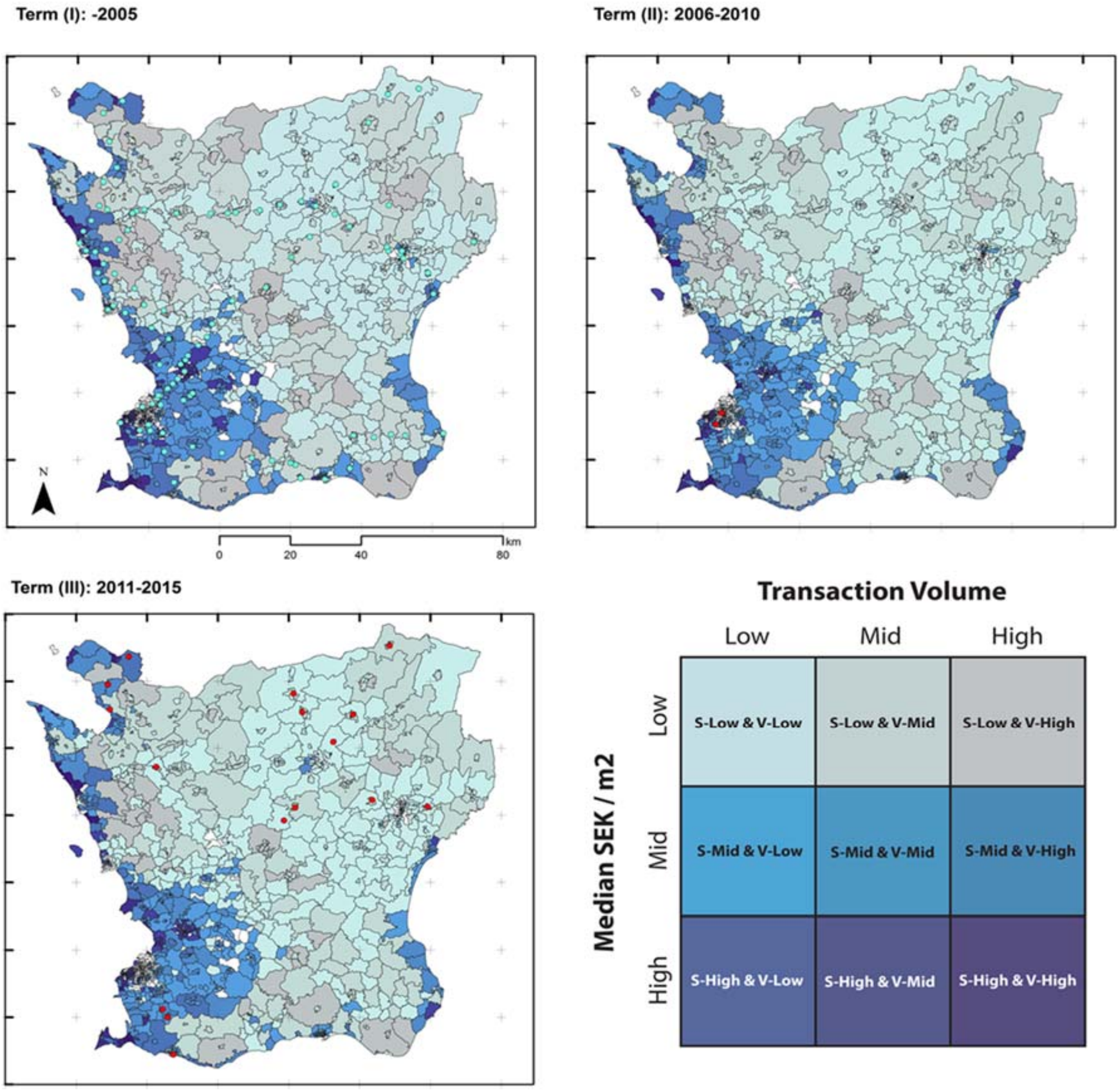
Source: Ljungquist

Figure 7. Small House Transaction Data (Median price change SEK/m2)



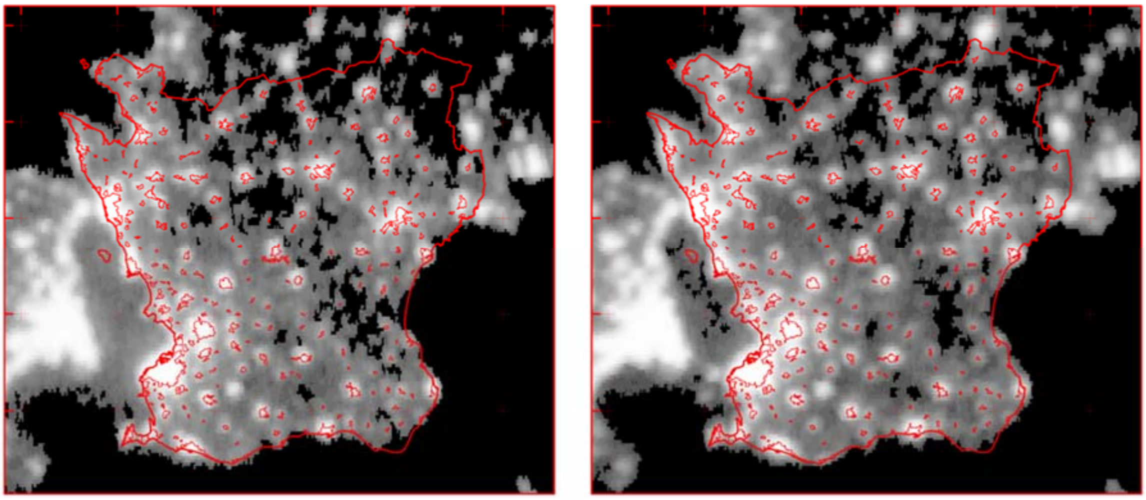
Source: Author´s calculation

Figure 8. Small House Transaction (Market Segmentation)



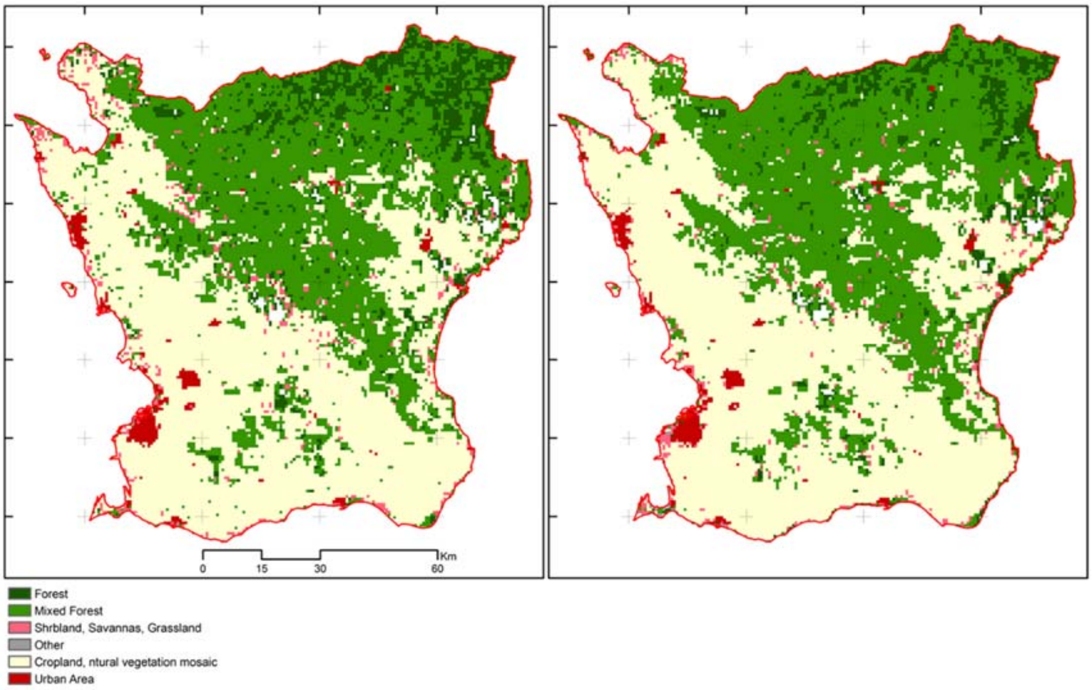
Source: Author´s calculation

Figure 9. Remote Sensing Analysis (NOAA DMSP-OLS Night Time Light Images)



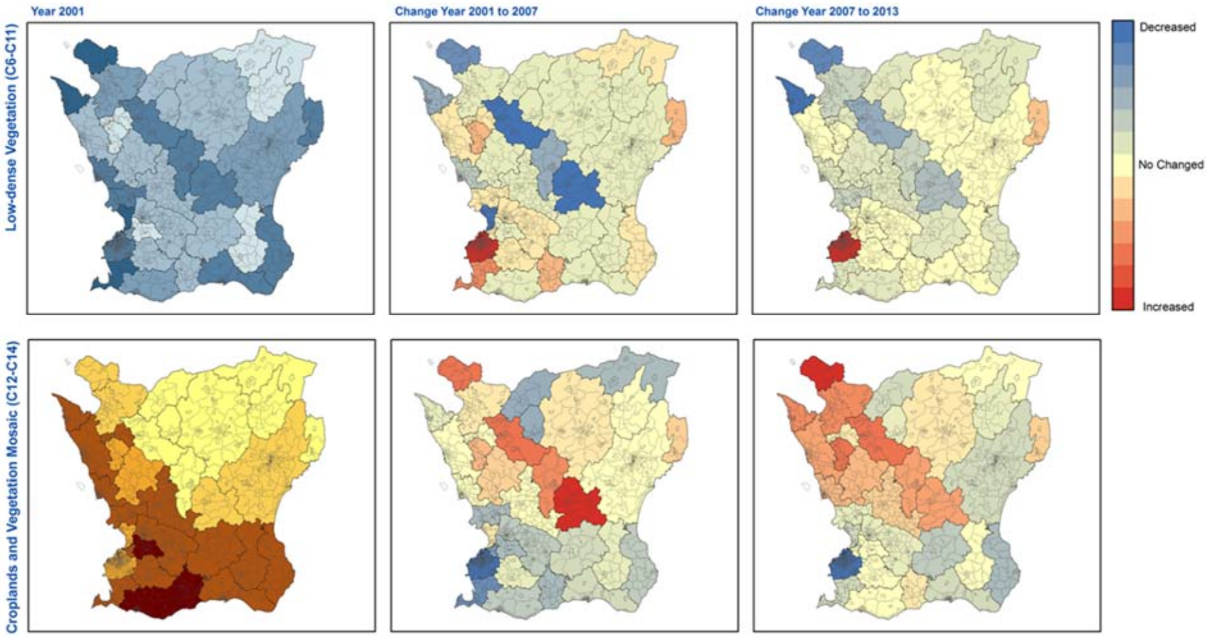
Source: NOAA DMSP-OLS

Figure 10. Remote Sensing Analysis NASA MCD12Q1 Land Cover Images in 2001 and 2013



Source: NASA MCD12Q1 Land Cover Images

Figure 11. Land Cover Analysis (NASA MCD12Q1 Land Cover Images: Change at the Municipality UNCIP Level)



Source: Author´s calculation

Figure 12. Spatial-Analysis: Visualization of the spatial model-building process