GROWING IN CITIES

rooftop urban agriculture for sustainable cities

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Abstract

The thesis takes into notice a rare case of integration of rooftop urban agriculture into sustainable development of urban areas. The current situation shows that the development of rooftop urban agriculture has not been adequately studied. This master thesis aims to enhance the understanding regarding planning opportunities and challenges for integration of rooftop urban farming in urban design and sustainable urban development with a focus on environmental benefits of its implementation. Furthermore, the thesis brings up a conceptual design programme «Malmö FIVE» that shows one of the ways how architects and urban planners could inspire city developers and municipalities to explore the ways of the redevelopment of the existing unused urban spaces into the new resilient environments.

The thesis based on a combination of literature review, analysis of planning materials, site visits, conducting interviews, discussions and attending seminars and lectures to answer the research questions. The research identified multiple challenges that can be encountered in the process of implementation of rooftop urban agriculture. The findings determined the importance of rooftop urban agriculture being approached from the strategic sustainability perspective to value its potential fully. Rooftop urban agriculture can provide significant environmental values thus have an essential role in the sustainable development of urban areas.
1. INTRODUCTION

1.1. Sustainable Development

Sustainable development was first defined in the Brundtland report in 1987:

«Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.»
- United Nations, Our Common Future- Brundtland Report 1987, p.34

The concept of sustainable development has extended rapidly and now has its application all over the world. However, during the recent years, urban environments have faced the greatest challenge of the degradation of natural resources and climate change, which was a result of various severe consequences. Urban activities have an enormous impact on the natural ecosystem that provides a healthy and sustainable environment for the human society.

There is current concern about the sustainable development of cities due to the fact of the rapid urbanisation of our planet. That concern raises many questions and discussions on the topic of the future sustainable development of the urban areas. Cities themselves became a human-dominated ecosystem, within the surrounding ecosystems, shaped by social and cultural factors (Grimm et al. 2001). However, most cities have become reliant on outside resources in order to sustain the population that resides within its borders. That created an open loop system in which humans populating cities use outside resources and produce only waste. Urbanization became a cause of the change of many ecosystem processes, such as a change in the water cycle, climate and other environmental processes. A healthy ecosystem, on the other hand, can work as a closed loop system to produce the resources that it needs within its boundaries (Knapp, 2013).

However, due to the inefficient land-use, poorly planned transport systems, urban sprawl and other consequences of the insufficient urban development, modern urban areas consume about 75% of the world’s resources that leaves a vast footprint per capita. These and other projections show the upcoming challenges that will be faced by the human society in the future as a result of the increased fossil fuel usage, environmental problems and population growth (Quesnel et al. 2011).

As a response to it, urban developers and planning policies focused their attention on the new strategies that will improve the quality of urban ecosystems. With sustainable urban development, the needs of the communities are provided while the natural resources are sustained.
1.2. Why Rooftop Urban Agriculture?

Modern agriculture is one of the most unsustainable industries on the planet that is dependent on the vast amounts of energy resources and is the cause of 25-30% of greenhouse gas emissions. There are a lot more issues that go back to the global food system, such as contaminated soil, uneven food supply and a tremendous amount of waste. There are various methods of stopping the process of permanent degradation of the cities ecosystem, such as bringing back green environment to the cities ecosystem, make the urban environment less dependent on the outside resources with the implementation of urban agriculture. Expansion of the local food production in the urban and peri-urban areas is one of the most efficient tools of sustainable maintenance the ecological balance in cities (Mullinix et al. 2009).

Different kinds of urban agriculture, both outdoor and indoor, could provide inhabitants with the food produce all year around and decrease food insecurity. By using walls, rooftops, underground spaces and other greatest unused resources or capacities of urban environments, cities ecosystem could be less disconnected from its natural state, not mentioning other environmental benefits, such as preserving biodiversity, tackling waste and reducing the amount of energy used to produce and distribute food (Vlijmen et al., 2005).

Rooftops of the building have much potential in becoming a substitute space for growing food in cities. It can also operate as an alternative use to the inner city areas that were previously served as landfilled sites or industrial spaces. As an example, due to one informal research, there is about 880 ha of the available rooftop area in Melbourne city that is available for the greening and various agriculture projects (Orsini et al. 2017). The municipality of Stockholm has many large buildings, more than 50% of the buildings have a larger area than 2000m2, and about 25% of the buildings has the area with more than 4000m2 of the unused rooftop space. That leaves the existing unused spaces with potential for the various smaller and bigger agriculture and green environment operations (Sen, 2018).

1.3. Aim and Objectives

This master thesis aims to enhance the understanding regarding planning opportunities and challenges for integration of rooftop urban farming in urban design and sustainable urban development with a focus on environmental benefits of its implementation. Furthermore, apart from the primary aim of the thesis project, the thesis brings up a conceptual design programme that applies rooftop urban farming and green environment programme on P-Huset in Malmö.

The study is focused on the environmental aspects of rooftop urban agriculture and green rooftops. It targets to look at at the range of the existing green roofs in the city of Stockholm ranging from roof-top community farming to industrial farms in greenhouses on the top of the building. Understanding the development path of the traditional urban agriculture in Sweden, failed and successful examples of the investigated precedents, makes it possible to conclude about the further development of the rooftop urban agriculture and the potential challenges with all the different rooftop green environments in the future.

1.4. Research Questions

The following research questions have been formed to guide the research:

- What are the challenges to successfully implemented rooftop urban agriculture?
- What are the tools of adapting rooftop urban agriculture in the sustainable development of urban areas?

Answering the following questions has been through a combination of literature review, analysis of planning materials, site visits, conducting interviews, discussions and attending seminars and lectures. Literature was chosen with the aim of finding contemporary opinions on the today's situation of rooftop urban farming and sustainable development in the cities with the focus on environmental perspectives. Site visits to the existing green roofs and urban farming projects in Sweden were chosen with the intent of understanding the current setting in the country.

The objective of using interview has been to achieve the better understanding concerning the importance of integration of urban farming in the city of Stockholm and the challenges that this field face at the moment. The interviews were conducted with several professionals, such as urban farming entrepreneurs, urban planners, landscape architects, developers and sustainable strategists. This particular approach of interviewing different professionals was made with the aim of exploring various perspectives on the challenges that are faced in the industry of urban farming and green roofs at the moment.
1.4. Thesis Structure

The project consists of two main parts. The first part examines the concept of rooftop urban farming with the focus on environmental benefits and the planning opportunities and regarding green rooftops and rooftop urban agriculture in literature, reports, study visits, interviews and discussions. It touches and discusses various forms of rooftop urban agriculture and green rooftop with the ambition of understanding the situation in Sweden and Stockholm today. The second part is a concept design programme «Malmö Five» on the transformation of the rooftop as example that shows the possibilities of the redevelopment of the existing rooftop of the parking garage in Malmö into the new resilient space with environmental, social and economic benefits.

1.5. Working with Scandinavian Green Roof Institute

From the very beginning of the project, I have been in contact with Scandinavian Green Roof Institute in Malmö. I wanted to do a design project on the existing site the concept of which could be later used as an inspiration for the renovation and further reconstruction. Together with Jonatan Malmberg, head of project and development at Scandinavian Green Roof Institute, we discussed different existing sites in Stockholm and Malmö where my future design proposal will be useful and later Jonatan offered me to work on the concept of “Malmö FIVE”, five rooftop parks that will be placed on the multi-storey parking lots and create a system of multifunctional rooftop public spaces with the elements of green environments, urban agriculture, production in the greenhouse and roller derby area. Although I have already started to work on the research part that was focused on the existing rooftop projects and planning policies in Stockholm, I decided to take the chance and make «Malmö FIVE» a part of my master thesis. On August 6, 2018, the concept design proposal was presented to the municipality of Malmö and the owner of the parking garage and got positive feedback. The conceptual design proposal is based on the research on urban farming and the site visits to the existing rooftop parks and urban farming projects.
2. THEORETICAL FRAMEWORK

2.1. Rooftop Urban Agriculture

Urban agriculture (UA) can be defined as a food and plant production in urban, suburban and peri-urban areas within or close to city borders (Smit et al. 1996). Besides supply production, urban agriculture produces economic, environmental and social benefits and values, such as waste recycling, water management, community cohesion and climate resilience (Dubbeling et al. 2017; Berglind 2012). Agriculture in cities exists in different forms and could be presented as a household gardening, commercial production, or social community gardening.

Green roofs, also known as ‘vegetated roofs’, are ballasted roofs covered with waterproofing membrane, soil (growing medium) and plants (vegetation). It also includes additional components, such as roof barrier and drainage layer (Quesnel et al. 2011). Originally, green roofs were established aiming to improve water management in cities (Weiler et al. 2009). Nowadays, well designed, maintained and engineered green roofs encourage ecological, economic and social resilience in various ways. Green roofs are being applied to manage buildings energy consumption, promote biodiversity and break the heat island effect. Besides mentioned, green roofs could improve the worker’s productivity and make the patients at hospitals heal quicker by having close access to the greenery.

Rooftop agriculture is a concept of a combination of green roofs and urban agriculture. Agricultural green roofs could range from growing vegetables in containers or bins by some neighbourhood community to the rooftop commercial farming in greenhouses with advanced hydroponic technology. That way, different stakeholders could be involved behind various agendas of implementation of rooftop farm or garden (Dubbeling et al. 2017). Since there are various types of rooftop agriculture ranging from intensive to extensive, container gardens and hydroponics, each of these types has its unique characteristics and distinguishing factors (Quesnel et al. 2011).

2.2. The Environmental Values for Rooftop Urban Agriculture

Urbanization and climate change are firmly related. As it is predicted, throughout the following 40 years, the population in the urban areas will increase by more than 3 billion people. That leads to the significant changes in the land-use and increase of the built-up urban areas by 250% in 2030 (Dubbeling et al. 2017). This way, climate change and adjustment to the new conditions will be a vital issue in the developed and developing countries (Loftness et al. 2013). The robust and quickened pace of the current urban development has influenced a considerable number of the planet’s
natural processes leading to the loss of the highly productive farmland, climate change, modification of hydrologic and biogeochemical cycles and reduction of biodiversity, to mention a few (Pledge et al. 2005; Seto et al. 2011).

Only in the 1970s, and in the mid-1980s, green roofs turned out to be more popular as an element of green construction, after the Swiss architect Le Corbusier implemented one of the green roofs in his project of the roof garden. (Busse, 2000) However, rooftop gardens have many historical precedents, such as hanging gardens in Babylon to Scandinavian sod roofs (Pledge et al. 2005).

The research stresses how we can see an impact of sustainability and urban resilience through rooftop urban farming. In the big populated cities like New York, up to 70% of the urban area is covered with concrete and asphalt, where roads, parking lots and rooftops take place. (Pledge et al. 2005) Adding green infrastructure will supplement the existing urban framework and mediate temperatures, maintain energy efficiency, slow runoff, absorb water, support biodiversity and regulate waste management. As some studies show, the increase of the green spaces in the urban areas by 10% would almost compensate for the rising temperatures expected to result from global warming by 2080 (Handley, 2006).

The heat-island effect is one of the many environmental stressors that urban areas face due to the surplus of the “grey infrastructure” and the specific properties of the urban materials, that cause convection, reflection and storage of solar energy and emission of heat from an anthropogenic process (Atem, 2007; Gartland, 2008). The extensive implementation of the “green infrastructure”, such as adding more cool roofs and urban greenery is one of the most promising strategies in the lowering the level of heat waves and heat island effect in the urban areas (Orsini et al. 2017). On the other hand, open-air rooftop initiatives also impact the energy efficiency of the buildings in a positive way, providing thermal insulation and minimising the heat losses in cold seasons and cooling the building during the summer, lowering the energy consumption for acclimatising the building spaces (Ottele et al. 2011; Ekaterini and Dimitris, 1998).

Notwithstanding the rising temperature, hydroponic cycle, a natural movement of water, has also been affected due to the intensive development of urban areas. Rooftop urban farming could be served as cost-effective stormwater management, retaining stormwater, reducing runoff volume and lowering the speed it enters the sewage system (Pledge et al. 2005). Furthermore, modern industrial farming requires nearly 70% of available fresh water for irrigation. After the plants absorb the needed nutrients and crop is harvested, runoff carries the chemicals from commercial fertilisers and pesticides and deposits them in our surface water, lakes, and oceans. Runoff causes more ecosystem disruption than any other single form of pollution. Current urban agriculture practices reduce the water use by switching to the rainwater harvesting systems and the building’s greywater for irrigation purposes (Thomaier et al. 2015). Due to Carlow (2009), the application of hydroponics, the process of growing plants without soil by using minerals and other nutrients, and recirculating systems while harvesting food in the urban environment could reduce the water consumption from 5 to 10 times in comparison to the current situation to the modern farming (Carlow, 2009).

Related to the sustainability, rooftop urban farming could support biodiversity in the cities. As it is known, most of the food, that is produced and transported to the cities for its residents, is grown on the one-crop fields (Paxton, 1997). Most of the rooftop urban farms and gardens have a wider variety of crops, including native plant species, in comparison to the traditional commercial agriculture nowadays.

Another function of the rooftop urban farming is in urban waste management (Hempstead, 2007). The current model of agricultural production creates waste at every phase of the food system. According to the Food and Agriculture Organization (FAO), about 30% of food that is produced is wasted (FAO, 2011), that, in consequence, leave the city with a mound of garbage, the sheer quantity, more than 3000 tons per day (White, 2010). The local food production could minimise those impacts by the reduction of the supply chain of food products (Orsini et al. 2017). Out-of-season production requires a tremendous amount of energy for transportation of the product from another region to the consumer that leads to the rise of the greenhouse gas emissions. Local food systems and the use of the vacant spaces in the urban areas such as roofs could support the «Zero-km agriculture» and lead to the further development of the local food chains (Cameron-Palma et al. 2012).

2.3. Rooftop Urban Agriculture and Green Environment Policies

To make an implementation of green rooftop systems possible, a lot of work and collaboration should be done among different kinds of actors on the different levels. There are examples of various policies on national, regional and city levels worldwide. Some types of policies concern actions in general and called ethical policies. There are also policies dealing with actions in certain areas, for example, food production or building construction (Orsini et al. 2017).

Dubbeling et al. (2010), highlight four principles that can be successfully used to support urban agriculture in the urban area. In fact, legislation in the process of supporting the development of agriculture in the urban environment, represented by laws, by-laws and ordinances, is one of the tools. Economic instruments, such as subsidies and taxes, as well as educative, urban planning and design tools are also necessary and can influence the behaviour of actors during the process of promoting and regulating rooftop urban farming. Very often in cities that serve a proactive and improvement-oriented approach to urban agriculture, one can often see examples of the usage of financial, educative and design tools. In order to achieve policies aimed at the
development of urban agriculture, an interaction of economic, informational and urban planning tools should be achieved, with the support of legal instruments in an effective political strategy (Dubbeling et al. 2010). For instance, one of the ways of supporting urban farming could be a provision of the space available for rooftop urban agriculture.

There are just a few examples of urban agriculture regulations could be found, while policies promoting green systems have been established in many countries throughout the previous decade, where local authorities take the lead throughout the process of green rooftop policy. The results of the research of Mees et al. (2013) shows the dominance of «hierarchical» arrangements in the context of green roof policies when local authorities define strategy and policy combinations to attract private-sector efforts. By comparing green roof environments in 5 cities (Basel, Chicago, London, Rotterdam, and Stuttgart), they conclude that, in the early stages, local authorities tend to confirm rooftop strategies and policies and later combine them to attract private-sector action. For instance, in Basel and Rotterdam, where strong environmental agendas have been established on the governmental level, there is a more significant percentage of green roof installation. These two cities were influenced by the broader mixture of various positive factors, such as strong green political climate and culture, long-lasting existing green roof policies and low installation costs for the green roofs, which made an implementation of the green environments on the rooftops of the new buildings mandatory and financially supported on the governmental and municipal levels (Mees et al. 2013).

In 2006, Lawlor at al. had established some practical recommendations for CMHC (Canada Mortgage and Housing Corporation) that could be helpful in the development of the green roof policy programme in the city (Lawlor et al. 2013).

Phase 1: Introductory and awareness.

The importance of the green roof environments and its beneficial characteristics should be introduced to the public as a starting point. Also, some green rooftop workshop could take place, where the practitioners visit some existing green rooftop and learn about the current green environmental policies.

Phase 2: Community Engagement.

At this point, a local leader of an existing rooftop might organise some meeting with a different variety of actors, such as community leaders, mayors, architects, urban planners, building owners etc., to outline the importance of implementation of a green environment in the sustainable city development. Some fundings and national programmes might be reached during the process at this stage.

Phase 3: Action plan development and implementation.

There might be a development of the rooftop advisory or working committee at this stage. Some green rooftop project might be launched for the demonstration purposes, and green roofs tours are planned for the review of various types and designs of green roof environments.

Phase 4: Technical research.

Setting up a demonstration project or installation of a rooftop as a manual for technical research that later could be demonstrated at some local or international conference. Usually, that kind of demonstration installations shows essential benefits for the sustainable cities development, such as stormwater management, urban heat mitigation etc.

Phase 5: Programme and policy development.

Involvement of more professionals, as landscape designers, urban planners and horticulturalists could initiate the establishment of various planning options and policy tools, such as planning new building with green roof environments.

Phase 6: Continuous improvement.

At this stage, a municipality, developers, and building owners got some understanding about the green roof system and how it can benefit to the cities development in sustainable, social and economic ways. Also, some constructive feedback needed to make some conclusions and regulations on the program and policy (Lawlor et al. 2016).

2.3.1. Planning and Governmental Policies

To make implementation of rooftop green infrastructures successful, green roofs should be seen as a valuable part of the Green Infrastructure global strategies. The EU Strategy on Green Infrastructure is a part of the EU 2020 Biodiversity Strategy, one of the main targets requires that “by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems” (EU strategy, 2012). Green infrastructure is presented as a ‘strategically planned network of natural and semi-natural areas’ that provides various economic, social and environmental benefits, such as water purification and climate adaptation (EU strategy, 2012). To support the development of green infrastructure policies in EU cities, various Green Infrastructure (GI) indicators have been established, such as a proportion of green space in the urban areas and its distribution throughout the city. In 2015 the French Parliament accepted a law that requires all new buildings in commercial areas be partly covered with solar panels or green systems, that could benefit biodiversity, lower indoor temperatures and create new green urban environments, such as green recreational areas and rooftop gardens. Similarly to Paris, Copenhagen was the first city in Scandinavia that adopted a policy regarding the installation of green roofs for all new buildings with all roof slopes that are less than 30 degrees. That new regulation was a part of a mission to become a carbon-neutral city by 2025 (Ceslfo/DICE, 2012).
Taking into consideration the Swedish planning system, Stockholm in particular, there is no formal green roof policy. However, green rooftop systems are implemented in some planning tools and strategies. In 2014, Stockholm Green Area Factor (Gröntytefaktor, GAF) was established by the Development Board, the Urban Planning Board and the Environment and Health Protection Board, aiming to improve the quality of life of the inhabitants of Stockholm, create new demands of sustainable values and manage the effects of changing climate conditions by promoting the green efficiency of the vegetation on the plots and the conservation of sufficient green structure (Olsson et al. 2015). Initially, the biotope area factor was established during the 1990s in Berlin, Germany aiming to increase green environments in the city. Later, Green area factor was used in Malmo in 2001 and was the main reason for intensive green rooftop implementation in the Western Harbour, mainly in the area of “Bo01” housing expo. GAF is an open source calculation model that could be efficiently used by urban planners and architects. It is estimated as the ratio of the scored green area to lot area. Green area factor promotes the use of green systems for various purposes such as aesthetic, recreation, purification of rainwater and shading.

2.3.2. Food policies

Food security strategies have been recognized as a national and international responsibility for many years. During the previous decades, cities started to be aware of the importance of the food security and its related issues. It gave a start to the development of local food policies. Oslo, a winner of the European Green Capital Award for 2019, has a revolutionary strategy concerning natural areas protection while facing climate change with its consequences of intense flooding, which started to be one of the major problems for the city for the past years. While Oslo has flooding challenges, a question of sustainability of the food system has also been raised. In the new cities strategy, the government pays attention not only to the control of international imports but also gives support and planning for its agricultural sector, including urban agriculture.

Meanwhile, The Healthy and Sustainable Food for London (London Development Agency 2006) promotes local food production within the city, dealing with all stages of the lifecycle from growing to eating and waste management. The policy has been established due to various important objectives, such as the economy, health, sustainability, food security, etc. However, some actions of increasing a volume of a food product in the city have been included in the policy, and there are no suggestions due to the rooftop farming. Whereas, in Vancouver (Canada), Food Strategy includes various advantages of the rooftop farming. The policy raises the discussion that awareness of citizens about the advantages of urban farming in cities is one of the most critical points of its spreading (City of Vancouver 2013).

In comparison to the other places, Stockholm is not so progressive in the development of its food policies. There are no mentions of any food strategy on municipal or national levels, whereas a national programme for advancing Swedish food (Matlandet Sverige) provides some suggestions on the food consumption and some dietary recommendations (Luokkala 2014).
3. DISCOVERING ROOFTOP URBAN AGRICULTURE AND GREEN ROOFS

3.1. Development of Traditional Urban Agriculture in Sweden

Urban farming in Sweden started its existence in the pre-industrial period; people were growing food for themselves in their backyards or the “cabbage gardens”, that was close to the urban areas (Berglind, 2012). Later on, when the cities started to grow and took larger space, it was considered hygienic to grow vegetables for the own household in the backyards in the centre of the cities, due to the established central sewage system and water supply. Whereas agriculture was moved back to the rural areas further from the cities, improved transportation system made it possible to allow food to travel longer miles. Urban gardening in the form of the modern allotment system was back in the Swedish cities at the beginning of the 20th century, when people started to need to grow their food in the urban areas again. For some, it was just the case of the leisure activities and connection to nature. For others, it was the way of supplying their families with food, due to the low income. Ever since, allotments started to gain popularity due to the various positive effects, such as being part of the social context and growing food themselves. However, nowadays it could be considered as an inclusive activity since there is not enough space to be given to the new allotments and citizens wait for years to get their desired spots. During the development of the Million housing Program many in the 1970s, the farming spots were installed as a part of the new housing systems with a purpose of making the outdoor environment more pleasant and helping its inhabitants to gather together and get to know their neighbours (Åkerberg, 2014). Nowadays urban farming in Sweden is seen as a social activity, gaining its popularity through the bottom-up initiatives.

3.2. Rooftop Urban Agriculture According to the Cities in Sweden

In the case of rooftop urban farming, only a few urban agriculture activities have emerged on the rooftops of the buildings in Sweden. Most of them are established in the forms of indoor vertical commercial production or bottom-up initiatives for the social purposes. Due to the extreme weather conditions and lack of the study on the constructions and materials that suit rooftop urban agriculture, people stay unaware of the possibilities of growing food on the rooftops of the buildings. Only a few research on the implementation of the rooftop agriculture have been conducted in Sweden, mostly on the south. At the moment, Kajodlingen is the only one rooftop urban farm in Sweden that could financially sustain itself by selling vegetables to the restaurants and individual customers. It is one of the largest rooftop urban farms in Sweden that was established in Gothenburg in 2015 with 600 sqm of vegetable production (Interview, Malmberg 06/2018).
3.3. Rooftop Urban Agriculture and Green Roofs in Stockholm

Fig. 1 Map of public green rooftop in Stockholm. Source: own survey
Tokadiarna Sergel is a Stockholm based growers association that grows tomatoes, beets, physalis and more on a roof terrace of Hötorgsskraporna in the centre of Stockholm city. It was established in 2013 on one of the rooftops, that was part of the Anova hospital rented space. The green rooftop with the elements of agriculture, which was about 1500sqm, is a product of a collaboration of the tenant company and urban agriculture activist Margaretha Stugulan, that created a bottom-up initiative and made rooftop agriculture possible. As Margaretha said, it was mostly made for the social purposes, to have a beautiful place for people to gather after work and have parties (Interview, Stuguland 13/06/2018). However, the members of the Takodiarna Sergel built different lots with the installed autonomous watering system for the outdoor cultivation, made a research on the plants that are suitable for the extreme rooftop conditions and built windbreaks. At current state Tokadiarna Sergel includes more than eight growing pots from 60 to 100 cm high, that are operated by five regular members and other activists who are willing to be a part of the bottom-up initiative and grow their food on the rooftop for the small fee. The rooftop initiative is not going to exist any longer after summer 2018 due to the end of the renting contract (Interview, Stuguland 13/06/2018).

3.5. Garnisonen

The rooftop cultivation on one of the Coop’s grocery stores in Stockholm consists of 350 m² outdoor commercial urban farming with a complimentary 40 m² passive house and two beehives. “Interest in urban agriculture has grown rapidly in recent years, but there is a dynamic place where we can demonstrate, test and develop new methods of farming and biodiversity in a larger scale”, says Josefina Odds Berg, founder of the Bee Urban (Coop, 2016). The rooftop project is also intended to serve as a platform for disseminating knowledge about sustainable urban development (Torma, 2017). Coop and the Consumers Association Stockholm are main partners, and Bee Urban has developed the technique of combining solar panels, cultivation and hives. One wishes to contribute to biodiversity through urban cultivation, according to Lars Ericson, President of the Stockholm Consumer Association (Coop, 2016).

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Table 1. Table of public green rooftop and green environments in Stockholm. Source: own survey

Fig. 2 Garnisonen
Source: https://www.coop.se
4. RESULTS

The thesis provided two research questions. The first research question was to explore the current challenges of the rooftop urban agriculture from the different perspectives: *What are the challenges of a successfully implemented rooftop urban agriculture?* The second research question was on the instruments and strategies of rooftop urban agriculture implementation: *What are the tools of adapting rooftop urban agriculture in the sustainable development of urban areas?* The interviews were conducted with the aim to collect different opinions and perceptions on the development of the rooftop urban agriculture and a possibility of its implementation in the sustainable city development to the literature review as well as to the research questions, and the discussion is arranged around the research questions.

4.1. Different Forms of Urban Agriculture

Starting the conversation from the wider angle could give a complete picture and answer the stated questions in more details. Due to that reason, in the beginning, I wanted to get an opinion on urban agriculture and its current situation in Sweden and Stockholm in particular. As it was discussed, urban agriculture could be considered from two different dimensions: the scale (small scale and a large scale) and the type (low-tech and high-tech), that could give various kinds of benefits when combining these two different dimensions (Interview, Anonymous B 27/06/2018). When urban farming is low tech and implemented at low scale, the healthiness becomes the primary concern rather than a value of food production. In such conditions, people also benefit from the food security; they know the sources of the produced food, the ways it can be grown and how old it is. Urban agriculture could also have an additional social profit, such as meeting new friends, making connections with the neighbours, helping immigrants with integration, food exchange, etc.

Urban agriculture has various downsides, which include high water requirements for agricultural activities, as well as economically and environmentally inefficient use of the property, so for that reason, specific technology should be used for the sake of making food production possible in the cities (Interview, Anonymous B 27/06/2018). Today, more than 50% of fruits and vegetables are imported to Sweden. Due to the transportation, they lose nutrients, taste and looks. It is tough for the customer to examine, where the consumed food comes from, how old is it and how much fibre and vitamins they get from it since many fruits and vegetables do not have any nutrition declaration. Dependence on the other countries for food supplies decreases the levels of food security. In a few years, due to the climate change and other several factors, urban farming and having own production of a various range of food will be very important (Interview, Anonymous A 02/06/2018). Food production nowadays is a global logistics
of retailers, producers, enabling technologies and supporting systems. When talking about smart cities, waste management systems go in the close correlation with IST (Innovative Sensor Technology), mobility, energy and water management. Nowadays, many companies all over the world talk about new industrial, ecological and symbiotic system, which enables and connects various systems to produce food, where the role of data management and circular economy plays a prominent role (Interview, Anonymous B 27/06/2018).

There are many problems with sustainability concerning cheap supply of food coming from different countries. With the economic, climatic and political changes, the situation on the market can have a rapid change so that food supplies can become more expensive. Because of that issue, a more resilient system for self-sufficiency is needed. Many people started to understand the importance of food security, that way urban agriculture can help in the shift.

Since urban agriculture is still a very unexplored topic in practice, there are two different platforms where some changes in the regulations needed (Interview, Anonymous B 27/06/2018). Firstly, right now food produced the cities cannot use the label «organic» on it, because the requirements and certifications are not suitable for urban agriculture. Since many urban farms use hydroponics instead of growing in the soil, there are issues with the food certifications. Nowadays, in the greenhouse industry, leafy green production is unsustainable, due to the reason that much soil for the food production is imported, and then leafy greens are sold in the small pots with soil (50 gr of basil with 200 gr of soil in a pot) that is later is just thrown away by the consumer (Interview, Anonymous A 02/06/2018). Secondly, when talking about the implementation of urban agriculture and smart cities, urban systems connect various processes, such as food, water, energy, waste management and intertwine with each other. When creating a production, food becomes an enabler of many smart city systems, that could exchange resources with other different projects and minimise food waste, recover nutrition and save water and energy resources within city borders (Interview, Tapper 25/06/2018).

4.2. Green Roof Environments and Its Purpose

In 2018, green rooftop urban infrastructure mainly serves an educational and inspirational purpose for both students/schools and the public in general. However, in the future, it could function as a factor in urban food production as well (Interview, Malmberg 02/06/2018). Green roof environments installed at the hospitals and other healthcare facilities help patients recover faster by reducing the physiological indicators of stress, improving mood and aiding in healing. Many studies are showing that spending three to five minutes in nature or viewing natural scenery help with the recovery better than grey urban spaces (Interview, Tapper 25/06/2018).

4.3. The Question of Unused Spaces

In case to establish new urban agriculture production, you should find the unused space that could be underground, in the old building, on the rooftop, and put an enabling factor in it and create an interconnected system. They are all equally suitable for the food production, but the only challenge with rooftop urban agriculture, when we talk about food production, there should be an appropriate infrastructure that will be able to make urban agriculture maintainable for a long term. The load-bearing capacity of the building is among the constraints specific to the design of rooftop farms. So nowadays, many buildings do not have a suitable existing construction with a conforming load-bearing capacity for that yet (Interview, Anonymous B 27/06/2018). It is a complicated process of strengthening the building construction, asking for permits and develop new building structures for the rooftop urban agriculture. Various types of green rooftop environments could be established at the unused rooftops. Since there are green rooftop environments with various benefits and purposes apart from food production, some of them could serve a social function, that will bring people together, add diversity to the grey urban environment and break heat islands.

When considering putting greenhouses for the food production on the rooftop, more infrastructure is needed. Nowadays, in Stockholm, there is no existing rooftop which structure has a load-bearing capacity that could serve industrial scale urban agriculture. If we consider using existing building for industrial scale urban agriculture that produces about 2 tons of food per day, underground space could serve that task easier due to the existing building structures corresponding required load-bearing capacity (Interview, Anonymous A 02/06/2018).

4.4. Challenges of Successfully Integrated Rooftop Urban Agriculture and Green Environments

Lack of a competent knowledge about green roofs construction and needs among architects and landscape architects is one of the most significant challenges of successfully integrated urban farming with regards to sustainable urban planning (Interview, Malmberg 02/06/2018). Many times architects do not have a required adequate knowledge of the constructions that will make an implementation of the green environment possible on the roof. Also, there is a lack of construction site inspection done by the project architects throughout the different stages of the building process. Since putting flower beds and installation of green environments is still not an everyday thing, builders are not aware of many important details that should be taken into account. That makes an impression of the installation of green rooftop environments as an uncertain process that requires a lot of money and attention from builders and supervisors (Interview, Tapper 25/06/2018).
Competent knowledge is also crucial for the bottom-up initiatives because growing food on the rooftop can be equated to the growing food in the extreme conditions with heavy wind and a lack of shadow (Interview, Stuguland 13/06/2018). When it comes to the usage of rooftops for urban gardens, there are particular methodology should be implemented for the better water leakage isolation. Leakage beneath the soil is one of the most common challenges, which can lead to the leakage of the water from the rooftop to the lower levels of the building through the constructions, as well as the travelling of the nutrients through the soil and building construction down in the water systems (Interview, Tapper 25/06/2018). Growing plants and food products high up requires consideration of the special conditions: wind exposure, temperature fluctuations are more extreme, increased sun, soil depth requirements vary between the types of plants, and to grow it sustainable and natural, organic fertilizers and nutrients should be used, that takes a lot of space and maintenance (Interview, Tapper 25/06/2018). Due to the load restrictions and the benefits of many harvests per year, leafy vegetables (salads, herbs) are the best-suited type of agriculture for the rooftops. If there is a built shelter from wind, cabbage and strawberries could be grown as well with just 10-15 cm of soil (Interview, Malmberg 02/06/2018).

Another question is the management and operation of green rooftops: many architects and urban planners put urban gardens and other green environments on the rooftops of the residential buildings, but very often, it is left unused and abandoned in reality, since residents lose their interest very fast and there are no people left to take care of the space, since green rooftop environments and urban gardens, in general, need more maintenance than traditional allotment gardens (Interview, Anonymous B 27/06/2018). There is always a challenge to find members for the urban farming initiatives who are willing to stay longer, so it takes much time to find enough people for the green roof maintenance (Interview, Stuguland 13/06/2018). The government and management system plays a significant role in sustaining that kind of systems. However, this kind of work sometimes seems too “idealistic” and therefore does not get the treatment among planning authorities as it should. Food production on roofs remains an uninvestigated topic among municipality and planning authorities (Interview, Malmberg 02/06/2018).

Back to 2014, when there was an establishment of one urban farming in Stockholm, it was still a challenge to find a space for its development, as real estate companies were not aware of such a precedent. However, nowadays, since there are more and more urban farming initiatives take its place, the situation gets better, and real estate companies want people to rent space for food production (Interview, Anonymous A 02/06/2018).

4.5. The Tools of Adapting Rooftop Urban Agriculture and Green Roofs in the Sustainable City Development

Sustainability and urban resilience concepts play an essential role in the development of many architectural projects. Usage of lifelong materials without any environmental impacts, reduced transportation of the selected substantialities, giving preferences to the local produce (Interview, Tapper 25/06/2018).

Urban agriculture was not a compelling agenda for many local governments till a couple of years ago. Several changes started to happen as a result of a push and initiative from a private sector that made a ‘mesosphere’ in the middle more active, various successful initiatives from a different range of actors showed that urban agriculture is a valuable concept and it could work and make cities more resilient (Interview, Anonymous B 27/06/2018). The government started to pay attention to that concept, taking into consideration an idea of growing food within city borders. In Stockholm, for example, the recently made research shows that 10-15% of leafy greens can be produced inside the city. There are many places around the world nowadays, such as Toronto, New York, Amsterdam, Stockholm where local governments consider urban agriculture as an alternative solution as the result of ‘the push’ from the bottom-up initiatives.

There is no promotion of the implementation of green roof environments from the government at the moment, but some local municipalities started to take this agenda seriously. For example, in Malmo, there is a programme promoting urban agriculture. In Stockholm, some architects from «White Architects» and other big architecture companies came up with the idea of creating a system of lots for urban agriculture, that could be rented all over the city. However, now there are not so many of them and the line to become a member is long (Interview, Tapper 25/06/2018). Also, there are some existing funding programmes for entrepreneurs and small businesses that you can apply for when starting a new urban farm initiative (Interview, Stuguland 13/06/2018).

A very few cities in Europe adopted green roof policy as Paris did in 2015 (Cesifo/DICE, 2012). However, regarding the success of green roof and spread of green roof environments, one of the most critical factors for both is a determination of a load bearing capacity number of square meters and existence of local guidelines for green roofs. For example, if there were a policy that each roof (or at least in dense city areas) should have a load bearing capacity of 300 kg per square meter, we would be able to grow food in the future on the roofs if ever needed to do so (Interview, Malmberg 02/06/2018).

There are different kinds of policies that could be tweaked. For example, there is a certification system for the buildings based on the sustainability standards. The implementation of green roof environments could be an add-on to the existing sustainability standard for which you get more points for the buildings. That way real estate develop-
ers will be more interested in putting green environments and urban agriculture on the rooftops of the buildings (Interview, Anonymous B 27/06/2018).

It is vital for the private sector to introduce alternative businesses to the real estate. The world’s situation changes, and there is a switch in many different areas. For example, now there is a vast change in the retail business, online shopping replaces shopping malls. Due to the changes in the climate and fast urbanisation, it could be predicted that selling local food production will have more demand than opening shopping malls (Interview, Anonymous B 27/06/2018).

### 4.6. The Future of Urban Agriculture

Nowadays, despite a rapid development of the urban agriculture technologies, leafy greens and herbs prevail in the inside system production. Urban agriculture could be seen as a complementary between rural, urban and peri-urban, since it’s impossible to grow some produce inside the cities, such as crops, weeds, etc. Cooperation of these three sectors could give better food security and logistic system. At the moment, no country could be self-sufficient when talking about food security, because some of the product should be grown in one specific climate, but there is predicted that 15-20% of the food will be grown inside the borders of cities. Many initiatives are happening when you combine growing food and fish production, for example, that could provide various alternative options for the food production. Many factors should work together, such as social, economic and sustainability, and create various solutions in the future. Agriculture is one of the worse and unsustainable industries on the planet, about 25-30% of greenhouse gas emissions come from agriculture production (UCDavis, 2018). A lot of more issues go back to our food system. We need dramatic changes as soon as possible (Interview, Anonymous B 27/06/2018).
5. DISCUSSION

RQ1: What are the challenges of a successfully implemented rooftop urban agriculture?

The research identified multiple challenges that can be encountered in the process of implementation of rooftop urban agriculture. Unawareness and the lack of knowledge among stakeholders, researchers, professionals and municipalities is the most common issue that inhibits the popularisation of rooftop agriculture. Unfortunately, there are still many prejudices about rooftop urban agriculture that hinder the development process.

As it was stated, growing leafy greens and other food on the tops of buildings is a production in the extreme conditions that required specific constructions such as windbreaks, sun shadows and particular irrigation systems. Water leakage stays one of the most common issues during the maintenance of such.

Lack of the rooftop policies and funding programs for rooftop urban agriculture make it problematic to start a new initiative and make people interested in the establishment of new production. Developers are not interested in renting spaces for the greens roofs due to the lack of demand from the market.

RQ2: What are the tools of adapting rooftop urban agriculture in the sustainable development of urban areas?

As the findings from the first research question defined, lack of knowledge and unawareness leave the topic of rooftop urban agriculture unexplored for the government, local municipalities and city developers. Introduction of more bottom-up initiatives from the private sector, local communities and businesses will increase the demand for the rooftop urban agriculture. Augustenborg Botanical Roof Garden in Malmö is an excellent case study of the green roof that serves a function of a presentation green roof for the municipality, urban planners and other individual initiatives.

A gain of the knowledge among architects, engineers and building constructors will improve the implementation of the rooftop agriculture in cities that will stop making it look like a problematic and impracticable task. Upgraded building constructions and urban agriculture systems will advance the quality of these environments and make the maintenance easier. Also, tweak in some regulations and sustainability standards will higher the demand among city developers.
6. CONCEPTUAL FRAMEWORK

6.1. Design Program

Parking structures were invented out of the need of handling the situation of exploding automobile population. Multistorey parking building is an example of one of them. These grey, featureless and harsh structures have an appearance of a bunker or a prison building.

Traffic is decreasing, and cities will face the challenge of handling significant vehicle pieces infrastructure that no longer will be in use, such as parking lots, tunnels and endless highways. One of the greatest urban challenges today is dealing with the challenge of the car-oriented cities. Multifunctional space with various benefits (sustainable, social and economic) and parking garages may seem like an unlikely combination, but in actuality, there are many compelling and complementary profits once the ‘union’ has been made (Falkerson, 2015).

“Malmö FIVE” is a concept of the five multifunctional green roof parks that that are placed on the rooftop of the existing multistorey parking buildings. It creates a system with rooftop public spaces with the elements of urban agriculture that will be accessible to the different range of people and will serve various purposes, such as social, environmental and economic.

In the design program, I focus on the "P-Huset Södevårn" parking building that later could be used as an example and inspiration for the renovation of the other parking buildings in the concept of “Malmö FIVE”. The concept serves the purpose of Phase 3: Action plan and development from Green Roofs: A Resource Manual for Municipal Policy Makers by Lawlor et al (Lawlor et al, 2006). It is a conceptual design proposal that could be presented for the municipality, city developers or building owners for the sake of funding programme and further design development. No further construction detailing, information about the suitable plants and crops, the economic value of the project was provided.
Fig. 3 "Malmö FIVE" concept
6.2. Malmö Södervärn

“P-Huset Södevärm” is a 5-storey parking building that is located nearby the bus station “Malmö Södevärm”. Södervärn area is located nearby the former railway station and district in Malmö. Nowadays, Södervärn is part of the southern inner city.

At the moment, the building serves only one function, which is storage for cars. It can accommodate 1654 cars. As it was noticed during the site visits, almost all of the times the top of the building is empty, due to the massive scale of the construction and uselessness of the rooftop. The grey sharp architecture image does not add any value to the neighbourhood, on the opposite, makes is unattractive and industrial.

The top floor of the “P-Huset Södevärm” is a parking area with the size of 8800m2. It has a capacity of about 330 cars. The rooftop can be entered by the drive in from the lower level as well as by the three vertical connections (stairs, ramps and elevators) that are put on the sides of the building. The sheds with a purpose of sun, wind and rain protection surround the perimeter of the rooftop.

The central concept of the design program is adding functions to the car-oriented space and make it a social place that could be used not only for the vehicle storage. Green environments such as green walls, roofs and urban agriculture are not usually seen in combination with the featureless building, but the integration of the vegetative building structures could add the value to these structures and transform it positively.

The sheer scale of the multistorey garage provides a sample space to develop not only a green park that is diverse in plants and trees but also roomy to allow several human activities. The design program demonstrates the integration of greenery onto a multi-story parking building that can be done smoothly to the benefit and enjoyment of the visitors. It could also serve various management purposes, such as retaining stormwater within the system of soil and vegetation. The thousands of square meters of concrete rooftop creates a substantial urban heat island effect which could be broken with the help of placing greenery on the rooftop of the building.

There were many successful examples when the car-oriented areas were transformed into the environments with green systems and landscapes. Kaiser Center in Oakland California is one of the oldest examples of such a transformation that is still used as a park and used by the different group of people with the different age. It is a 3.5-acre park with the elements of the garden that is located on the top floor of the 5-story parking garage (Falkerson, 2015).
6.3. Concept Design

There are four main areas in the design program, which are roof garden, greenhouse, urban farming and roller derby area. The garden area is organized around the elevated flowing meandering walkways; mounded soil for trees, meadow system and green beds were planted over structural support columns of the level below. Trellis systems, seating corners, playgrounds and pergolas create rooms that give a private space that is detached from the surrounding of the garden and offers a variety of outdoor communal facilities. The landscape also features pockets of sports and activity spaces to bond and gather.

The rooftop greening provides a sense of natural biodiversity atop of the hidden concrete flooring. A different type of modular wooden rooftop furniture, which is made out of recycled materials, provides a diverse choice for seating options. It is constructed in a way it can be quickly moved, combined and replaces within the space. There is also vegetation along the perimeter to erase the rooftop’s rectilinear nature.

The greenhouse functions as a vegetable, leafy green and herb production. There is a local cafe in the same space where customers could purchase “straight from the greenhouse” organic produce. The large area surrounds the greenhouse on the platform where movable furniture is placed for the visitors of the cafe surrounded by the planted trees and other vegetation. Playground for kids is located straight nearby the seating and contains various activities on the different levels.

Urban gardening is a system of lots of different sizes and shapes. The lots could be rented by anyone interested for a season or a more extended period. Beehives on the side support the natural climate of the urban farming, pollinating the diverse range of vegetable life. Roller derby area is a spacious space with various multilevel seating options that could be used for the roller derby training and competitions as well as other music and cultural events.
Fig. 12 rooftop garden area, visualization

Fig. 13 rooftop garden area, detailed plan

Fig. 14 section B-B

Fig. 15 different types movable furniture
Fig. 16 rooftop urban farming area, visualization

Fig. 17 rooftop urban farming area, detailed plan

Fig. 18 section 1-1
7. CONCLUSION

The findings determined the importance of rooftop urban agriculture being approached from the strategic sustainability perspective to value its potential fully. Rooftop urban agriculture can provide significant environmental values thus have an essential role in sustainable development of urban areas. From this follows that when planning a city or new city districts, including areas with green rooftop environments can be beneficial not only from the ecological perspective and healthiness of the community but also in a matter of social and economic development.

The current situation shows that the evolution of rooftop urban agriculture has not been adequately studied. Unawareness of rooftop urban agriculture amongst the professionals, policymakers and the public, in general, appeared as the most severe challenge that this field faces at the moment. To enhance the growth within the field, demand from the private sector should be created. Consequently, that will result in the development of rooftop urban agriculture and green roof policies and guidelines that will be beneficial for the future collaborations among city developers, green roof stakeholders, constructors and other practitioners. The design program “Malmö FIVE” showed one of the ways how the architects and urban planners could inspire city developers and local municipalities to explore the ways of using existing spaces within the urban environment. Rooftop Urban agriculture is one of the effective ways how the built environment can be redesigned in the spaces that are more sustainable, healthy and joyful.

This research showed that urban agriculture and food system in overall is closely interrelated with retail, transportation, water and waste management systems. To create the most effective sustainable solutions in the future, all these systems should beneficially work together and intertwine with each other. As it can be predicted, the food system will face many serious challenges in the future decades, so the whole structure should be reconsidered, some new alternative solutions should take its place as soon as possible.
8. REFERENCES


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