Urban agriculture in central Helsinki: How much food could the rooftops of Pasila supply?

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Agroekologia
2018

HELSINGIN YLIOPISTO — HELSINGFORS UNIVERSITET — UNIVERSITY OF HELSINKI

Tiedekunta/Osasto — Fakultet/Sektion — Faculty Maatalous-metsätieteellinen tiedekunta		Laitos — Institution — Department Maataloustieteiden laitos
Tekijä — Författare — Author Kristina Jansson		
Työn nimi — Arbetets titel — Title Kaupunkiviljely Helsingin keskustassa: Kuinka paljon ruokaa Pasilan katoilla voisi tuottaa?		
Oppiaine —Läroämne — Subject Agroekologia		
Työn laji — Arbetets art — Level Maisterintutkielma	Aika — Datum — Month and year 04/2018	Sivumäärä — Sidoantal — Number of pages 52 s.

Tiivistelmä — Referat — Abstract

Suomen ruokaturva on tällä hetkellä hyvä, mutta myös Suomen on varauduttava luonnon tai ihmisen aiheuttamiin kriiseihin ja ilmastonmuutokseen, sekä tuontiresursseihin liittyviin riskeihin. Tämä maisterintutkielma tarkastelee kaupunkiviljelyn potentiaalia osana kaupunkien ruokajärjestelmää. Helsingin Seudun Ympäristöpalvelujen (HSY) keräämä kattoja koskeva data, satotilastot ja Suomalaiset ravitsemussuositukset 2014 toimivat pohjana tapaustutkimukselle, jossa lasketaan ruokaomavaraisuusprosentteja, ravintotekijöitä ja varjostusta lähellä Helsingin keskustaa sijaitsevalle Pasilan alueelle.

Kun laskelmissa käytetään avoviljelyä sekä koko potentiaalisten viherkattojen alaa, Pasila voisi tuottaa perunalla energiaa 4,51 %:lle väestöstä tai herneellä proteiinia 3,87 %:lle väestöstä. Jos puolet pinta-alasta käytetään perunan ja puolet herneen viljelyyn, omavaraisuusprosentit laskevat, mutta tuotetun energian ja proteiinin suhde on tasaisempi. Lisäämällä viljelyyn lehtikaali, voidaan kasvattaa tuotettujen vitamiininen ja kivennäisaineiden määrää. Yhdessä, 500 g kutakin em. kasvia täyttää saantisuosituksen kahdestatoista Suomalaisten ravitsemussuositusten listaamasta yhdeksästätoista vitamiinista ja kivennäisaineesta. Peruna yksin ei täytä näistä yhtään ja peruna yhdessä herneen kanssa seitsemän.

Käytettävissä olevan pinta-alan lisäksi omavaraisuusprosenttiin vaikuttavat ainakin viljelymenetelmä (esim. avoviljely, vesiviljely tai kasvihuone), viljelykasvin satoisuus, ruokavalinnat ja ruokahukka. Helsingissä varjostuksesta saattaa kärsiä jopa puolet kattopinta-alasta, mikä on huomioitava kasvien valinnassa sekä arkkitehtuurissa, esimerkiksi sijoittamalla korkeimmat rakennukset alueen pohjoisreunalle.

Vaikka Pasilan kattoviljelyn ruokaomavaraisuusprosentti on alhainen, yksittäisten ruoka-aineiden osalta tilanne on toinen. Pasila voisi tuottaa yli oman tarpeensa perunoita tai herneitä, tai lehtikaalissa mitattuna 46 % kuluttamistaan tuoreista vihanneksista. Kysymykseen siitä, voisiko kaupunkiviljelyllä edistää Helsingin ruokaturvaa tai lisätä ruokajärjestelmän joustavuutta, on kuitenkin vaikea vastata ilman, että kaupunkiviljelyn tavoitteita on määritelty. Olisikin tärkeää miettiä, onko kaupunkiviljelyn tavoite maksimoida tuotetun energian ja ravintoaineiden määrä, tarjota vaihtoehtoisia ruoan lähteitä, luoda uusia mahdollisuuksia viljelijöille jatkaa ammatissaan, edistää alueen taloudellista hyvinvointia, vai tukea ruokajärjestelmää jollakin muulla epäsuoralla tavalla.

Oikeilla toimintatavoilla ja sääntelyllä kaupunkiviljely voisi edistää Maatalouden ilmasto-ohjelman tavoitteista ainakin hiilen sitomista maaperään, ruokahävikin vähentämistä ja ruokavalion muuttamista kasvispainotteisempaan suuntaan. Kaupunkiviljely voisi myös osaltaan tukea EU:n yhteisen maatalouspolitiikan tavoitteita, kuten ympäristönsuojelua, työpaikkojen luomista ja säilyttämistä, sekä kasvattaa yhteisöjen elinvoimaisuutta monimuotoistamalla elinkeinoelämää.

Avainsanat — Nyckelord — Keywords
Suomi, kaupunkiviljely, ruokajärjestelmä, ruokaomavaraisuus, varjostus

Säilytyspaikka — Förvaringsställe — Where deposited
Maataloustieteiden laitos ja Viikin kampuskirjasto

Muita tietoja — Övriga uppgifter — Further information
Työtä ohjasi Juha Helenius

HELSINGIN YLIOPISTO — HELSINGFORS UNIVERSITET — UNIVERSITY OF HELSINKI

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Faculty of Agriculture and Forestry	Department of Agricultural Sciences

Tekijä — Författare — Author
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Agroecology

Työn laji — Arbetets art — Level	Aika — Datum — Month and year	Sivumäärä — Sidoantal — Number of pages
Master's thesis	04/2018	52 pp.

Tiivistelmä — Referat — Abstract

The Finnish food security is currently good, but Finland must respond to threats linked to natural or man-made disasters, climate change and reliance on imported resources. This master's thesis examines the potential of urban agriculture (UA) as part of the urban food system. Rooftop data, crop yield statistics and the Finnish Nutrition Recommendations 2014 are used to build a case study in which self-sufficiency percentages, nutritional factors and shading are calculated for the Pasila area in central Helsinki.

Calculations based on the total potential green rooftop area and open rooftop farming in Pasila show that 4,51 % of the resident population's energy needs could be supplied with the potato, or 3,87 % of their protein needs with the green pea. Allocating half of the area to the potato and half to the green pea decreases the self-sufficiency percentages, but results in a more even ratio between energy and protein. Adding kale increases the number of essential vitamins and minerals which can be supplied: 500 g of each of the three plants covers the daily recommended intake for 12 of the 19 vitamins and minerals listed in the Finnish Nutrition Recommendations 2014, compared to zero for the potato only and seven for the combination of the potato and the green pea.

In addition to the available area, at least farming methods (e.g. open field, aquaponics and greenhouses), crop yield potential, food choices and food wastage influence the food self-sufficiency potential. In central Helsinki shading may affect as much as half of the rooftop area, which needs to be considered in the choice of plants and architecture; strategies such as placing the tallest building on the northern edge of the area may be beneficial.

Though the total self-sufficiency based on open rooftop farming is low, Pasila could be a net producer of potatoes or peas, or grow 46 % of its fresh vegetables measured in weight (kale). Whether UA can contribute to local food security, or food system resilience, may therefore depend on how its objectives are defined: maximum energy and nutrient content, alternative food sources, new opportunities for farmers, wealth retention, or some other indirect mechanism.

With the right policies, UA could advance the Ministry of Agriculture and Forestry's Climate Program by increasing carbon sequestration, reducing food waste and promoting a more plants-based diet. It may also serve the objectives of the Common Agricultural Policy (CAP), including a healthier environment, preserving and creating jobs, protecting local financial interests and contributing to a sound development of our areas.

Avainsanat — Nyckelord — Keywords
Finland, urban agriculture, urban farming, urban food systems, food self-sufficiency, shading conditions

Säilytyspaikka — Förvaringsställe — Where deposited
Department of Agricultural Sciences and Viikki Campus Library

Muita tietoja — Övriga uppgifter — Further information
Supervisor(s): Juha Helenius

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1 Introduction

While preparing to write this thesis, I spent nine months in South-East Asia. I saw urban gardens with fruit trees and tilapia ponds, buildings that had their walls covered with plants, markets where old ladies sometimes offered only a few herbs for sale, chickens in the center of Ho Chi Minh City and the covered vegetable gardens between buildings in Cameron Highlands. It seemed food could be grown anywhere, if someone wanted to.

For most urban Finnish consumers, food is not part of the city landscape. It comes from the shelves of a supermarket and involves a choice. As consumers we may be asked to make "responsible choices" without a real understanding of what those are (Lang and Heasman 2015 p. 245). But even when nutritional, environmental and agroecological knowledge is available, we are still free to choose our food within our financial means. The choices that are made may be right or wrong, but many people feel passionately about them (Boesveld 2015).

Food is linked to culture, consumerism, economic status, and it is both international and local (Esnouf et al. 2013 p. 2). It also exists in a context of urbanization, poverty, global markets, politics, industrial organization and climate change. Food, no doubt, is complex, even if we ignore that there are issues with how it is consumed and that much of it is wasted.

More than 40 % of the earth's arable land surface is already devoted to human food production, yet population growth, increased meat consumption, and the production of biofuel add to the demand for more agricultural land (Sandström et al. 2014), all while it is no longer viable to clear more land for farming (Foley 2011). Biel (2016 p. 2), like many others, argues that conventional farming is a high-input, highly mechanical system that is destroying the land. Cartels, subsidies and trade barriers are politically driven decisions, which can trigger or worsen resource scarcity, drive up prices and increase price volatility (Ellen McArthur Foundation 2013 p. 19). Climate change is already affecting farming and expected to add new challenges to many existing food systems (FAO 2016).

Urban Agriculture (UA) is a way of producing food in the city, for the city. Rooftop farming takes place on rooftops, making use of available spaces without competing with street-level uses of land. In the developed countries, urban agriculture and rooftop farming have often been described in the context of social, environmental and health-related benefits. As an example of this, the European Cooperation in Science and Technology (COST) did research into how urban agriculture can contribute to sustainability, vital urban spaces, and the ecological qualities of European cities (COST

Association 2017). In fact, the impacts of green roofs in a changing climate are well researched, but data on agricultural rooftops is still quite scarce (Dubbeling and Massoneau 2015).

The realization that urban food systems could be under threat, has sparked recent interest in the food security aspect of urban agriculture in the developed countries. Toronto released an urban agriculture action plan in 2012 (Hunter College New York Food Policy Center 2017) and Melbourne recently investigated its city food bowl and the vulnerabilities in its food supply (Sheridan et al. 2016). In the Netherlands, the first National Day of Urban Farming was organized in 2012 (RUAF Foundation 2014), and the Dutch are experimenting with "food forests" in and around cities like Rotterdam and Almere (de Groot and Veen 2017). The Milan Urban Food Pact, signed by 160 cities, and the CITYFOOD Network, with 15 local and regional government members, are both aiming to create cooperation around urban agriculture and resilient food systems (MUFPP 2017, RUAF Foundation and ICLEI 2013).

Finland has not yet actively participated in urban agriculture initiatives, and whether urban agriculture could be scaled up to have an impact on the food security of Helsinki is unclear. The studies that have been done in countries such as Cuba, Italy, and even England (Clouse 2014, Bakker et al. 2000, Orsini et al. 2014), are based on local conditions and hence the results may not be applicable in the colder climate and shorter growing season of Helsinki. Helsinki might even have an additional challenge of substantial shadowing in urban agriculture, due to the angle of sunlight this far to the north.

The aim of this thesis was to contribute numbers to the discussion around the role of urban agriculture in the food security or food system resilience of Helsinki. Through a case study of rooftop farming, it seeks to answer the following three questions: 1) What percentage of food self-sufficiency could be achieved by rooftop farming in a central area of Helsinki? 2) How should the available rooftop area be allocated to maximize the amount of energy, protein, vitamins and minerals? 3) How big is the share of rooftops that are affected by shading in an urban setting in Helsinki?

1.1 The nutritional aspects of food

There are many perspectives to food, but given the context of the research questions, defining food as "nutrition" seemed to be the most appropriate.

From a nutritional perspective food is a source of water, carbohydrates, proteins, lipids (fat), vitamins, minerals, and fiber. Nutrients are either essential or non-essential, depending on whether the body can synthetize them from other nutrients at the necessary speed or not. Essential nutrients must be ingested from food or otherwise obtained from the environment to prevent deficiencies and even death, and include certain amino acids, fatty acids, vitamins and minerals (Aro et al. 2012 pp. 17-18). Fiber is not considered a nutrient, but is seen to promote health (Aro et al. 2012 pp. 17-18).

Food contains energy, which is measured in “joule” (mostly in units of kJ) or in “calories” (mostly in units of kcal). One kcal equals 4.184 kJ and is the amount of energy needed to increase the temperature of one liter of water by one degree Celsius. Although “joule” is the official unit for energy, “calories” are commonly used to refer to nutritional food energy content.

Carbohydrates, fat, protein and alcohol are sources of energy. Carbohydrates and protein contain the same amount of energy, 16.8 kJ/g, while lipids contain 37.8 kJ/g (Gibney et al. 2009 pp. 31, 33). In most diets, carbohydrates are the main source of energy, simply because they are abundantly available (Gibney et al. 2009 p. 74). Proteins, on the other hand, contain indispensable amino acids (Gibney et al. 2009 p. 49), and fats contain essential fatty acids (Aro et al. 2012 p. 61).

A person’s energy requirement is the amount of energy needed to maintain the body size, body composition and physical activity that leads to good health in the long term (Gibney et al. 2009 p. 31). The Finnish Nutrition Recommendations 2014 (Suomalaiset ravitsemussuositukset 2014 by Valtion ravitsemusneuvottelukunta, 2014) recommend that 45-60 % percent of the total energy intake come from carbohydrates and 25-40 % from lipids. The recommended protein intake for adults aged 18-64 is 1,1-1,3 g for each kg of body weight (Valtion Ravitsemusneuvottelukunta 2014). This means that a person’s energy and protein needs are to some extent individual.

Gibney et al. (2009 p. 31) estimate that the average adult needs 4000 MJ each year to maintain their energy balance. In the Finnish Nutrition Recommendations 2014, the average energy intake recommendation for physically active women and men aged 18-30 is 4325 MJ per year, and for non-active 3851 MJ per year. There is a daily intake recommendation for calcium, iron, iodine, potassium, magnesium, phosphorus, selenium, zinc, folate, niacin, copper, vitamins B6, B2, B1, B12, A, C, D and E (Valtion ravitsemusneuvottelukunta 2014). Of these, B12 is not available in plants and vitamin D in only a few plants (Terveyden ja hyvinvoinnin laitos 2017).

Nutrient profiling is a way of rating food based on its nutritional value: food can be energy dense or nutrient dense. Energy density describes the amount of energy per gram of food (British Nutrition Foundation 2018). In a similar way, food that is high in nutrients relative to energy, is called nutrient dense (Drewnowski and Flugoni 2014). For example, the commercially developed Aggregate Nutrient Density Index (ANDI) adds up the beneficial nutrient content to give each food a total score of maximum 1000 (Fuhrman 2017). The Nutrient Rich Foods (NRF) models score foods based on nutrients that are considered beneficial, as well as ones to be avoided, and can link food and price to indicate which foods are both healthy and affordable (Drewnowski and Flugoni 2014).

1.2 Food security

The definition of food security has changed over the years, but currently the most widely used one is the definition by the 1996 World Food Summit: *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (Mechlem 2004, FAO 2008). On a more practical level, food security consists of availability, access, utilization and stability (FAO 2006). Even though food security discussions often focus on securing a sufficient amount of food energy to reduce hunger and safeguard survival, there are strong links between nutrition and well-being, and the decisions that are made regarding food security have health-related, economic, environmental and societal consequences (Fanzo 2015).

Food systems, on the other hand, can be explained as follows: *"Dynamic interactions between and within the biogeophysical and human environments lead to the production, processing, preparation and consumption of food, resulting in food systems that underpin food security"* (Gregory et al. 2005).

A multitude of factors threaten food security. Tendall et al. (2015) group them into 1) multiple processes of global change, 2) unexpected shocks, and 3) the unexpected responses that food systems can have to these. Together, they create complexity and uncertainty, which is difficult to control. Leichenko and O'Brien (2008 p. 10) use the term "double exposure" to explain how two different processes, like climate change and globalization, can affect the capacity to respond to shocks and stresses caused by either one.

Climate change puts new pressure on food production. The FAO (2016 p. 3) concludes the following: *"While impacts on agricultural yields and livelihoods will vary across countries and regions, they will become increasingly adverse over time and potentially catastrophic in some areas."* The effects of climate change vary regionally, but the general agreement is that a temperature rise of 2° C could reduce world food supplies and aggravate hunger (Dutch 2010 p. 15-16). The estimates are based on climate models, and it is thought that crossing greenhouse gas (GHG) thresholds could cause abrupt climate change at any time (Cox 2004 p. 184). According to the FAO (2016), producing food: "*will require more systemic changes, such as major shifts in the loci of production of specific products and species, compensated by changes in both trading and consumption patterns."*

At the Paris Climate Conference in December 2015, the first-ever universal, legally binding global climate deal was adopted by 195 countries, including Finland. Some of the key elements of the agreement are the reduction GHG emissions through mitigation, and strengthening societies' ability to deal with the impacts of climate change through adaptation (European Commission 2017).

Food is increasingly a commodity that is traded on global markets, where its price is defined by complex interactions of many different factors. Agricultural markets are generally characterized by higher price volatility (degree of variation) than other markets, and international markets by more volatility than national markets (Hansen 2013 p. 146).

In 2007-08 and 2010-11 there were two food crises that led to sharp increases in food prices on the global market. Hansen (2013 pp. 37-38) describes how the food crisis of 2007-08 was caused by a number of temporary or random factors. First, below-average harvests, combined with global consumption that was higher than production, over several consecutive years, led to low reserves (at times only about two months' global consumption). Then, a financial boom in many countries increased demand for food in general, and animal-based food in particular. Because grain is also used to feed animals, this affected the demand for grain even further. Lastly, a tighter food market situation attracted speculators fleeing the declining property market in the US, and the result was hoarding and panic, which made the situation even worse.

The demand for food is expected to grow, while the increase in production is limited (Hansen 2013 pp. 146-149). Most observers seem to agree that the price rises indicate a shift towards less excess production and a tighter supply, and that food commodity prices will continue to increase (Esnouf et al. 2013 p. 10-12). Baldos and Hertel (2015), are among the few who argue that the price rises are temporary. In their opinion, agricultural productivity growth will offset population growth and lead to lower prices, but even they caution that climate change could have a negative impact.

The UNEP Finance initiative (2016 p. 3) believes that climate change, along with environmental degradation and limited water supplies, will lead to food scarcity, while the demand for food will inevitably rise because of the global population growth and increase in income. The result could be an imbalance between supply and demand, leading to volatile prices and a higher likelihood of price shocks.

To be able to function in an uncertain environment, food systems need to be sustainable, but also resilient, i.e. capable of long-term functioning despite disturbances (Tendall et al. 2015, Beermann 2009). Resilience is also one of the five key principles of FAO's vision for sustainable food and agriculture (FAO 2016 p. 15).

1.2.1 Food security in Finland

Currently, Finland as a nation has a high level of food security. Access to food is good, and the Finnish population has the purchasing power to source food from the global market (Sandström et al. 2014, Niemi et al. 2013 p. 4). In 2006, the total Finnish household expenditure for food was only 12 % (Sandström et al. 2014).

However, even Finland's food security has its weaknesses, which it shares with many developed countries. Though Australia is on the other side of the globe, Finland and Australia both depend on imported resources such as fertilizers, fuel and machines (Niemi et al. 2013 p. 4, Carey et al. pp. 14-15). Both countries also have a "lean supply chain", which has been optimized to deliver what is needed at the last moment, and not to stock excess food. This makes them vulnerable to disruptions caused by extreme weather, fuel delivery, pandemics or IT failures (Carey et al. 2016, p. 15, Niemi et al. 2013 p. 4). Niemi et al. (2013 p. 45) add terrorism, nuclear disasters, wars, plant and animal diseases, droughts, floods, earthquakes, asteroids, as well as issues related to trade and the functioning of the global market, to the list of potential risks for the Finnish food security.

Finland, again just like Australia, sources part of its food from the global market, and relies heavily on imported soy for animal husbandry, from countries which could be negatively affected by climate change. (Maa- ja metsätalousministeriö 2014, FAO 2016 pp. 24-25, 44). The amount of land outside Finland, which is used to produce food for the Finnish market, has continued to increase in 1961-2007 (Sandström et al. 2014). Whilst buying from the global market can in many cases be efficient, Carey et al. (2016 p. 14) warn that: *"Becoming dependent on 'somewhere else' to meet growing shortfalls in the food supply is likely to be an increasingly risky strategy".*

Finland is in one of the few regions of the world that could potentially get some benefits from climate change (FAO 2016 pp. 24-25, 44). Based on the current models, Finland will likely have longer hot periods in the summer, less snow or ice and more rain, including heavy rainfall, in the winter (Ilmatieteen laitos 2017). To manage these changes and mitigate the negative impacts, the Finnish Ministry of Agriculture and Forestry has written a climate program for agriculture, listing carbon sequestration into the soil, as well as reducing food waste and changing dietary habits to more plant-based food, as some of its key measures (Maa- ja metsätalousministeriö 2014). If Finland can manage the risks associated with the changes, it could gain agricultural production capacity, and perhaps be expected to contribute more to the global food market.

In their study, Puupponen et al. (2016) concluded that although the Finnish food security is currently good, the discussion around it is fragmented and a comprehensive policy is still missing. The key to preparing for future risks is flexibility, i.e. the ability to cope if the flow from the primary sources is disrupted (Niemi et al. 2013 p. 55).

1.3 Urban agriculture

Sunlight is the primary source of energy for ecosystems and comes in the form of electromagnetic waves. 40-60 % of the radiation that reaches the surface of the earth is visible as light and has wavelengths between 400 and 750 nm; this is known as photosynthetically active light (PAR), and it can vary in terms of quality (colors), intensity and duration (Gliessman et al. 2000 p. 41). Factors affecting it are seasonality, altitude, latitude, topography, air quality and the structure of the canopy (Gliessman et al. 2000 pp. 41, 45-46). Photosynthesis is the process in which plants use solar energy to convert water and carbon dioxide into glucose. Plants are autotrophic (self-nourishing) (Gliessman et al. 2000 p. 31) and it is the carbohydrates that they produce using sunlight that serve as a basis for all food consumed by people.

Evidence of urban agriculture, e.g. irrigation systems, have been found in most ancient civilizations that had big concentrations of people (Egziabher 1994 pp. 1-2). Cities need large amounts of food in a reliable manner, and where refrigeration and infrastructure is unavailable, food has to be produced locally. It was only the invention of canning in the early 1800s and cold storage by the 1870s that made transporting and storing food for extended periods possible (Blay-Palmer 2008 p. 18).

Crises that disrupt the food system, such as major political changes, wars, hurricanes or other natural disasters, often lead to a temporary surge in urban agriculture (Egziabher 1994 p. 5). As an example, Americans were encouraged to grow vegetables in their backyards during World War II (Wessels Living History Farm 2017) and Cuba turned to urban agriculture to feed the citizens of Havana, when it was cut off from imports of food, oil and fertilizers from the Soviet Bloc in 1989 (Clouse 2014 p. 33). Nevertheless, urban agriculture can be used to diversify the food system and spread risks even in non-crisis times.

Themes that are linked to urban agriculture in the literature include urban growth and poverty, food security, economic benefits, the local food movement and health aspects, as well as social, recreational, educational and environmental aspects.

1.3.1 Definition and characteristics

The definition of urban agriculture, according to Veenhuizen (2006 p. 2) is: *"The growing of plants and the raising of animals for food and other uses within and around cities and towns, and related activities such as the production and delivery of inputs, and the processing and marketing of products. Urban agriculture is located within, or on the fringe of, a city and comprises a variety of production systems, ranging from subsistence production and processing at household level to fully commercialized agriculture."*

Urban agriculture is also often referred to as “urban farming”. This seems especially to be the case when the content is aimed at the broader public; an example of this could be home-owners potentially interested in growing vegetables in their backyards. The reason might be that most people associate food with the word “farm”, rather than thinking of food as something produced by “agriculture”. The divide is not clear and some authors, like Veenhuizen (2006), use both terms in their work. For the purposes of this thesis, both are considered to mean the same the thing.

The literature lists categories of urban agriculture by size and type of farm, or by whom it is owned and/or farmed. Many of these definitions are based on a single country and its circumstances, such as those listed and described for Cuba by Clouse (2014 p. 76-91). Veenhuizen (2006 p. 10-11) uses a simple, but logical, way to categorize farms into three types: subsistence oriented, market oriented, and multifunctional urban agriculture. The **subsistence oriented** produces food and medicinal products for the consumption of the own household, saves in expenditure and supplements income through the sale of surpluses. The **market oriented** urban agriculture produces to sell and focuses on income generation. While it provides a livelihood for families or organizations, it also uses more inputs and externalities. **Multifunctional** urban agriculture combines food production with other goals like education, recreation, urban greening and water storage.

Depending on the production method used, urban farming can also be divided into **soil based** or **non-soil based**, which in turn consists of **hydroponics, aquaponics and aeroponics** (Craig Johnson, lecture at Disruptive Innovation Festival 2016). Often urban agriculture is about growing plants, but it can also be about keeping animals (Egziabher p. 1) such as poultry, fish, rabbits, snakes, guinea pigs etc. for food. Bakker et al. (2000) list Havana as having as many as 63 000 pigs and 700 rabbit-rearing units. Which animals are considered edible, varies per country: guinea pigs and dogs are kept for food in some countries, but considered pets in many others.

Urban agriculture is perceived as something that happens in urban and peri-urban areas, but there is no common definition for what this means in terms of density or building characteristics (Egziabher 1996 p. X of the Foreword). Other characteristics listed by Veenhuizen (2006 p. 2) include being close to the market (the urban consumers), competing for a limited amount of land, and using waste materials and waste water available within the city. Urban agriculture is often highly specialized and mostly produces perishable products (Veenhuizen 2006 p. 2).

For the urban farmers that rely on the crop for food and a regular income, the cropping system needs to be risk-free, yet create high value on a small plot (Veenhuizen 2006 pp. 177-178). Typically, leafy vegetables are low-risk because they grow fast, allowing for a short cycle and regular cash generation. Vegetables and ornamental plants fetch a higher price, but also need longer cycle times and thereby present a higher risk. As land price increases, crops often shift from food to market gardening, flowers, or fish farming, and urban agriculture found in the central parts of a city is usually more labor- or capital intensive (Egziabher 1994 p. 18, Veenhuizen 2006 p. 180).

Cities are in constant change and economic up- and downturns influence the use of land. During economically good times building activity is high, in slump times lots bought for development can be left standing unused waiting for better times. Urban agriculture is a permanent part of the city, but the locations of the plots often shift over time (Veenhuizen 2006 p. 187).

1.3.2 Urban growth and poverty

By 2050, 69 % of the world's population is expected to live in cities (United Nations 2011). Already, more than 50 % of the world population is urban; in Europe, North America and Australia as much as 80 % of the population lives in cities (Picket et al. 2013 p. 43).

According to a study by Sheridan et al. (2016) 15,080 tons of food is produced each day for Melbourne's 4.37 million inhabitants. It's an enormous amount of food, which needs to be produced and transported at a considerable cost. As people move to cities, their diets and eating habits often change, so they demand a different kind of food than they did before (Satthertwaite et al. 2010).

The more of its budget a household spends on food, the higher its food insecurity becomes (Egziabher 1994 p. 10). In cities, a lack of income also tends to translate more directly into a lack of food (Veenhuizen 2006 p. 3). The urban poor have fewer coping strategies, and malnutrition is more common in urban slums than in rural areas (Egziabher 1994 p. 11). As cities continue to grow, urban poverty and hunger are becoming structural, and urban farming may be turning into a long-term social security net for many poor households (Veenhuizen 2006 p. 9).

A lack of food in cities is often associated with developing countries, but hunger and food deserts (areas where affordable nutritious food is unavailable because there are no supermarkets or other distributors) also exist in the developed countries. In the US alone, an estimated 49 million people (14 % of the population) are food insecure (Philips 2013 p. 6). The biggest difference may be that poor people in developed countries often benefit from more public assistance (Koc et al. 1999 p. 13).

Even currently food secure cities may not be able to take their food systems for granted. As an example, Carey et al. (2016 p. 11-13) conclude that chronic stresses such as population growth and urban sprawl, as well as prolonged drought and floods brought on by climate change, are likely to influence the food systems of Australia's major cities significantly.

1.3.3 Urban agriculture and the economy

In his treatise *The Isolated State*, which was published in 1826, von Thünen explained his contribution to spatial economics. His theory, simplified, was that for each crop there is an optimum distance from the center of a city, where cultivating it is profitable. If the distance is shorter, the rent of the land will be too high, if the distance is longer, then the transportation cost will be too high (Braeuer 1951 p. XXXV-XXXVIII).

While the cost and technical possibilities for transport have changed since the times of von Thünen, the core idea remains valid. The closer to the center of a city, the more expensive land becomes and the less of it will be available for agriculture. Hence, high-value perishable products like herbs and lettuce are more likely to be grown in an urban environment. Low-value crops, such as cereals or tubers, which can be stored and transported at a lesser cost, are mostly grown outside the city.

Because food and farming are subordinated to the socio-economic system, they suffer from the same underlying problem as the rest of the system, i.e. the accumulation of wealth. By purchasing commercial seeds, pesticides and agrochemicals, farmers can be trapped in contracts that they cannot control with big companies, resulting in debt and even suicides (Biel p. 7). However, it is not just the producers, but also the consumers, who are facing the big actors. In the 1970s French consumers spent only 5 % of their food expenditure in supermarkets, today they spend almost 70 % (Esnouf et al. 2013 p. 104). The same trend is visible in Finland: in 2011, the two major retail chains had a market share of more than 80 %, and 27 % of the food was bought not just in supermarkets, but in hypermarkets (Niemi et al. 2013 p. 39). This kind of concentration creates a strong dependency on, and transfers much power to, a few actors in the food chain (Esnouf et al. 2013 p. 104).

Next to power concentration, relying on just a few big actors may involve other risks. Industrial food chains are based on infrastructure such as roads, refrigeration and cheap fuel. Energy is used to process, pack and transport food from one part of the industrial food chain to the next. In the US food system, as much as 7.3 units of (primarily) fossil fuel energy is used to produce one unit of food energy (Heller and Keoleian 2000 p. 40). If the price of energy rises sharply, it will have direct effects on the commercial industrial food chains, and therefore on the availability of food.

Urban agriculture today is often about local food and small actors. Community Supported Agriculture (CSA) is a system where the farmer sells “shares” to the community. The “shares”, which are bought at the beginning of the season, entitle shareholders to a part of the crop that the farmer produces during the season. This set-up spreads the risks, benefits and commitment from a single farmer to a bigger group of people (Veenhuizen p. 148).

Ladner (2011 p. 117) explains how buying locally produced food, whether it be in a rural or urban setting, works for the local economy: it helps struggling farmers and creates spin-off spending. Each dollar spent on a local farm has the impact of 3-4 dollars spent on a business owned outside the community (Ladner 2011 p. 105). The practical implications for local food security are described in a report by Meter and Phillips Goldenberg (2014), which found that there are considerable issues with the food security of Alaska. Alaska imports 95 % of its food through long supply chains, and the main source of local food in Alaska is subsistence hunting, fishing and gathering of food. The cost of fuel, weather change, flooding, and shifting migratory patterns are threatening subsistence resources, while the Alaskan food industry exports most of what it produces. This has implications for both the food security and economy, because by buying its food from the outside, Alaska is exporting money which could be used for setting up local businesses to grow food. In another study from the US, Grewal & Grewal (2012) calculated that an enhanced food self-reliance could retain as much as USD 29-115 M annually in the Cleveland area.

The economic implications of urban agriculture can sometimes be more indirect, or even ones that we do not necessarily associate with agriculture. For example, abandoned buildings and vacant lots create a perception of urban decline, which leads to lower property values. By contrast, well-maintained and aesthetically pleasing urban agriculture can increase property value. Clements et al. (2013) estimate that landscaping and trees may increase property values by an average of 2-5 %.

1.3.4 Health and the local food movement

In his article Schnell (2013) shows that the claim of food traveling an average of 1500 miles between production and consumption has been misinterpreted. Whatever the real number is, it’s clear that much of the food consumed has come a long way. Coffee, avocados, peanuts and cane sugar, just to mention a few, simply do not grow in Northern Europe, and much of the processed food comes from abroad.

The industrial food chains that supermarkets are part of, have generally given consumers a bigger variety of products, better food safety and lower prices (Esnouf et al. 2013 p. 104). However, moving food around the globe can also be a pathway for the spread of food related illness. 130 million European citizens are affected by food borne diseases every year, with some of the best-known food scares related to the Mad Cow and Creutzfeldt-Jacob diseases, salmonella in eggs and the avian flu (Blay-Palmer 2008, p. 87). There is also concern that viruses, such as the avian flu, can develop into highly pathogenic strains because of the global nature of the food industry (Blay-Palmer 2008 p. 103). Most far-away food does not pose a health risk, but the longer food is stored and transported, the less fresh it becomes, and the more nutrients are lost.

Consumer concern over the industrialized food system has led to an interest in local food, which is visible in the growing number of initiatives such as farmers' markets, community-supported agriculture, food co-ops and farm-to-school programs (Schnell 2013). Like the name implies, the local food movement is founded around the principle of producing and consuming food locally, but there is no universal definition of what classifies as local food; in Finland, the government defines "local food" as food produced within the region (Albov 2015). Sometimes the term "locavore" is used to describe people who eat food grown within a certain distance from their homes, typically 100 or 250 miles, or within a certain region (Roehrig 2011).

Local urban food provides fresh and accessible alternatives to processed food, which may be transported long distances before being consumed. In contrast to industrial food systems, which focus on quantity and large-scale production, much of the local food is produced by alternative food systems and distributed through farmer's markets, direct-sell stalls or organic box deliveries (Blay-Palmer 2008 p.3). The proximity to the market allows for frequent contact between producers and consumers, and therefore keeps producers from cheating on product quality (Veenhuizen 2006 p. 187). When food is grown locally, customers may be able to see the actual lot or yard where it is coming from - which is also a common motivation for buying food from a CSA (Schnell 2013).

Ladner (2011 pp. 18-20) reminds us that local food is not per definition the most energy efficient, cheapest or easiest alternative, and that the distribution of fruit and fresh vegetables has significant regional differences and obvious consequences for locavores. The best choice for food security may in many cases be a combination of local and foreign.

1.3.5 Social, recreational and educational aspects

Community gardening can be a catalyst for neighborhood development, social interaction, producing nutritious food, beautifying neighborhoods and encouraging self-reliance. It can also create opportunities for recreation, exercise, therapy and education (Veenhuizen 2006 p. 146, Ledant 2017).

When urban agriculture is community-driven and community-managed, it can be called Community Based Urban Agriculture (CBUA) and usually takes place in community gardens or allotments, school gardens, cooperative farming, or commonly owned sites (Veenhuizen 2006 p. 147). Community based urban agriculture stems from a need for food for the community, but it also creates a mini-economy around food, often empowering women and the youth, and can act as a framework for involvement and inclusion, a sense of community, dignity and accomplishment (Veenhuizen 2006 p. 147). By providing settings for exercise as well as reducing stress, ultraviolet radiation and air pollution, urban green can have an impact on physical and mental health (Veenhuizen 2006 p. 415).

1.3.6 Environmental aspects

It is estimated that agriculture contributes up to 25 % of carbon dioxide emissions, 60 % of methane emissions and 80 % of nitrous oxide emissions (Dutch 2010 p. 15-16). Transportation and logistics accounts for 30 % of the food system's energy consumption in the UK (Esnouf et al. 2013 p. 15). Bulky, perishable foods are big contributors to traffic, and as much as 50 % of the all traffic linked to agricultural products in the Paris region in 2005 was caused by vegetables and fruit (Esnouf et al. 2013 p. 118).

One way of measuring the sustainability, or carbon footprint, of food is "food miles", which describe the distance travelled by food in the global trade (Bender 2014). Coley et al. (2011) argue that the mode of transport is just as important as the distance, and it is obvious that individual consumer behavior, like driving long distances to specialist food stores, can influence the carbon footprint.

A study from Rosario, Argentina, concluded that replacing imported lettuce with locally grown could reduce the transport-related GHG emissions of lettuce consumed in the area by 90 % (Piacentini et al. 2015). It is tempting to think that local food will automatically lower the GHG emissions of food transport, but it is not always the case. A study from Almere, The Netherlands, where the aim was to produce 20 % of the total food of the residents within the city, found that most of the food that could be grown locally was already produced in the Netherlands and transported a maximum of 150 kilometers (Viljoen and Wiskerke 2012 p. 317). The heavy truck transport in this case accounted for less kilometers than the car transport by consumers who did their shopping by car (Viljoen and Wiskerke 2012 p. 317).

Most of the time, however, local food does decrease transport-related GHG emissions. Produce from urban agriculture is mainly distributed through short marketing chains: it is sold at farmers' markets or otherwise directly to consumers (Veenhuizen 2006 p. 185). Small-scale farming, like urban agriculture, typically depends less on fossil energy than larger-scale farming because it needs less transport, refrigeration and packaging, and is better able to use leftovers (Veenhuizen 2006 p. 360).

Agriculture indirectly affects the climate through the clearing of forests and other ecosystems for agricultural use (Dutch 2010 p. 16), which leads to higher GHG emissions. Higher concentrations of GHG are linked to increased heat waves, severe storms, floods and elevated sea levels (Dutch 2010 p. 15-16). More frequent extreme weather events in turn affect production stability and predictability, and thereby increase the insecurity of the food markets. The IPCC (2014) predicts that all aspects of food security could be affected by climate change.

Water is becoming increasingly scarce in many places, so cities are competing for water with rural agriculture and other uses. While using raw wastewater in urban agriculture can be a health hazard, treated grey water can provide safe irrigation water at a low cost and make more efficient use of the available water (Veenhuizen 2006).

Composting is a way of recycling nutrients, but also of reducing the cost of waste management, especially if composting is done in a decentralized way either on a community level or in the back yards (Veenhuizen 2006 p. 213). Locally composted organic waste benefits urban agriculture by providing nutrients and organic material, which improves soil fertility (Veenhuizen 2006 pp. 212-213).

Urban agriculture plays a role in supporting biodiversity by providing a place for experimenting with diverse crops, or attracting wild species like pollinators to the cities (Ledant 2017). Green rooftops are potential habitats for wild species (Madre et al. 2014), especially if the plots create “ecological corridors” facilitating the movement of seeds and animals across the urban environment.

Climate change mitigation means reducing or preventing GHG emissions (UNEP 2017) and is, in addition to adaptation, a central response to climate change. Though most studies have been done in northern climates, they show substantial energy savings for cooling under green rooftops (Clements et al. 2013, Dubbeling and Massoneau 2015, Picket et al. 2013 pp. 29-46). Storm water management through urban agriculture and retaining rainwater for rooftop farming saves costs, reduces flood risks and decreases the amount of waste water that needs to be treated (Clements et al. 2013, Cohen and Wijsman 2014). Urban agriculture can even reduce the noise levels (Orsini et al. 2015)

FAO (2016b) uses the term “climate smart agriculture” to describe agriculture that it envisions to be both sustainable and efficient. Sustainability and efficiency are not automatically part of urban agriculture, because they depend on the methods used for farming; what Ulrich Schmutz (2017) calls “factory farming in the city” has little to do with agroecology. With the right choices and an integrated environmental policy, however, urban agriculture can contribute to a greener city, healthier environment and smaller ecological footprint (Veenhuizen 2006 p. 90).

1.3.7 The challenges of urban agriculture

Like agriculture anywhere, urban agriculture has its challenges, some of which are related to the urban environment.

Urban agriculture has spatial constraints, so it cannot exploit economies of scale in farming. Processing food on a small scale can be hindered by cost (small producers cannot afford to invest in the necessary equipment) or the availability of services (processing may only be available on a regional scale) (Ladner 2011 pp. 119-120). The distribution alternatives are often limited, and most urban farmers still sell through farmer's markets, through a CSA, or directly to restaurants, rather than through bigger grocery stores, where most people go to do their shopping (Ladner 2011 p. 97). As Morgan et al. (2006) point out, one of the issues of the local food movement may be precisely that it is local, and therefore unable to make a difference on a larger scale.

Veenhuizen (2006 p. 4) lists five categories of health risks in urban agriculture: 1) the contamination of crops with pathogenic organisms, 2) the spread of human disease via mosquitoes or scavenging animals, 3) the contamination of crops through a prolonged use of agrochemicals, 4) the contamination of crops with heavy metals due to traffic and industry and 5) the spread of diseases via animals kept in close proximity to humans. As the volume of urban agriculture is increasing, so are the risks, but according to Veenhuizen (2006 p. 4) information on actual health impacts is still scanty and adequate regulatory and preventive measures are often missing.

A safe and reliable water supply is essential for urban agriculture, but as more and more water is consumed by cities, untreated wastewater may end up in urban agriculture, where is can pose a health risk (Veenhuizen 2006 p. 244).

Though newcomers to cities commonly lack employment, they also lack access to land and are not the ones most likely to engage in urban agriculture (Egziabher 1994). Farmers who do not own their land often have difficulties securing loans for tools and materials, so they rely on savings and subsidies in addition to credit (Veenhuizen 2006 p. 92). Urban agriculture also has a gender aspect. Approximately 65 % of the urban farmers are female and promoting urban farming without due attention to gender can lead to further increases in the workloads of women (Veenhuizen 2006 p. 4).

In many cases, regulation for urban farming can be lacking, but in other cases, urban agriculture may need to adhere to strict rules that were originally developed for rural farming, rather than for the urban setting (Orsini et al. 2015). Even different types of

urban agriculture need different kinds of policies. Social policies are important for the subsistence kind of urban farming, economic policies for the market oriented, and environmental policies for the multifunctional urban farming (Veenhuizen 2006).
One of the key goals of urban design is to improve human well-being, which includes healthy and affordable food (Picket et al. 2013 p. 58). For urban agriculture to achieve its full potential, it needs to be integrated into city planning, regulations, financial incentives, commercial structures and food security. Local, provincial and national governments play an important role, because they can ensure the availability of land, water and public services, as well as approve regulations and standards (Veenhuizen 2006 p. 29).

1.3.8 The potential of urban farming in feeding a city

Cuba seems to be the most prominent example of urban agriculture in the literature. During 1959-89 Cuba imported 57 % of its perishable food from the Soviet Bloc (Clouse 2014 p. 38). When the Soviet Bloc collapsed in 1989, the flow of food, fertilizers and pesticides into the country disappeared almost overnight (Clouse 2014 p. 33). To feed its people, the Cuban government supported urban agriculture through land ownership transfers and permissible forms of entrepreneurship, invited the public to participate in food production and supplied farming materials (Clouse 2014 pp. 39-41). By 2002, 12 % of the area of Havana was cultivated, using biopesticides and biofertilizers (Clouse 2014 pp. 33-35).

The amount of food that Havana produces, 3.2 million tons in 2002, is cited by Clouse (2014 pp. 33-35) and several others, but it is unclear where this number originally comes from. According to Bakker et al. (2000) Havana produces 58 % of all vegetables and 39 % of all fruit consumed, but again, it is not clear what the origin of these numbers is.

Most literature seems to agree that urban agriculture is a good way of providing fresh food, such as leafy greens and vegetables. Altieri et al. (2017) even find that city-level self-sufficiency of vegetables is potentially achievable. The biggest limitation to full food self-sufficiency may be the fact that tubers and cereals, which provide a large part of the carbohydrates in most diets, usually come from rural areas. Even so, well designed urban farms can be up to 15 more productive than rural farms (Altieri et al. 2017).

The estimates of how much urban agriculture can produce varies. According to Altieri et al. (2017) yields of up to 20 kg of vegetables per square meter are now grown in urban agriculture in Cuba. Orsini et al. (2014) estimate that 82 hectares of soilless rooftop gardens in Bologna, Italy, could provide more than three quarters (12500 t) of the vegetables that the city needs. A study (Peck 2003, cited by Orsini et al. 2015) estimated that rooftops in Toronto, Canada, could generate seven kg of vegetables per square meter. Another study from 2000 calculates that given a productivity level of 10.7 t/ha and the WHO daily recommended intake of 500 g of fruit and vegetables, London could supply 18 % of the needed fruit and vegetables (Bakker et al. 2000). For Vancouver, a study estimates that if all private open vegetated areas (15.8 % of the total land surface) were used grow two crops of beans each year, 5000 people per square kilometer could be supplied with their vegetable requirement, equaling 6.5 % of their total energy intake (Johnson et al. 2015).

Bakker et al. (2000) listed percentages of achieved self-sufficiency for developing countries. Given the food insecurity and warm climate in these countries, it is not surprising that the percentages were higher than those mostly seen for Europe or North America. The numbers quoted by Bakker et al. (2000) include 90 % of all vegetables for Accra, Ghana, and 100 % of all leafy vegetables for Vientiane, Laos.

Grewal and Grewal (2012) constructed three different scenarios for Cleveland (US). If 80 % of all vacant lots were used for growing food, between 22-48 % of the city's demand for vegetables and fruit could be met locally. Adding 62 % percent of the commercial and industrial rooftops, as well 9 % of occupied residential plots, increased the number to 46-100 % of fresh produce. In addition, this last-mentioned scenario could generate 94 % of both poultry and eggs. They concluded that significant levels of self-reliance are possible in post-industrial North American cities.

Ladner (2011 p. 100) is concerned that current urban agriculture in the developed countries may focus too heavily on high-end products such as daily fresh sprouts or purple potatoes, for which the demand is limited. Ladner (2011 pp. 103-104) continues that aquaponics and indoor farming may be alternatives for affordable urban food production, and that cities should aim for food security, rather than food self-sufficiency, because relying fully on local urban produce would make food more expensive and more monotonous. A food system that depends one source only, is per definition not very resilient.

1.3.9 Urban agriculture in Helsinki

Albov (2015 p. 6) categorizes urban agriculture endeavors in Helsinki into those that are institutionalized at the municipal level (allotment gardens and cottage allotments), and those that are the result of grassroots organization efforts (box or sack gardens and CSA initiatives). There are 39 allotment gardens and nine cottage allotments, which operate on land owned by the city of Helsinki (Albov 2015 pp. 66-68). The box and sack gardens are more recent initiatives and many of them are the result of work done by the environmental organization Dodo (Albov 2015 pp. 70-71).

The Herttoniemi CSA (Ruokaosuuskunta Kaupunkilaisten Oma Pelto) is probably the best-known urban agriculture initiative in Helsinki. It was founded in 2010 by members of the Herttoniemi food circle (Albov 2015 p. 72). It rents 3,5 hectares of fields in Korso, Vantaa, where it grows vegetables for approximately 200 shareholders and employs a staff of three people. It grows some 40 species and varieties chosen based on diversity, soil preservation and the wishes of the shareholders. Crop rotation determines what is planted where, but in terms of both area and volume, potato is the biggest crop. The yield is divided between the shareholders, and the CSA provides recipes and tips on how to use the vegetables (Interviews with Heidi Hovi on 19.9.2017 and Orest Lapzeka 1.9.2017).

Other commercial urban agriculture initiatives are Stadin Puutarhuri, which sells its produce to restaurants, and the Perho Green City Farm, which operates as part of the Perho Business College.

2 Aims

The aim of this study was to understand how much food rooftops in in central Helsinki could supply. To do so, I looked the following questions:

1) What percentage of food self-sufficiency could be achieved by rooftop farming in a central area of Helsinki?
2) How should the available rooftop area be allocated to different crops in order to maximize the amount of energy, protein, vitamins and minerals?
3) How big is the share of rooftops that are affected by shading in an urban setting in Helsinki?

3 Materials and methods

The questions were approached by means of a case study, using secondary quantitative data from multiple sources (Saunders et al. 2009 pp. 145-147, 256, 414).

The main sources were:

- Helsingin seudun ympäristöpalvelut, HSY (Helsinki Region Environmental Services Authority)
- The Finnish Nutrition Recommendations 2014 by Valtion ravitsemusneuvottelukunta, EVIRA (Finnish Food Safety Authority)
- The website fineli.fi by Terveyden ja hyvinvoinnin laitos, THL (National Institute for Health and Welfare)

- Tilastokeskus (Statistics Finland)
- Ilmatieteen laitos (Finnish Meteorological Institute)
- Luonnonvarakeskus, Luke (Natural Resources Institute Finland)

3.1 Area

The case study had as aim to simulate the food production potential in a real urban setting, and hence the studied area had to be located close to the center of Helsinki, as well as be densely built with multi-story buildings. After some research on different areas, Pasila (60° 11′ 58″ N, 24° 55′ 58″ E) was chosen as the location.

Pasila is a mix of large office buildings and residential flats, and it covers an area of 4,22 square kilometers (Helsingin Kaupungin Tietokeskus 2014). Pasila has a busy train station, 9147 residents (SeutuCD'16. Information quoted by Outi Kesäniemi at HSY on 2.11.2017) and approximately 25000 jobs (Helsingin Kaupungin Tietokeskus 2014).

The area was marked out by drawing a line along major roads, or on the edge of the built area (see Figure 1).

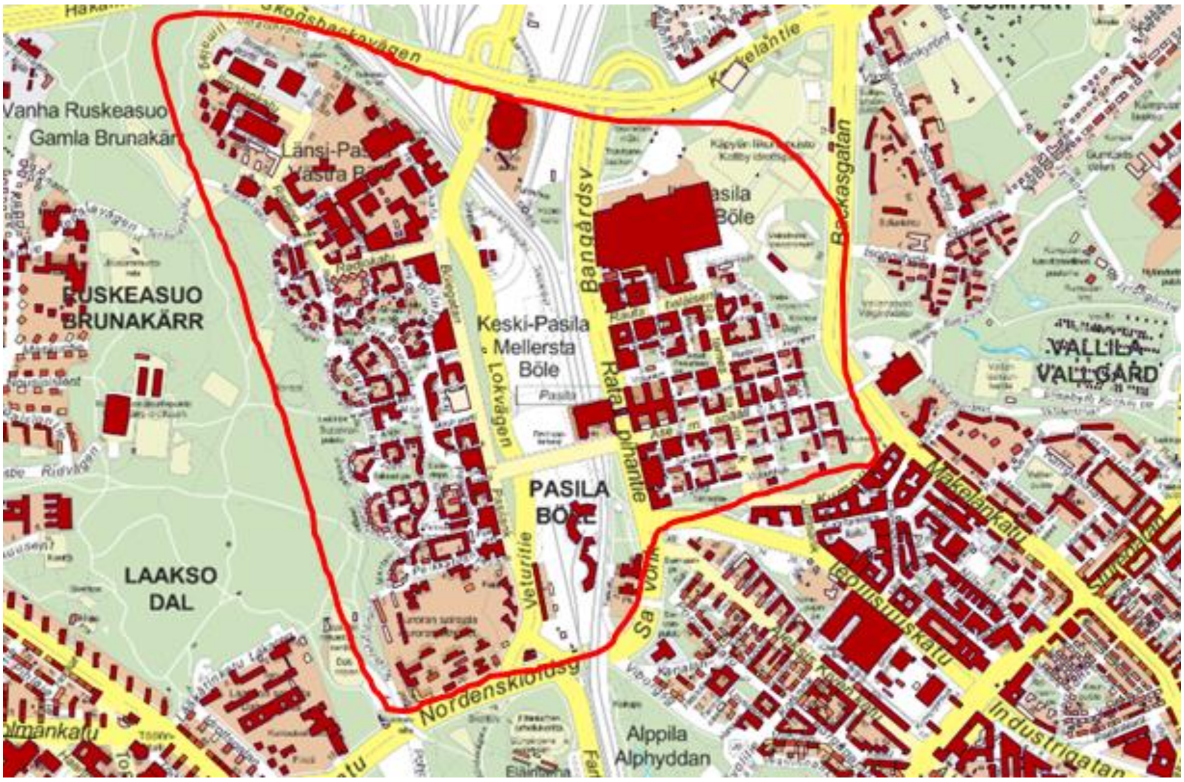

Figure 1. Area included in the case study. Map obtained from HSY.fi.

The characteristics of Pasila, such as the density and height of the buildings, mean that space restrictions, shadowing and concrete cover are a hindrance for street-level agriculture. On the other hand, data from Helsingin seudun ympäristöpalvelut (HSY) indicates that most of the rooftops are potential green roofs, and Messukeskus (Helsinki Expo and Convention Center) in Pasila is singled out by HSY as one of the buildings in Helsinki with the highest potential for solar energy production (4800 MWh per annum). Against this background, the choice to limit the study to rooftop farming seemed sensible.

3.2 The growing season and conditions

The Finnish Meteorological Institute defines the growing season as follows: it begins when the average temperature rises above 5° C for ten consecutive days and ends when the average temperature falls under 5° for a 10-day period, or alternatively when night frost or a snow cover is recorded on several consecutive days (Ilmatieteen laitos 2018b). The average length of the growing season in the Helsinki area in 1981-2010 was 185 days. The average DD (day degrees) in the same period was approximately 1400 and precipitation 380 mm (Ilmatieteen laitos 2018b). Most of the total solar radiation is received in the months of March-September (Vihanninjoki 2015 p. 7), which to a big part coincides with the growing season. See Figures 2, 3 and 4 for temperature, precipitation and radiation data.

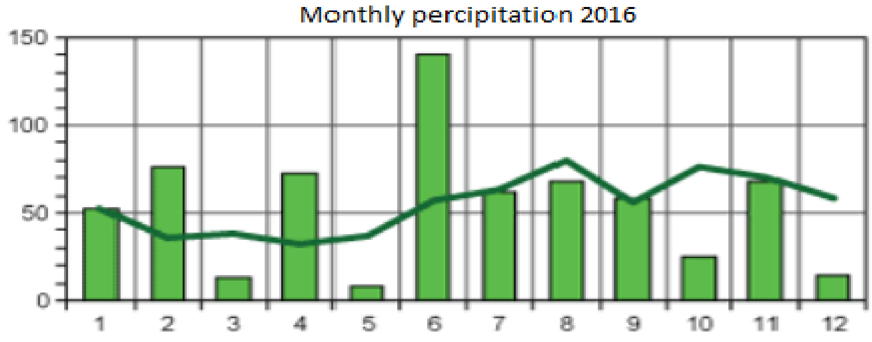

Figure 2: Monthly precipitation in Helsinki (Ilmatieteen laitos 2018).

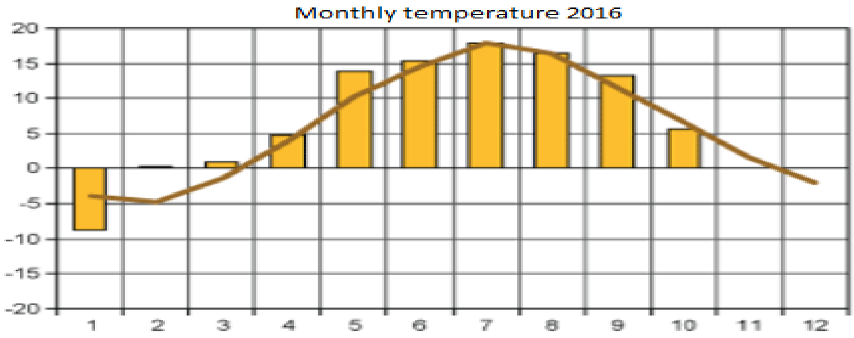

Figure 3: Monthly average temperatures in Helsinki (Ilmatieteen laitos 2018).

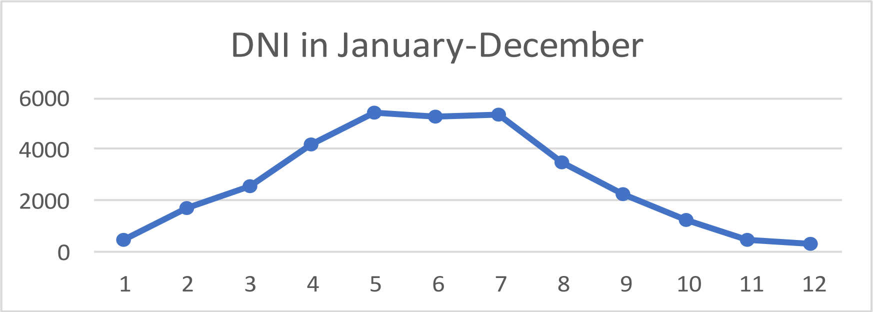

Figure 4: Direct normal irradiation (DNI) Wh/m^2/day for Helsinki in 2001-2012 (European Communities 2018).

3.3 Rooftop area data

The map of the area, the available area in square meters and the radiation data used for the calculations were obtained from Helsingin seudun ympäristöpalvelut (HSY). The HSY data had been collected as part of a project mapping solar energy potential, and posted in the form of a publicly accessible interactive map on the website. This data was much more suited to my case study than any data that I could have collected by adding up available square meters.

In the HSY interactive map, the options "Viherkatot – potentiaaliset" (Green roof - potential) and "Viherkatot – rakennetut" (Green rooftops - built) were chosen. This selection displayed potential and existing green rooftops, as well as their area in square meters per rooftop. Potential green rooftops were rooftops with a flat area (a slope of less than 12^o), which exceeded 10 % of the total area (if total area was less than 100 m^2), or 5 % (if the total area exceeded 100 m^2). The area was displayed if it was a minimum of 5 m^2, and at least 50 cm from the edge of the roof.

As a second step, the option "Rakennusten aurinkosähköpotentiaali" (Solar energy potential of the buildings) was chosen. This displayed the area of each rooftop that received more than 847 kWh/m2/year, had a uniform area of at least 5 m^2, at a distance of at least 50 cm from the edge of the roof. The assumption was made that if an area received this amount of solar radiation (which is enough for efficient solar energy production), it did not suffer from significant shadowing.

The buildings were numbered and the data for each building entered into Microsoft Excel, where the calculations were done. Buildings, for which the data were missing or incomplete, were excluded from the study. Finally, 10 % of the total area was deducted to allow for maintenance corridors and sheds.

3.4 Crops

The crops were selected based on nutritional factors, but they also needed to be viable for local conditions and rooftops, as well as be part of an accepted local diet. After some deliberation, the following nine plants were chosen for an initial comparison: green peas (*Pisum sativum*), iceberg lettuce (*Lactuca satica* var. *capitata*), kale (*Brassica oleracea* var. *sabellica)*, faba bean (*Vicia faba)*, potato (*Solanum tuberosum),* carrot (*Daucus carota)*, tomato (*Solanum lycopersicum)*, zucchini (*Cucurbita pepo*) and cabbage (*Brassica oleracea* var. *capitate)*. Cereals were excluded from the study based on their unsuitability for urban agriculture.

Energy density is the measure of how much energy a food contains per gram of weight. Nutritional density tools, like NRF and ANDI, aim at maximizing the nutrient content versus the energy content of foods, and they give total scores rather than a nutrient-by-nutrient score. This study required maximizing energy, protein, as well as vitamins and minerals, so neither energy density or nutritional density tools could be used as such. Instead, the rating was done using the THL-run website fineli.fi.

The crops were rated on the following 30 nutritional factors: energy content, carbohydrates, total fat, protein, dietary fiber, n-3 polyunsaturated fatty acids, n-6 polyunsaturated fatty acids, calcium, iron, iodine, potassium, magnesium, natrium, phosphorus, selenium, zinc, tryptophan, folate, niacin equivalent, niacin, carotenoids, as well as vitamins B6, B2, B1, B12, A, C, D, E and K. For each factor, the crop containing the highest amount per 100 g was awarded a point. The total points for each crop were added up to form a total “nutritional factor score”.

In most diets, carbohydrates provide the majority of the energy. Therefore, the first of the three crops for the study was selected based on its carbohydrate content (the potato). The second crop was selected for protein (the green pea) and the third one based on its total nutritional factor score (kale).

The yield and consumption statistics for the green pea were based on dried peas, but dried foods contain more energy and nutrients per 100 g than fresh ones. Hence, in the nutritional factor scoring, the nutrient contents for fresh green peas, fresh unpeeled potatoes and fresh kale were used.

3.5 Expected yields

Helsinki is located in the Uusimaa region, so the statistics for Helsinki and Uusimaa were applicable.

For the case study, it was assumed that all farming would be done in soil on open rooftops. Firstly, this was because had I included hydroponics and aquaponics, I would most likely have had to use yield data from outside the local area. By limiting the study to open rooftop farming, the conditions were also more comparable to farming in a field, and hence the regional yield statistics for field farming could be used.

The calculations were based on the average yield (kg/ha) for 2014-2017: 20890 kg/ha for the potato, 2080 kg/ha for the green pea and 7353 kg/ha for kale. For the potato and the green pea, the statistics were obtained from Luke.fi (2017), and for kale, the actual yield numbers from the CSA Kaupunkilaisten Oma Pelto were used (Text messages from Heidi Hovi 2.10.2017 and 12.12.2017).

The yield of the pea was measured as dried peas, whereas the yield for the potato and kale was given as fresh produce.

3.6 Per capita nutritional needs

Nutritional needs are individual and depend to some degree on age, weight and physical activity. The amount of energy and protein that a 4-year-old needs differs from what an adult requires. Although both are children, a 4-year-old and a 12-year-old also have different nutritional requirements. The nutritional needs even vary between adults, but adults are probably the most homogenous group of the population. They are also the group consuming the most, and therefore using adults for the calculations resulted in the minimum number of people that can be sustained on a certain amount food. Therefore, I chose to assume that all residents of Pasila were adults, 50 % women and 50 % men.

Gibney et al. (2009 p. 33) estimate that the average energy requirement for an adult is 4000 MJ annually. This was used as the energy requirement in the study.

The protein requirement given in the Finnish Nutrition Recommendations is 1,1-1,3 g per day per kg of bodyweight. According to the Finnriski 2012 study (Borodulin et al. 2013), the average Finnish female weighs 70,4 kg and male 85,5 kg. The average weight of each resident was therefore assumed to be 78 kg and the protein need 1,2g x 78 = 94 grams per day, adding up to 34,16 kg per year.

The recommended daily intake of vitamins and minerals varies per age group and gender. In adults, the fertile age group 18-30 has a higher recommended intake of folate and iron, so using the recommended intake for this group ensures that the needs of most of the population is covered. Again, an average value for women and men was used for the study.

There were 19 vitamins and minerals, for which the Finnish Nutrition Recommendations 2014 specify a recommended daily intake. Of these, 18 were included in the study and one excluded; fineli.fi did not list values for copper.

The average Finn annually consumes 52,3 kg of fresh potatoes (2012), 1,2 kg of dried peas (2009) and 51,4 kg of fresh vegetables, excluding tomatoes (Luke 2017b). Fresh peas were included in the number for fresh vegetables, and frozen peas in “frozen vegetables”, which were excluded from the study.

For the purposes of this study, it was assumed that each resident would be willing to eat a daily portion of 500 g of fresh green peas, 500 g of kale and 500/1000 g of potato. This may seem like a lot, but in terms of energy it equals less than the daily requirement of an adult.

3.7 Scenarios

First, the area available for urban agriculture was calculated. This “total area” included the full potential green rooftop area. The “prime area” only included areas that received a minimum solar radiation of 847 kWh/m2/year. From both, 10 % was deducted for maintenance corridors, sheds and the like, before the following calculations were done.

Three scenarios were constructed (see Figure 5) to compare the amounts of energy, protein, as well as vitamins and minerals supplied by the crops.

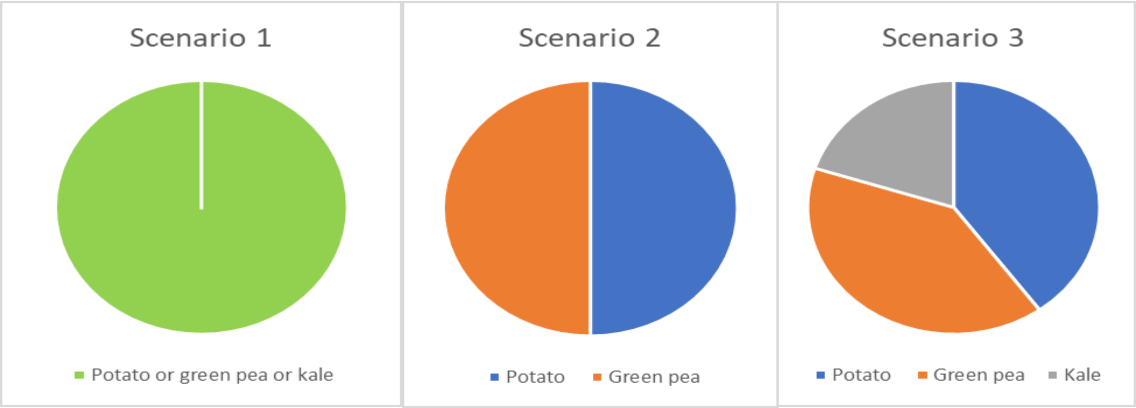

Figure 5. The share of each crop in the three scenarios.

In **Scenario 1**, the total available area was used to grow one plant only: potatoes, green peas *or* kale. In **Scenario 2**, 50 % of the area was used to grow potatoes and 50 % to grow green peas. In **Scenario 3**, 40 % of the area was used to grow potatoes, 40 % to grown green peas, and 20 % to grow kale. In every scenario, the potential yield was calculated by multiplying the area (ha) with the average statistical yield of each crop. This resulted in the amount (kg) of potato, green peas or kale that could be grown.

Next, the amount (kg) was multiplied with the 1) energy content and 2) protein content of each crop. These were divided by the average energy and protein needs of one person, resulting in the number of people whose energy and protein needs could be met with the yield of each crop. Then, the numbers were translated into a percentage of the population of Pasila.

The vitamin and mineral content of 500 g of each of the crops, and their combinations in the scenarios, were compared with the recommended daily intake of the essential vitamins and minerals listed in the Finish Nutrition Recommendations. After that, the portion of the potato was increased to 1000 g and the same comparison of content versus recommended daily intake done. The number of vitamins and minerals covered by each plant, or combination of plants, was counted.

Finally, the calculated yields were divided by the per capita yearly consumption for each crop in Finland. This resulted in how many people's consumption of each crop Pasila could supply.

4 Results

4.1 Plant scorings

In the nutritional factor scoring, the crops were rated on 30 nutritional factors and given a point for each nutritional factor that they had the highest content of per 100 g. There was no point awarded for iodine, because the content of it was equal in several of the crops, or vitamins B12 and D, because the crops did not contain these. After summing up the points, it was possible to compare the total nutritional factor scores of the crops (see Figure 6).

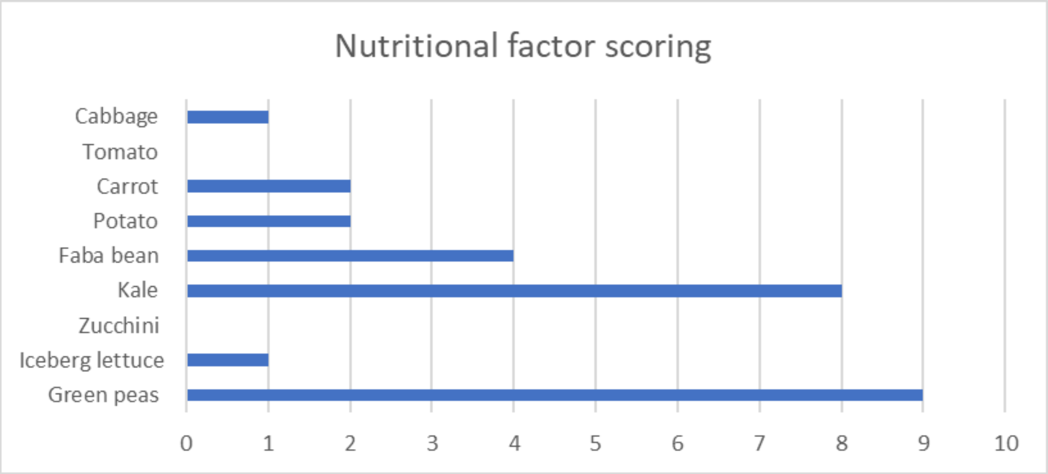

Figure 6. The number of points awarded to each plant based on its nutritional factors.

One plant each was selected on carbohydrate content, protein content, and the total nutritional factor score. The potato had the highest carbohydrate content, and it also holds a traditionally important role in the Finnish diet. The second plant was selected for protein, and though the faba bean had a slightly higher protein content, the green pea was included in the study because of its high total nutritional factor score. The third plant, which was selected based on its total nutritional score only, was kale. A comparison of the carbohydrate and protein content of the selected plants is shown in Figure 7.

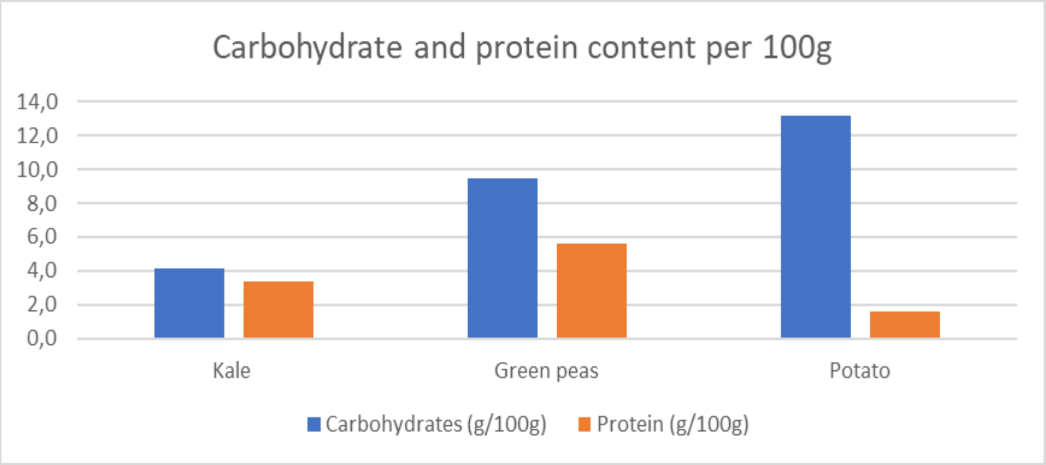

Figure 7. The content (g) of carbohydrates and proteins found in the crops selected for the study.

4.2 The total area and prime area

There was a total of 296 buildings in the surveyed area. Of these, 29 had no listed potential green roof area and 39 were missing data, and were therefore excluded from the study (not all, but many of these, were small buildings like sheds). After summing up the total area of the remaining buildings, 10 % of the area was deducted for maintenance areas and the like. The remaining total potential green roof area was 29,42 hectares.

When the areas that received less than 847 kWh/m^2/year were excluded, the remaining area (excluding 10 % for service areas) was 14,34 hectares, which equaled approximately half of the total area. The Messukeskus convention center accounted for 27 % of this “prime area”.

4.3 Energy and protein

In Scenario 1, where the total area was used to grow only one crop, the potato produced the most energy, the green pea the most protein, and kale the least of both. For a comparison of the total yield of the three plants, see Figure 8.

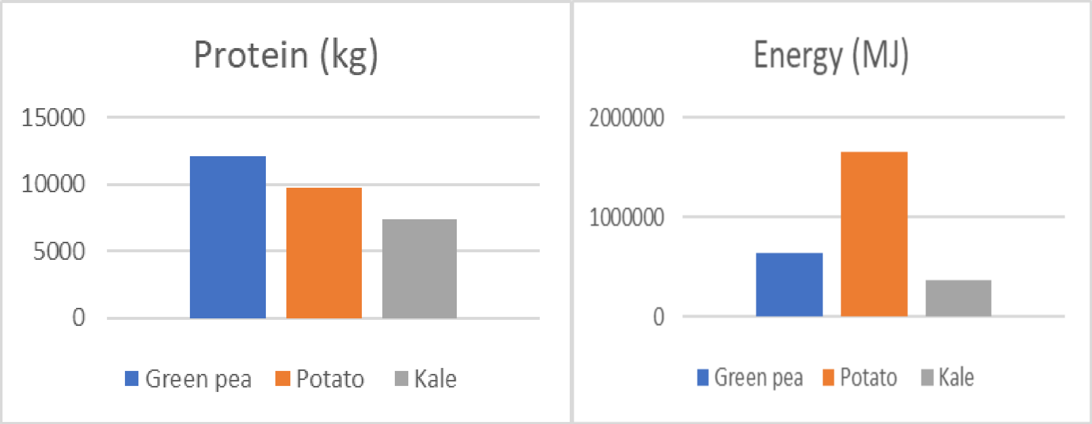

Figure 8. The energy content (left) and protein content (right) of the yield of each plant in Scenario 1.

In Scenario 2, 50 % of the total area was allocated to the potato and 50 % to the green pea. The potato was the major source of energy, and the green pea contributed a little over half of the protein. Even in Scenario 3, where 40 % of the area was used to grow potato, 40 % green peas and 20 % kale, the potato continued to be the main source of energy and the green pea the main source of protein. The shares of energy and protein produced by each plant in Scenarios 2 and 3 are shown in Figures 9 and 10.

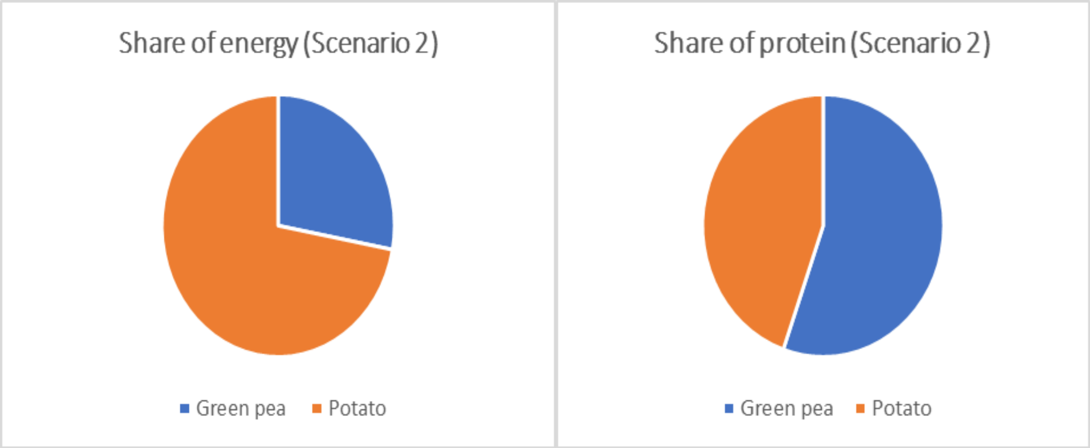

Figure 9. The share of total energy and protein from each plant in Scenario 2.

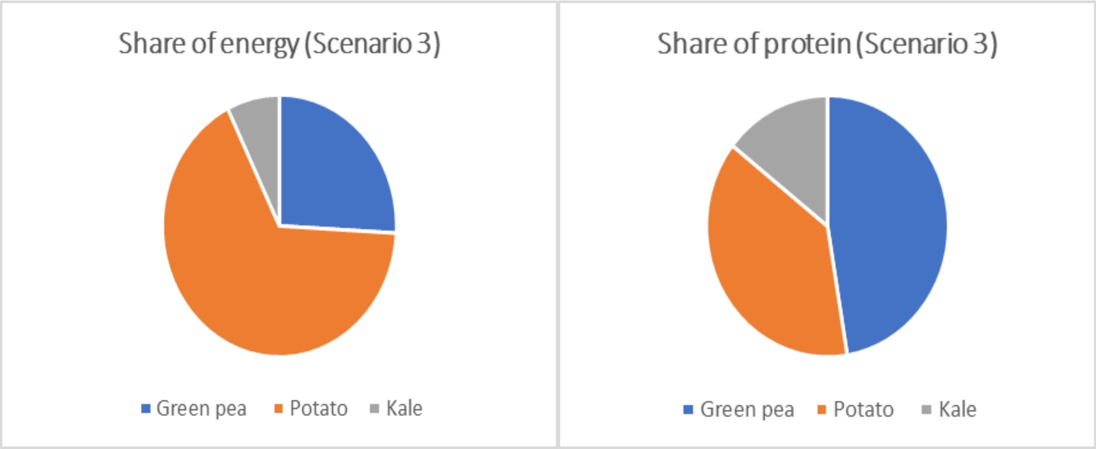

Figure 10. The share of total energy and protein from each plant in Scenario 3.

4.4 Food self-sufficiency percentages

The highest energy self-sufficiency percentage was achieved in Scenario 1 with potato only, and the highest protein self-sufficiency percentage in Scenario 1 with the green pea only. The lowest self-reliance percentages for both energy and protein was seen in Scenario 1. In Scenario 2, where potatoes and green peas were grown, the distribution between the number of people supported for energy and protein was the most even. See Table 1 for the results.

Table 1. The number of people and percentage of the population whose energy and protein needs were met in Scenario 1 (potato *or* pea *or* kale), Scenario 2 (50 % pea, 50 % kale) and Scenario 3 (40 % potato, 40 % pea, 20 % kale).

People supported	Energy	Energy (%)	Protein	Protein (%)
Scenario 1				
Green pea	160	1,75	354	3,87
Potato	413	4,51	285	3,12
Kale	90	0,98	215	2,35
Scenario 2	286	3,13	320	3,50
Scenario 3	247	2,70	299	3,27

4.5 Minerals and vitamins

There were 19 vitamins and minerals, for which the Finnish Nutrition Recommendations listed a recommended daily intake. Of these, vitamin B12 and vitamin D cannot be obtained from the three plants studied, and the amount of iodine and selenium is very low. Copper was excluded from the study, because fineli.fi does not list values for it.

The number of vitamins and minerals, for which at least the daily recommended intake could be obtained varied depending on which plant and quantity was studied (see Figure 11). 500 g of potato alone did not meet any of the requirements; green peas and kale both contained enough of a few of the vitamins and minerals. When 500 g of potato was combined with 500 g of kale, the daily recommended intake was met for seven of the vitamins and minerals. The combination of 500 g potato, 500 g green peas and 500 g kale met the requirement for 12 of the 18 studied vitamins and minerals. The full comparison per vitamin and mineral is available in the appendix.

When the portion of potato was increased to 1000 g, it met the recommended intake for three vitamins and minerals. 1000 g of potato combined with 500 g of peas met the recommended intake for 10 vitamins and minerals, which is just two less (vitamins A and B2) than in the earlier combination of 500 g each of potato, green peas and kale. The number of vitamins and minerals covered by all three plants together did not change when the amount of potato was increased to 1000 g. See Figure 12.

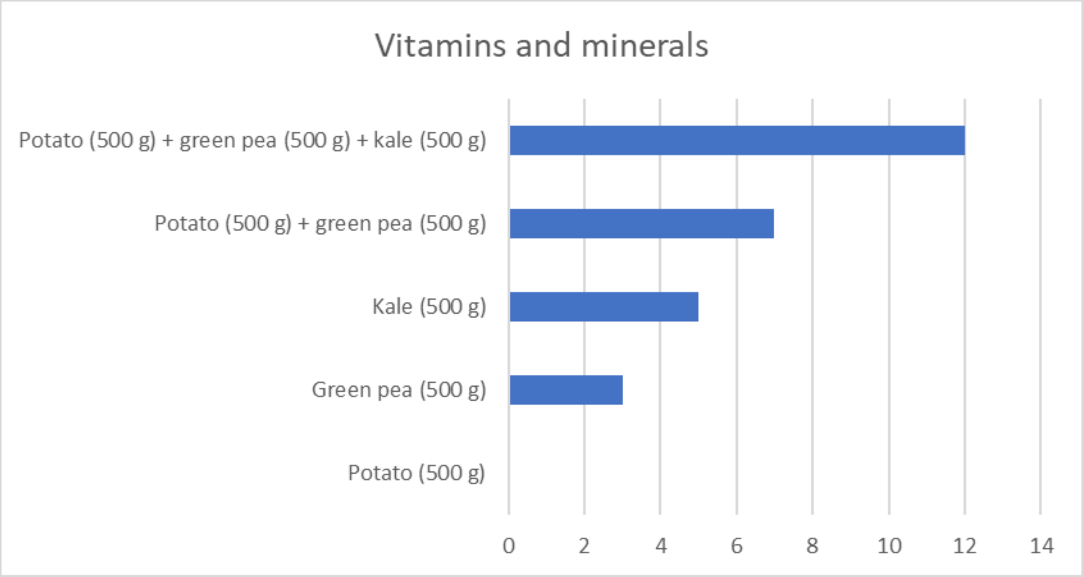

Figure 11. The number of vitamins and minerals, for which the recommended daily intake was satisfied by the plants and their combinations, when the amount of each plant was 500 grams.

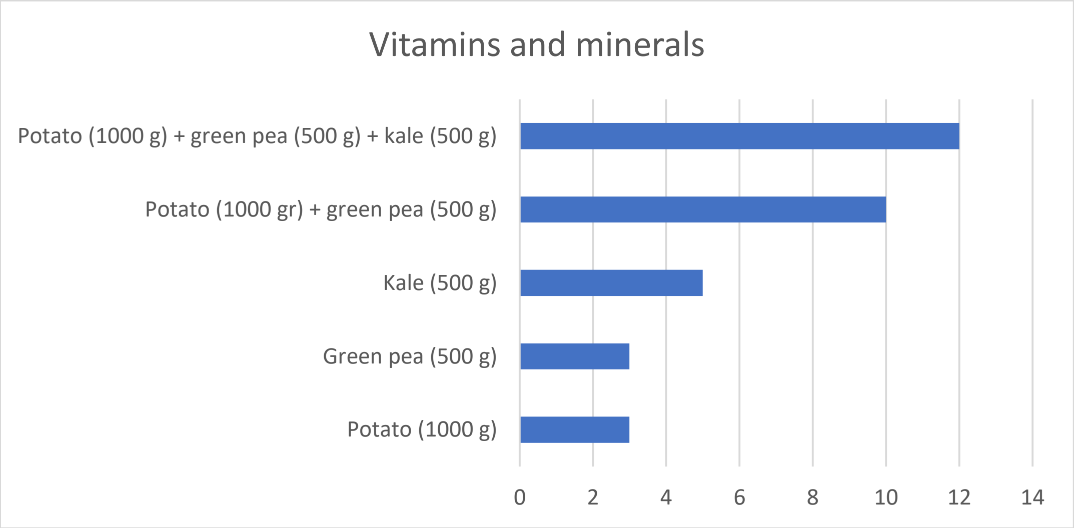

Figure 12. The number of vitamins and minerals, for which the recommended daily intake was satisfied by the plants and their combinations, when the amount of the potato was increased to 1000g.

4.6 Comparison with current consumption

The annual per capita consumption is 52,3 kg potatoes, 1,2 kg of green peas and 51,4 kg of fresh vegetables (excluding tomatoes). Based on these figures and the total potential green roof area, it would be possible to grow more potatoes than the resident population of the area consumes (see Figure 13). Alternatively, Pasila could produce five times the dried green peas that it consumes. Even in terms of vegetables, Pasila could produce 46 % of what it needs, if consumption figures are compared with the potential yield for kale.

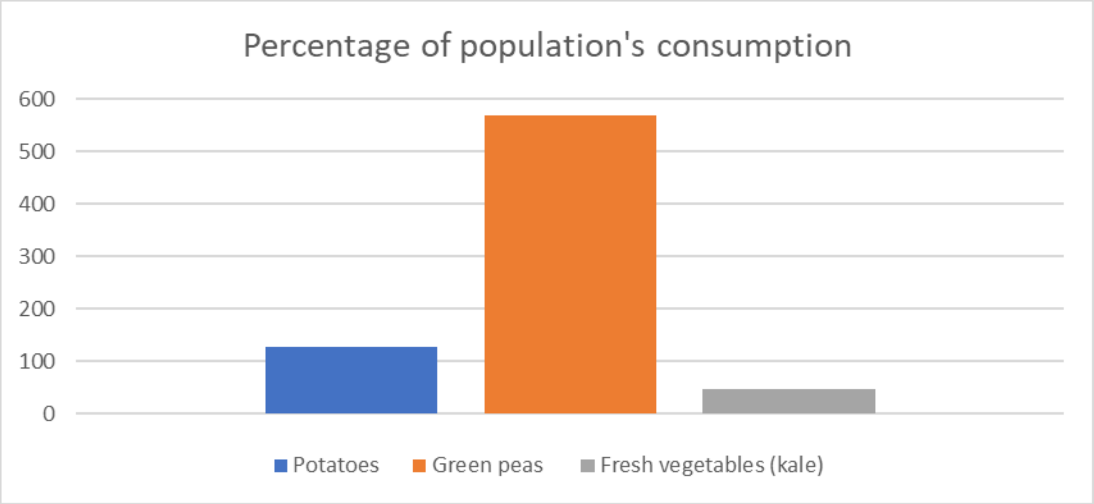

Figure 13. The percentage of the per capita annual consumption that Pasila could grow on its potential green rooftops.

4.7 Discussion

The studies that have been done about the food production potential of urban agriculture list their results in different ways, such as kg/m2, total tons of food, or as a percentage of the vegetables and/or fruit consumed by the city. They may also include other methods of urban farming, whereas the Pasila case study limited itself to rooftop farming. It is therefore difficult to compare the results directly.

Based on the Pasila calculations it is clear, that in contrast to the results of Altieri et al. (2017), open rooftop farming in Helsinki probably cannot provide self-sufficiency in vegetables, nor the 20 kg/m^2 vegetable yields cited for Cuba (Altieri et al. 2017). Comparing the potential kale yield of Pasila with the per capita annual vegetable consumption shows that Pasila could produce 43 % of the vegetables (excluding tomatoes) consumed. This is less than the three quarters that Orsini et al. (2014) estimate that the rooftops of Bologna could produce, and perhaps more comparable to the 18 % of fruit and vegetables that London could grow (Bakker et al. 2000). In the Cleveland study, using 62 % of the available commercial rooftops generated 15-31 % of the required fruit and vegetables, depending on whether conventional gardening, intensive gardening or hydroponics was used.

Considering the colder climate and shorter length of the growing period, it comes as no surprise that urban agriculture does not have the same potential in Helsinki as it has in Havana, and that the numbers for Helsinki are closer to the 7 kg/m^2 estimated for Toronto (Peck 2003, cited by Orsini et al. 2015).

The results show that the total food self-sufficiency that could be achieved through open rooftop farming in the Helsinki area is quite low. It is, however, important to remember that self-sufficiency in vegetables and fruit does not equal self-sufficiency in energy and protein. Even the Cleveland study, which included many more areas than just rooftops, and as well as poultry and eggs, translated its results into a total self-reliance of 4,2-17,7 %, measured in weight (Grewal and Grewal 2012). In a study from Vancouver, two yearly crops of beans on all open vegetated spaces yielded approximately 5 % of the calories of the resident population (Johnson et al. 2015). One important reason why full self-sufficiency is hard to reach in cities is most likely that cereals, which generate a large part of the carbohydrates that are consumed for energy, are typically grown outside the urban environment.

If the results are examined for individual crops, or even for food groups, the situation looks different. The Cleveland study found a self-reliance of 46-100 % of fresh vegetables and fruit to be achievable. Pasila could be a net producer of potatoes or peas, or grow almost half of its vegetables, if kale is used for the calculations. If these results could be scaled to all of Helsinki, it would be a considerable amount of food.

In the Pasila study, it was necessary to rate the plants to *maximize* the intake of energy and protein, as well as vitamins and minerals. Nutritional density tools, such as NFR or ANDI focus on *minimizing* energy in relation to other nutrients, and energy-density only looks at how much energy food contains. These rating tools were therefore not directly applicable. Scoring the crops based on the nutritional data provided by THL, made it possible to simultaneously see the energy, protein and other nutrient content of the crops, as well as generate a total score. The highest score went to the green pea, rather than kale, which was rated the highest in the ANDI scoring system (Dr Furhman 2018). This is probably at least partially explained by the fact that the green pea was awarded a point for the highest fat content in the Pasila scoring, while the ANDI scoring system would have considered the relatively high fat content a negative quality.

Minnich (1983, cited by Grewal & Grewal 2012) calculated that in an average growing year and a growing period of 130 days, a 10 by 10 m plot could yield a household's requirement of vitamins A, C and B complex, as well as iron. In the Pasila case study, the combination of potato, kale and green peas could cover the same vitamins and minerals, except for B2 and B12, and add the recommended intake for folate, potassium, magnesium, phosphorus, zinc and folate.

While the potato produced the bulk of the carbohydrates, the other two crops influenced the ratio between energy and protein: in Scenario 2, where potato and green peas were grown, both the protein and energy needs could be filled for almost the same number of people. Together, the three plants could provide the recommended daily intake of 12 out of 18 of the vitamins and minerals. It was clear that quantity can to some degree compensate for quality: when the quantity of the potato was doubled to 1000 g, the potato and the green peas were able to provide just two vitamins and minerals less than the three plants together.

B12 cannot be obtained from plants, and very few plants contain vitamin D. It is therefore unrealistic to expect that all 18 essential vitamins and nutrients could be obtained from rooftop farming, with any combination of plants. This could change if fish, insects, or other animals are integrated, but adding animals to rooftop farming would require feed and additional structures, even if only reared during the normal plant growing season. The exception could be small-scale rearing of e.g. chickens fed on food waste. Which animals and rearing methods have the most potential in Helsinki, is a topic for further research.

A study from Australia (Sheridan et al. 2016) found that 3,45 kg of food per day was produced for each person living in Melbourne, but only 1,2 kg of it was ingested, and the rest was either wasted or discarded as inedible parts. The Cleveland study by Grewal and Grewal (2012) used food availability data for calculating food intake, whereas the Pasila case study used nutritional needs. Neither of them considered waste, which means the Cleveland study may overestimate the amount of food needed, whereas the Pasila study may underestimate the amount of food necessary to feed the area. That all Pasila residents, regardless of their actual age, were assumed to have the nutritional needs of an adult, may to some degree have compensated for food waste.

Another aspect, which is mostly ignored in UA studies, including the Pasila study, is that food production requires seed material. This either needs to be produced locally, reducing the yield that can be consumed, or imported from outside the city. As cities are normally not food self-sufficient and depend on food being brought in from the outside, this aspect probably does not pose a big issue.

It was a conscious choice to use Pasila as the area for the case study, because of its characteristics favorable to urban agriculture: it had a high percentage of potential green roofs and the Messukeskus convention center, which made up a considerable part of the potential green rooftop area. Therefore, it is likely that there are areas in Helsinki which will have a lower self-sufficiency potential based on rooftop farming.

In many places urban farmers intentionally create shade for their crops and in a warming climate, shading can be a benefit rather than a problem. In the most northern parts of the world, however, sunlight is less intense and comes at a smaller angle, so it is important to utilize it efficiently. The Vancouver study that was done with beans estimated a median yield reduction of 3.5 % for shaded areas (Johnson et al. 2015). Although the possible yield reduction in Pasila is a topic for further research, it is presumable that the high percentage of shaded areas has an impact on the yield potential.

In their study, Grewal and Grewal (2012) calculated average yields and found that hydroponic rooftop gardening had the highest yield (19,53 kg/m^2/year), followed by intensive urban agriculture (6,20 kg/m^2/ year), commercial rural farming (2,42 kg/m^2/year), and conventional urban agriculture (1,28 kg/m^2/year). Sanyé-Mengual et al. (2015) also found hydroponic rooftop gardening to have a higher economic yield in some cases. These studies underline the differences in yields between farming methods. In a similar way, the necessary construction investments required for buildings or equipment vary for different farming methods. More research is needed to understand what investments are needed for open rooftop farming, as well as what could be achieved at what cost, if more intensive farming methods, such as greenhouses and hydroponics installations, were to be used in Helsinki.

The Cuban government supported urban agriculture through land ownership transfers and permissible forms of entrepreneurship, as well as by handing out materials (Clouse 2014 p. 45). A possible area of further research is whether government support could increase the urban agriculture activity in Helsinki, and by how much.

To be able to perform the calculations, it was necessary to make assumptions about the population and its nutritional needs, as well as farming methods. Therefore, the results of the case study are only indicative. They may be overly optimistic, on the one hand, because they assume all rooftops can be used for all plants, and pessimistic on the other hand, because they do not include more productive farming methods such as greenhouses or aquaponics. Nevertheless, the results can serve as a basis for decisions on what further research is warranted.

4.8 Conclusions

As little as half of the rooftop area may receive full sunlight in a densely built area of Helsinki, and because rooftops are likely to have an advantage over street-level plots, shading is probably even more prevalent at ground level. If maximum yields from urban agriculture are targeted, it may be necessary to consider planning solutions, such as placing the tallest buildings to the north of the area, and/or select crops based on their shade tolerance.

In addition to available space and solar radiation, the energy content, nutritional density and yield potential of a crop can significantly influence the number of people that the area can feed. Hence, it is necessary to use multiple selection criteria to understand which plants can best meet the desired outcome.

Food choices can influence the ability of an urban area to feed its resident population. Animal rearing may add individual nutrients which are otherwise unavailable, but will in most cases require growing feed and take away already limited space and resources from other food production. This is likely to result in smaller self-sufficiency percentages.

Full self-sufficiency clearly cannot be achieved based on open rooftop farming in Helsinki, and is unlikely even if other spaces and techniques are utilized. This does not necessarily mean that urban agriculture should not play a role in the food system of Helsinki. Whether urban agriculture can contribute to the food security of Helsinki, or the resilience of its food systems, may in the end not be a question of how much urban agriculture can produce, but of how its role is defined. The following questions are some of the ones that need to be answered. 1) Does urban agriculture need to maximize the calories and protein that it produces? If yes, it needs to include crops such as tubers, which are mostly produced outside the city. 2) Or should urban agriculture create resilience by diversifying the sources of food? In that case, plants like zucchini, kale and pumpkin may be better suited. 3) Perhaps the role of urban farming is to create new opportunities for farmers and support domestic food production, recycle water and nutrients, or increase the awareness of food choices and food waste? Or perhaps it should retain money in the local economy? Then strawberries, herbs and garlic could be just as suitable. Or Helsinki may not even be interested in food production, in which case planting trees could be enough to sequester carbon, cool the air and absorb rain water.

Supporting urban agriculture could potentially advance the Finnish Ministry of Agriculture and Forestry’s climate program, which in addition to other goals aims to sequester carbon into the soil, decrease food waste and promote a more plant-based diet. Urban agriculture could also serve the objectives of the EU Common Agricultural Policy (CAP), including protecting the environment, promoting food safety, preserving and creating jobs, and contributing to the sound development of, in this case, our urban areas. While urban agriculture is not per definition climate smart agriculture, it can be steered in the right direction through policies.

The food security of Helsinki is currently good, but the risks in the future are real, and Helsinki needs to think about adding resilience to its food system. Whether Helsinki decides to include urban agriculture in its future food security strategy or not, the growing interest in urban agriculture on a global level will ensure that there is an increasing pool of research and technology to draw from, if necessary.

5 Acknowledgements

I would like to thank my supervisor Professor Juha Helenius for his support throughout the writing process. I am also grateful to Heidi Hovi and Orest Lapzeka from Kapunkilaisten Oma Pelto, as well as Outi Kesäniemi from HSY for contributing with their insights and data.

I was fortunate to be welcomed into the Master's Degree Program in Agroecology by Professor Juha Helenius. Without his encouragement to start and continue my studies, I would not have written this thesis.

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Appendix

A sample of the numbering of the buildings in Pasila.

The vitamins and minerals contained by 500 g of each plant and their combinations.

Daily recommended intake satisfied by 500 g of potato, 500 g green peas and 500 g of kale	Potato (500 g)	Green pea (500 g)	Kale (550 g)	Potato (500 g) + green pea (500 g)	Potato (500 g) + green pea (500 g) + kale (500 g)
Calcium (mg)					
Iron (mg)				x	x
Iodine (µg)					
Potassium (mg)				x	x
Magnesium (mg)					x
Phosphorus (mg)		x		x	x
Selenium (µg)					
Zinc (mg)					x
Folate (µg)			x	x	x
Niacin (mg)					x
B6 (mg)			x	x	x
Riboflavin (B2) (mg)			x		x
Thiamin (B1) (mg)		x		x	x
Vitamin B12 (µg)					
Vitamin C (mg)		x	x	x	x
Vitamin A (µg)			x		x
Vitamin D (µg)					
Vitamin E (mg)					

The vitamins and minerals contained by 1000 g of potatoes, 500 g of green peas and 500 g of kale, and their combinations.

Daily recommended intake satisfied by 1000 g of potato, 500 g green peas and 500 g of kale	Potato	Green pea	Kale	Potato + green pea	Potato + green pea + kale
Calcium (mg)					
Iron (mg)				x	x
Iodine (µg)					
Potassium (mg)	x			x	x
Magnesium (mg)				x	x
Phosphorus (mg)		x		x	x
Selenium (µg)					
Zinc (mg)				x	x
Folate (µg)			x	x	x
Niacin (mg)				x	x
B6 (mg)			x	x	x
Riboflavin (B2) (mg)			x		x
Thiamin (B1) (mg)	x	x		x	x
Vitamin B12 (µg)					
Vitamin C (mg)	x	x	x	x	x
Vitamin A (µg)			x		x
Vitamin D (µg)					
Vitamin E (mg)					