Food on the Roof

Developing an IT platform to visualize and identify suitable locations for roof farming in cold climates

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Abstract

The aim of this project was to explore the possibility to smartly integrate food production in cold urban environments. The main objective was to sketch an intelligent platform to guide a comprehensive, city-wide approach to urban farming in winter cities and assist city stakeholders.

We have worked with large databases related to energy consumptions, performances, building stock and size, solar radiation, and so forth. The challenge for us was to integrate big data in a manner that is easy to understand and visualize for all audiences while matching the ambitions of local stakeholders for urban farming.

Urban farming (UF) has social, economic, and environmental benefits: socially UF will bring people closer to nature and it can become a source of education for local schools and community; economically, UF targets the rapidly growing market of premium, fresh, biological food that is proudly produced locally and can be sold to local restaurants and other customers; environmentally, UF will decrease our reliance from far away and poorly controlled food chains, while decreasing environmental costs for transportation.
The project

• Recent concerns around climate change have stressed the importance to address national food security.

• The northern part of Sweden is the region most threatened by disruptions to the food supplier chain as it lies in a sub-arctic climate area that is difficult to cultivate during the winter.

• Food security is an urban issue as most people live in cities.

• The challenge is to produce food within cities that are located in cold climate regions.

• The idea of this proposal is to develop a tool that uses data related to buildings, their energy performance, demographics, and so forth to identify suitable location for rooftop greenhouses.
Glossary

**PUA:** Peri-Urban Agriculture. It is the common source of food in a given region.

**USF:** Urban soil-based framing. It is food grown within urbanized land.

**RF:** Rooftop Farming (open-air). It is a cheaper solution (although less productive) and often is soil-based. Issues come with structural loadings and water.

**RTG:** Rooftop Greenhouses (protected). It is more expensive (because of the climate control) and productive solution. Hydroponic and aquaponic solutions are often adopted.

**URF:** Urban Rooftop farming (includes RF and RTG)

**CEA:** Controlled Environment Agriculture

**Hydroponic:** cultivation based on fluids

**Aquaponic:** cultivation based on fluids enriched by fish's manure
Literature review & Case Studies (1)
Definition & Purposes

Definition (Urban Agriculture Committee of the CFSC, 2003:3):

UA is defined as ‘the growing, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities’

Purposes (Sanyé-Mengual et al, 2016)

• Food security (complementing peri-urban agriculture)

• Response to economic crises for low income groups

• Sustainability (reducing food transportation, improving waste recycling, etc.)

• Enhance urban biodiversity (pollination for RF)

• Climate change
UA and the Metabolic Rift

- "Metabolic Rift": each technological evolution leads to ecological crises (e.g., soil fertility crises, natural disasters, etc.).

- The Metabolic Rift idea is based on Marx's analysis of capitalism as a force that separates humanity from nature.

- Already in 1878, Engels advocated for a "fusion of town and country" as the opposite of capitalist specialization between industrial towns and countryside.

- The Metabolic Rift can be understood in terms of: Ecological, Social, and Individual Rifts

*Ecological Rift*: "Rifts" are followed by "shifts" as any attempt to address crises lead to its geographic displacement somewhere else (e.g. the need of fertilizers is sought at the expenses of ecosystems in other countries). **UA can then be a key for a circular economy whereby cycles are closed locally (e.g., between bio-waste and production).**

*Social Rift*: internal and international migration brings new people to cities. Then **UA can be a reaction to food shortage but also to community integration** (especially in developing countries or during economic/political crises). If food is a commodity (to be bought and sold according to market) then the relationship between humanity and nature is broken.

*Individual Rift*: the alienation of nature from humanity in ever more abstract ways (e.g., TV, Internet, etc.) is key to understand behavioral disorders (NDD) among children. **UA can provide that link between nature and humanity that allow us to metabolize the surrounding landscape.**

Source: McClintock, 2010
Swedish National strategy for food safety

Reasons for a food strategy:

• Climate change
• Crisis preparedness
• Swedish food exports
• Job creation

The vision:

"In 2030 the Swedish food supply chain will be globally competitive, innovative, sustainable and an attractive sector to operate in."

The overall objective:

"... aiming to generate growth and employment and contribute to sustainable development throughout the country ... An increase in production of food could contribute to a higher level of self-sufficiency."

Source: Government bill 2016/17:104
Different stakeholder perceptions of urban farming/1

- Two paradigms for UA (Sanyé-Mengual et al, 2016):
  - **Food production**: food production is central for the economic viability of the project(s). PUA is central. Within this paradigm, RTG is seen as a useful technology to enhance productivity for UA.
  - **Social activity**: the focus is on community empowerment, health, social cohesion, inclusion and education. USF and RF are popular while RTG and PUA are perceived too intensive.

- One paradigm is not necessarily alternative to the other but studies show that different stakeholders have different perspectives about UA.

Source: Sanyé-Mengual et al, 2016
Different stakeholder perceptions of urban farming/2

Aspects to consider:
- Integration in existing buildings,
- structure loading,
- legal barriers for rooftop usage,
- logistic constrains,
- need of trained staff,
- users acceptance,
- competition with other uses (solar),
- investments costs
- Access to consumers (usual distribution channels Vs. Direct channels)

Benefits:
- recycling of CO2 and heat waste
- Reducing distance between source and consumers
- Naturalization of the city
- Improving community food security
- Increasing access to fresh, high-quality (no pesticides or antibiotics) food
- Linking consumers to food production
- Community building (integration of new Swedes?)
- Better use of unused space
- Community image (branding)
Commercial rooftop greenhouses (SLU)

- **85 percent** of the country’s population now reside in urban areas.

- distance between producers and consumers keeps on increasing.

- In this literary review an attempt is made to investigate the possibility of growing food products on a commercial scale in rooftop greenhouses.

- The results show that rooftop greenhouses differ very little from ordinary greenhouses on the ground.

- They also benefit the city.

- However rooftop greenhouses are not without problems. A primary concern is related to the high investment costs, low profit margins on food products as well as long payback times.

Source:

*Robin Meijer, 2015, SLU Master Thesis*
Estimating the impact of urban food production

- A study in Bologna has attempted to quantify the potential for urban food production
- First they studied a pilot case to calculate the different yields according to food type and production system (soil-based, NTF, floating)
- They designed a model rooftop garden to maximize production
- They then calculated the surface of flat roofs and terraces across the city (Google, GIS, CAD)
- They calculated the food requirement of the city and found that with the implementation on a large scale of their model they can provide up to 12,000 t/year of vegetables, to cover 77% of the food needs in the city
- Attempted to estimate the impact in ecosystems (pollinations, water, etc.)

Source: Orsini et al, 2014
Growing Power in Milwaukee, Wisconsin

The prototype for Community food centres is the Growing power facility

With space no larger than a small supermarket (two acre) live some 20,000 plants and vegetables, thousands of fish, and a livestock inventory of chickens, goats, and bees.

• Dedication and education
  • Founder Will Allen promises to give everyone that enters the farm a round tour.

• Using planning to adapt the farm to the local environment and developing a space efficient farm

• With modern technologies they reduce the amount of water, space and pesticides

Source: http://www.growingpower.org/
Foodmet, Brussels

A public limited company drives business in Abbatoir and markets.

- longstanding sustainability policy, extending to every aspect of their activities.

- additional employment as part of a “chain” of operations involving companies that do not seem to have an obvious connection

- autonomous installation for water treatment, which is used to purify all the waste water from the site.

Source:

Lufa farm, Quebec Montreal
growing on no new land; capturing rainwater; recirculating 100% of irrigation water and nutrients; reducing energy use; composting green waste; using biological controls instead of synthetic pesticides, herbicides, and fungicides; and delivering produce to customers on the same day it’s harvested.

• The first and largest commercial rooftop farm.
• Growing for 2000 people
• Demonstrating that large urban and peri-urban rooftop farms are a commercially viable ways to feed cities

Source:
Farming in and on buildings: Zero-Acreage Farming

- Studied 73 ZFarms
- ZFarming generates innovative practices that may contribute to a sustainable urban agriculture.
- Besides growing food, it produces a range of non-food and non-market goods.
- It involves new opportunities for resource efficiency, new farming technologies, specific implementation processes and networks, new patterns of food supply and new urban spaces

Source:
Thomaier et al. 2014

Table 1. Different forms of ZFarming (absolute frequencies, n = 73).

<table>
<thead>
<tr>
<th>Absolute frequencies (n=73)</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop farm/garden</td>
<td>47</td>
</tr>
<tr>
<td>Indoor farm</td>
<td>17</td>
</tr>
<tr>
<td>Rooftop greenhouse</td>
<td>6</td>
</tr>
<tr>
<td>Façade</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>
Sky Vegetables

Sky Vegetables develops and operates urban hydroponic rooftop farms as part of its mission to grow fresh and local produce sustainably. Sky Vegetables and its produce are pesticide-free. Sky currently operates an ~8,000 sf rooftop farm in the Bronx, twenty minutes from Manhattan.

Source: www.skyvegetables.com
Socially acceptable urban agri-businesses

Fig. 3 General preferences for (productive) urban land use in Berlin: [Q1] Which of the following uses of green and open space would you like to have in your direct living environment?

Source: Specht et al. 2016
Multidisciplinary approach for assessing the sustainability of RTG

Presents method that combines

- evaluation of stakeholder perception
- geographic information systems to quantify the potential roofs for implementing URFs (urban rooftop farms)
  - availability of space, sunlight, resistance and slope, and legal and planning requirements.
- life cycle assessment for URF environmental impact
- life cycle costing

Source: Sanyé-Mengual et al. 2015

Figure 1. Multidisciplinary methodological scheme for assessing the sustainability of rooftop farming.
Green Power
Using waste heat from data centers

PROJECT GOAL

Develop a methodology to measure heat, humidity and airflow from datacenters and create computer models that can be used to design and evaluate greenhouse and energy transfer solutions and find a balance between waste heat and other energy sources for greenhouse operation in cold climates.

PARTNERS

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BODEN BUSINESS AGENCY
HUSHÄLLNINGSSÄLLSKAPET
ENACO
ERICSSON
SICS NORTH

PROJECT DURATION: MARCH 2015 – JUNE 2017
Green Power
Using waste heat from data centers

Tool to assess possible green house designs

Energy transfer model

Outside temperature

Greenhouse design
Needfinding (2)
Meeting with stakeholders

A workshop was organized with planners at the department of planning in the municipality of Luleå to discuss the potential and implications for planning of Urban farming (UF). We met on 1st of June 2017 in the Kommunshuset in Luleå.

The workshop was attended by three members of the research team (Agatino Rizzo, Marcus Sandberg, Johan Wenngren), one master student who is writing a thesis on UF (Patrik Rönnqvist), one planner at Luleå Kommun (Malin Jansson), and one food scientists (Shaojun Xiong, SLU, Umeå).

The topics for discussions can be summarized in the following agenda: presentation of the project, introduction to the topics, crops suitable in cold climates, needs discussion.

The discussion can be summarized as the following:

- Mushrooms is a good source of protein. WHO recommend eating maximum 25 kg meat per year and we eat 55 kg in Sweden. Mushrooms needs approximately 40W heat per m2, hygienic conditions (no microorganisms), 85-90% humidity, lights at 500 lux (LEDs are enough). If combining growing of different crops in the same space at different times a year then ozone can be used to clean the space.

- The biggest impact of our IT tool could go into the comprehensive plan which is currently under development. The kommun has the objective to launch a green infrastructure plan soon. Perhaps food production could be part of this plan.

- It is important to understand how to manage urban farms. If public buildings such as schools have optimal locations for UF, we cannot ask schools to run them. We should think of a system by which privates can lease the space.
• It is important to include industrial sites because they are the biggest consumer of energy and have optimal space for farming (e.g., flat roofs)

• UF can be labor intensive, therefore automation and AI should be deployed for precision agriculture, which reduces running costs and optimize inputs.

• Although a tool to guide planners to consider UF in their plans is interesting, in the specific case of Luleå there is no political interest on the topic at the moment (later in the project, we discovered a bigger interest on the topic in Kiruna which is setting a Kiruna Sustainability Center partly funded by Vinnova)
Data and IT Tool Draft (3)
Steps

A first identification of relevant data sources was carried out in relation to the issues and needs explore in the previous steps (see table in the following page).

As the base for the IT tool, we deployed the architecture of a previous study developed by Tim Johansson in his PhD thesis about building an energy atlas for Sweden which was based on ETL technology i.e. Extract, Transform and Load.

Then a system of rules was set. The main idea was to use building energy declarations (which we had access to) to identify buildings with low energy performance (and therefore with high energy waste). The higher is the energy waste from the ventilation system the better is to use this waste to power an adjacent greenhouse for food harvesting.

We also had to make sure that roofs were suitable to install greenhouse, which meant they had to be flat, and with a reasonable size to lower the running costs per unit of products (i.e. not too small).

Another issue was to target buildings which had the probability to structurally withstand the greenhouse load on their roof. This meant that we had to rule out minor structures such as garages or cottages. Finally, we wanted to capitalize on location advantages given by a good sun radiation all year along.

Assumptions for the tool:

- Energy class:E,F,G or energy use >100 mWh (e.g 4 villas)
- Flat roof std < 0.1 (inner roof buffer =-2 m)
- Roof area > 25 m2
- Detaljtyp = HUS (no HUSÖVR)
- SUNRAD > 500 kwh/m² (per year)
## Analysis of possible data sources

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Ägare</th>
<th>Kommentar</th>
<th>Åtkomst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energideklarationen</td>
<td>Boverket</td>
<td>Innerhåller tyvärr inte industriinformation (tillverkningsindustri t.ex)</td>
<td>Beställning med tillståndsprüvning</td>
</tr>
<tr>
<td>Fastighetsregistret</td>
<td>Lantmäteriet</td>
<td>Få info om byggnaden behöver renoveras. Info om kompletterande ytor, byggnadsår, ombyggnadsår, värdeår, typbyggnad. Databas</td>
<td>Beställning med tillståndsprüvning</td>
</tr>
<tr>
<td>GSD Fastighetskarta</td>
<td>Lantmäteriet</td>
<td>Byggnadsytor, fastighetsgränser</td>
<td>Laddas ner från maps.slu.se</td>
</tr>
<tr>
<td>Nationell höjmodell</td>
<td>Lantmäteriet</td>
<td>Punktmoln för att beräkna hushöjder och markhöjder</td>
<td>Laddas ner från maps.slu.se</td>
</tr>
<tr>
<td>Fjärrvärmedata</td>
<td>Luleå Energi</td>
<td>Innerhåller förmodligen mer detaljerad energidata</td>
<td>Oklar</td>
</tr>
</tbody>
</table>
Test
Food On Roof Simulation Tool
Flat floor and > 25
Flat floor and > 25
Flat floor and > 25
Validation of Tool Draft (4)
Meeting

A workshop was organized with the Tekniska Verken in Kiruna AB to discuss the IT tool. We had a conference call on 4th of December 2017.

The workshop was attended by Agatino Rizzo, Marcus Sandberg, Johan Wenngren, and Joakim Norman (Tekniska Verken in Kiruna AB).

We first introduced the topic of our study followed by the presentation of the IT tool on Google earth Platform.

Joakim was very interested on our work in the project and saw many possibilities with the tool. He saw connections to a solar cell park project connected to LKAB as we have solar radiance data included in the tool. A comment Joakim had is that the city transformation needs to be handled in the tool. There is a GIS project with LKAB and Sweco connected to the Sweco Cube project Kent Karlsson has been working with. This can be discussed with LKAB as it has connections to our project.

He mentioned that they have more than 13 project proposals in the Kiruna Sustainability City effort and one is very connected to Food on the roof. This project deals with cultivation in the city and in the mine using hydroponics. The restaurant called Spis owns the mushroom cultivation in the mine and is part of the project.

He saw the potential to use the Folkhögskola or the Högalidsskolan (our tool showed these as candidates for growing food on the roof) as examples for testing food on the roof ideas and other cultivation ideas since the land is municipally owned. Maybe trying both hydroponics and growing on land using heated ground. There seem to be waste heat from the district heating return pipe that could be used as well.
Joakim has discussed food growing with RISE but they lack botanic competence. Marcus said that from the Green Power we have contacts with Shaojun Xiong from SLU who knows mushroom growing and Hushållningssällskapet who knows greenhouse growing.

He saw connections to city planning and how to make unused areas more attractive by growing food. The White architect firm also had ideas connected to this.

Finally, Joakim advised us to discuss with Kristina Nilsson (LTU) about how we at LTU should prioritize our effort since she and Chriser Åhlund decide how to use the money LTU has got.
Conclusions (5)
The aim of this project was to explore the possibility to smartly integrate food production in cold urban environments. The main objective was to sketch an intelligent platform to guide a comprehensive, city-wide approach to urban farming in winter cities and assist city stakeholders.

The platform will integrate various data sources - geographic, population and building data (e.g., location, orientation, size), energy performance (e.g., energy declaration) - and food-science knowledge to be able to identify suitable locations for UF.

Urban farming (UF) has social, economic, and environmental benefits: socially UF will bring people closer to nature and it can become a source of education for local schools and community; economically, UF targets the rapidly growing market of premium, fresh, biological food that is proudly produced locally and can be sold to local restaurants and other customers; environmentally, UF will decrease our reliance from far away and poorly controlled food chains, while decreasing environmental costs for transportation.

The Food on the Roof project is aligned to the Swedish National Strategy for food safety (2016/17:104) which aims "in 2030 the Swedish food supply chain will be globally competitive, innovative, sustainable and an attractive sector to operate in."

What we found is a sea of opportunities for urban farming by capitalising on closing energy circles in place (e.g., recycling heat and CO2 from buildings ventilation) and exploiting the innovations already exist in sustainable lighting and precision agriculture. Our contribution to tackle this challenge is at the city/planning scale as we have gathered knowledge and sketched a digital support systems for planners and stakeholders to identify areas that are suitable for urban farming.

We have worked with large databases related to energy consumptions, performances, building stock and size, solar radiation, and so forth. The challenge for us was to integrate big data in a manner that is easy to understand and visualize for all audiences while matching the ambitions of local stakeholders for urban farming.
Growing food across seasons in the north is not a taboo any longer. By combining knowledge on buildings, urban spaces, climate and energy with already available technologies, private and public actors can enter the urban food business arena with social, economic, and environmental benefits.

In a small scale, we are testing some of this assumptions and idea in master thesis at LTU. One good example is Patrik Rönnqvist’s (forthcoming in 2018) master thesis in urban planning where he developed a container based system to grow vertically vegetables (supervisor: Agatino Rizzo). His system is flexibly enough to be adapted to many urban space situations and builds up on research and expertise on climate building and planning and urban farming.

However, further funding is needed to be able to develop what today is a rough prototype in something that is usable by planners and stakeholders. Our main ambition is to start a larger project in collaboration with local authorities and big energy users to develop and validate our methods and tools.
References


Orsini, F., Gasperi, D., Marchetti, L., Piovene, C., Draghetti, S., Ramazzotti, S., & Gianquinto, G. (2014). Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: the potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna. *Food Security, 6*(6), 781-792.


Swedish government bill 2016/17:104 "A national food strategy for Sweden – more jobs and sustainable growth throughout the country".