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Lund in 2050. A scenario-based approach on the development of urban sprawl and its effects on agricultural land in the municipality of Lund, Sweden.

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Abstract

The world population increases while farmland is decreasing on a global scale. One of the core sources for the loss of agricultural land is the growth of cities. While urban sprawl is mostly associated with North America, the European Union increasingly raises awareness for the greater loss of valuable soils through development processes within its member states. The variables driving the loss of farmland differ and strongly depend on the region studied. The municipality of Lund was chosen as the case study area due to its location in an agricultural area in the south of Sweden and its strong increase in population in recent years. The main drivers identified for the area are beside the growing population, the amount of built-up area per person and governmental growth management. Possible combinations of the factors were analysed and became the basis for three scenarios for the year 2050. The scenarios show possible futures depending on the focus set by the planning authorities and their effects on the loss of farmland. The results show, that the municipal authorities have an important role to play in safeguarding agricultural soils. Hence taking decisions towards sustainable growth of the urban areas, can be a means to protect farmland actively. Safeguarding arable soils contributes not only to higher self-sufficiency in Swedish food production, but also to feed the growing population of the future.

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Popular Science Summary

What will Lund look like in 2050?

With the combination of an increasing world population and growing cities, agricultural land is becoming more important for food security and simultaneously more threatened to be sealed permanently. This is the case on a global scale but also on a European and subsequently, Swedish level. The issue is of high importance for Sweden as its self-sufficiency in terms of food supply has decreased drastically over the last several decades. At the moment it is at only 50%, meaning only half of the food consumed in the country is also produced within the country. Self-sufficiency is one of Sweden's key points to improve its competitiveness as well as its preparedness in case of a crisis. Therefore, this thesis is addressing how urban growth, specifically urban sprawl, affects farmland in the municipality Lund, Sweden. The municipality was chosen not only because of its high amount of good-quality agricultural soils but also because its population has been growing continuously over the last years.

Protecting the Swedish farmland is not only important when discussing food security as soils provide many benefits to the local citizens, such as recreational areas, cultural landscapes and habitat for animals and plants. On the other hand, is urban sprawl mainly connected to negative impacts such as increased commuting times due to farther distances and more traffic, higher pollution, increased costs for infrastructure and loss the aesthetics of typical landscapes. With these potential negatives in mind, it is therefore worth taking a deeper look into what drives urban sprawl and how these patterns can be shaped. Therefore, three different scenarios were created and investigated for how Lund can grow until the year 2050.

With the local authorities as the main decision-makers, they bear the responsibility to make sustainable decisions and protect local farmland. Thereby, not only municipalities maintain the benefits of the unsealed land but also contribute to Sweden's goal of higher self-sufficiency and support global food security. With climate change and the growth of cities, fertile land is a scarce resource that needs to be protected. Therefore, it is important to ask oneself, how should Lund grow and what will it look like in the next 30 years.

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1 Introduction

In 2015 the Food and Agriculture Organization of the United Nations (FAO) prognoses a world population of 9.1 billion people, 24% higher than currently. Since 2008 about half of the global population is living in cities (Högblom Moisio *et al.*, 2016). These urbanisation processes will continue, and about 70% of people will live in urban areas by 2050 (FAO, 2009). Food production must equally increase by 70% until 2050 to feed the growing population (FAO, 2009; Myrdal & Morell, 2011). This will be a challenge for agriculture, not only because of the adverse environmental effects of intensive farming and a shift from food to energy production but also because people initially settled in the most fertile regions which are now consumed and lost for cultivation through the growth of cities (Myrdal & Morell, 2011; Fina, 2017). Therefore, the conflict between land for agricultural use and urban development is likely to intensify (Högblom Moisio *et al.*, 2016).

While issues such as urban sprawl are often seen as a problem for cities in North America, the metropolitan areas in the USA only account for about 1% of the total land area (Couch *et al.*, 2007; Nabielek *et al.*, 2016). In comparison, the urban area in Europe accounts for approximately 17% - therefore, a sense of land shortage is present (Couch *et al.*, 2007). Between 2000 to 2006, about 252 hectares of land per day are lost in Europe, mainly because of urban sprawl (European Commission, 2012). The so-called 'no net land take' goal by 2050, which refers to the loss of undeveloped land to human-developed land, was presented as part of the Roadmap to a Resource Efficient Europe, to address the increasing loss of soil (Science for Environment Policy, 2016). Nevertheless, at the moment no specific EU legislation is in place to achieve such a goal and protect valuable soil, and it is therefore up to its Member States to provide such protection (European Commission, 2006).

With Sweden's self-sufficiency dropping to nearly 50%, meaning that only half of the food eaten in the country is also produced there, urban sprawl and the preservation of farmland has become a more present topic (Bågenholm & Svensson, 2011; Granvik *et al.*, 2015). While only 8% of Swedish land area is agricultural land, about 3000 hectares of arable land were converted between 2006 to 2010 (Granvik *et al.*, 2015). The Food Strategy issued by the Swedish government aims to ensure food security and self-sufficiency to improve the countries competitiveness and preparedness in case of a crisis (Swedish Ministry of Enterprise and Innovation, 2017).

The goal of the Swedish Food Strategy to become self-sufficient in terms of food production can only be met if actions are taken to safeguard agricultural land and contribute to sustainable development (Swedish Ministry of Enterprise and Innovation, 2017).

1.1 Problem definition

While the awareness and commitment are rising on EU level and national level, most decisions on land development remain with the actors on the local level (Humer *et al.*, 2018). In Sweden, the municipalities have the primary planning responsibility (Granvik *et al.*, 2015). Even though the preservation of farmland is considered necessary by many municipalities, housing development is usually prioritised (Granvik *et al.*, 2015). The preference for housing development leads to an increase in the built-up area and a decrease of open soil and its essential functions, including food production (EEA & FOEN, 2016).

The municipality of Lund is in the county Skåne, where about half of Sweden's food is produced (Region Skåne, 2014). About 46% of the total land area of Lund is arable land that surrounds the central urban locations (SCB, n.d.; Granvik *et al.*, 2015). Lund, together with Malmö and Helsingborg, are considered attractive, regional hubs in Skåne and were witnessing fast growth in the last years (Region Skåne, 2014). Therefore, balancing urban development and agriculture is a critical problem in Lund, which needs to be addressed (Lunds Kommun, 2018c).

1.2 Research objective

The objective of the thesis is to identify trends and determine the interrelations between urban sprawl and the loss of agricultural land in Lund in the future (2050) by comparing different alternative scenarios based on trend extrapolation and assumptions. The factors that drive urban sprawl in the municipality are analysed conducting extensive literature research and using statistical data. The impacts of the different scenarios are evaluated and compared. Measures are suggested based on already existing actions in other European countries to manage urban sprawl.

The research can help to protect valuable soils, thereby contributing to the overall Swedish goal of higher self-sufficiency in food production. Further, alternative paths for development can increase the awareness of local authorities to their responsibilities and possibilities to manage land more sustainable. Consequently, this research can be useful for decision-makers and stakeholders not only in Lund but also in other similarly situated communities in Sweden and across Europe. In this work, the following two research questions are analysed:

1. Which impacts do the alternative developments have on the loss of agricultural land around the municipality of Lund?
2. Which factors drive urban sprawl in Lund, and which measures can be applied to influence urban sprawl?

2 Background - Urbanisation, agriculture and the planning system

It is necessary to look at the evolution of urban development in Sweden and the regional planning system that determines it to understand the current situation of urban sprawl in Lund. This chapter gives an overview of the situation in Sweden and Lund in the past and present.

2.1 From the past to the present

Today's cultivated landscape began many thousand years ago, and since then, agriculture is one of the most significant forces of landscape and environmental change (Myrdal & Morell, 2011). It took until the 20th century, for the industrial sector to overtook agriculture in Sweden, and urban areas began to grow (Hall, 1991; Myrdal & Morell, 2011). This transformation came along with economic growth, social reforms, and improved living conditions (Hall, 1991). The increase in consumption led to newly built homes in the major metropolitan regions, affordable cars and holiday cottages with little interests in the possible adverse effects (Hall, 1991). According to the study on agrarian history in Sweden by Myrdal & Morell (2011), a first policy to protect farmers and agriculture was adopted in 1947. The main goals were securing an equivalent income to industrial workers, creating stronger farms and increasing the total production to ensure domestic supply in the events of a war (Myrdal & Morell, 2011). Sweden was supposed to run under complete self-sufficiency in the long run (Myrdal & Morell, 2011). Towards the end of the 1960s and the beginning of the 1970s large areas were ascribed for housing development, mostly in peripheral locations on the outskirts of the larger towns (Jonsson, 1985 cited in Hall, 1991). For the so-called Million Programme (1965-75), one million housing units were built in an often monotonous design reminding of the American suburban areas (Hall, 1991; Myrdal & Morell, 2011). Urbanisation in Sweden continued to increase and does so since then (Högblom Moisio *et al.*, 2016). When entering the EU in 1995, national policies for agriculture were removed, and the EU agricultural policies took over, with the Common Agricultural Policy (CAP) as the main instrument to allocate subsidies for farming within the country (Myrdal & Morell, 2011).

In the last 40 years, population growth was mostly taking place in and close to the largest cities, with surpluses of population growth up to 70% in suburban municipalities (Högblom Moisio *et al.*, 2016). The division between town and country grew with farmers being under increasing pressure and city residents looking at the countryside for their recreation (Myrdal & Morell, 2011). The over-exploitation of natural resources and the question of a global food shortage in the modern age directed Sweden to a shift in perspective (Ibid.). Still, the values associated with agriculture remained, such as the conservation of nature, culture and the open landscape (Ibid.).

Table 1 Country Profile Sweden 2016 (World Bank, 2018).

Sweden (2017)	**Amount**
Population	10.07 million people
Population growth	1.4 %
Population density	24.7 people per km^2 land area
Urban population growth	1.8 % annually
Total surface area	447.4 thousand km^2

Table 1 gives a short profile of Sweden (World Bank, 2018). The population increased to over 10 million people in the last years, which corresponds to a growth of 1.4% and a population density of about 25 people per km^2 (World Bank, 2018). The increasing development in urban population (1.8%) is explained by strong international immigration processes as well as by in-migration from rural and peripheral areas to cities (Hörnström *et al.*, 2015; World Bank, 2018). Figure 1 shows the division in percentage between the rural and urban population in Sweden (FAOSTAT, 2017).

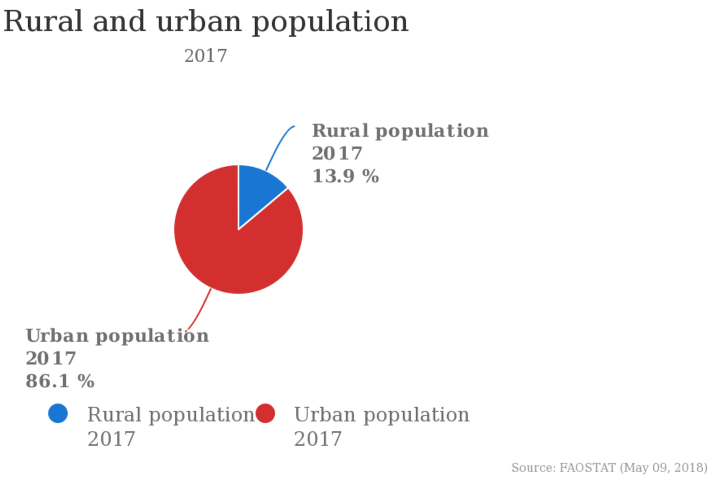

Figure 1 Sweden: Rural and urban population (FAOSTAT, 2017).

Sweden is the third-largest EU Member State with two-thirds of the country being covered by forest while about 60% of the arable land is on the fertile plains in the south (Prokop *et al.*, 2011; Jordbruksverket & SCB, 2018). Due to the size of the country and the amount of sparsely populated areas, the share of the artificial, sealed surfaces is among the lowest within the EU 27 (Prokop *et al.*, 2011). However, the amount of artificial surface per person is one of the highest in Europe (ESPON, 2006). Most of the area in Sweden is unfavourable for urban development, therefore urbanisation is concentrated in the south of the country (Couch *et al.*, 2007). With both cultivation and population growth taking place primarily in southern Sweden, the arable land available per person steadily decreases, which is shown in Figure 2 (The World Bank, 2018). Nevertheless, the production volume of Swedish agricultural goods is maintained with less land and fewer animals, on larger farms with a lower number of farmers (Fogelfors *et al.*, 2009).

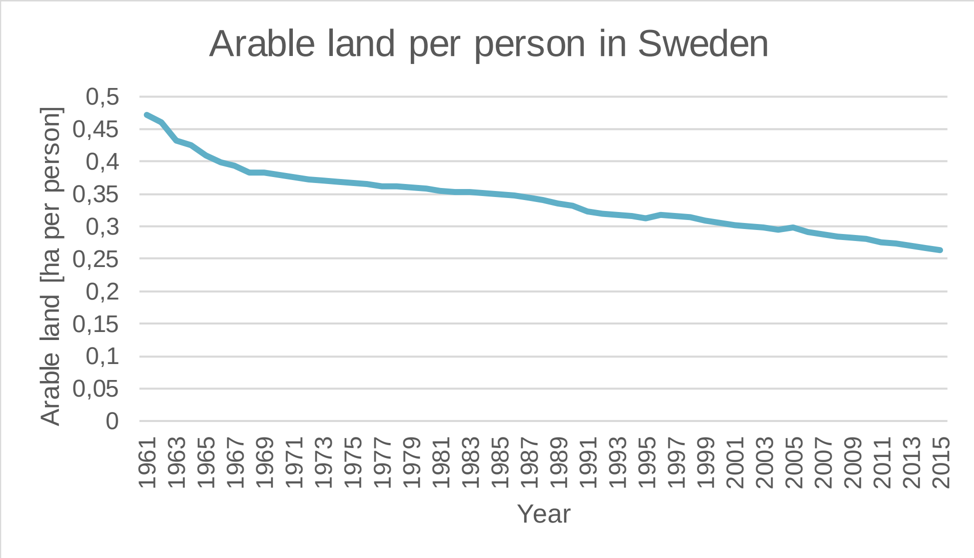

Figure 2 Arable land per person in Sweden (The World Bank, 2018).

2.2 The Swedish Planning System

Sweden's administration is divided into the state, the regions or counties and the municipalities (Persson, 2013). There is no national institute for spatial planning, but instead, it is regulated directly through legislation, namely the Planning and Building Act and the Environmental Code, and indirectly through initiatives such as investment programs (Persson, 2013). The Environmental Code states the national importance of agriculture and forestry and that valuable farmland should only be used for housing or other facilities if it is a vital social interest which can't be met by using other lands (Ministry of Environment and Energy, 2000; Jorgen *et al.*, 2013). The Planning and Building Act applies the Environmental Code to the planning and decision making (Jorgen *et al.*, 2013). However, the primary planning responsibility in Sweden falls to the local authorities (Persson, 2013).

The main instrument for physical planning is the municipal *översiktsplan* or comprehensive plan, which is a legally not binding document to outline the future land use development of each municipality (Persson, 2013). The plan covers the whole area of the municipality, a period of 10-20 years and must be reviewed at least once

during the four-year term of office by the municipal council (Persson, 2013). Besides the comprehensive plan, municipalities develop area regulations and a detailed development plan (Boverket, 2017). Area regulations address the municipality's land and water use if necessary, for the comprehensive plan or national interest (Ibid.). The legally binding detailed plan is prepared when new construction is taking place, outlining an area more precise, for example, the building height, site boundaries, and other specifics (Ibid.). The local authorities must submit documentation to the county administrative boards (*Länsstyrelserna*), which can intervene in issues related to national interests, environmental quality, flooding or erosion, issues of health and safety, and inter-municipal benefits (Högblom Moisio *et al.*, 2016). With the introduction of the 'new regional policy,' the county administrative boards must also formulate so-called regional development strategies (*Regionala utvecklingsstrategier– RUS*) which are economic oriented policies and tools to promote economic growth (Gruber *et al.*, 2019). Besides the coordination with the local level and states interests, the county administrative boards are limited in the planning process itself (Högblom Moisio *et al.*, 2016; Gruber *et al.*, 2019).
The comprehensive plan and detail plan should be applied by the municipality to justify the use of the arable land and the essential societal interest behind it (Jorgen *et al.*, 2013). The state gives the local authorities autonomy over planning with the assumption that sensible development decisions are taken (Jorgen *et al.*, 2013). Nevertheless, the "municipal planning monopoly" can drive urban sprawl (Larsson & Granvik, 2014). Couch *et al.* (2007) state that the smaller and more independent the units of local government are, the higher the competition between them to attract development – thereby encouraging sprawling patterns. The local authorities interest is to generate income and therefore, compete with other municipalities by offering cheap land for development (Larsson & Granvik, 2014).

In the period between 2011 - 2015, the exploitation of agricultural land in Sweden was 2,916 hectares, of with 672 hectares were converted in Skåne (Granvik *et al.*, 2015; Lindeberg *et al.*, 2017). The main reasons for the conversion are the construction of housing (68%), road and railway systems (21%), and non-residential buildings (11%) (Lindeberg *et al.*, 2017). The loss of agricultural land due to construction and soil sealing is permanent, meaning that it cannot be used for food production in the future (Prokop *et al.*, 2011). A paper by Granvik *et al.* (2015) analyses three studies on the preservation of agricultural land in a planning context in Swedish municipalities. The results show that even though most local governments consider safeguarding agricultural land as necessary, building urban development is given priority (Ibid.). The lack of policies on the preservation of agricultural land or the absence of their execution in many municipalities, with or without access to fertile land, highlights this prioritisation (Ibid.).

3 Defining Urban Sprawl

Numerous descriptions of urban sprawl are found in the literature (Siedentop & Fina, 2010). But no commonly accepted definition of urban sprawl exists, which makes it difficult to compare different regions and time scales with each other (Siedentop, 2005; Jaeger & Schwick, 2014). The rough common understanding of urban sprawl is the uncontrolled growth of the built-up land area in a problematic and unsustainable way (Weilenmann *et al.*, 2017). In this section, the meaning of urban sprawl is described, including its impacts and control measures implemented in some European countries.

Siedentop & Fina (2010) divides urban sprawl into four dimensions commonly discussed in the literature. The first group refers to sprawl as conversion from non-urban to urban land uses (1). The second category relates to urban density by describing urban sprawl with decreasing densities over time in newly urbanised areas or density losses in existing residential areas (2). Another dimension refers to urban sprawl as decentralisation - locating population, job growth and other metropolitan activities from central cities to suburbs and rural areas (3). The fourth group ascribes specific characteristic to sprawl, such as irregular, discontinuous urban land-use patterns (4).

The following definition by Jaeger and Schwick (2014, pp. 295), highlights those dimensions of sprawl:

> 'Urban sprawl is a phenomenon that can be visually perceived in the landscape. A landscape suffers from urban sprawl if it is permeated by urban development or solidary buildings, and when land uptake is high. The more area built over and the more dispersed the built-up area and the higher the land uptake per inhabitant or job, the higher the degree of urban sprawl.'

The different dimensions and the definition show that urban sprawl is a complex issue with various features. Similar is also the case of possible implications of urban sprawl, which can vary strongly and are explained in the next section.

3.1 Impacts of Urban Sprawl

Urban sprawl can further be examined based on its consequences (Siedentop & Fina, 2010). The reduction of urban densities (*density dimension*) results in higher travel distances and car dependency (Siedentop & Fina, 2010). More cars and longer commuting times can be related to more pollution, road accidents and traffic congestions, including lower physical activity leading to higher obesity rates and diseases such as diabetes, heart diseases and lower life expectancy (Ewing & Hamidi, 2014; Thaler, 2014; Litman, 2018). The lower densities, together with the typically fragmented pattern (*pattern-related dimension*) of sprawling regions, increase the costs for transport and social infrastructure (Siedentop & Fina, 2010; Litman, 2018). The dispersed land use pattern leads to landscape creating barriers for animals and plants and threatens biodiversity (Siedentop & Fina, 2010; Thaler, 2014). The changes in the landscape and loss of open space can additionally alter the cultural identity of a region and lower the value for recreation and tourism (Thaler, 2014). The *surface dimension* describes the conversion of an agricultural, natural or semi-natural surface to the built-up area (Siedentop & Fina, 2010). A high land consumption per capita goes hand in hand with the sealing and loss of fertile arable land as well as ecologically valuable habitats and services (Siedentop & Fina, 2010; Litman, 2018). The higher amount of impervious surfaces reduces water infiltration of the soils and increases the risk of flooding (Thaler, 2014). Figure 3 shows some of the impacts concerning the different dimensions of urban sprawl and their interactions (Siedentop & Fina, 2010). In this thesis, the main focus will be on the surface dimension and as marked in yellow, the loss of prime farmland.

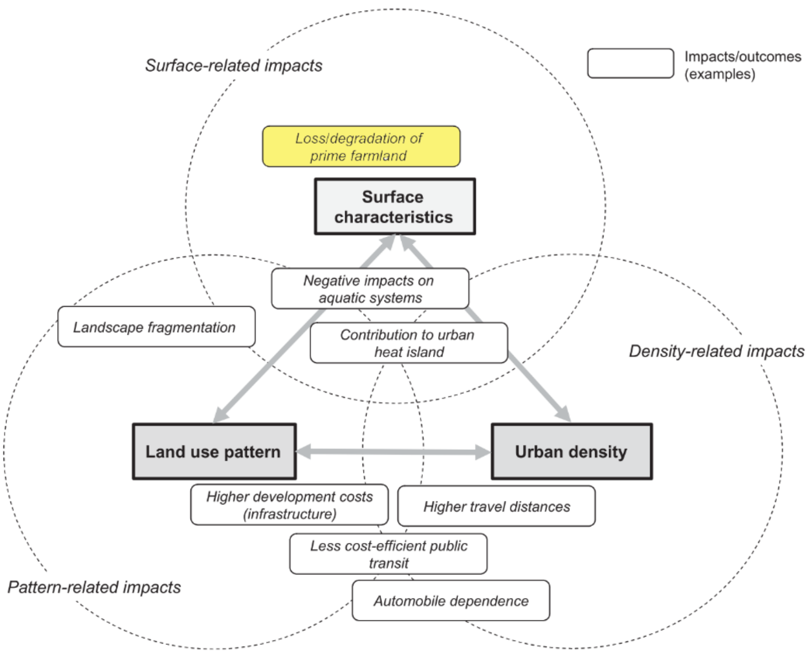

Figure 3 Impacts of urban sprawl by its dimensions (Siedentop & Fina, 2010, p.79).

Some aspects of urban sprawl found in the literature are considered positive, such as lower land prices in the suburbs, which make it possible to afford more living space per person (Thaler, 2014). Further, it offers residents, especially families, the often-preferred possibility of living in a peaceful and low-density neighbourhood with (private) green spaces (Ibid.). In combination with modern mobility and communication systems that established a connection to the city, it is possible to live and work remotely (Ibid.). Nevertheless, the literature is dominated by negative consequences (Ibid.). Therefore, the next section of this chapter is used to introduce several measures already implemented in some European countries to control or mitigate the adverse effects of urban sprawl.

3.2 Urban Sprawl Management Measures

Containment of urban growth depends on the countries shared norms and values for land development (Hayek *et al.*, 2011). Strategies to address urban sprawl include regulatory, legal planning, economic-fiscal, co-operative and informational approaches (Nuissl & Schroeter-Schlaack, 2009; Artmann, 2014a). Besides greenbelts and other zoning measures, examples are development permits, minimum and maximum density requirements, fees or taxes and others (Carruthers, 2002; Siedentop *et al.*, 2016). In the following, some management measures are presented to provide an overview of possible options to address urban sprawl.

The most common measures are regulatory, legal planning tools which can vary strongly but are in general considered efficient due to their often binding character (McLaughlin, 2012; Artmann, 2014b). The most commonly used tool is zoning, which can determine land use, nature conservation but also the intensity of development within each zone using measures such as minimum lot sizes, open spaces or height restrictions (McLaughlin, 2012; Broitman & Koomen, 2015). Those measures can influence the land consumed actively; for example, building two-story instead of one-story buildings reduces the amount of sealed area by about 50% (Seher & Grossauer, 2018). While a detached single-family house requires around 1,000m², row houses need about 500 m², multi-dwelling apartments require, depending on the construction style, 300 m² to 100 m² (Dallhammer, 2014). The **United Kingdom** is a famous example of zoning policies with a greenbelt established around Greater London already in 1935 (Prokop *et al.*, 2011). The aim is the creation or maintenance of recreational areas and attractive landscapes around towns, the encouragement of urban land recycling and the prevention of a take-over by urban areas and sprawl (Prokop *et al.*, 2011). **Denmark** also applies a stricter zoning regime and development plans (Jorgen *et al.*, 2013). The country is divided into land use zones, for urban areas, holiday homes and rural areas which should prevent urban sprawl (Jorgen *et al.*, 2013). Additionally, Danish municipalities are obligated to defend agricultural land from building processes (Jorgen *et al.*, 2013). The planning system in the **Netherlands** also referred to as “the planning paradise”, is based on regulations, zoning or planning by permission as well as planning to facilitate development (Korthals Altes, 2006). The conservation of the so-called Green Heart is the cornerstone of the national urban plan (Korthals Altes, 2006).

Another legal approach is setting targets which need to be reached such as the 30-ha goal introduced by the **German** government in 2002 to reduce land consumption (Siedentop & Kausch, 2004). The political objective is the reduction of land conversion to 30 hectares per day by 2020 from originally 129 hectares per day in the year 2000 (Storch & Schmidt, 2008; Science for Environment Policy, 2016). The consumption of land must be reduced together with more efficient use of the existing and newly built residential areas as well as transport infrastructure, to reach the 30-ha goal (Siedentop & Kausch, 2004; Storch & Schmidt, 2008). The German Building Code, for example, supports infill processes by allowing faster and more flexible development, setting aside an environmental impact assessment (Artmann, 2014a). The quantitative reduction of further soil sealing is included by a soil protection clause in the Building Code to protect natural areas at the urban fringes (Artmann, 2014a).
Similar quantitative limits are in place in Luxembourg, France and Switzerland (Science for Environment Policy, 2016). **Luxembourg's** national plan for sustainable development sets the goal to reduce land consumption to one hectare per day by 2020 (Ibid.). **France** has the target to halve the rate of agricultural land take by 2020 (Ibid.). In **Switzerland**, the public voted on the topic, and 63% of the Swiss population was for a stricter national law on spatial development (Weilenmann *et al.*, 2017). A clear boundary to spatial growth was set by limiting the settlement area at 400 m^2 per person (Weilenmann *et al.*, 2017).

In 2002, the **Austrian** Strategy for Sustainable Development declared a reduction of the annual sealing of soil to one-tenth of its initial value until 2010, which wasn't met (Prokop *et al.*, 2011). The planning measures are primarily set by the Austrian federal states and vary substantially (Prokop *et al.*, 2011). Prokop *et al.* (2011) sum up some of the some implemented actions such as newly issued building permits with expiration dates, which should limit land speculations with no real building intentions of the owners. In some parts of Austria, specific protection for priority farmland and green areas is in place. Further, co-operative measures such as contracts between municipalities and land developers can increase the opportunity for more efficient use of the building land. As stated by Artmann (2014b) co-operative measures between regions, investors, developers and municipalities can promote a mix of uses and foster infill development. Co-operative responses usually have high acceptance, and their implementation is less demanding (Artmann, 2014b).

Some countries have implemented a mixture of legal and economic incentives, to avoid further land take of the most valuable farmland and landscapes (Prokop *et al.*, 2011). In the **Czech Republic,** a soil protection law defines five classes of soil (Janků *et al.*, 2016). The first and second classes are the most valuable soils and are strictly protected (Ibid.). Only if the public interest outweighs the benefit of the protection such as roads and railways construction is allowed (Ibid.). Economic-fiscal instruments are in place to reduce land take, such as fee payments according to the soil quality (Ibid.). Fees for agricultural land conversion are also in place in **Slovakia**, **Poland** or **Bulgaria** (Ibid.). The income of such compensation payments can be directed to an environmental fund or actions to compensate for the loss of soil function with restoration measures somewhere else (Prokop *et al.*, 2011). Even though the land in most countries is traded by market mechanisms, the cost of land consumption has little impact on real costs (Nuissl & Schroeter-Schlaack, 2009). Economic approaches try to quantify those external effects of urban sprawl and provide value for ecological and social functions of soil (Ibid.). Besides land taxation, which adds a financial burden on development, tradable land development permits or subsidies rewarding avoidance of new development is incentive-based economic instruments (Ibid.).

A vital component of environmental regulations is monitoring (Nuissl & Schroeter-Schlaack, 2009). Jorgen *et al.* (2013) introduce **Norway's** planning system as one with strong protection of agricultural land since 1950. Additionally, to the target approach of the Norwegian government to half the consumption of farmland by 2010 and maintaining it by 600 hectares per year afterwards a tracking system to monitor development is in place (Ibid.). The monitoring system (KOSTRA) gathers information on the exploitation of agricultural land including the amount of converted land, the type of property, and the various interests for allowing the development of farmland (Ibid.).

Due to an increased import of food products, many people forget about the primary role of land for food production (Janků *et al.*, 2016). The protection of land is instead looked at as an obstacle for business and growth (Janků *et al.*, 2016). Further, the lack of restrictive targets is also due to the lack of acceptance by local decision-makers (Artmann, 2014b). Therefore, an important measure used for the protection of farmland around cities is the creation in public for the importance of soil (Seher & Grossauer, 2018). Common strategies are soft actions such as the transfer of knowledge and consulting as well as including key persons (Artmann, 2014a; b). Informal strategies further can contribute to a more sustainable lifestyle, which is essential to slow down increases in living spaces in Europe (Haase *et al.*, 2013). A study by Siedentop *et al.*, (2009) in Germany shows that in the states where the attention and political interest for the topic of land consumption and urban sprawl is higher, a trend towards less use can be witnessed. Therefore, raising the awareness and communication of the importance of soils to the public and policymakers is crucial (Bouma et al., 2012 cited in Artmann, 2014b).

Applied growth management techniques vary between the countries, and it is not clear, which of the introduced measure is most efficient. But the examples show that in general not a single action but a mix of policies are implemented to achieve land use goals and reduce urban sprawl (Nuissl & Schroeter-Schlaack, 2009).

4 Methods

A mix of different approaches is used to analyse the development of urban sprawl and the conflict between urban development and agriculture to answer the research questions. Scenarios are created to look at possibilities for the future. Recommendations are drawn based on the analysis of the created scenarios. This chapter is used to explain the methods used in detail.

4.1 Literature

To get a better understanding of urban sprawl and land use planning and management in Sweden and Lund, systematic literature research was conducted using scientific databases, including scientific reports, articles, and books. The most frequently used databases were Google Scholar, ScienceDirect and Scopus with a keyword search for ‘urban sprawl,’ ‘urban development,’ ‘loss of agricultural land/farmland.’ Additionally, similar keywords were also used in German. Furthermore, governmental and regional reports were looked at to get a deeper understanding of trends and drivers influencing urban sprawl in general and in Lund specifically. Statistical data was taken mainly from Statistics Sweden (SCB - Statistiska centralbyrån). The literature research is combined with the method of scenario planning and provides information and data for the creation of alternative futures.

4.2 Scenario planning

Since the 1990s, the main aim of planning is sustainability and balancing its economic, environmental and social dimension (Parker & Doak, 2012). Planning decisions reflect social choices about the built and natural environment and play a crucial role in shaping the course of resource use (Ibid.). Therefore, planners influence the future and have a responsibility to consider global challenges such as climate change and food security (Ibid.) One of the challenges for land use planning is to find a balance between urban development and the preservation of farmland and natural resources (Carsjens, 2015). In practice, the decision often favours urban development (Ibid.). Scenario tools can help to change the perspective and to look at alternatives and therefore improve awareness and decision making (Ibid.). The following section outlines the planning and creation of scenarios and describes the application of the method in this thesis.

Scenarios create a picture of how the future may look like based on today's situation and assumptions about its development (Hayek *et al.*, 2011). Everyone thinks ahead and processes information about what may come; therefore, continuously creates scenarios for the future (Lindgren & Bandhold, 2003). One definition used to describe a scenario is the consistent and challenging description of possible a future (Van der Hejden, 1997, cited in Chermack & Lynham, 2002). The farther away this respective future is, the higher the possibilities (Lindgren & Bandhold, 2003).
Scenario planning is commonly used when the problem is complex, and only a small amount of information and data is available (Wytrzens, 2018). It's is a strategic planning tool for the medium or long-term, which helps to understand driving forces and develop strategies (Mintzberg, 1994 cited in Lindgren & Bandhold, 2003). Figure 4 shows the method of scenario designing used in this work. The steps of scenario planning are used after the lecture manuscript by Wytrzens (2018) on methods of rural development and are modified using other literature on scenario planning.

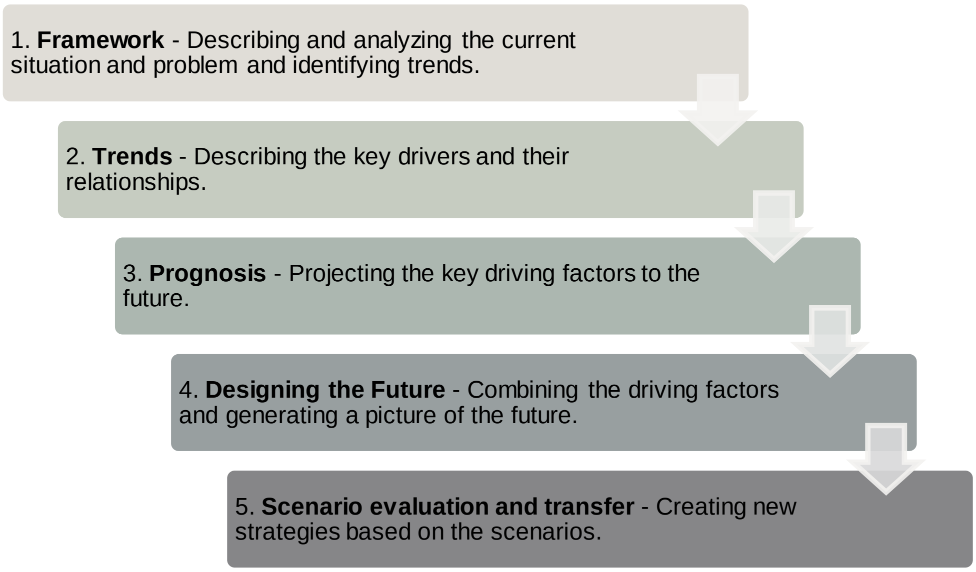

Figure 4 Steps of Scenario planning (Wytrzens, 2018, p. 69, modified).

The first step creates the framework for the scenarios. The basis is a summary of the current state of the case study to understand the problem and identify important driving forces or trends of change within the case study area (Penker & Wytrzens, 2005; Wytrzens, 2018).
The second step is a detailed description of the key drivers and their relationships (Wytrzens, 2018). The classification of important trends and uncertainties and their potential impacts on a region are the foundation of the scenarios and are used later to explore the future conditions and construct alternatives (Carsjens, 2015). Both the framework and the identification of key drivers are built on a literature review

and quantitative data on demographic and economic factors of Sweden and Lund as well as commonly identified determinants of urban sprawl (Weilenmann *et al.*, 2017).
The third step serves to create possibilities on how key drivers might change in the future (Wytrzens, 2018). Inputs for the prognosis are trend extrapolations, that can be artificially intensified (Lindgren & Bandhold, 2003; Jaeger *et al.*, 2008). The aim is not to predict the future but to show possible alternative paths and to understand the possible outcomes of specific patterns (Jaeger *et al.*, 2008).
In a fourth step, the driving factors are combined in different ways to create the scenarios (Wytrzens, 2018). As there is not only one version of a possible future, multiple interpretations of the relationships of trends and their eventual outcome are investigated (Corsico & Roccasalva, 2012).
The final step is the evaluation and comparison of the scenarios and the transfer into strategies (Wytrzens, 2018). Scenarios can be used for policy recommendations or to raise awareness for a problem among stakeholders, municipal authorities or citizens (Chakraborty & McMillan, 2015; Grafton *et al.*, 2015). Creating alternative futures can also serve as inspiration for new ideas or drive change and initiate follow-up projects (Lindgren & Bandhold, 2003; Grafton *et al.*, 2015). This last step of the scenario technique is in the result chapter, as it summarises the outcome and implications of the research.

Classified by the questions the scenarios try to answer, they are commonly separated into three main types (Börjeson *et al.*, 2006; Chakraborty & McMillan, 2015). The predictive (*What will happen?*), explanatory (*What can happen*?) or normative (*How can a target be reached?*) scenario (Börjeson *et al.*, 2006; Chakraborty & McMillan, 2015). In the following work, a predictive scenario (trend scenario) and two explanatory scenarios are created (alternative scenarios). The predictive or Business as Usual Scenario (BaU) is a particular form which follows current trends to predict the most likely future under stable conditions (Stiens, 1998). It can be used to compare with the alternative scenarios, where future states are changed (Dorning *et al.*, 2015; Lavalle *et al.*, 2017). The two explanatory scenarios paint two extreme developments, often named Best-Case or Worst-Case Scenario. In this work, the Best-Case Scenario creates a future with a definite goal to protect agricultural soils and is called ‘Balanced-Growth Scenario’. The Worst-Case Scenario alters the current trends in a way that farmland is not protected and is titled ‘Urbanisation Scenario’.
The timespan that the scenarios are covering should be short enough to create a probable scenario but also long enough to imagine changes with an impact on the future (Lindgren & Bandhold, 2003). The time horizon is set in 2050 future, about 30 years from now. The period was chosen because of the vision of the European Union to reach the aim of ‘no net land take’ by 2050. To achieve this goal member states should ‘better integrate direct and indirect land-use and its environmental impact in their decision making and limit land take and soil sealing to the extent possible’ (European Commission, 2011, p.5)

4.2.1 Scenario Context

Siedentop *et al.* (2009) distinguish between global, regional and local drivers. Global trends are the same for the whole region of Sweden and are very hard to influence (Siedentop *et al.*, 2009). Hall (2009) describes some basic parameters that reflect long and deep structural trends on a global level. Those trends are underlying long-term conditions for planning in a region and are in this work the same for all three scenarios (Johnson, 2012). While regional and local drivers are specific and therefore, included in the analysis, the global trends serve as a context for the case study area (Siedentop *et al.*, 2009).

The main patterns of economic and social transformation can be expected to continue, such as further changes from a manufacturing to an informational mode of production and the importance of education and training for entering the labour force (Hall, 2009). The role of developing countries in the global economy grows stronger, and the competition increases further (Johnson, 2012). The average income will increase, but income inequalities are likely to intensify (Hall, 2009). Employment patterns are predicted to change with disappearing middle-level jobs (Hall, 2009). For all scenarios, the case study area will benefit from such changes, with the main employment sectors being education, research, healthcare and business services (Hall, 2009; SCB, 2018d).

First steps to strengthen the growth engine Lund further are already taken by enhancing the region's connectivity to Copenhagen with the Öresund bridge and investments in the science park (Region Skåne, 2014). The vision for the whole county Skåne includes ensuring long-term housing availability as well as transport and communication infrastructure throughout the region by increasing its international accessibility with high-speed trains to Hamburg, Berlin, Oslo and Stockholm (Region Skåne, 2014). Therefore, in none of the three scenarios, any significant or sudden changes in the region’s economy are predicted, while average income and wealth are likely to stabilise or increase (Öborn *et al.*, 2011). In general, Lund follows a growth-oriented planning approach with a focus on the management of the growing population, workplaces, residential areas and transport areas (Wytrzens, 2018). The aim is to guide land use and determine zoning areas for building purpose but also the protection of open space (Müller & Siedentop, 2004, cited in Wytrzens, 2018).

Another global trend is the existing robust scientific consensus projecting that global warming will change the climate (Hall, 2009). Increasing temperatures will influence agriculture, forestry, social structures, economy and ecosystems (Johnson, 2012). Additionally, the risk for environmental catastrophes such as flooding, storms, massive rainfall events and droughts rises (Johnson, 2012). Living conditions in some regions will become harder and trigger mass migration processes (Hall, 2009). Sea level rise is predicted to threaten many coastal areas leading an expansion away from coasts into the country and the higher-lying regions (Hall, 2009). In northern Europe, including Sweden, the temperature rise will lead to higher precipitation during winters (Öborn *et al.*, 2011). In the south of Sweden, much drier summers and heat waves will change the requirements for irrigation and drainage but with an overall expectation of longer growing seasons and higher yields (Ibid.). New crops might be able to grow in the region, but also more pests and weeds will be present (Ibid.). An additional risk for agricultural production is a possible shortage of good quality phosphors and therefore, a deficit of nutrients (Rockström *et al.*, 2009). But also the high energy input which is needed for industrial food production is a concern as increasing energy prices pose a risk (Öborn *et al.*, 2011). On the other hand, technological development could increase energy efficiency and the development of renewable energy sources (Öborn *et al.*, 2011). Because of the changing trends and thereby included uncertainty for the near and farther future, those factors are not included in the scenarios. The current climate and production levels in agriculture are maintained in the context of the thesis.

4.2.2 Framework – Lund municipality

The municipality of Lund was chosen as the case study area because of its strong growth in population, housing demand and the location in an agricultural area (Madureira & Möllers, 2006). The location of the case study area is shown in figure 5. In the following chapter, Lund is introduced in more detail to describe the current state and drivers.

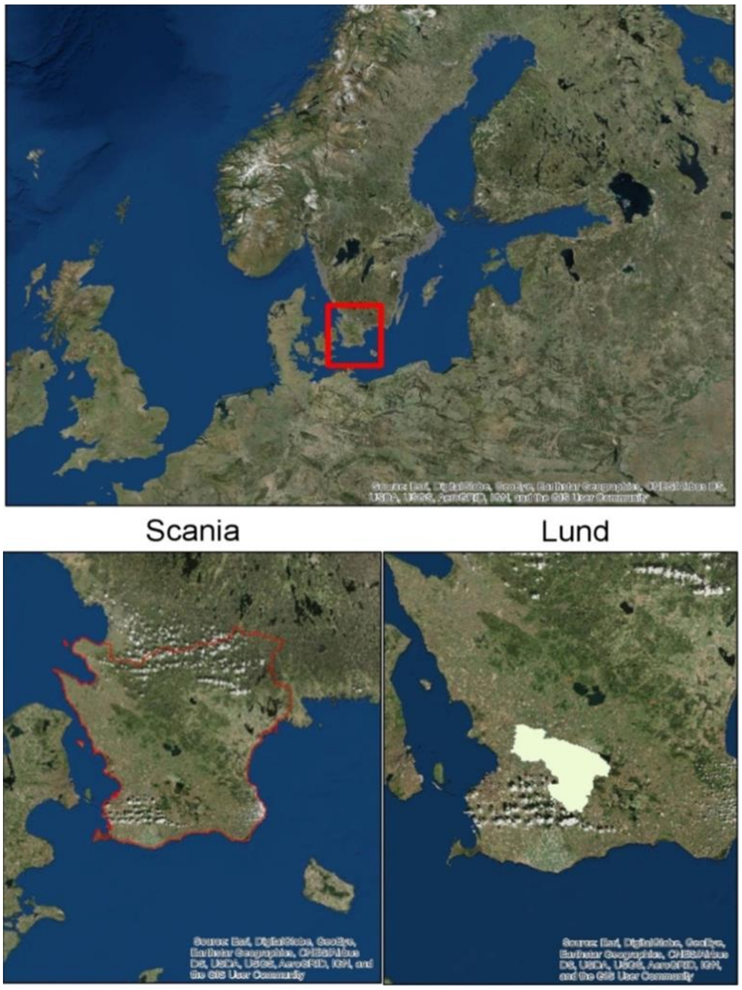

Figure 5 Map of the case study area (Esri et al., 2019, modified).

With 42,707 hectares Lund is a relatively large municipality in the south of Sweden in the county Skåne - or Scania (SCB, n.d.). The main metropolitan area is the city of Lund, which is one of the oldest in Sweden, dating back to the year 990 (Wickström, 2018). The municipality includes nine localities and a small part of Bergströmshusen (1) which partly belongs to the jurisdiction of Lund (SCB, 2016). Figure 6 shows the municipalities’ border and its localities.

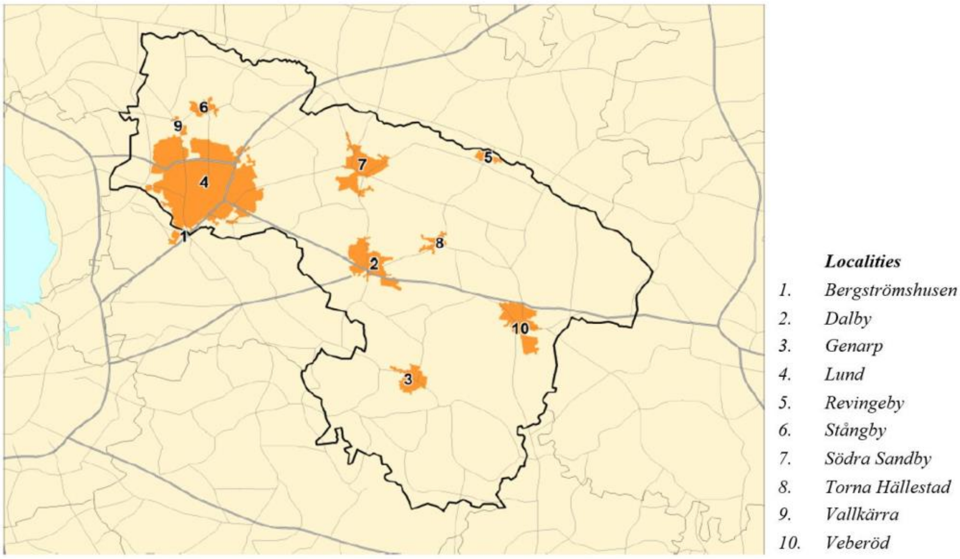

Figure 6 Localities within Lund municipality (SCB, 2018c).

Population, population growth or density are commonly used variables to describe urban growth (Weilenmann *et al.*, 2017). The more people, the more living space is required (EEA & FOEN, 2016). The current population in Lund is 121,274 people, which is 2,732 inhabitants more than the previous year (SCB, 2018g). The average population density for the municipality is 284 inhabitants/km^2 (SCB, n.d.). The population is not evenly distributed within the area, with the city of Lund having by far the highest agglomeration of people (SCB, 2018c). Table 2 shows the localities, their area and population density. Over the last years, the population increased in almost all localities and is expected to keep on growing (SCB, 2018c). One of the main factors contributing to this growth is foreign migration (Lunds Kommun, 2018a). The number of people immigrating varies but has been positive since 1997 (SCB, 2018e). In 2017 migration accounted for 60 percent of Lund’s population growth, which was the most significant increase in the history of Lund (Lunds Kommun, 2018a).

Table 2 Population and area distribution within Lund (SCB, 2018c).

Locality	**Population in 2017 (people)**	**Area in 2015 (km^2)**	**Population density (people/km^2)**
Dalby	6464	4.12	1531
Genarp	2928	1.96	1522
Lund	91074	26.29	3318

Revingeby	537	0.66	810
Stångby	2008	1.02	1907
Södra Sandby	6322	4.35	1450
Torna Hällestad	694	0.80	849
Vallkärra	411	0.41	1006
Veberöd	4937	3.95	1229
Outside localities	5899	-	-

Not only the number of people but also age and household size contribute to sprawling patterns (EEA & FOEN, 2016). Households in Europe are generally getting smaller, and the traditional concept of the family is losing importance, with single households, cohabiting couples, single parents and shared flats becoming more widespread (Haase *et al.*, 2007). This pattern is also visible in Lund. Of the approximately 57,700 households, 21% are single-person households, 26.5% two-person households, 15.8% three- and 21.3% four-person households (SCB, n.d.). A majority of the households are without children (40,705) (SCB, 2018d). While Sweden is considered a transition state with a low birth-rate and an ageing population, the average age in Lund is rather young with 38.6 years (Haase *et al.*, 2007; SCB, 2018a; SCB, n.d.).

The growth in population and workplaces in Lund makes the provision with affordable housing crucial and urgent for the municipality (Madureira & Möllers, 2006). In large parts of Skåne, including Lund, the construction of homes is not matching up with the population increase, which results in a lack of housing (Region Skåne, 2014). Additionally, the increase in smaller households does not necessarily mean lower housing requirements (Haase *et al.*, 2007). Very different settlement patterns, levels of infrastructure and living environments can be created depending on how the land is built or rebuilt (Humer *et al.*, 2018). Low-density buildings, for example, are a typical characteristic of urban sprawl (Madureira & Möllers, 2006). Therefore, the type of housing is critical to consider in the analysis of urban sprawl (Madureira & Möllers, 2006). A trend towards a higher amount of multi-dwelling buildings can be observed in the municipality, as shown in Figure 7 (SCB, 2018f). The number of total dwelling are rising in both one- or two-dwelling buildings and multi-dwelling buildings, but with stronger growth of the latter (SCB, 2018f). The distribution of housing types varies in Lund (Lunds Kommun, 2018b). While the city of Lund holds a high amount of multi-dwelling buildings, the localities mainly consist of single-family buildings, showing a more sprawled characteristic than the city (Lunds Kommun, 2018b).

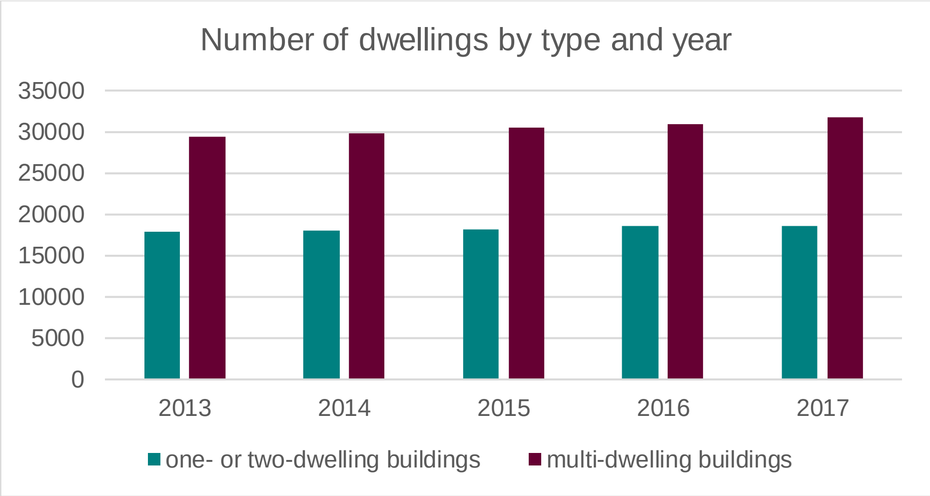

Figure 7 Number of dwellings by type of building and year (SCB, 2018f).

Lund is part of one out of two labour market regions in Skåne and one of its eight so-called regional hubs (Region Skåne, 2014). About 32,266 people work and live in the municipality; additional 37,544 people commute to the municipality (SCB, n.d.). In comparison, only 21,770 leave the municipality for work (SCB, n.d.). Most people living in Lund are employed in healthcare and nursing (22%), education (17%) followed by trade (14%) and business services (13%). Only a tiny fraction is employed in the sector agriculture, forestry and fishing (1%) (SCB, 2018d). A big part of Lund is its University with 40,000 students and 7,400 staff members (Lund University, 2018). The newly built research facilities in the northeast of Lund in the new district of Brunnshög are closely linked to the university (Science Village Scandinavia AB, 2016; Lund University, 2018). The two main experimental facilities are the MAX VI synchrotron facility and the European Spallation Source (ESS). The MAX VI laboratories produce X-rays to investigate material properties and were finished in 2016 (Rekers & Sandell, 2016). About 200 people are currently employed there. The ESS construction is ongoing and designed to generate neutron beams for research in different scientific disciplines (Science Village Scandinavia AB, 2016). Just over 300 people are employed at ESS at the moment (Rekers & Sandell, 2016). The facilities themselves and the research performed there are seen as an economic driver for Lund and all of Europe (Science Village Scandinavia AB, 2016). MAX IV and ESS can be used by researchers from different disciplines, also meaning that a lot of the users will be visitors while being employed elsewhere (Rekers & Sandell, 2016).

Knowledge-intensive services and research-intensive industries usually are looking for high-quality infrastructures like universities with good reputations, availability of specialised education, global companies, good accessibility by high-speed trains or aeroplanes (Krätke, 2007; Lüthi *et al.*, 2013). Strengthening the knowledge and research-intensive economic sector leads to growing numbers of workplaces and employment and raises the productivity and innovation capacity of regional economic centres (Krätke, 2007).

The average income in Lund is 290,000 Swedish Krona (SEK), around 2,800 euro (EUR), which is about the average for Sweden (SCB, 2018a; c). In theory, increasing wealth has a positive influence on urban sprawl (Weilenmann *et al.*, 2017). A wealthier municipality is expected to develop faster with a higher income often relating to a particular lifestyle which includes living in detached housing in the urban periphery and owning a car (EEA & FOEN, 2016; Weilenmann *et al.*, 2017). On the other hand, Siedentop *et al.* (2009) conclude that living preferences are much more differentiated, with the city as living place growing in attractiveness. The city of Lund is growing stronger than the more rural localities in the municipality indicates a higher draw to a more urban lifestyle (Lunds Kommun, 2018b).

The municipality is part of the so-called Öresund region (Madureira & Möllers, 2006). It's not only close to Malmö but with the Öresund bridge also very well connected to Copenhagen and therefore has convenient to access internationally (Region Skåne, 2014). Good accessibility does make Lund an attractive living place not only within Sweden but also for inhabitants with a foreign background (Ibid.). The growth of the region does not only depend on a good connection outward but also good accessibility within its borders (Ibid.). To increase the region's ability to grow further, investments in transport infrastructure are essential (Ibid.). But better accessibility with a car or public transport also supports a life further away from urban centres and can create more dispersed housing suburbs and increase commuting (Madureira & Möllers, 2006; EEA & FOEN, 2016). The city of Lund is known for its high bicycle use with students forming the base of a bicycle culture (Ljungberg, 2007). Still, the total number of passenger cars in Lund increased steadily over the last years (SCB, 2018h). However, the number of vehicles per 1000 inhabitants stayed constant over the same period, which displays that the increase is in line with the population increase (SCB, 2018h). The public transport in Lund is provided by trains and buses connecting the municipality locally and regionally (City of Lund, n.d.). Additionally, a new tramway is planned between Lund central and the newly built science centre in Brunnshög (Strand Larsson, 2017). 30% of the city's future expansion is expected around the area of the new tramway (Strand Larsson, 2017). The continuous investments in the transport infrastructure of the municipality and the county contribute to an attractive work and living place and foster an increase in population, workplaces and thereby also an urban structure.

With 46.6% of the municipality being agricultural land most of the new urban structure will be on farmland (SCB, n.d.; Lunds Kommun, 2018c). For example, the area where the 18 hectares extensive facilities ESS and MAX IV were built used to be farmland, meaning the planned expansion in this area would also be mostly on agricultural land (Kaijser, 2016; Science Village Scandinavia AB, 2016; Strand Larsson, 2017). The conversion of farmland and pastures due to buildings, roads, and railways in Lund between 2011 and 2015 was about 40.8 hectares (Lindeberg *et al.*, 2017). Although the exploitation of land varied from year to year and was reduced in the last years, the overall trend is still a continuing loss of agricultural land due to the built-up area. This trend is shown in figure 8 (Jordbruksverket, 2006; Edman *et al.*, 2013; Lindeberg *et al.*, 2017).

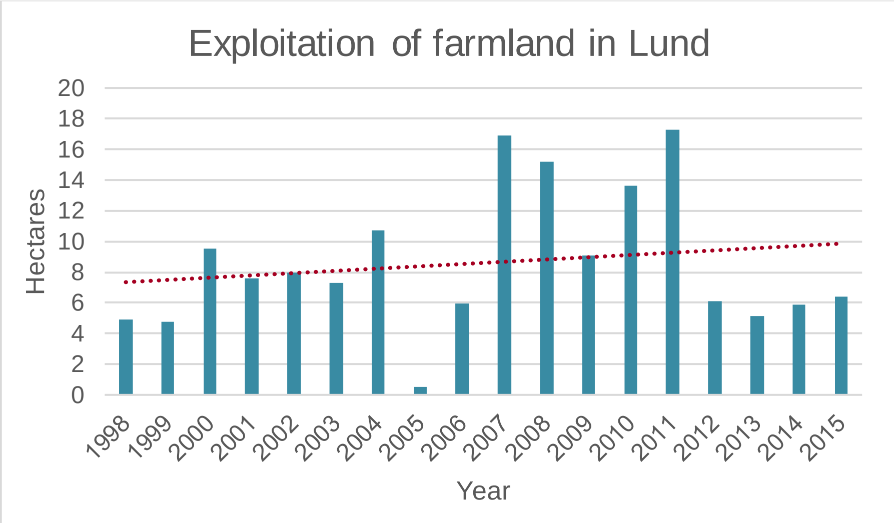

Figure 8 Exploitation of farmland in Lund per year in hectares (Jordbruksverket, 2006; Edman et al., 2013; Lindeberg et al., 2017).

The farmland belongs to the most fertile in all of Sweden, and almost half of the region is arable land, producing about 50 per cent of the countries food (Region Skåne, 2014). The soil type is according to FAO classification, mainly Eutric Cambisol classified as loam or loamy sand with a clay content from 5% to 35% (Söderström & Piikki, 2016). Eutric Cambisols in Temperate Zones are among the most productive soils on earth and are good agricultural land and generally used intensively (FAO, 2014). The fertile soils provide farming areas for different cultivations among which winter wheat, spring barley, sugar beets, hay and fodder plants are the most frequent (SCB, 2011).

Brueckner & Fansler (1983) state that high-quality and high-prices farmland is more resistant to urban expansion, balancing the growth of urban land. Since Sweden joined the EU in 1995, the average price for agricultural land and meadows increased continuously (Jordbruksverket, 2018c). In the south, the costs increased by 56% (Jordbruksverket, 2018c). In southern Sweden (Sydsverige) the price 18,765€/ha in comparison to 2,875€/ha in the northern part (Norra Sverige), with the average land price of the country being 8,708 €/ha (Eurostat, 2019). Not only the price for arable land is increasing but also its assessed value (SCB, 2019a). In Lund it increased between 2010 and 2015 from 145,905 SEK/ha (13,881 €/ha) to 174,497 SEK/ha (16,601 €/ha) (SCB, 2019a). But even though the soil is excellent for agricultural use and the value and prices for land are high, agricultural land-rich areas are under pressure to be sealed and transformed into residential or commercial areas due to the closeness to existing urban areas (EEA & FOEN, 2016). The topography of the area affects the space available for built-up areas; therefore, boost or limit urban sprawl (Ibid.). While for example, in mountainous terrain, the spread of urban land is less feasible, most arable lands are in almost flat areas easily converted into urban land uses (Ibid.). The trend is also visible in Lund, where the agricultural area decreases while the amount of urban, built-up area increases (Granvik *et al.*, 2015). The productive agricultural land is surrounding the central urban locations (Granvik *et al.*, 2015). Table 3 shows the change in land use for arable land and built-up land in 2011 and 2015. The conflict between land use for development and the preservation of natural and cultural values, primarily farmland, is therefore critical (Region Skåne, 2014).

Table 3 Arable and built-up land in Lund (SCB, 2018b).

Land use in Lund	2010	2015
Arable land	20282 ha	19917 ha
Built-up land	4610 ha	4741 ha

The framework introduces the current state in the case study area. Thereby, an understanding of the situation in Lund is created, which makes it possible to identify the most critical drivers for the future. In the next chapter, the trends pushing urban sprawl are presented, and the key drivers and their impacts are explained in detail, including the estimations for future change.

4.2.3 Trends and prognosis of the drivers

Lindgren & Bandhold (2003) describe a trend as a significant change in a specific direction which occurs over time. It is essential for the creation of scenarios to identify drivers and their consequences and to see how trends interact (Lindgren & Bandhold, 2003). Land-use changes, like the conversion of agriculture to urban land use, depend on both macro drivers and local dynamics (Baranzelli *et al.*, 2014). While external macro drivers define the demand for land, the local characteristics define the suitability for the land-use change (Baranzelli *et al.*, 2014). Different articles state a vast number of drivers as well as indicators to explain urban sprawl (Siedentop *et al.*, 2009; Weilenmann *et al.*, 2017). Table 4 gives an overview of some variables found in the literature.

Table 4 Summary of drivers for urban sprawl.

Drivers	Descriptions	Indicators	Source
Population; Population growth; Population density	The more people, the higher the demand for living space.	Total population; Inhabitants/m², Population growth	Weilenmann *et al.*, (2017); EEA & FOEN (2016); Brueckner & Fansler, (1983); Siedentop *et al.*, (2009); Jaeger *et al.*, (2008)
Ageing	A higher proportion of seniors live in single households.	Retired inhabitants; Ageing index	Weilenmann *et al.*, (2017); EEA & FOEN, (2016); Siedentop *et al.*, (2009)
Economic wealth; Income	Higher-income increases living space and housing demand	GDP, GDP per capita; change in GDP; household	Brueckner & Fansler, (1983);

	and lead to a larger city.	income; income per capita	Weilenmann *et al.*, (2017)
Land price	Higher prices for agricultural land increase the costs for expansion and make the city more compact.	Price per hectare land (building or agricultural) land	Brueckner & Fansler, (1983); Siedentop *et al.* (2009)
Transportation cost, commuting time; Accessibility; Cars	Increasing costs for commuting leads to denser cities. Better public and private transport attract more people and increase the built-up area. Cars make it possible to live farther away from work.	Cars per 1000 inhabitants; In-commuters, Out-commuters; Highway access; Road and Rail density; Fuel price	Brueckner & Fansler, (1983); Siedentop *et al.*, (2009); Weilenmann *et al.*, (2017); EEA & FOEN, (2016)
Employment	Not only the number of workplaces but also the sector of employment can influence the amount of land consumed.	Number of employees in primary, secondary or tertiary sector; Change in the employment sector; Employment rate	Weilenmann *et al.*, (2017); Siedentop *et al.*, (2009)
Household size	In a single household, the person generally uses more space per person than in a household with more people.	Number of single households; Inhabitants per household	Weilenmann *et al.*, (2017); EEA & FOEN, (2016)
Governance, Political drivers	Commuting Subsidies, tax releases for new houses or developing infrastructure and public transport can increase urban sprawl. Stricter regulation on building or protected land can limit urban sprawl.	Planning regulations, Number of decision bodies; Natural protection sides; Awareness for urban sprawl	Siedentop *et al.*, (2009), EEA & FOEN, (2016)
Topography	A high amount of irreclaimable space limits the settlement	Irreclaimable area (Lakes, Mountains, glaciers, swamps); Relief energy; Coastal area	Siedentop *et al.*, (2009); EEA & FOEN, (2016)

	area. Flatland is easily converted into a settlement.		

Table 4 shows only a selection of authors and the variables used to explain growth processes. The classic economic model of a monocentric city uses four variables to describe growth processes, population, income, land prices and transport prices (Brueckner & Fansler, 1983). Siedentop *et al.* (2009) divide the drivers into demand and supply oriented. The classic drivers led by the demand of a growing population, their housing preferences and income is losing importance while the supply with building land, subsidies for commuting and infrastructure increasingly gain explanatory power (Siedentop *et al.*, 2009). The report on urban sprawl from the EEA & FOEN (2016) states among many others, population density, road density, railway density, household size, governmental effectiveness and the number of cars per inhabitant as well as two environmental variables as the most important driving forces of urban sprawl in Europe (EEA & FOEN, 2016). Weilenmann *et al.* (2017) compared several variables and came to the result that accessibility is the primary explanatory variable for the increase in a built-up area.

This selection shows the multitude of existing drivers, which makes it challenging to identify the most dominant variables in a specific regional context (Fina, 2017). Furthermore, predicting future settlement development is difficult because the possible combinations of many different factors lead to entirely different alternatives (Ulfarsson and Carruthers, 2006 cited in Hayek *et al.*, 2011).

The actual impacts are often a result of a combination of the main drivers within a geographical setting (Fina, 2017). Therefore, it is essential to identify the drivers central to the consumption of agricultural land within a region but also which ones can be managed in a more efficient way (Fina, 2017). Based on the literature research on drivers of urban sprawl and the analysis of the case study area, a small set of indicators was chosen based mostly on the study by Jaeger *et al.* (2008) to create the three scenarios. The adopted variables are population, the amount of settlement area per inhabitant, and the choice of non-building zones on the best arable soils (taboo zones) (Jaeger *et al.*, 2008). In the following, the main drivers selected are explained and extrapolated into the future.

Population

Population or population growth is the most widely used variable to capture urban growth (Weilenmann *et al.*, 2017). The assumption is simple; the more people, the more space is needed for housing, transportation and public services and therefore more pressure on agricultural land will be exerted (Johnson, 2012; EEA & FOEN, 2016). While projections predict a substantial decline for the population in Europe, the world population will rise (Hall, 2009). Medical advances will prolong the life span and increase the ageing population (Ibid.). Areas with favourable climate and low living costs, witness immigration of older retired people (Ibid.). Other regions experience a decline in population, which leads to shrinking cities with substantial increases in social service costs and falling tax revenues to pay them (Ibid.). Even

though the effect of population growth in Europe is considered generally low, as the population is predicted to decline, the population in Sweden is estimated to increase by more than 2.5 million people by 2040 (Nilsson, 2011; EEA & FOEN, 2016).
Still, population growth does not necessarily lead to urban sprawl as it can be accommodated in two types of spatial development, densification and expansion (Broitman & Koomen, 2015). New construction can take place on the land outside of a city, leading to increase of built-up area or it can take place within the existing built-up area, leading to denser cities (Broitman & Koomen, 2015). It is often argued, that population growth is not the key driver for urban sprawl anymore, as urban sprawl has continued in many regions, where the population stopped growing or even declined (Siedentop *et al.*, 2009; EEA & FOEN, 2016; Fina, 2017).
Nevertheless, population growth is included as a driver for urban sprawl in Lund in this work because Lund's population is increasing steadily with the most significant growth in its history in 2017 (Lunds Kommun, 2018a). The population growth is expected to continue because of a continuing immigration, the attraction of new residents by the new job possibilities as well as an increase in students due to the higher births in Sweden in the late 1990s and early 2000s which will come to the age to study at university (Lunds Kommun, 2018a). The literature estimated a rise in population in Lund to about 145,000 inhabitants by the year 2030 (Lunds Kommun, 2018a). An exponential trend analysis further increases this number to about 185,000 people in 2050. This trend extrapolation was done in two simple steps. First, the population growth rate (r) was calculated (Giffinger *et al.*, 2011):

1. Growth rate $r = (\text{Population}_{\text{end}} / \text{Population}_{\text{beginning}})$ ^ (1 / period in years) -1

$$r = (121{,}274/64{,}790) \wedge (1 / 49) - 1 = 0.013$$

The statistical data was used from Statistics Sweden. Data were available from 1968 until 2017, which are used for the beginning and end year for the calculations, giving 49 years.

The following formula was used in Excel to extrapolate the trend for the years 2018 until 2050 (Giffinger *et al.*, 2011):

2. $P = \text{Population}_{\text{beginning}}$ * (1 + population growth rate r) ^ period in years

$$P_{2018} = 64{,}790 * (1 + 0.013) \wedge 50 = 122{,}836 \text{ people}$$
$$P_{2050} = 64{,}790 * (1 + 0.013) \wedge 82 = 184{,}981 \text{ people}$$

It is calculated that Lund's population will increase by 63,707 people, which corresponds to a rise of about 52% between 2017 and 2050. The number fits into the range of the estimation by Nilsson (2011), who predicts an increase of around 42.3% in population for the whole county of Skåne for the period of 2015-2050 with the highest concentrations in the cities Malmö, Helsingborg and Lund (Nilsson, 2011; Stenmark, 2015). Figure 9 shows the calculated changes in the population until the year 2050.

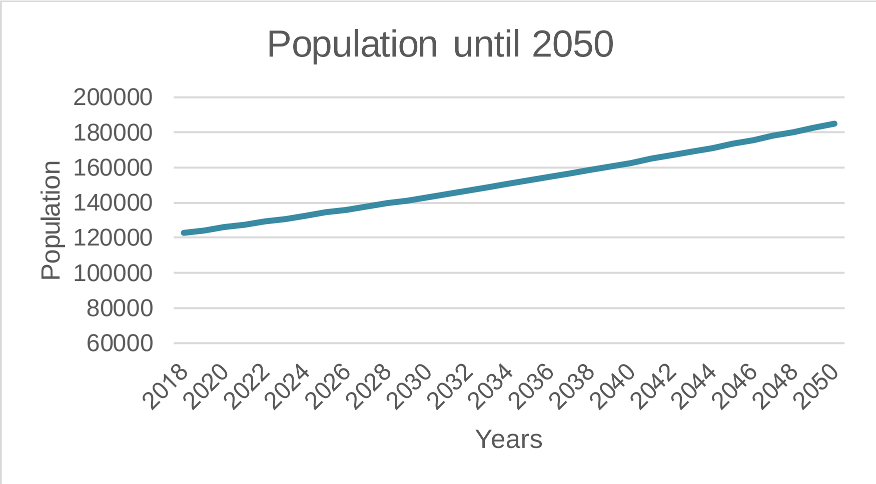

Figure 9 Extrapolation of the population to the year 2050.

A sharper increase in population for the Urbanisation Scenario in the future would be possible as a continuing rise in immigration and asylum applications due to conflicts and the climate crisis is likely (Missirian & Wolfram, 2017). Implementations that restrict birthrights and immigration even if possible are conflicting and will, therefore, not be considered for a Balanced Growth Scenario (Stenmark, 2015). While Jaeger *et al.*, (2008) varied the population increase for the scenarios it was decided to use the same extrapolation of population increase for all three scenarios in this work, so the impact of policy regulations are emphasized and not only the change in the external factor which cannot be changed (Baker *et al.*, 2004). Table 5 shows the population number used for the scenarios, rounded to an even number.

Table 5 Scenario modifications for the population in Lund.

Scenario modification	Business as usual	Balanced Growth	Urbanisation
Population	185,000	185,000	185,000

Built-area per person

The built-up area per person shows the relation between the inhabitants of a region and the land which is built up per person in square meter (Barbosa *et al.*, 2017; Lavalle *et al.*, 2017). The built-up area per person can reflect the effects of land use planning, government subsidies, urban policies and individual consumption decisions of households and business (Kolankiewicz & Beck, 2001). If the urban area is used by fewer people, a lower population density is the result (Kolankiewicz & Beck, 2001). Or in other words, the less land is consumed per inhabitant; the more efficient is the use of the sealed land (Barbosa *et al.*, 2017). Within Europe, the general trend shows the farther north, the higher the amount of land consumed per person (Kasanko *et al.*, 2006). Further, Lavalle *et al.* (2017) show that land use is most efficient in cities and decreases further away from the centres. The scenarios created by Jaeger *et al.*, (2008) for Switzerland showed that the settlement area per person had the most substantial influence on the sprawling development for the future.

Table 6 shows information for the total built-up area in Lund for the year 2010 and 2015. The number of urban area increases by 131 ha. Dividing the built-up area by the population number in the respective years, it shows a decrease in built-up land from 417 m² per inhabitant in 2010 to 405 m² per inhabitant in 2015, showing a slight trend towards less consumption per person.

Table 6 Built-up land in Lund (SCB, 2018b).

Lund	Urban area [m²]	Population	Built-up area person [m²/person]
2010	46100000	110488	417
2015	47410000	116834	405

To calculate the built-up area per person (a), a simple formula is used dividing the total area of urbanised land in a city and its suburbs (A) by its population (P) (Kolankiewicz & Beck, 2001):

$$a = A/P$$

The amount of new urban area added in the scenarios is determined by the predicted amount of urban area per person multiplied by the estimated increase in population size in the municipality (Jaeger *et al.*, 2008). Figure 10 shows the linear extrapolation of the built-up land in hectares until the year 2050. Only two points in time were accessible for the extrapolation of the urban area in Lund, which is not a reliable basis. Unfortunately, more information was not available to the author.

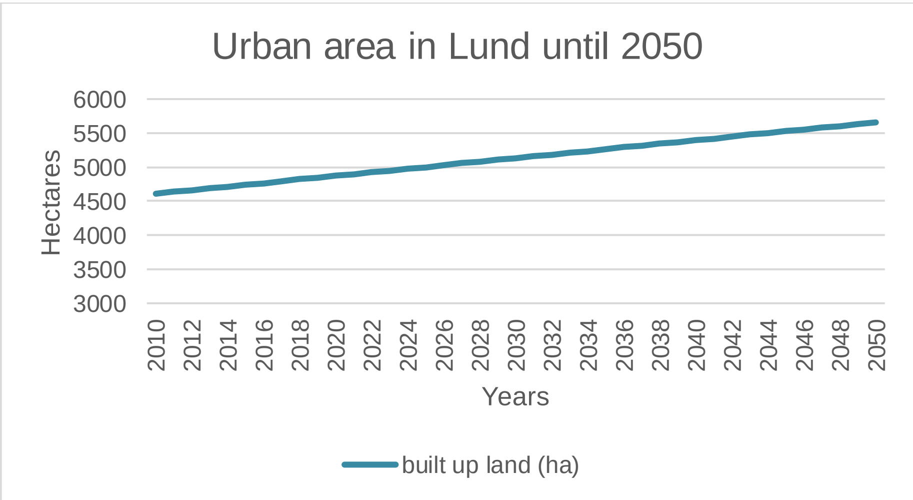

Figure 10 Linear extrapolation of the urban area in Lund.

For the Business as Usual Scenario, the built-up area was linearly extrapolated to the year 2050, resulting in 5,658 hectares urban area. Divided by the future population (185,000 inhabitants), the built-up area per person is 358 m^2. This further reduction of built-up area per person shows that even with an increasing amount of urban area, the land consumed individually decreases, meaning the population density increases.

Estimating the values for the Balanced Growth and Urbanisation scenarios information from the European LUISA modelling Platform was used. The model projects a scenario, assuming official socioeconomic trends and policies with direct or indirect territorial impacts (European Commission, 2016a). The Urban Data Platform provides information on cities and their surrounding area and makes it possible to compare them at different points in time (European Commission, 2016c). For 2050 the area covered classified as urban, industrial and commercial as well as urban green leisure for Lund is estimated to be 465 m² per inhabitant (European Commission, 2016a). It should be mentioned that the calculated built-up area for Lund by the LUISA model for the year 2010 is higher than calculated in this work, which is likely to contribute to the higher estimated built-up area for the year 2050. The amount increased from 446m² in 2010 to 465 m² in 2050, which is a significantly higher value per person than the calculated Business as Usual Scenario (European Commission, 2016b). The LUISA model value of 465 m² per person, is used for the Urbanisation scenario.

Reduced land consumption per person can moderate the competition between future development and farmland. Therefore, for the minimising scenario, the built-up area per person in the Urbanisation Scenario was reduced by half to 232 m² per inhabitant. Before implementing the estimated amount of built-up area per person the plausibility was controlled by comparing Lund with other municipalities built around a historic university city (Quinn Calder, 2014). The selected municipalities have a university located in their area, a population smaller than 200,000 people and are projected to grow until 2050 (European Commission, 2016c). The forecasts for the comparison again are used from the European Urban Data Platform (European Commission, 2016b). Table 7 shows the comparison of the built-up area per capita.

Table 7 Comparison of the built-up area per capita between Lund and European municipalities (European Commission, 2016b).

City	Inhabitants (2010)	Built-up area per person [m²/person] (2010)	Inhabitants (2050)	Built-up area per person [m²/person] (2050)
Lund [SE]	112 698	445.7	152 417	464.6
Uppsala [SE]	197 900	566.8	256 435	574.3
Oxford [GB]	149 357	211.4	202 406	180.9
Heidelberg [DE]	146 910	205.9	168 231	196.6

Leuven [BE]	100 147	325.9	163 727	267.8

In contrast with other municipalities, the amount of built-up land per person displayed in Lund can be considered very high and is estimated to grow until 2050. Only Uppsala, another city in Sweden, shows a higher amount of urban area per capita than Lund (European Commission, 2016b). Further, the comparison demonstrates that it is possible to consume less built-up area. Hence, the smaller amount of urban area per person in the Balanced Growth scenario, as well as the higher amount in the Urbanisation Scenario, were implemented for the year 2050. Table 8 shows the applied built-up area used in different scenarios.

Table 8 Scenario modifications of the built-up area per person in Lund.

Scenario Modification	**Business as Usual**	**Balanced Growth**	**Urbanisation**
Built-up area per person (m^2/person)	358	232	465

Governmental growth management

The objectives of growth management are the preservation of natural land and farmland, the provision of cost-efficient urban infrastructure and vitalised existing urban areas (Pendall *et al.*, 2002; Siedentop *et al.*, 2016). Growth management measures try to contain urban sprawl while still recognising the need to accommodate growth through coordinated and well-planned land use (Carruthers, 2002).

Jaeger *et al.*, (2008) states that the most efficient way to reduce urban sprawl is by slowing down population increase, densify settlements within existing urban borders and by reducing the amount of built-up area per person. If it is not possible to avoid the newly built-up area, the focus should be on compact new settlement instead of dispersed development and the protection of large, consistent natural areas (Jaeger *et al.*, 2008).

But growth management is not only seen positively in the literature (McLaughlin, 2012). Conventional zoning can be insufficient to address urban sprawl and reduce land consumption (Siedentop *et al.*, 2016). While zoning regulations can protect entire open spaces, it does not necessarily control urban sprawl (Carruthers, 2002). The limit of available housing in the contained zone can transfer the urban growth beyond the controlled zone or to neighbouring municipalities (Dawkins & Nelson, 2002; Siedentop *et al.*, 2009). The reduction of building land lowers the number of new houses and can lead to an increase in land and housing prices (Dawkins & Nelson, 2002). The rise in housing prices can make affordable housing an issue for low-income households (Carruthers, 2002; Dawkins & Nelson, 2002).

Even though the adverse impacts of growth control measures are discussed in the literature, smart growth policies can likewise favour compact city development and higher densities by increasing land prices and thereby achieving a reduction in land consumption (Siedentop *et al.*, 2009; McLaughlin, 2012). Further, the environment is preserved, and car ownership, travel distances, and public service costs are reduced (Carruthers, 2002; McLaughlin, 2012; Litman, 2018). Looking at the UK, where greenbelts have been a spatial planning tool for over 50 years now, it shows that with increasing prices for building plots, houses were constructed on smaller lots at higher densities to economise the increasing costs (Denman, 1964 cited in Dawkins & Nelson, 2002). The importance of growth management is also highlighted by a study by Jaeger *et al.* (2008) showing that a consistent restriction of a dispersed building pattern, especially outside of designated building areas is necessary to avoid a worsening of urban sprawl. Even in the applied minimum scenario by Jaeger *et al.* (2008), with a decline in the population growth towards 2050, dispersed urban settlement continued, indicating that only stronger densification can maintain or reduce urban sprawl. Therefore, growth management was adopted in the thesis and differentiated into three categories a restrictive planning environment, weak/moderate growth management and no restrictions (Siedentop *et al.*, 2009).

The Business as Usual Scenario includes the targets set in the current comprehensive plan, as it is the official planning document issued and it is assumed that it is in the interest of the municipality to comply with it, even if it is not legally binding. The scenario includes a clear statement to the importance of the protection of the natural resources and land around the urban areas, as well as statements for increasing densities and encouragement for infill processes (Lunds Kommun, 2018c).
The Urbanisation Scenario represents a complete laissez-faire planning situation with no restrictions or recommendations for urban development. There is no focus on a specific way of construction or allocation of new development. The new built-up area will be placed within the localities according to the current trends.

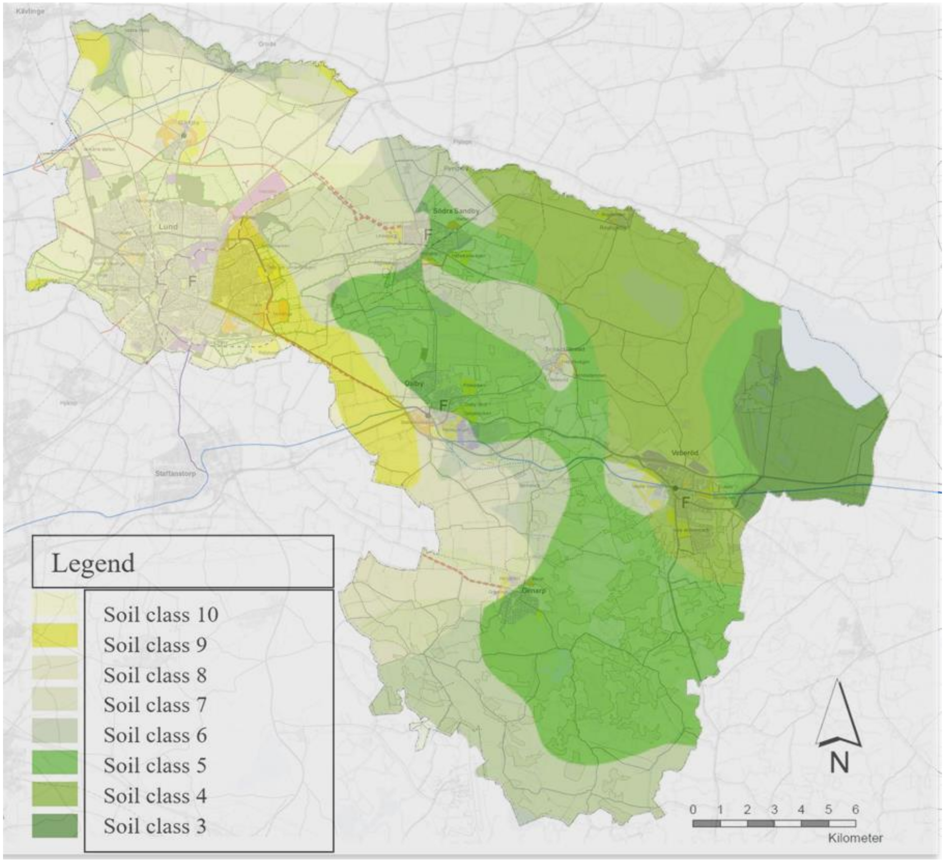

Figure 11 Soil classification for the area of Lund (Lunds Kommun, 2018b, modified).

The loss of prime farmland is a big concern for the competitiveness and sustainability of agriculture as they are essential for its viability in the long-term (Hasse & Lathrop, 2003). Therefore, the Balanced Growth Scenario includes a strict protection regime for the best agricultural land. By creating specific zones, the best soil classes 8 to 10 next to Lund are preserved, and more compact development is enforced, preventing the growth into the high-quality farmland.

The Swedish arable land was graded in 1970 according to its production capacity (Länsstyrelsen Skåne, n.d.). Of the ten classes, the highest-rated farmland classes are 8 to 10, which are only about 7% of the total arable land in Sweden (Länsstyrelsen Skåne, n.d.). The classifications are based on the economic return from harvesting statistics in 1969 (Ann-Marie Karlsson, 2013). The mean crop value in Sweden is 20,174 SEK per hectare (Roth, 2016). To calculate the different production capacity values, a multiplier from 0.8 for class 1 to 1.25 for class 10 is used (Roth, 2016). The potential value of the soil class 7 would be 20174 * 1.10 = 22,191 SEK/ha (Roth, 2016). Figure 11 shows, the highest-graded soils can be found around the city of Lund. Therefore, the best agricultural soils are presumably secured by creating a protected area around Lund as well as the localities Stångby and Vallkärra. Table 9 shows the growth management categories applied in the three scenarios.

Table 9 Scenario modifications for growth management in Lund.

Scenario Modification	Business as Usual	Balanced Growth	Urbanisation
Growth management measures	Weak/moderate growth management	Restrictive planning environment	No restrictions

4.3 Scenario Creation

In this section, the results of the key factors of the previous chapter are summed up and put together to create the three scenarios for the year 2050, including its impacts on the loss of arable land in a narrative way. Table 10 sums up the applied modifications for each scenario, as explained in the previous chapter.

Table 10 Summary of the applied scenario modifications.

Scenario / Key drivers	Status quo	Business as Usual	Urbanisation	Balanced Growth
Population	121,274	185,000	185,000	185,000
Built-up area per person (m^2/person)	405	358	232	465
Growth Management Measures	Weak/moderate growth management	Weak/moderate growth management	Restrictive planning environment	No restrictions

4.3.1 Business as Usual Scenario (BaU)

Urban sprawl and the loss of agricultural land receive increasing attention from the European Union and its member states, including Sweden. Still, there is a lack of restrictive regulations to save natural resource soil. A growth-oriented mentality is present, with emphasis on job creation and economic development. To comply with the increasing awareness for the protection of soil and locally produced goods - Lund strives for more growth, with the emphasis on densification and a better division of development between the localities. Nevertheless, most of the extension takes place on the best soils around the city of Lund.

The MAX IV and ESS create an attractive environment for co-location of further research and innovation facilities thereby creating job possibilities and continue to encourage the growth of Lund and its role as a growth engine for the region Skåne. Accommodating the expected increase in population and work is a priority of the municipality. Strong demand for housing is expected from young people, mainly students but also the countryside and people making use of the spin-off effects of research and knowledge facilities.

At the same time, the need for sustainable management of land is acknowledged (Lunds Kommun, 2018b). Densification and revitalisation of existing areas are emphasised as vital, and the conflict between the expansion of the urban area and agricultural areas is recognised (Lunds Kommun, 2018b). Around half of the new urban area will be provided by densification processes the other half will be by expanding in undeveloped land. The proportion of multi-family homes is increasing not only in the city but also in the smaller towns in the municipality, thereby reducing the expansion of the urban area (Lunds Kommun, 2018c). Further, the newly built homes are distributed stronger between the city of Lund and the localities (Lunds Kommun, 2018b).
Two-thirds of the new homes will be constructed in the city of Lund and one-third in the localities. The city expansion is planned primarily east along the new public transport routes to Dalby and Södra Sandby (Lunds Kommun, 2018b). The latest development should take place around public transport stops and stations, for example, the transportation connection between Brunnshög and Dalby. With most of the land around the urban area being farmland, the amount of extended built-up land equals the loss of farmland. With two-thirds of the developing processes happening around the city of Lund, more than half of the built-up area will be at the cost of the best soil classes 9 and 10 (Lunds Kommun, 2018c).

The additional urban area is the built-up area per person multiplied with the increase in population:

$$\text{Population}_{(2050)} - \text{Population}_{(2018)} = 185{,}000 - 121{,}274 = 63{,}726 \text{ people}$$

$$\text{Population}_{(change)} \text{ x built-up are per person}_{(BaU)} = 63{,}726 \text{ x } 358 = 2{,}281 \text{ ha}$$

$$\text{Half of the extension on undeveloped land} = 1{,}141 \text{ ha}$$

With half of the additional built-up area being integrated into existing urban areas, the extension will be 1,141 hectares. As explained earlier, this amount equals the loss of farmland. If not sealed the land could be used to grow food. The average yield of winter wheat in the region of Skåne is 8,520 kg per hectare (SCB, 2019b). On an area in Lund of 1,141 hectares, 9,721 tons of winter wheat could grow. With an average yield of 63,400 kg per hectares, 72,339 tons of sugar beets could potentially be harvested (SCB, 2019b). The harvested produce could theoretically be used to bake about 14,970,832 loaves of bread or approximately 8,900 tons of sugar.

1,000g wheat ~ 700g flour →1-hectare wheat produces about 6,560kg flour. 1,141 ha ~ 748,5416 kg of flour Calculating with about 500g of flour per bread that would add up to **14,970,832 loaves of bread.**	1-hectare sugar beets ~ 7.8 tons sugar 1,141 ha ~ **8,900 t sugar** (FAO and EBRO, 1999)

Of those 1,141 hectares two-thirds, about 742 hectares will be around the city of Lund where the best soil classes are distributed. Calculating the monetary value according to Roth (2016), with a distribution of the new urban areas on the soil classes similar to the comprehensive plan of the municipality, results in a loss of 2,574,542 EUR of potential income of yearly food production (Lunds Kommun, 2018c). Table 11 shows the Business as Usual scenario with its distribution on the various soil classes and the monetary value lost.

Table 11 Distribution and potential yearly income in food production in the BaU Scenario.

Soil Class	10	9	8	7	6	5	4	Total
Distribution in %	50	15	5	5	10	5	10	100
New built-up area (ha)	571	171	57	57	114	57	114	1,141
Monetary value (thousand SEK)	14,387	4,143	1,324	1,266	2,417	1,151	2,187	26,874
Monetary value (thousand EUR)	1,378	397	127	121	232	110	209	2,575

4.3.2 Urbanisation Scenario

To increase economic stability and foster growth in the region of Skåne, a strong focus on accessibility and economic growth is present. With Lund being one of the main growth hubs in the county, investments into the transport infrastructure, job creation, especially in the innovation and research sector, and the supply with adequate housing receive the most attention. As a consequence, higher educated people are drawn to the offered (often temporary) work possibilities, increasing the average income, living standards and the need for single housing opportunities and temporary living spaces. While agricultural land is still an essential part of the landscape and identity of the area, the public perceives it foremost as a recreational area.

All land which is not already built on and which is not permanently protected open space, therefore excluded for future development, is considered available building land in the Urbanisation Scenario (Conway & Lathrop, 2005). The focus on individual preferences in development structures in the scenario leads to a higher number of single-family houses or two dwelling houses in a central location near the old town instead of taller, more-dwelling buildings. The desire for increased privacy generally leads to dispersed low-density settlements with a higher amount of built-up area per person (Hayek *et al.*, 2011). The research facilities MAX IV and ESS create a centre for science and knowledge in Lund, drawing educated workers to the area and creating an attractive pull not only to study at the University of Lund but to continue looking for work after graduation. The investment in the Science Village places Lund more into international attention and attracts businesses to settle down in the surrounding area, creating a knowledge centre.

The focus of the municipality lies on the provision of sufficient housing opportunities for different preferences between students, workers and young families. Next to affordable homes and temporary living arrangement in apartment buildings also the need for more privacy is served by providing one and two-family houses with private green spaces. To avoid the loss of public spaces in the city and the attractive, sought-after amenities of the low-density localities, urban structures are instead expanded. To develop not only the city of Lund but also the smaller towns, investments are taken to increase the road and railway accessibility. Nevertheless, the city of Lund grows the strongest. The localities Stångby and Vallkärra are getting closer to the city, blurring the lines between Lund and the towns. Dalby, Södra Sandby and Veberöd witness stronger growth processes as well due to their closeness and the excellent connection to the city of Lund. The balance between urban and the countryside is necessary to maintain the attractiveness of Lund by sustaining a particular lifestyle, which includes access to nature and recreation areas.

$$\text{Population}_{(\text{change})} \text{ x built-up are per person}_{(\text{Urban})} = 63{,}726 \text{ x } 465 = 2{,}963 \text{ ha}$$

Two-third of the extension on undeveloped land = 1,975 ha

The higher demand for living space increases the built-up area per person leading to a more considerable increase in the urban area. Not all of the new area will be created on undeveloped land but one-third, about 988 hectares, will be established within existing urban areas. Therefore, 1,975 hectares of arable land will be lost due to urban growth processes in the scenario. The growth scenario needs 834 hectares more new ground than the business as usual scenario.

1,000g wheat ~ 700g flour →1-hectare wheat produces about 6,560kg flour. 1,975 ha ~ 12,956,790 kg of flour Calculating with about 500g of flour per bread that would add up to **25,913,580 loaves of bread.**	1-hectare sugar beets ~ 7.8 tons sugar 1,975 ha ~ **15,405 t sugar** (FAO and EBRO, 1999)

To put this in other units again, the loss of 1,975 hectares of land equals the loss of 16,827 tons of wheat. The amount of grain could be used for the production of approximately 25,913,580 loaves of bread. The amount of sugar beets lost is about 125,215 tons, which results in the loss of sugar production of 15,405 tons of sugar. Again, the most substantial increase will take place around the city of Lund therefore also a stronger loss of the most valuable soil classes. The potential income of yearly food production results in a loss of 4,504,086 EUR. The distribution on the soil classes and the calculated monetary value are shown in table 12 for the Urbanisation Scenario.

Table 12 Distribution and potential yearly income in food production in the Urbanisation Scenario.

Soil Class	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**Total**
Distribution in %	55	15	5	5	5	10	5	100
New built-up area (ha)	1,085	296	99	99	99	198	99	1,975
Monetary value (thousand SEK)	27,393	7,172	229	2,191	2,092	3,984	1,893	47,016
Monetary value (thousand EUR)	2,624	687	219	210	200	382	181	4,504

4.3.3 Balanced Growth Scenario

With the Swedish Food Strategy and its aim to reach higher self-sufficiency, the country's ability to produce food is a priority. Under the national goal, a stronger commitment from the counties and municipalities to protect its agricultural resources can be witnessed. Restrictive regulations are introduced to safeguard the most fertile soils. Agriculture is not only part of recreation and the landscape in Lund but is seen together with its focus on research and innovation as an integral part of the municipality's future. The growth of urban land is not limited to zero, but the best soils around the city of Lund are protected together with a strong focus on densification and multi-dwelling buildings to reduce the amount of built-up area.

The Balanced Growth Scenario focuses on a balance between growth and sustainability and the protection of agricultural land, leading to less extension on undeveloped land and a denser building structure with less built-up area per person (Hayek *et al.*, 2011). The priority is to place construction within existing urban areas (Schwick *et al.*, 2011). If infill development is not possible, the new settlement areas are built compact directly next to existing urban areas (Schwick *et al.*, 2011). More compact construction and high-density areas are authorised together with a focus on strengthening and revitalising the core areas of the municipality (Jaeger & Schwick, 2014).

The area continues to be attractive, offering job opportunities in the new research facilities but also the field of agricultural production and the food sector; therefore, the demand for housing maintains. It is possible to spread more than two-thirds of new housing construction to other localities besides the city of Lund (Lunds Kommun, 2018c). Increasing development outside of Lund can help to counteract the polarization between urban and rural (Lunds Kommun, 2018c). By providing mainly homes in multi-dwelling buildings, the amount of living space available for each person is reduced. Adding more apartment buildings and business to the localities will change their appearance, consequently, it is vital to maintain the identity of the towns while integrating a more compact form of housing. Transport infrastructure is provided accordingly to prevent an increase in the use of private cars.
Additionally, locating housing and businesses to other places with lower soil quality, the most valuable arable land is protected (Lunds Kommun, 2018c). By creating specific zones, the best soil classes 8 to 10 next to Lund are preserved, and more compact development is enforced, preventing the growth into the high-quality farmland. Besides Stångby and Vallkärra next to Lund in the protected zone, all localities will increase in urban areas.

$$\text{Population}_{(\text{change})} \text{ x built-up are per person}_{(\text{Min})} = 63{,}726 \text{ x } 232 = 1{,}478 \text{ ha}$$

Half of the extension on undeveloped land = 740 ha

With densification processes still going on half of the additional built-up area will be located within the city of Lund, where the demand for housing is the greatest. The loss of 740 hectares farmland would be equal to the loss of 6305 tons of wheat or 4,685 tons of sugar beets, resulting in a potential loss of about 9,696,271 loaves of bread and 5,764 tons of sugar.

1,000g wheat ~ 700g flour →1-hectare wheat produces about 6,560kg flour. 740 ha ~ 4,848,135 kg of flour Calculating with about 500g of flour per bread that would add up to **969,6271 loaves of bread.**	1-hectare sugar beets ~ 7.8 tons sugar 740 ha ~ **5,764 t sugar** (FAO and EBRO, 1999)

Table 13 shows the distribution and potential production income for the Balanced Growth Scenario with no growth outside the existing boundaries of the city on the soil classes 8 to 10. The amount of 1,571,067 EUR of potential yearly food production value would be a loss in the Balanced Growth Scenario.

Table 13 Distribution and potential yearly income in food production in the Balanced Growth Scenario

Soil Class	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**Total**
Distribution in %	0	0	0	15	20	50	15	100

New built-up area (ha)	0	0	0	111	148	370	111	739
Monetary value (thousand SEK)	0	0	0	2,460	3,280	8,200	2,460	16,399
Monetary value (thousand EUR)	0	0	0	24	314	786	24	1,571

4.4 Limitations

The thesis addresses a complex topic which is influenced by many factors. Therefore, not everything can be taken into account within this work. Some restrictions made by the author and constraints through the method used are mentioned in this section.

First, it should be mentioned that the case study and thesis are placed in Sweden, but English was used as the language for the research. Therefore, it may be the case that important information was overlooked and not included. Some literature, primarily national and regional reports but also scientific papers, was translated into Swedish, using translation tools such as 'Google translate'. Misinterpretations due to the language barrier are possible. The work was revised by a Swedish speaking supervisor, Anders Larsson, thereby reducing the uncertainty related to the language. Nevertheless, the language barrier as a possible restriction to this research is important to be considered when reading this thesis.
Further, a vast amount of literature is found on the topic of urban sprawl and its impacts. Some of the terms are sometimes used interchangeable such as land take, soil sealing and urban sprawl. Narrowing down the literature was therefore challenging. To set limitations literature on urban sprawl was mainly used from articles concerning Europe and some from North America. Further, the focus was put only on the dimension of the loss of soil by building processes of housing, not industry and commercial areas.
Additionally, a vital attribute of sprawl is it's dispersed spatial form, which is mentioned previously but was not analysed further for the case study area. Although scattered development is an essential aspect of urban sprawl, including pattern related impacts such as landscape fragmentation and infrastructure costs, it is not considered in this thesis. The focus is put on the sealing of arable soils and therefore, the additional built-up land per person, and its rough distribution is considered sufficient to analyse the impact of urban sprawl on farmland.

Another limitation of the measure is the calculation of yield losses using soil classes from the year 1970. It is likely that the yield calculations fo not represent current production levels, which is also mentioned by the Swedish Board of Agriculture (Jordbruksverket, 2018a). Unfortunately, more recent soil class data was not available to the author of the thesis. With technological progress, the production amounts increased since 1970. Therefore, awareness needs to be raised, that the calculated losses in agricultural production yields of sugar and flour in this thesis are possibly higher than presented in this work.

When calculating the potential losses in the three scenarios, other monetary values were not included, such as potential cost savings by the municipality through compact development. Regions with sprawling patterns generally have higher costs for infrastructure, water supply, sewage disposal, traffic and electricity distribution (Jaeger *et al.*, 2008). The costs can be up to three times higher (per person) than in compact development (Jaeger *et al.*, 2008). Unfortunately calculating these costs for the three scenarios was too complex and time consuming to address within the scope of this thesis.

5 Results

Most decisions on land development lie with local authorities. Therefore, the priorities set by the municipality impact future development and farmland in Lund. The three scenarios illustrate that the land consumed per person and the location of new building areas influence not only the amount of sealed land but also the potentially grown goods and the income of thereof. Thus, the decisions of the municipal authorities on where and how to build have a significant influence on the preservation of farmland and food production. Table 14 shows the results of the three scenarios. In the following section, the outcomes are compared and connected with Swedish agriculture and consumption as a whole.

Table 14 Comparison of the three scenarios

Scenarios	**Business as Usual Scenario**	**Urbanisation Scenario**	**Balanced Growth Scenario**
Total amount of new built area (ha)	2,281	2,963	1,478
Expansion on farmland (ha)	1,141	1,975	740
Potential yearly food production value (EUR)	2,574,542	4,504,086	1,571,067
Potential yield of winter wheat (tons)	9,721	16,827	6305
Possible loss in bread production (loaves)	14,970,832	25,913,580	9,696,271
Potential yield of sugar beets (tons)	72,339	125,215	4,685
Possible loss in sugar production (tons)	8,900	15,405	5,764

The main impact of the three scenarios is the loss of agricultural land. With 1,975 hectares, the Urbanisation Scenario has the most substantial loss of farmland followed by 1,141 hectares of new built-up area in the BaU Scenario and lastly 740 hectares in the Balance Growth Scenario.

The loss of farmland comes along with a loss in potential yearly food production. The calculated food production value of the alternative scenarios is compared to the annual income of total crop production in Swedish agriculture, which was 27,717 million Swedish Krona in the year 2017 – about 2,591 million euros (Jordbruksverket, 2018d). In the Urbanisation Scenario, the potential food production value amounts for 4.5 million euros, which is 0.17% of the total crop production income in the year 2017. The BaU Scenario with about 2.5 million euros production value amounts for about 0.10% and the Balanced Growth Scenario with 1.6 million euros for 0.06% of the total Swedish crop production income. With the highest decline in arable land in the Urbanisation Scenario, naturally, also the loss of potential food produced and money earned through cultivation is the highest. Although the percentages seem small, it must be considered that the comparison is between all of Sweden and the newly urbanised land in one municipality.

With a focus on growth and no constraints on building development on arable soils, the high loss of land in the Urbanisation Scenario is rather unsurprising. But the consumed soil is accompanied by a decline in potentially harvest, for example, winter wheat and sugar beets. Comparing the results with the current production in Skåne and all of Sweden exemplifies the potential impact of the declining arable land in Lund. The harvest of winter wheat in Skåne in 2018 was 375,400 tons, in all of Sweden 1,399,900 tons (SCB, 2019b). The loss of 16,827 tons of winter wheat in the Urbanisation Scenario equals 4.48% of the yield in Skåne and 1.20% of the total production in Sweden. On the land lost in the BaU scenario, 9,721 tons of winter wheat could be grown, which accounts for 2.59% of Skåne's output and 0.69% of Sweden's production. In comparison, on the build over land in the Balanced Growth Scenario, 6305 tons of wheat can be produced, accounting only for 0.17% of the winter wheat production in Skåne and 0.05% in Sweden. Figure 11 shows the winter wheat production in 2018 in Sweden and Skåne in comparison with the potential production values of the three scenarios.

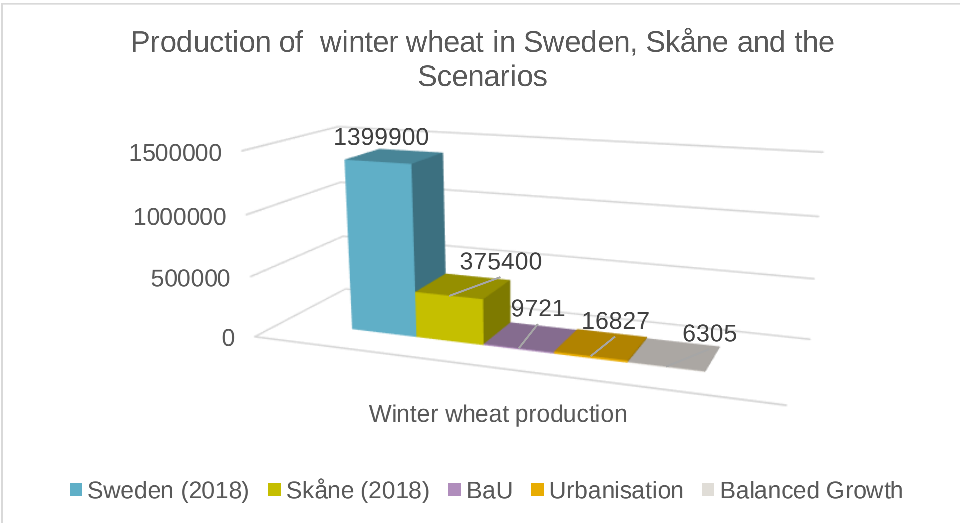

Figure 11 Comparison of winter wheat production.

The harvested amount of sugar beets in Skåne in 2018 was 1,636,900 tons, in all of Sweden 1,698,400 tons (SCB, 2019b). The Urbanisation Scenario suffers the most considerable decrease in sugar beet production. The potential harvest on the built over arable soils in Lund amounts to 7.65% of all of Skåne's output and 7.37% of Sweden's. The losses in the BaU Scenario amount for 4.42% of Skåne's and 4.26% of Sweden's sugar beet production in 2018. The potential loss of harvest in the Balanced Growth Scenarios amounts to 0.29% of the output in Skåne and 0.28% of all of Sweden's production. Figure 12 shows the production of sugar beets in 2017 in Sweden and Skåne in comparison with the potential production values of the three scenarios. With almost all of the sugar beet production taking place in Skåne, the loss of arable land in Lund has considerable influence. The significant variations between the three alternatives highlight the impacts of the different development intentions of the three scenarios.

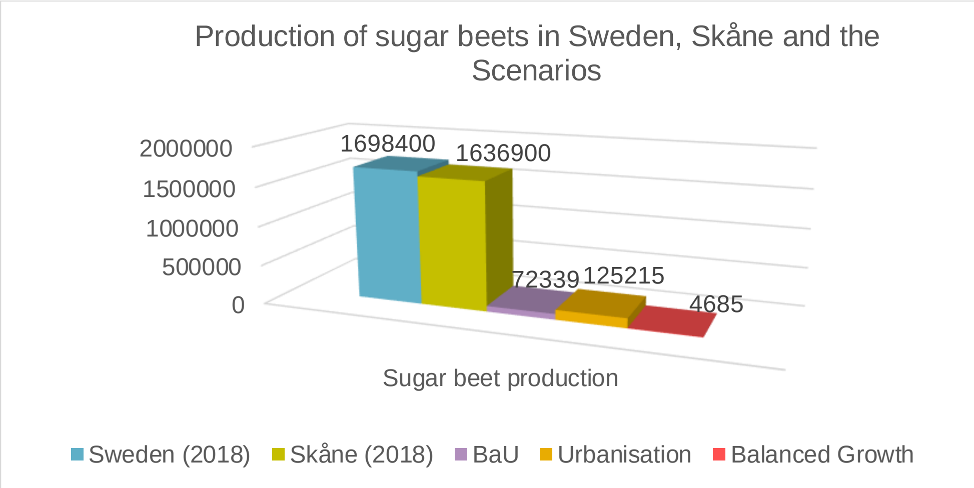

Figure 12 Comparison of sugar beet production.

The expansion of urban areas leads to a loss in potential land for foodstuffs production. The calculated production losses of the scenarios are put into context by comparing them to the current total consumption of the Swedish population. The examined examples are bread and sugar.

The total bread consumption (including pastries) amounts to 737,8 million kg in all of Sweden in the year 2017 (Jordbruksverket, 2018b). If the sealed agricultural land in Lund is used for growing wheat, the produced flour can be used for the production of bread. In the Urbanisation Scenario, about 26 million loaves of bread can be provided, which accounts for 3.5% of the total consumed bread and pastries in Sweden. In the BaU Scenario, around 15 million loaves of bread are potentially produced, which accounts for 2% of the total consumption. With 1.3% of the entire Swedish bread consumption, the Balanced Growth Scenario accounts for the lowest loss in potentially produced bread.

The similar approach is used to compare the total consumption of white sugar in Sweden with the potential output of the lost arable soils. The total consumption of sugar, directly used and added to processes products, in Sweden amounts 277,4 million kg, in the year 2017 (Jordbruksverket, 2018b). The growing sugar beets on the

farmland in Lund can be used to produce sugar. The about 15,405 tons of sugar produced in the converted agricultural land in the Urbanisation scenario accounts for 0.005% of the total sugar consumption in Sweden. The potentially produced 8,900 tons of sugar in the BaU Scenario accounts for 0,003% of the total sugar consume while the 5,764 tons of sugar in the Balanced Growth Scenario account for 0,002% of the overall Swedish sugar consumption.
Figure 13 shows the comparison of the potential bread and sugar production of the three scenarios with the consumption in Sweden. Although around 95% of the sugar beet production is taking place on soils in Skåne, the lost arable land contributes only very little to the overall sugar consumption. A possible explanation is that both sugar and bread consumption numbers for Sweden include products from within the country but also imports from abroad; therefore the share of the arable land in Lund is rather small (Jordbruksverket, 2018b).

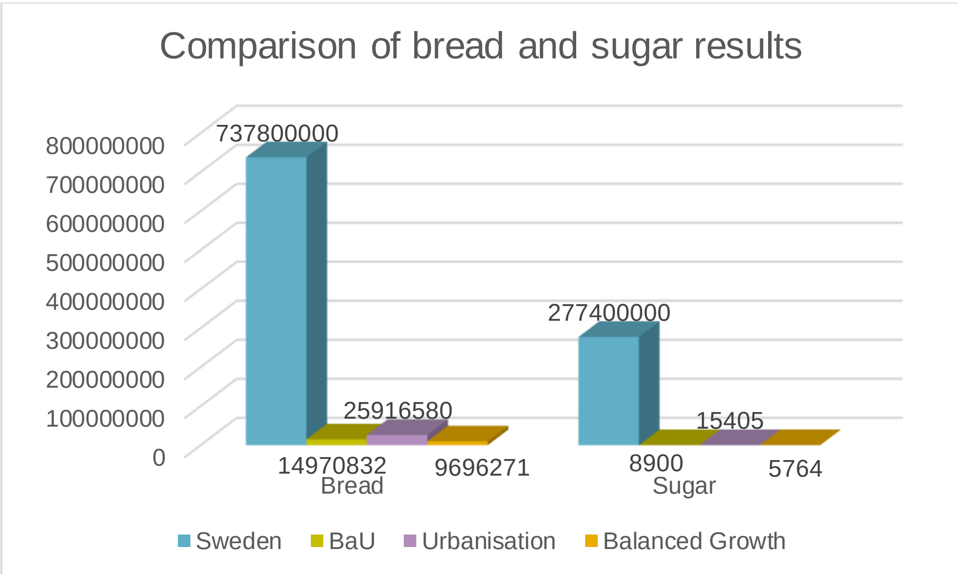

Figure 13 Comparison of bread and sugar consumption with potential production loss.

Summing up the outcome of the scenarios, the highest amount of newly built-up area in the Urbanisation Scenario is accompanied with the most substantial declines in harvest and food production and therefore also potential food production value. Following the current development intentions in the BaU Scenario, the losses are smaller. By far the lowest numbers for all calculations show the Balanced Growth Scenario. What those results implicate and options to address them is discussed in the following Discussion chapter.

6 Discussion

In this thesis, it is not analysed whether or not Lund will grow but instead how and on what land. The three alternative scenarios show how different outcomes of local land-use decisions can influence the loss of agricultural land in Lund. The research helps to understand what drives or hinders urban sprawl and further, what measures could be implemented to protect agricultural land.

The scenarios include a selection of drivers - population, built-up area per person and governmental growth management – that were combined in alternative ways. The outcome of each alternative shows the relations between and the impact of the drivers and the land lost to urban sprawl. With the population number being the same in all three scenarios the connection between the built-up area per person and the amount of farmland being lost is evident. The more land a person claims, the more area is consumed in total – this is also the case for Lund.
Governmental growth management can transfer development processes to certain areas and increase the density of the built-up land. It can be argued that the development restriction on the best soil classes, rather influences the quality of land than the amount that will be built over, as it is the case for the Balanced Growth Scenario where the restrictions lead to a stronger increase in the growth of smaller localities, which are surrounded by poorer soil classes. In the case of the municipality Lund, the localities happen to have more room for infill and densification than the city, which influences the amount of land consumed in total. Additionally, in the other two scenarios, efforts are made to densify, not only to meet environmental criteria but also because an increasing amount of people are interested to live in central locations, as the strong growth of the city of Lund demonstrates.
The scenarios represent an ongoing trend in the municipality towards smaller amounts of built-up areas per person and a trend towards living in central locations. Nevertheless, it is shown that with governmental growth management tools in place, the amount of soil lost to building processes can be reduced even further. With the soil quality playing an important role in the ability to produce food, steering development towards the poorer soil classes can make an additional difference for reaching the goal of higher self-sufficiency in Sweden. This statement is supported by the results of a higher loss of potentially produced food and yearly income in the Urbanisation Scenario, where soil quality is not considered in planning processes.

The selected drivers clearly influence urban sprawl, but the alternative futures additionally demonstrate, that they can be actively steered by the decision taken by the municipality. By protecting certain areas and providing less built-up area per person, the authorities can direct development towards a more resource-friendly future. But as the Urbanisation Scenario shows, the decisions by the municipality could likewise lead towards a future, where more land is being sealed. Therefore, it is important to implement actions, which address urban sprawl actively. Looking at the already implemented measures by other European countries it is clear, that several techniques are available and could be applied also in Lund.

To respond to the research question of appropriate measure to address urban sprawl, the scenarios indicate that restrictive measures, such as zoning of non-building areas, are effective tools for the prevention of further land consumption. Likewise, the provision of multi-dwelling buildings, with a smaller built-up area per person than single-family houses are an efficient measure to reduce land consumption. Already the current comprehensive plan highlights the importance of such measures, however, the majority of new construction planned remains on the best soils around the city of Lund. Therefore, it can be assumed that the issue of soil protection is not given priority by local authorities and a shift in the attitude and encouragement for sustainable decision-making is necessary in order to protect natural resources. As stated by Artmann (2014b) municipal authorities hold the primary responsibility in influencing urban development and should, therefore, act as a leader to find solutions and steer in a sustainable future. A study by Siedentop *et al.*, (2009) highlights the importance of awareness-raising for soil protection by showing that regions with an active discussion about land protection are witnessing a declining trend in the consumption of soils. Consequently, the awareness and the motivation of the municipality to achieve such outcomes is crucial. Political actors in Lund need to be made aware and educated about the problem and different methods to address urban sprawl actively. In order to accept the decisions made also the population living in the municipality need to understand why it is important to protect farmland. With an increasing distance between consumers and agriculture, the publics general desire to protect local farmland is weak (Jorgen *et al.*, 2013). Thus, an increase in knowledge for the value of agriculture and food, cultural heritage, biodiversity and ecosystem service can positively influence the protection of farmland in Lund (Jorgen *et al.*, 2013).

To successfully limit urban sprawl, measures of co-operation are essential. A coherent planning environment can prevent side effects of local growth management tools, such as spillover effects to neighbouring municipalities (Carruthers, 2002) Further, municipalities are more likely to implement growth control policies if nearby jurisdictions do so as well (Brueckner, 1998 cited in Ehrlich *et al.*, 2018). Therefore, growth measures should be integrated into national, regional and local policy levels to create an even regulatory landscape (Carruthers, 2002).
A first step was implemented recently with the adoption of a mandatory regional plan for the counties of Stockholm and Skåne (Sverige Riksdagg, 2018). The regional plan should outline the use of water and land areas as well as the location of buildings and structures concerning two or more municipalities, thereby providing

guidance and increase the coordination between national, regional and local plans - hence creating more unity in the country (Sverige Riksdagg, 2018).
A best-practice approach recommended by a survey by Prokop *et al.* (2011) can serve as a guideline to implement several of the mentioned measures as efficient protection of soils can only be achieved by improving the awareness and commitment, establishing incentives and introducing legal requirements in Lund. To achieve is, a method similar to the logic in waste management is suggested, namely to reduce the loss of soil by applying the ‘prevent, limit and compensate’ principle by the municipality (Prokop *et al.* 2011). The idea is to prioritize the prevention of the consumption of undeveloped land. If development is necessary, it should be limited as far as possible. Only if the first two options are unattainable, the development should take place but be compensated with measures, for example restoring soil somewhere else (Prokop *et al.*, 2011).

The results might not be surprising and there is no one clear way how to address urban sprawl. Nevertheless, the outcomes of the three scenarios show clearly that all decisions made by the municipality make a difference in the amount and quality of farmland being built over. Further, the research demonstrates that if there is a willingness to move towards a more resource-friendly way of growing, farmland in the municipality of Lund can be protected.

6.1 Discussion of the method

The scenario method shows different possible outcomes, depending on decisions made by the municipality Lund. In this section, uncertainties related to the scenario technique and aspects which the author was not able to consider during the research are presented.

The scenario method itself does have some limitations and uncertainties. The method is claimed to have a lower scientific background compared to quantitative modelling and forecasting approaches (MacDonald, 2015). Further, the developments applied in the scenarios are hypothetical (Dorning *et al.*, 2015). The alternatives are limited to the influencing factors chosen in this thesis. Various other possible future developments exist beyond the scale of the study (Dorning *et al.*, 2015). The selected drivers, even though based on a literature review, are also based on the author’s personal choice on what to include and what not. Thus, some factors, as mentioned in the previous section, were not included in this work — for example, energy supply with or without fossil fuels, the future economic situation, climate change, technological advances in agriculture. Although these variables can have a significant impact on the case study area, the potential yields of agricultural land and the need for homes and infrastructure, it is not possible to include all variables in this thesis.

6.2 Future research

This thesis shows that there is room for the municipality to take precis actions. Future research should address which actions would be accepted best by the responsible authorities and the public to achieve the best results in the protection of their arable lands. Additionally, the awareness and decision by municipal authorities for the protection of agricultural soil are crucial. Therefore, future research should address how the awareness of local decision-makers and the public could be increased to increase sustainable planning in Lund and the region of Skåne. It is recommended that further research activities include local stakeholders, such as the municipal government, developers, the agricultural sector, and residents to simultaneously increase the awareness for the issue of urban sprawl and its impacts.

7 Conclusion

This work contributes to a better understanding of the drivers of urban sprawl in the municipality of Lund and shows how different futures may look like depending on development decisions taken by local authorities. The Urbanisation Scenario, with its focus on development and growth, causes the most severe losses in fertile soil. The current path, presented in the BaU Scenario, leads towards more sustainable growth and takes first steps towards a more resource-friendly future. But as stated in the valuation of the comprehensive plan, there is room for more actions, in terms of development distribution, infill processes and compact building structure (Lunds Kommun, 2018c). The Balanced Growth Scenario reflects the future with an even stronger focus on land protection and sustainable growth. The best soil classes are spared and the amount of built-up area per person reduced with the result, that not only the lowest amount of soil is lost but also the smallest damages to potential agricultural products and income out of it is achieved. The three scenarios show clearly - the decisions of the municipality have an impact on the amount and quality of agricultural land consumed.

The availability of land in Sweden is high, and therefore, urban sprawl doesn't seem to be a topic of as much urgency as in other countries. But the current rate of population growth and the location of most settlement areas in the agricultural regions of Sweden make the topic relevant. To provide food security and the landscape for future generations and to increase the self-sufficient within Sweden, it is essential to protect farmland. Land is a limited resource and should be acknowledged and treated accordingly (Jaeger *et al.*, 2008). Therefore, it should not be seen as a restriction when talking about limiting urban sprawl but as a way to deal with a scarce resource (Jaeger *et al.*, 2008).
Measures are needed to protect the soil. Those can be regulatory, legal planning, economic-fiscal, co-operative, informational approaches or a mix (Nuissl & Schroeter-Schlaack, 2009; Artmann, 2014a). Integrating a management approach like Prokop *et al.*, (2011), based on the principles of 'prevent, limit and compensate' can be considered a good guideline (Prokop *et al.*, 2011). Nevertheless, to be efficient, legally binding restrictions seem necessary to protect the farmland in Lund together with measures to raise the awareness and knowledge about urban sprawl and its impacts. Only if the recognition and commitment are high, environmental

sustainability will be seen as equal to economic growth, enabling a balanced urban development.

Fertile land is a key aspect of the national and global context of food security. Additionally to the regional and national importance of farmland in Sweden, its value will likely become even more relevant in the global context and the security of food (Lunds Kommun, 2018c). By protecting the valuable soils in the municipality of Lund, the production of agricultural good can be maintained or even increase, contributing not only to the Swedish Food Strategy but also to reach the goal of the European Commission to achieve the aim of no 'no net land take' by 2050. This is essential for Sweden to become more self-sufficient again.

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