The Productive Fringe

Making Gothenburg Self-Sufficient in Vegetables and Fruits by Exploring Urban Agriculture in the Intermediate City

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Abstract

Food production, which is linked to social-ecological sustainability and food security, is a major concern in Sweden. Sweden imports double the amount of agricultural food items that it exports. If an unforeseen tragedy or crisis strikes, Swedish agriculture will be unable to function without imported fertiliser and fodder. Agriculture is one of the most essential operations since it produces food for the human race. Many of the sustainability concerns posed by urbanisation and a growing population can be mitigated by urban agriculture.

This thesis aims to present ways to implement agriculture in the intermediate city, which can be defined as the link between rural and urban, by utilising residual spaces within existing typologies and fabric, such as rooftops, facades, courtyards, streets, parks, and undeveloped spaces. Furthermore, the aim is to explore if the intermediate parts of the city can make the whole municipality of Gothenburg self-sufficient in vegetables and fruits. This investigation is addressed by picking a site that depicts a typical configuration of the intermediate city in Gothenburg and then calculating a potential yield in this specific area.

In order to highlight the benefits of agriculture in a project, it is also intended to enhance the practical skills of architects and planners at all stages of the planning process. At the end of the research, a handbook is produced showcasing today's agriculture systems and design ideas on how to integrate these systems into the built fabric and the open spaces in their surrounding.

The exploration of the research questions consisted of utilising the knowledge gathered through literature studies and reference projects about the agricultural systems and their productivity. Combining this information with various analyses of the selected site allowed the programming of the land according to its optimal agricultural functions. The simple answer to the question is: yes, urban agriculture in the intermediate city can produce enough vegetables and fruits to make Gothenburg self-sustaining.

Keywords:

Urban agriculture, self-sufficiency, intermediate city, agricultural systems, food production.

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Why Rurban Transformation?

We both have an interest in urban farming, Linnéa having worked with it in a project from the bachelor program, and Lina reading a lot about the ecological effects in the studio Social-Ecological Urbanism. This knowledge is used in the research and design process of our master thesis. We believe that the rurban spaces are perfect for urban farming interventions. The combination of what historically has been a rural action with the configuration of the modern city can create an interesting interaction to explore further.

Content

Chapter One

Introduction

1

Introduction

The Situation in the World

Feeding a population of 9 billion people by 2040 will be one of humanity's greatest challenges. How we feed our cities is becoming an increasingly pressing matter as a result of fast urban expansion and the challenges posed by the climate emergency. By 2050, cities will consume 80 percent of the world's food (The Veolia Institute, 2019). Bringing food production closer to the people is worth looking into because it addresses the issue of food being transported long distances and to aim for a higher food self-sufficiency rate within each nation.

Food security, as described by the United Nations Committee means that *"All people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life"* (IFPRI, n.d.). When an unanticipated disaster strikes, it becomes evident how important self-sufficiency and food security is. The ongoing conflict between Russia and Ukraine is one example of that. Ukraine and Russia account for 30 percent of world wheat production and 20 percent of corn, two crops that are the staple food for billions of people. Wheat and corn prices are increasing because of the conflict – we are currently experiencing the highest wheat prices in over 30 years. Still, several countries are capable of covering non-Ukrainian exports. The issue is how to deliver wheat to countries in desperate need. Large areas of Africa and the Middle East are reliant on Ukraine and Russia for food imports. 90 percent of the wheat consumed in East Africa is coming from the two warring countries. As a result, Ukraine's crisis is not only devastating for the Ukrainian people, but also for people far away. The United Nations' *World Food Program*, WFP, estimates that around 45 million people in 43 countries are at risk of starvation (Grossman, 2022).

Food demand is anticipated to rise by up to 70 percent in the future decades, implying that more land and resources will be utilised by food production, putting further strain on the planet. In the future, the entire food system will need to be considerably more resource-efficient and have fewer negative repercussions. Faced with the acceleration of these trends and a need to reimagine food policies, urban agriculture is emerging as one of the driving forces behind this strategy (The Veolia Institute, 2019). Furthermore, urban agriculture could restore and strengthen the relationship between urban and rural areas. There are also personal motives such as the joy of working together with others and the satisfaction of being able to influence one's physical immediate environment.

We are constantly presented with potential solutions to many of the problems, yet few of these are implemented on a scale big enough to make a change. Rooftop gardens in Bologna, Italy, can provide 77percent of the vegetables necessary to sustain the population of the city (Orsini et al, 2014). Similarly, Franzén came to the conclusion that Sweden can become completely self-sustaining when it comes to food production simply by utilising the flat rooftops for urban agriculture (Franzén, 2019). Read more about agriculture in Sweden in chapter two.

Looking at a city, there are many spaces that can be used for urban agriculture to promote sustainable food production.

Reading Instructions

This thesis consists of a booklet and a handbook. The booklet explains the entire thesis process: background, aim, theory, method, result and discussion. In order to understand the full scope of the thesis, it is important to read the handbook as chapter three of the booklet as it contains information vital to the following explorations in chapter four. The handbook can be read as an independent product and does not need the context of the booklet to be understood. Some parts of the handbook are similar or identical to some parts of the booklet.

If you are reading this in digital format, the handbook will naturally follow when you reach chapter three. If you are reading this in printed format you will need to locate a copy of the handbook as they are printed separately.

Urban fringe: "the transition zone between the city and its suburbs, and the countryside".

The term ***"intermediate city"*** will be used as a synonym for the urban fringe throughout the thesis.

(Oxford, 2009)

Aim, Research Questions & Delimitations

Aim

The aim of this thesis is to present a way that agriculture can be implemented in the intermediate city by using residual spaces within existing typologies and fabric, for example, rooftops, facades, courtyards, streets, parks and underdeveloped areas. Throughout the thesis, an understanding of the possibilities of the systems used in agriculture will be developed which will result in design strategies that can be implemented on scales between the rural and urban.

The focus is to enhance the practical skills of architects and planners in all stages of planning to showcase the qualities that agriculture can provide in a project. The result is a handbook in agriculture systems and design ideas on how to integrate the systems into the built fabric and the open spaces in their surrounding. Lastly, this thesis explores the possibility to make the city of Gothenburg self-sustaining in vegetables and fruits by investigating the intermediate city.

Research Questions

- What design opportunities can be found for urban agriculture in the intermediate city?

- Can urban agriculture in the intermediate city produce enough vegetables and fruits to make Gothenburg self-sustaining?

Delimitations

In focus: The thesis is built upon a theoretical background in order to formulate relevant strategies for agriculture in the city fabric. The design proposals are suggestions of how to implement these strategies in different settings and are mainly shown on a conceptual level with a few additional details. Functions and buildings are shown in a typology in relation to a specific site, where the focus is put on the exterior rather than the interior.

The first focus is on the yield from vegetable and fruit production through geoponic and hydroponic growth systems. The second and main focus is the implementation of these systems in the intermediate city of Gothenburg.

Minor focus: The complexity of the food system in its entirety is not explored, but rather briefly touched upon. There is a minor exploration of densification in the intermediate city. The thesis will also mention concepts related to social space. However, these topics are not the true focus of the thesis, in order to delimit the scope of the thesis.

Not in focus: The thesis relates to urban metabolism-related topics and concepts related to construction, biodiversity, water management and social space, but this is not discussed or applied in the work. Furthermore, the thesis does not consider financial feasibility as the goal is to showcase design strategies that prioritise ecological values over financial profit.

Method

The method used in this thesis is a combination of research for design and research by design, starting with literature studies, reference projects and investigation of possible existing agricultural systems.

Parallel to the background research, the handbook is being developed. The first two chapters of the handbook are a result of the initial thesis research which describes the background and the agricultural systems. This is combined into a number of strategies that can be applied to build environments of different scales and urbanity, which is what the third chapter of the handbook consists of. These strategies are shown on a specific site in Gothenburg but can also be applied in other similar contexts.

The research question of whether or not Gothenburg can become self-sustaining when it comes to fruits and vegetables is explored through literature studies, Geographic Information System (GIS) and previous research about the agricultural systems. This is then done on a previously selected site that represents a common configuration of the intermediate city in Gothenburg and calculating the possible yield in this specific area. The data is used to make a rough calculation of the possible food production for the intermediate city as a whole.

Process

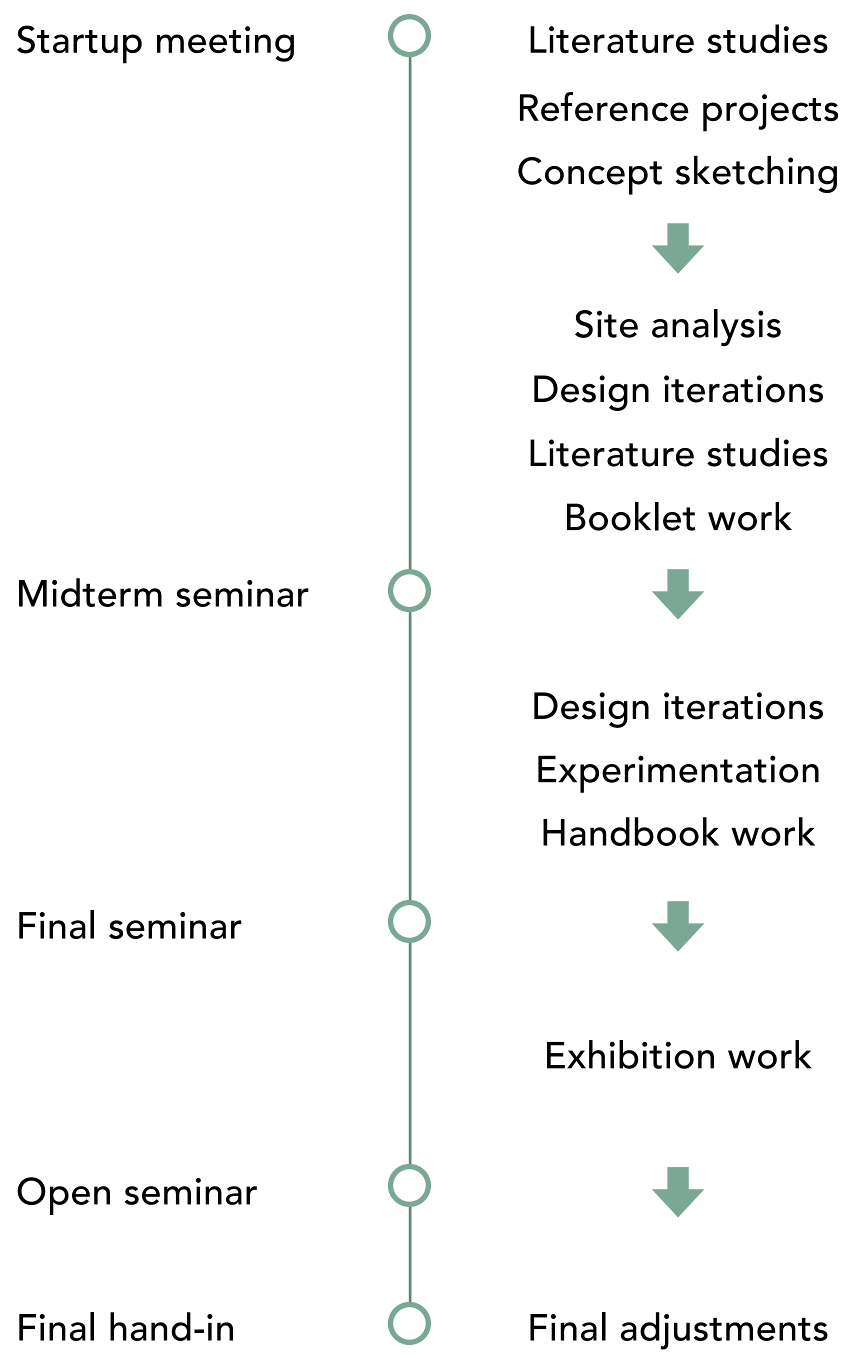


Figure 1.1: Process diagram

Chapter Two

State-of-the-Art

2

Background

The Situation in Sweden

Sweden's farmers produced 75percent of the country's food in the early 1990s. Sweden consists of a lot more people now, but we don't generate any more food. We put trust in the import, which every other bite consists of (Lantbrukarnas Riksförbund, 2022). Today, self-sufficiency in Sweden has dropped to 50 percent, compared to our neighbouring country Finland, where the degree of self-sufficiency is 80 percent Farms in Finland are generally smaller than those in Sweden, and they are dispersed throughout the country. Furthermore, Finnish agricultural assistance brings relatively big cash flows to sparsely inhabited areas, threatening the existence of many towns and small municipalities (Fors, 2018).

Food production is of significant concern in Sweden, as it is linked to social-ecological sustainability and food security. Sweden imports twice as much agricultural products and food as we export (Jordbruksverket, 2022). If there is an unforeseeable tragedy or crisis, such as the coronavirus, Swedish agriculture will be unable to continue operating without fertiliser and fodder from other countries around the world (Ulfbecker, 2018).

Warmer temperatures and longer growing seasons can help to create a more suitable area for agricultural production, which can help to compensate for Sweden's currently fragile and dangerous food system and increase self-sufficiency. Furthermore, the circumstances for agriculture vary greatly depending on where one is in our long-stretched country. There are benefits of many hours of sunlight per day in the summers and long, cold winters that deal with diseases. The horticulture sector in Sweden is centred around Skåne, where more than 70percent of all vegetables, fruits, and berries are produced. The soil, sun, and farming season all influence what is possible to grow and where. Götaland and Svealand account for almost 90percent of all food production. Götaland produces the most, accounting for around 64percent of total production (Lantbrukarnas Riksförbund, 2022).

The Situation in Gothenburg

Gothenburg is Sweden's second-largest city, with a population that is expanding at a rate of 1,5 percent per year, implying that demand for food and food security is increasing. The majority of the land suitable for farming in the peri-urban area of Gothenburg is used for grazing and monoculture, like potatoes (Wästfelt & Zhang, 2018). As a result, based on current land use, more food, especially vegetable products, will still need to be produced in the future in order to supply food for local residents.

The city's current densification initiatives jeopardise biodiversity, access to green spaces and open public spaces, air quality, and ecosystem function, all of which are vital to our well-being. Moreover, the greenery close to the city in Gothenburg municipality is decreasing. A study at the University of Gothenburg shows that the municipality of Gothenburg's land lost a significant proportion of greenery between 1986 and 2019. The study shows that from 1986 to 2019, avenues and green areas have decreased by four and a half percent (Blinge, 2020).

Green spaces in the city are habitats for many different insects and animals, but they are also important for human health. In addition to contributing to aesthetic environments, green areas have important functions such as rainwater management, sound attenuation and regulation of the local climate. In what the city of Gothenburg calls the intermediate city (the contiguous urban area that is cut off from the inner city by the major traffic routes) and in the suburbs, the proportion of green space has decreased due to residential areas and shopping centres built on old arable land, grasslands and forest. The study shows that areas with large-scale industry and logistics have accounted for the largest reduction in green space, followed by the city centre, the inner city and the suburbs (Blinge, 2020).

The city of Gothenburg will be used as a case study for this thesis.

Swedish Agriculture and Sustainablity

A significant part of the imported food consists of products that we do not produce ourselves, like bananas, citrus fruits and coffee beans. However, we also import a substantial amount of goods that directly compete with Swedish production. Meat, various fruits and vegetables and dairy products are all examples. Furthermore, food consumption is a large source of carbon dioxide emissions in Sweden, with imported food accounting for 60 percent of these emissions (Lantbrukarnas Riksförbund, 2019). In other words, 50 percent of the food consumed in Sweden accounts for 60 percent of these emissions.

Food production is regarded as one of the most environmentally damaging operations on a worldwide scale. It depletes ecosystems through intensive land usage, disrupts the natural nitrogen cycle, and contributes to about one-third of global greenhouse gas emissions (IPCC, 2019). It is clear that Sweden's and the world's current food system is putting a toll on the environment, and that a new, circular food system is required to more sustainably feed future generations. Fortunately, there is a great deal of interest in what people are eating in Sweden. Many people's knowledge stretches even further, to include the origin of their food.

Urban agriculture could be established in underutilised urban locations. It has the potential to provide a more sustainable food source than the present food system, while also increasing public knowledge of the food chain and sustainable consumption. Simultaneously, urban agriculture helps cities adapt to climate change while also contributing to their greening and communal cohesion (FAO 2018). Supplementing traditional agricultural practices with innovative urban farming may be one approach to address the growing demand for food produced locally while also promoting a more sustainable food system.

The Food System

A food system includes land use, food production, processing, distribution, marketing, consumption, and waste. The function of the food system plays an important part in the urban context, and most cities must discover ways to make their current food systems more sustainable. This includes reducing food travel distances, protecting local farms, ensuring food security, an understanding of how food is produced and providing organic waste recovery facilities. A sustainable food system is, according to the Food and Agriculture Organization, FAO, *"a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised"* (FAO, 2018).

Land and Space for Agriculture

Urban agriculture can occur in practically any free place where it is possible to obtain land. Urban farming can for example be found in residential yards, industrial areas, parking lots, brownfields, vacant land, boulevards, parks, basements, facades and rooftops. There are primarily two land use categories where urban farming occurs, private commercial land and public land, each with its own set of obstacles. Private commercial land can be secured through a contract arrangement or lease with the landowner. Depending on the form and applicable legislation, public land often necessitates some sort of agreement with the local government, and the procedure may necessitate community involvement. Underutilised municipally held land, such as vacant areas or boulevards, may only necessitate a leasing deal. To evaluate whether there is community support for urban agriculture in public parks, a more thorough process, involving public involvement may be required (Buchan, 2013).

Figure 2.1: The food system components

Farming and Food Production

Primary food production encompasses the cultivation and harvesting of crops, as well as the breeding and slaughter of livestock. Soil-based agriculture needs fertilizer and Sweden is completely dependent on the import of artificial fertilizers. However, nutrients from toilets could replace the imports of fertilizers by up to 45 percent (Jönsson, 2019). To achieve high yields in limited urban spaces, urban agriculture systems tend to be more intensive using techniques such as hydroponics. For example, aquaponics is a system that combines aquaculture (growing aquatic animals in tanks) with hydroponics (cultivating plants in water). Due to the fact that urban farms are often located on smaller plots, and therefore prioritise high-value crops and low-impact growing practices, they circumvent some of the historical obstacles related to integrating agriculture where people live, work, and socialize. Lastly, to reduce or prohibit the use of agricultural pesticides in cities, urban farms should be organic (Buchan, 2013).

Processing and Distribution

Primary processing of foods entails a variety of post-harvest activities such as cutting, cleaning, packaging, storage, and refrigeration to ensure that they are not spoiled before reaching the consumer. Furthermore, food distribution serves as a link between those who produce food and those who sell it. Distribution plays a big role in why food is transported over long distances. Larger and competitive distributors may only purchase from bigger farms that provide a consistent supply of goods at low prices, even if it means transporting the food halfway around the world. Urban and smaller-scale farming could avoid these issues by "cutting out the middleman" and selling directly to consumers, for example, at Farmer's markets, as shortly described in the section below (Buchan, 2013).

Trading

Food produced by urban agriculture is primarily distributed primarily through four channels: *Community Supported Agriculture* (CSA), *Farmer's markets*, *Food retailers* (grocers and restaurants), and *Farmgate sales*.

Community Supported Agriculture (CSA): consumers make an initial investment in exchange for weekly farm produce deliveries.

Farmer's markets: provide a venue for product sales because they need no upfront investment and therefore provide farmers with access to a ready customer base.

Food retailers: some speciality grocery stores, like organic health food stores, or stores that specialise in local foods, will sell produces from urban farmers. In the restaurant industry, there is a growing interest in serving local cuisine.

Farmgate sales: Farmgate sales are trading that takes place on the farm itself. Farmgate sales, like many small rural farms, can offer an additional distribution channel for urban agriculture (Buchan, 2013).

Consuming

The linked advantages of urban farming extend to multiple aspects of a city's health and prosperity. It can include education about eating local food, enhanced understanding of where food comes from and farming education, all of which are in high demand as the older generations of farmers retire and urbanisation rises. The consuming part involves food preparation, processing and household food decision-making and cooking at both home and community levels (European Environment Agency, 2021).

Food Waste and Recovery

Food waste from urban farming has the potential to be recycled into compost for food production. Reusing organics for agriculture is a form of energy recovery, and given that more hydrocarbon energy is required to produce food energy, this is a critical component of making agriculture more sustainable. To encourage food waste reduction, urban agriculture could also provide composting education to the general population on how to recover essential food components and recycle them within the food chain, in an economical and sustainable manner (European Environment Agency, 2021).

UN Sustainable Development Goals

The Sustainable Development Goals (SDGs) are a set of 17 goals to address the challenges we are facing today. The aim is to achieve a more sustainable world and future for everyone with a time horizon of 10 years from now (United Nations, 2018). The goals have received a lot of attention as 192 countries are on the agenda and it will put some pressure on politicians and leaders to act for a more sustainable society.

Six of the seventeen UN Sustainable Development Goals could be applied to urban farming: number 3 (*good health and well-being*), number 6 (*clean water and sanitation*), number 11 (*sustainable cities and communities*), number 12 (*responsible consumption and production*), number 13 (*climate action*) and finally number 15 (*life on land*) (United Nations, 2018).

- *Additional vegetation space*
- *Place for recreaction in a busy city*

- *Rainwater drainage is delayed*
- *Water collection*

- *A place for social gatherings*
- *Making neigh-bour-hoods more*
- *inclusive More public and open space*

- *Urban farming and allotment gardens*
- *Locally produced food*

- *Adaption to climate*
- *Reduction of global warming*
- *Increasing the long-term viability of building stock*

- *Space for greenery*
- *Increasing biodiverstity*
- *A safe place for animals like birds and insects*

Theory

Sweden's population is expected to grow to 13 million people by 2070 (Statistikmyndigheten, 2021). Of these people, 93 percent of the population will be living in cities. To feed the world's still steadily growing population, more food will have to be produced. 90 percent of Sweden's 3 million hectares of arable land is already used for agriculture, leaving a small room for expansion (Horn, Ferreira & Kalantari, 2021). Sweden needs to use systems other than conventional agriculture and food importation for us to be able to deal with conceivable crises and a growing population. Sweden's food supply vulnerability could be addressed through urban agriculture.

Food Self-Sufficiency

Self-sufficiency in general is a theory of how groups or societies could support themselves without barter and foreign exchange trading. According to the Food and Agriculture Organization, FAO, *"the concept of food self-sufficiency is generally taken to mean the extent to which a country can satisfy its food needs from its own domestic production"* (FAO, 2016).

Food self-sufficiency can be characterised as a country having zero food trade, both imports and exports, and focusing its resources on its own agriculture in order to be able to produce all of its food needs domestically. However, in reality, such an extreme policy approach is not existing today, just as no country relies entirely on other foreign countries for its food.

The above definition of food self-sufficiency can be seen as extreme, instead, a more reasonable definition could be defined as *"a country producing a proportion of its own food needs that approaches or exceeds 100 percent of its food consumption"* (FAO, 2016). Food self-sufficiency is here expressed as a percentage of consumption. This is a definition that does not exclude trading. However, even if some of the food products consumed by its population are not the same as those farmed domestically, a self-sufficient country produces as much as or more food than it consumes in terms of calories (FAO, 2016).

Moreover, starvation and malnutrition can affect a section of the population even though the country is considered self-sufficient. While such countries may be able to produce sufficient quantities of certain crops, they may still require considerable imports of for example fruits and vegetables in order to maintain a healthy diet. Some self-sufficient countries may also have higher poverty rates, making it difficult for the entire population to get enough access to food while other self-sufficient countries may have no trouble providing enough nutritious diets for their citizens (FAO, 2016).

Countries face different circumstances with respect to levels of food self-sufficiency and food security

	Countries with SSR<80%	**Countries with SSR>120%**	**Countries with SSR = 80-120%**
Consumption at or above adequate nutritional intake	These countries are net food importers and easily meet their domestic dietary needs (hunger < 5%). Examples: Japan, United Kingdom, Republic of Korea, Iceland, Mexico	These countries typically meet their dietary needs (hunger < 5%) and export surplus food. Examples: United States of America, Australia, Argentina, Canada, Kazakhstan, Sweden	These countries roughly produce the same amount of food that they consume, meet dietary needs (hunger < 5%), and may export some food. Examples: South Africa, Brazil, Russian Federation, Germany
Consumption below adequate nutritional intake	These countries are net food importers but experience elevated levels of hunger (>15 % of the population). Examples: Liberia, Zimbabwe, Namibia, Yemen, Mongolia, Haiti	These countries experience mild (5-14.9%) or elevated (>15%) levels of hunger. Some of these countries still export food. Examples: Pakistan, Guyana, Thailand	These countries produce roughly the same amount that they consume, but experience mild (5-14.9%) or elevated (>15%) levels of hunger. Some of these countries still export food. Examples: India, Bolivia (Plurinational State of, United Republic of Tanzania, Chad, China

(FAO, 2016)

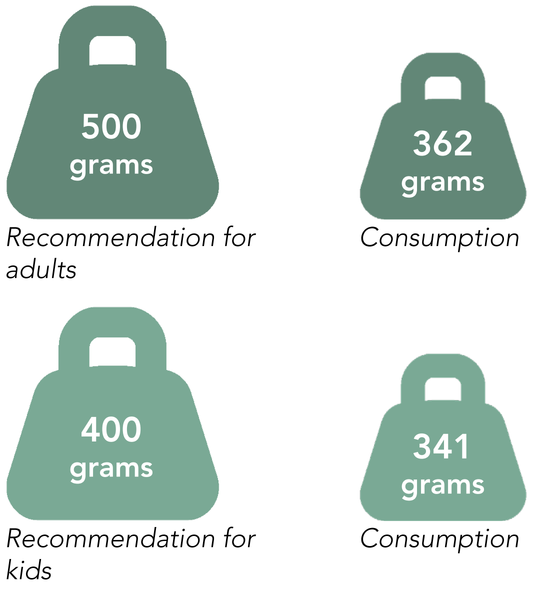
Figure 2.2: Food self-sufficiency in different countries

Being Self-Sufficient in the Production of Vegetables and Fruits

Sweden's food production has been declining since farming in Sweden is more expensive than elsewhere in the world, where wages are lower and pesticides are widely utilised in large-scale crops. Even foods we can easily farm ourselves, like tomatoes, are imported due to price discrepancies (Tengby, 2017). As previously noted, the majority of arable land in the peri-urban area of Gothenburg is used for grazing and monoculture (Wästfelt & Zhang, 2018). As a result, depending on present land use, more food, particularly vegetables and fruits, will need to be produced in the future to feed the local population.

The fact that eating fruits and vegetables is beneficial for health is not a controversial notion. Health trends come and go, but the knowledge of the benefits of fruits and vegetables on one's health dates long back. Consumption of fruits and vegetables in adequate amounts has long been a fundamental component of dietary guidelines.

According to Livsmedelsverket, it is recommended for us to eat 500 grams of vegetables and fruits per day, about half the amount of fruits and half vegetables. Potatoes are not to be included in the 500 grams of greens per day. A daily portion can consist of three fruits and two handfuls of vegetables. Half of the vegetables (125 grams) should be coarse, such as carrots, broccoli, cabbage, beans and lentils (Livsmedelsverket, 2021). However, only 17 percent of Swedish people (21 percent of all women, 13 percent of all men) reach that amount. Women eat an average of about 350 grams of fruit and vegetables per day and men about 300 grams. 70 percent of women but only 50 percent of men eat fruits and berries at least once a day (Livsmedelsverket, 2011).



The fibre and healthy carbs found in root vegetables, vegetables, legumes, fruits, and whole grains are essential for most of us. The body will get many vital nutrients whether eating fruit, berries, or a handful of vegetables. Important nutrients that our bodies need to feel good are fibre, vitamin C, folate /folic acid, vitamin K, potassium and antioxidants like carotenoids. Vitamin C, vitamin B6, potassium, fibre, and carotenoids are all found in potatoes and root vegetables. Vegetable sources of iron include legumes and green leafy vegetables. Protein is also abundant in legumes. It is beneficial to consume a variety of greens since different types of fruit and vegetables contain different nutrients (Livsmedelsverket, 2021).

Figure 2.3: The consumption of vegetables and fruits in different age groups

Reference Project

Østergro: Farming on Rooftops - Denmark

About

ØsterGro, Denmark's first rooftop farm, opened in 2014 on top of an old car auction house, Nellemannhuset. The idea became a reality with a visionary area renewal, a trusting building owner and supportive foundations, who all believed in the project of creating an organic farm in the middle of Copenhagen. A sponsorship from Nellemann Holding (an establishment by Copenhagen's Climate Quarter), the Foundation for Organic Agriculture and a strong collaboration with Byggros was thus the starting shot for ØsterGro. Today ØsterGro has 600 square meters of organic vegetables, fruit, greens, herbs and edible flower fields. The roof garden works like a regular mini-farm with vegetables, bees, chickens, rabbits and a greenhouse that is also used as a restaurant (ØsterGro n.d.).

How

The former empty roof got transformed into a beautiful farm. In April 2014, 110 tonnes of soil was placed onto the roof of the old car auction house, which had been prepared with underlay and edges made by carpentry apprentices from Copenhagen Technical School. The structure is made of a classic *BGreen-it* roof garden with a 40 mm water reservoir, filter cloth and finally 400-500 mm soil substrate. To create optimal growing conditions for vegetables and plants, a special mixture of soil substrates with extra high content of organic material is used. To get the largest possible plant areas, the soil substrates have been placed in raised plant beds.

With the help of over a hundred neighbours and volunteers, the field was laid out as fast as in one weekend. In collaboration with the farms, Seerupgaard and Stensbølgård, ØsterGro is organised as a *Community Supported Agriculture* (CSA) and sells its produce. ØsterGRO is cared for, nurtured and developed by two of the initiators, employees and all the committed members and volunteers who want to take part in the community. Seerupgaard itself supplies several of the crops that require slightly more soil, such as potatoes. Members pay for half of the harvest season in advance, in exchange for a weekly part of the harvest (ØsterGro n.d.).

Concept

Sustainability is the key concept in ØsterGro as well as the keywords involvement, dissemination and experiences. The vision is to make the city greener and to make ecosystems less foreign. ØsterGro is a platform for knowledge sharing and an appetizer for both young and old generations to inspire one another to a more sustainable way of life. However, the vision behind ØsterGro is not that the city itself should be self-sufficient in food production in the future by farming on rooftops. The aim was to create a link between the rural and the city, as urbanization has contributed to a loss of basic knowledge about how our food is grown and produced. With the ØsterGro project, the hope is to bring that knowledge back to the city (ØsterGro n.d.).

Figure 2.4: The roof top's greenhouse

Figure 2.5: A picture of the beautiful roof top with all types of vegetables in raised soil plant beds

Reference Project

The Cultivation Network of Seved: Farming on walls - Sweden

About

In a district in Malmö called Seved, the Seved Cultivation Network brings together people and property owners to farm the land in front of their homes. The land is leased to the property owners, and the organization *Odla i Stan* assists in the establishment of plantations and provides information through cultivation meetings. Residents learn more about organic gardening during the workshops and are inspired and supported to cultivate their own vegetables and herbs. Around 250 persons are involved in the farming network, of which 30–40 live in Seved. The majority of plantations are near residences, where property owners ensured that the grass was removed and replaced with 70 centimetres of organic soil (Odlingsnätverket Seved, n.d.).

How

Seved developed a big vertical edible plant wall in 2013. The plant wall is unique in the sense that it is edible and can be harvested throughout the year. The wall functions as a vertical community garden, which residents maintain and harvest. It is primarily composed of kale plants and perennial herbs during the winter. These vegetables are then replaced in the spring. In the summer the wall is brimming with lettuce, onions, chard, tomatoes, chickpeas, strawberries, and a variety of herbs. Each plant is grown in a textile bag that contains soil and is watered via drip irrigation. The bags are then placed in compartments that form a checkerboard pattern along the 50 square meters large and 5 meters high plant wall (Odla i Stan, n.d.).

Concept

Seved's cultivation network's role is to assist locals in getting started, as well as to encourage, motivate, coordinate, and educate communities about organic urban gardening. Not only is knowledge about farming exchanged, but also stronger relationships between people can be formed. This is referred to as socio-ecological agriculture. The main concept is that property owners offer the land and are responsible for providing equipment, soil, pallet collars, and irrigation options. Residents pay for seeds themselves.

Today, the Seved Cultivation Network is not limited to local residents, the association is accessible to the public and the large neighbourhood garden attracts visitors from outside Malmö's city limits as well. What began as a pair of pallet collars has now grown into full-scale urban agriculture in courtyards, walls and neighbourhood plots, totalling over 800 square metres of farming space in the heart of the city (Odlingsnätverket Seved, n.d.).

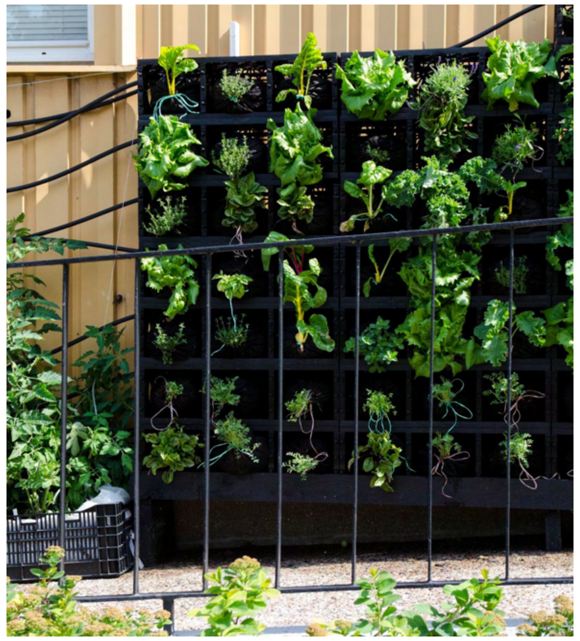


Figure 2.6: A closer view of the wall

Figure 2.7: The placement of plants in the wall

Figure 2.8: The wall in full growth

Reference Project

Glasir: A Tree Assembles in Brooklyn - U.S.

About

Glasir is a project based in Brooklyn that utilises a unique configuration of modularity and vertical farming to produce food. The preface to the project is the unsustainability of current agriculture, it being water-intesive, causes deforestation, loss of biodiversity due to land use, huge need for transportation and logistical infrastructure. Glasir resembles a tree, both in appearance and development of the structure. This is intentional to reap the benefits of the mental and physical health, property value and cultural significance that trees contribute to while maintaining a small footprint that makes this structure possible to build anywhere. Glasir also tackles problems of food poverty by increasing the accessibility to locally produced, high-quality food (Framlab, n.d.).

How

Glasir uses prefabricated modules to minimize waste, cost and construction time. The modules grow the food through aeroponics, which is a soilless growing method that generates comparable crop yield while using 10 percent of the area of traditional agriculture, 10 percent of the water and reduces the need for fertilizers and pesticides. Additionally, the roots absorb a higher level of minerals and vitamins which generates more nutritional vegetables. One module can produce approximately 218 kg per year, and a tree can produce approximately 21 800 kg per year. Access to the food is created through a subscription service and the modules are distributed through drones (Framlab, n.d.).

Concept

There are different types of modules with different functions: growth, production and access. All modules can connect to each other which allows a big variety of configurations to take into consideration the local context. Just like a normal tree, Glasir grows according to needs. It uses an AI to optimize growth and distribution within its own structure as well as neighbouring trees. In other words, the trees communicate with each other to adapt and relocate modules to each other and households. Energy is harvested and stored for charging devices. There is also a rainwater collection system that stores, purifies and pumps water to the aeroponics modules.

There is a correlation between food security and health risks. Glasir is placed in the poorest neighbourhoods of Brooklyn to combat these issues and increase awareness. It plants a seed for better mend in the economy and society (Framlab, n.d.).

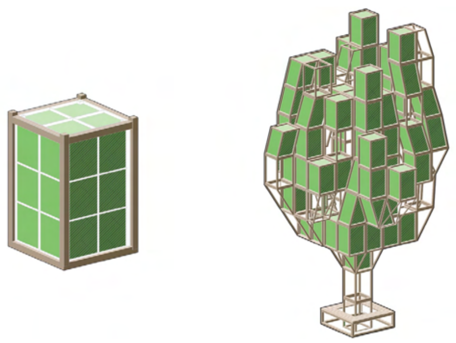


Figure 2.9: A prodction module and a full tree

Figure 2.10: The Glasir tree placed on an empty plot of land

Figure 2.11: The tree creates room for interaction and adds to the green structure of the city

Chapter Three

Handbook on Urban Agriculture

Food and the City

3

The following chapter consists of the handbook *Food and the City* that can be read independently of the booklet. It is a fact-based handbook about the agricultural systems and their possible implementation in the city fabric.

Food and the City

CHALMERS
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May 2022

This is a product of the master's thesis *The Productive Fringe: Making Gothenburg Self-Sufficient in Vegetables and Fruits by Exploring Urban Agriculture in the Intermediate City.*

Foreword

It is a late afternoon in August and a light breeze grabs the hammock you are laying in, high above the rooftops. Then imagine only having to reach out your hand to pick a sweet raspberry. Or having a stroll in the courtyard to harvest fresh spices for dinner. Cooking food that is locally grown is a blessing. There are personal motives that include the satisfaction of being able to influence your immediate environment and the joy of working and farming with others.

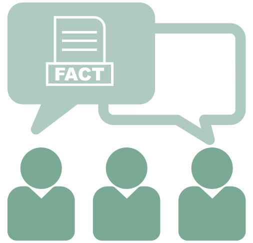
Urbanisation is accelerating at the same time as it is becoming harder to find leases and increasingly expensive to buy a condominium. In addition, the availability of green spaces and places for recreation and farming needs to increase. Farming on roofs, courtyards, parks, balconies and facades is all part of an improvement of ecological diversity. Each place contributes to a green corridor in an urban landscape. A variety and richness of species allow insects to find the plants they need to survive.[1] Your own balcony thus contributes to a more sustainable city. The agricultural ideas for different typologies and places can be scaled up or down depending on the size of the surface.

Another positive side of agriculture is social sustainability. Urban agriculture acts as an interconnecting link between the city and the countryside and at the same time, it has an important social function. Via farming, meetings are created across societal norm boundaries and contribute to strong cohesion. Farming can create solidarity, together people make something of great importance.[2] Urban agriculture also functions as a public space, a development of the traditional park as people are more active and can function in new ways.

In this book, you will learn how to succeed with agriculture in a project. You get to read about how to make a convincing case as to why you should implement urban agriculture, some of the different agricultural systems available today, which plants thrive in which systems, how to arrange suitable growing conditions and finally discover design strategies for integrating these systems into your project. Whether your project is an urban design, a new building, a renovation or an extension, you will find inspiration in this handbook!

Reading Instructions

1 Look in the "Why" chapter for arguments and to build a strong case about why you should implement an agricultural system in your project.



2 Look in the "How" chapter for information about the different systems to find the best fit according to yield, water needs, weights, crop type and typology.

3 Look in the "Where" chapter to find information about the placement within the city fabric.

4 Look in the "What" chapter to find inspiration on the design possibilities to implement urban agriculture.

Content

WHY?

1

Why is it necessary to get started with urban farming? This chapter discusses the urban challenges we are facing today and what farming could contribute to within the urban context. This gives insight into the opportunities and possibilities of urban agriculture.

Urbanisation and Food Production

Feeding a population of 9 billion people by 2040 will be one of humanity's greatest challenges. How we feed our cities is becoming an increasingly pressing matter as a result of fast urban expansion and the challenges posed by the climate emergency. By 2050, cities will consume 80 percent of the world's food. Bringing food production closer to the people is worth looking into because it addresses the issue of food being transported long distances, before reaching a shop or consumer.[3] Furthermore, to restore and strengthen the relationship between urban and rural areas. There are also personal motives such as the joy of working together with others and the satisfaction of being able to influence one's physical immediate environment.

We are constantly presented with potential solutions to many of the problems, yet few of these are implemented on a scale big enough to make a change. Rooftop gardens in Bologna, Italy, can provide 77 percent of the vegetables necessary to sustain the population of the city.[4] Similarly, Sweden can become completely self-sustaining when it comes to food production simply by utilizing the flat rooftops for urban agriculture.[5] Looking at a city, there are many spaces that can be used for urban agriculture to promote sustainable food production.

UN Sustainable Development Goals

The Sustainable Development Goals (SDGs) are a set of 17 goals to address the challenges we are facing today. The aim is to achieve a more sustainable world and future for everyone with a time horizon of 10 years from now. The goals have received a lot of attention as 192 countries are on the agenda and it will definitely put some pressure on politicians and leaders to act for a more sustainable society.

Six of the seventeen UN Sustainable Development Goals could be applied to urban farming: number 3 (*good health and well-being*), number 6 (*clean water and sanitation*), number 11 (*sustainable cities and communities*), number 12 (*responsible consumption and production*), number 13 (*climate action*) and finally number 15 (*life on land*).[6]

- *Additional vegetation space*
- *Place for recreaction in a busy city*

- *Rainwater drainage is delayed*
- *Water collection*

- *A place for social gatherings*
- *Making neighbour-hoods more inclusive*
- *More public and open space*

- *Urban farming and allotment gardens*
- *Locally produced food*

- *Adaption to climate*
- *Reduction of global warming*
- *Increasing the long-term viability of building stock*

- *Space for greenery*
- *Increasing biodiverstity*
- *A safe place for animals like birds and insects*

Plant Categories

All vegetables consist of substances that are important to us in different ways. Vegetables and fruits can further be divided into roots, legumes, leafy greens, vine plants, fruit trees and fruit plants.

Roots

Root vegetables are a great source of energy and consist of important antioxidants, vitamins, minerals and fibres. Root vegetables are usually biennial plants. The nutrients are collected in a root, which produces flowering and seeding the following year, after which the plant dies. Crop rotation is necessary for good harvests and to prevent invasive insects and fungal diseases from becoming established.[7] Examples of root vegetables are: carrot, parsnip, celeriac, black root, Swedish turnip, beetroot and radish.

Legumes

Legumes contain carbohydrates and fibre, and in many cases also protein. Dried legumes contain about as much protein as meat and fish, about 20 grams per 100 grams. Legumes that are soaked and cooked, as they usually are when we consume them, contain around 8-12 grams of protein per 100 grams. Different varieties give long harvest periods and also food for the winter in the form of dried beans and peas.[8] The legume family of plants includes lupins, peanuts, chickpeas, and all kinds of beans and peas.

Leafy greens

Leafy greens are edible leaves of various vegetable plants. They are packed with vitamins, minerals, antioxidants and fibre. Leafy greens do not require a large space to grow and if sown in batches, harvest is possible from early spring to late autumn. Examples of leafy greens are chard, spinach, pak choi, kale, cabbage, lettuce, arugula, asparagus and herbs.[9]

Vine plants

Vine plants are a collective name for vegetables whose fruit is consumed. In general, all vine plants want a sunny position and protection from wind. Since the Swedish hot summer period is short, vine plants often need to be pre-grown. This means sowing them in a pot indoors already in February or March, to give the vine plants a head start for when it is time to replant them outdoors.[10] Examples of vine plants are avocado, tomatoes, peppers, cucumbers, eggplant, pumpkin and squash.

Fruit trees

Fruits generally have high fibre, water, vitamin C and sugar levels. In Sweden, it is possible to grow a number of different fruits in the garden. Preferably fruit trees should be positioned in a sunny place so that the fruits get sweeter and ripen faster.[11] Fruit trees are generally large, but there are also weak-growing ones that are grown to fit on a terrace or balcony. Examples of fruit grown on trees are apricot, fig, apple, kiwi, cherry, peach, plum and pear.

Fruit plants

Berries contain most of what is useful in fruits and vegetables, but in extra large amounts. Berries are generally more nutritious than fruits, for example, vitamins C and E.[12] Examples of fruit plants are blackberries, blueberries, raspberries, strawberries, gooseberries, wild strawberries, lingonberries and currants.

Framework

In order to optimally position the agricultural systems the framework was created. It shows the sunlight needs, the harvest season and in which agricultural system each vegetable and fruit group can be grown. The harvest season does not take into consideration climate-controlled systems such as greenhouses with artificial lighting, which can prolong the harvesting to all year round.

As a designer on a specific site, you need to take into consideration the local sunlight quality, soil quality and related functions in the area. The framework is merely a help to pick the system and food types of interest and will.

Plant Type	Light	Harvest Season	Agricultural System
Roots	Sunny Partial shade	All year around	Flood & Drain, Drip System, Traditional Agriculture, Roofs
Legumes	Sunny	Late Spring Summer Fall	Flood & Drain, NFT, Soil bed, Traditional agriculture, Roofs, Green walls
Leafy Greens	Partial shade	Summer Fall	All systems
Vine Plants	Sunny	Summer Fall	Flood & Drain, Drip System, Aeroponics, Soil bed, Traditional agriculture, Roofs, Green walls
Fruit Trees	Sunny	Summer Fall	Traditional agriculture, Roofs
Fruit Plants	Sunny	Summer Fall	All hydroponics systems, Soil bed, Traditional agriculture, Roofs

HOW?

2

In order to make an impact on a city scale, optimization of urban agriculture is vital. This chapter introduces the fundamental principles of urban agriculture, different cultivation methods and their respective yields.

Systems

Several techniques and principles can be implemented for urban agriculture. This handbook shortly describes the two main methods, *geoponics* and *hydroponics*. Which system to use varies from place to place and the scale of a project. Hydroponics could be excellent for large scale projects and industrial purposes, as hydroponics is more technologically advanced and uses superior techniques. However, if working on a small scale, it is unlikely that a garden would make use of the full potential of a hydroponics method. In this case, geoponics simplifies the process, will use less energy on a small scale and will require fewer additional products to be bought by the users..

Geoponics

Geoponics means the art or science of cultivating the earth, agriculture. The term geoponic in farming practice refers to growing plants in normal soil. This usage is mainly found when soil growing is contrasted with techniques such as hydroponics, where the plants are grown in water.[13]

Hydroponics

Hydroponics is a cultivating technique that is soil-free. Instead, the plants grow on a substrate made of sand, clay or rock material. The roots are submerged in a nutrient solution made of water and macronutrients like nitrogen, phosphorus, sulphur, potassium, calcium and magnesium. The major benefit of this technique is the reduced water use of 60-70percent compared to traditional outdoor agriculture.[14]

There are a few different systems to implement hydroponics with different benefits and challenges. These are *The Drip System, The Flood and Drain System, Raft Culture, Nutrient Film Technique (NFT).* Other systems that are included, but slightly differ from regular hydroponics, are *aquaponics* which uses the waste of fish as a part of a closed-loop nutrient cycle, and *aeroponics* which is a system where the plants are grown in a mist of nutrient solution.[15]

Traditional Agriculture

Traditional agriculture can be seen as a primitive form of food production that relies on indigenous knowledge, land utilisation, organic fertiliser, traditional equipment and the farmers' cultural beliefs. It is still the most prevalent method of food production in agriculture, with half of the world's population reliant on it. Technology has advanced over time, and new equipment has been introduced to make farming quicker and more efficient. However, five traditional farming methods are still used and popular today:

Agroforestry: refers to the deliberate planting and maintenance of trees on the same plot of land as agricultural crops.

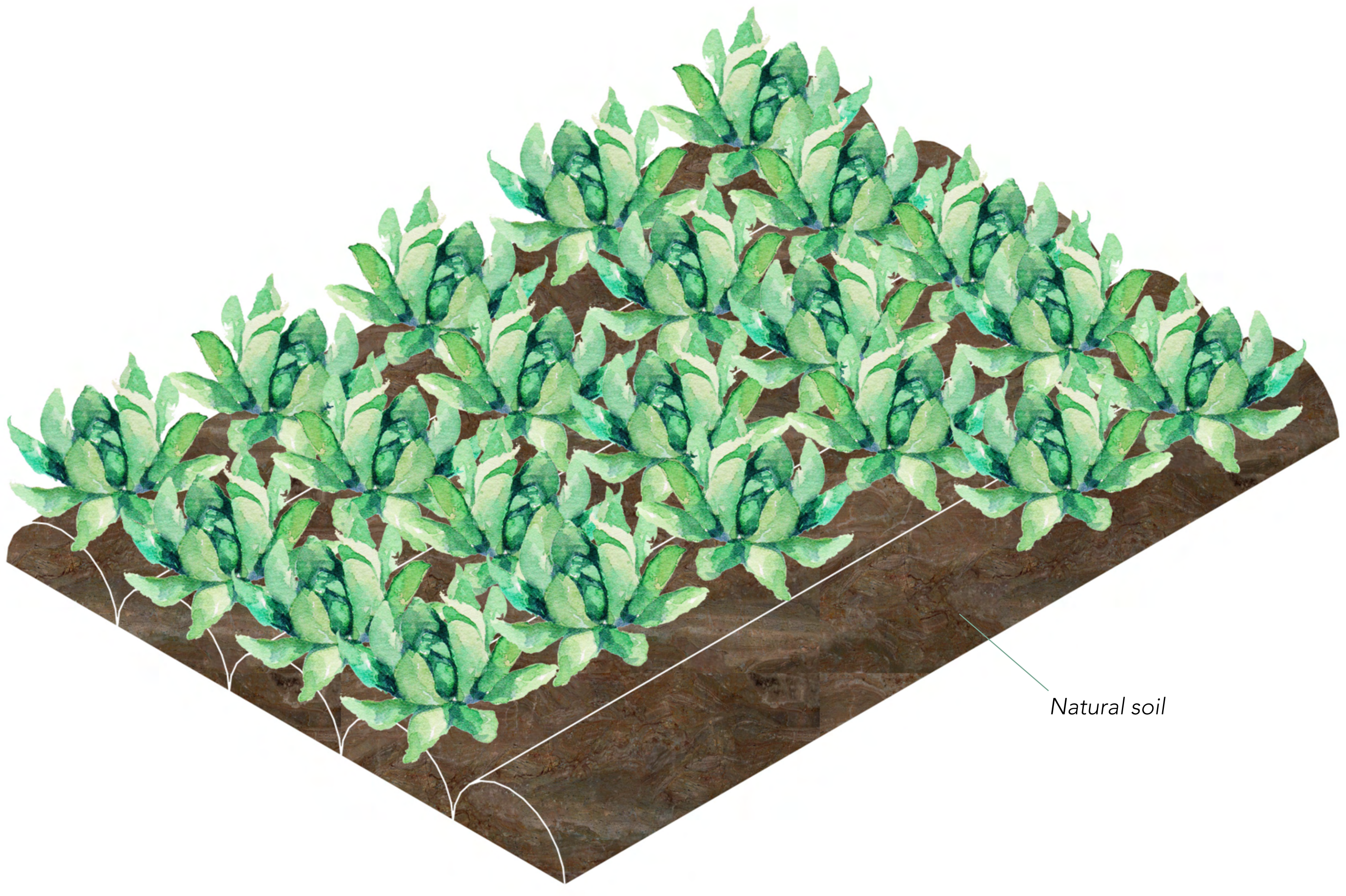
Crop rotation: is the process of growing different crops on the same piece of land at different times of the year, based on the seasons.

Intercropping: sowing more than two crops at the same time. Intercropping is a great way to make the most of the resources.

Polyculture: is another method of growing a large number of plants of various species in the same space.

Water harvesting: reduces the demand on wells while also providing safe drinking water. Rainwater is usually collected from roofs and used on agricultural crops or stored for further agricultural use.[16]

Place:	Outdoor
Typlogy:	Parks, court yards, ground
Crop:	Vegetables and fruits
Yield:	1,5 - 2,5 kg/m^2
Water needs:	60 l/kg
Weight:	–
Construction cost:	Low



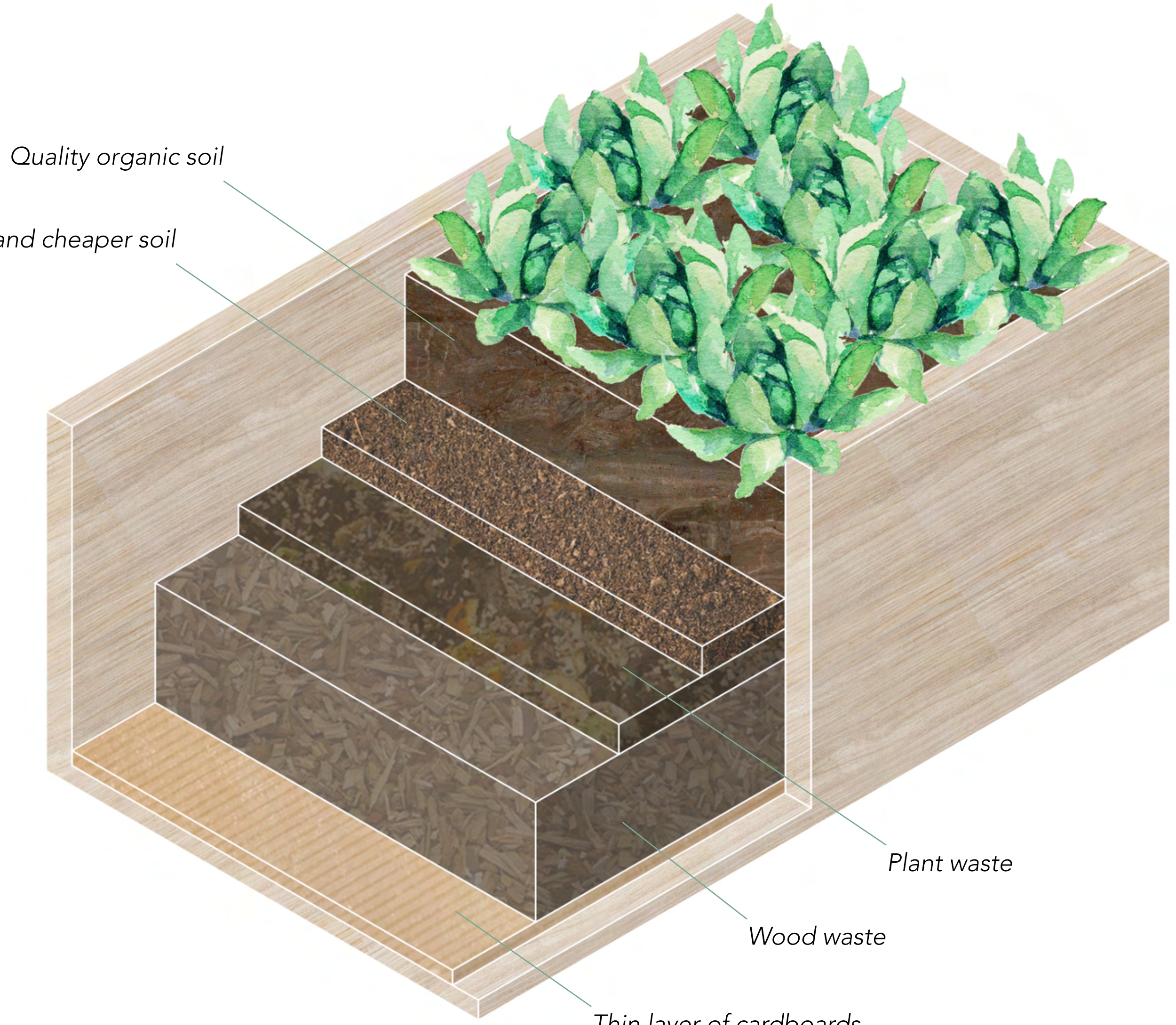
Raised Soil Bed

One of the most critical components of a successful harvest is healthy soil. A soil bed can be filled with a soil blend that is superior to the existing native soil in the yard, therefore raised soil beds can give an immediate advantage over traditional agriculture.

A soil bed consists of different layers. To create a bountiful environment the soil should be amended with organic material such as rotten hay, plant debris and compost. Wood waste takes a long time to decompose which makes it a good organic material as the plant roots can trek deeper into the raised soil bed to receive nutrition. It will act as a large sponge, retaining water and ensuring that a good moisture level is maintained.[17]

A raised soil bed is also one way to extend the season, it makes it possible to grow and harvest vegetables up to months earlier as the soil itself is heated naturally by manure and hay.[18] Most vegetables require at least eight hours of full light per day for optimal yield. The more sun, the better, so the soil bed should be positioned in the brightest position. Low, rainy regions where the soil could become saturated should be avoided.

	Place: Outdoor
	Typlogy: Parks, court yards, roofs, balconies
	Crop: Legumes, leafy greens, vine plants, fruit plants
	Yield: 2 - 3 kg/m^2
	Water needs: > 20 l/kg
KG	***Weight:*** 340 - 730 kg/m^2 (point load)
	Construction cost: Low

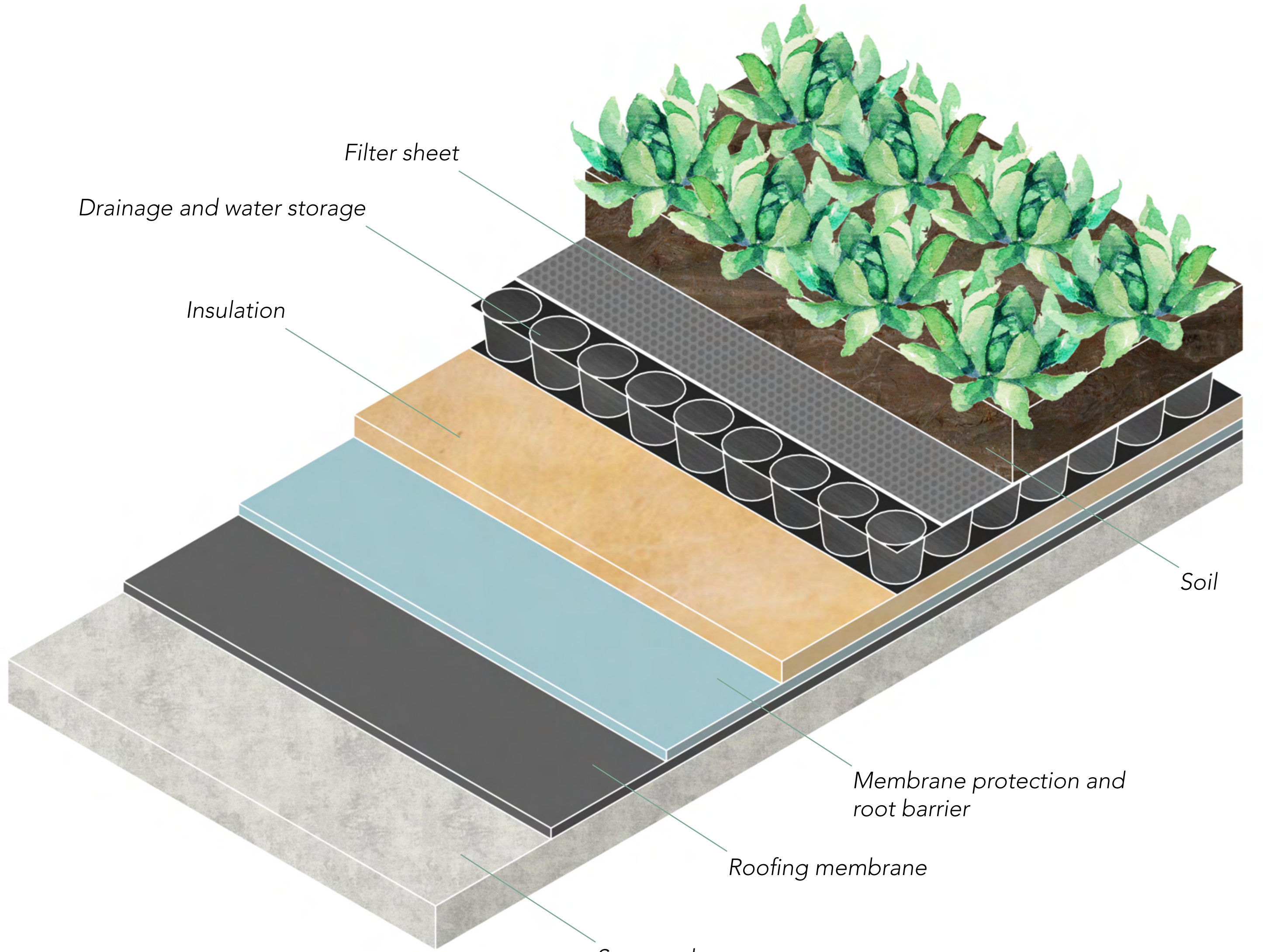


Green Rooftop

A green roof refers to everything from a thin layer of sedum plants to thicker plant beds with bushes and trees. In Sweden, we have a long tradition of green roofs where grass and peat grow on a suspended roof of strong planks covered with birch twigs. Today most roofs are made of sedum plants when talking about green roofs. A sedum roof consists of herbs and succulents that can cope with a thin layer of soil and can withstand drought well, for example, plants such as yellow cloves, chives and different herbs. Sedum roofs can be placed on existing roofs without reinforcement and can withstand roof slopes up to about 30 degrees.

How deep the plant bed is on the green roof determines what vegetation is possible and what load it will constitute, which in turn affects the design of the floor, the choice of the waterproofing system, and insulation. Green roofs can store a lot of water, especially when compared to traditional roofs that don't have any water storing capacity. Water is taken up by vegetation and evaporated back into the atmosphere. In addition, this helps to delay stormwater and relieves pressure on the city's water system.[19] The image to the right showcases a typical green roof, although the different layers depending on how deep the soil bed is.

	Place: Outdoor
	Typlogy: Roofs
	Crop: Vegetables and fruits (depends on soil/medium depth)
	Yield: 2 - 3 kg/m^2
	Water needs: > 20 l/kg m^2
KG	***Weight:*** 50 - 200 kg/m^2
	Construction cost: Medium

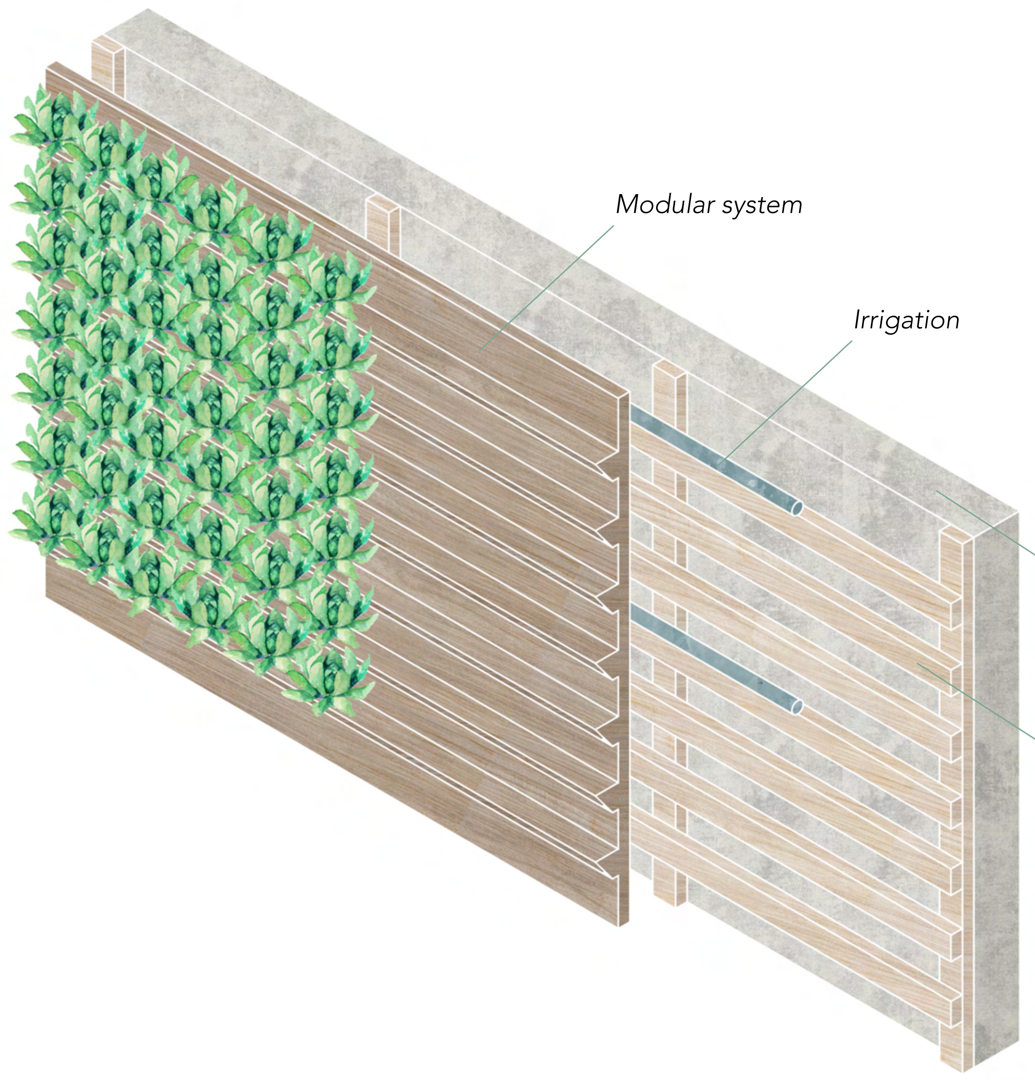


Green Wall

Green walls or living walls as they also are called, are vertical structures that can consist of various types of plants, vegetables, and other greenery. The plants are frequently grown in soil, stone, or water. To create a green wall, pre-vegetated modular panels or integrated fabric systems are affixed to a structural wall or frame. The modular systems typically consist of sloping boxes stacked tightly on top of each other, or larger blocks of vertical cassettes with holes where the plants are grown. These systems are sometimes pre-planted. The advantage of pre-grown systems is that they cover the wall with greenery from the start and they are often simple to install. However, site-established systems have the advantage of allowing for more flexibility in plant selection and allowing the plants to become accustomed to the specific location where the green wall is installed.

Water for an automatic drip irrigation system should be connected prior to the installation of the wall. A green wall is a bright and wind-exposed growing area, which means that the plants' water needs are grand. Finally, green walls can be installed both inside and outside, as freestanding installations or as extensions of existing host walls, and in a variety of sizes.[20]

Place:	Outdoor/indoor
Typlogy:	Facades and walls
Crop:	Leafy greens, vine plants, legumes
Yield:	2 - 3 kg/m
Water needs:	> 20 l/kg m^2
Weight:	90 - 110 m^2
Construction cost:	Medium

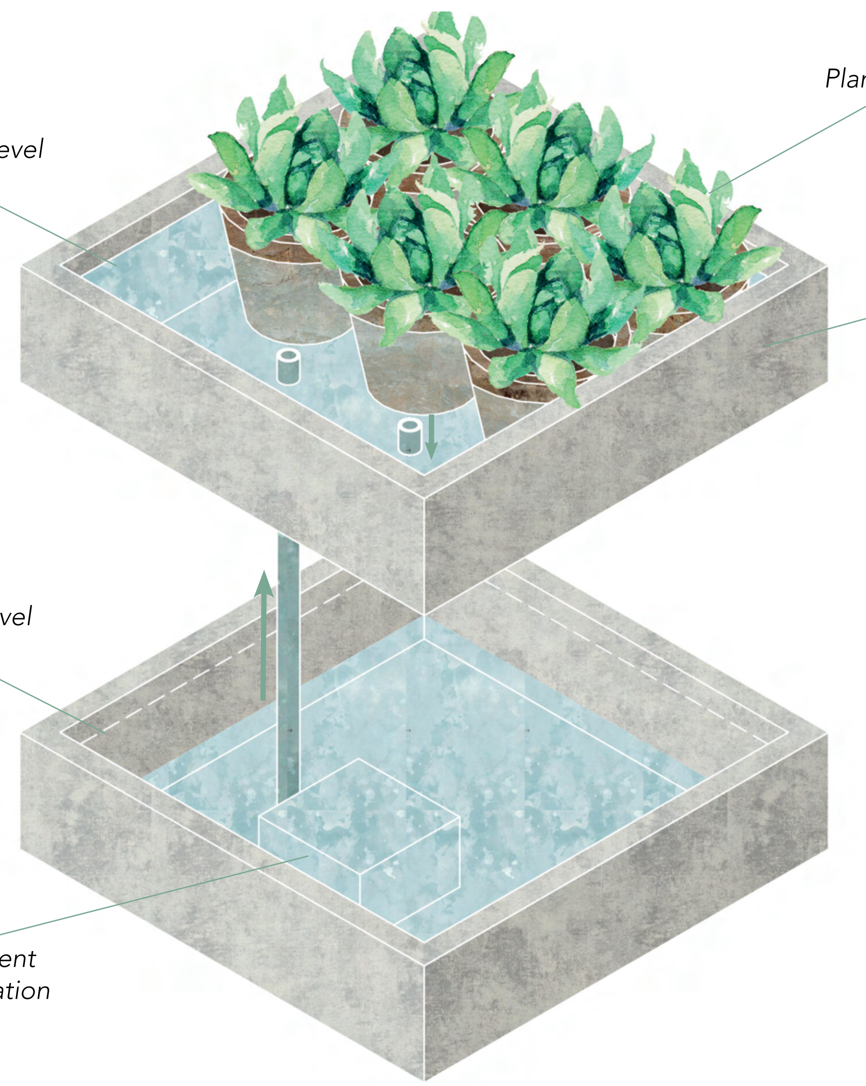


The Flood and Drain System

The Flood and Drain System is mainly used for commercial agriculture of deep-rooted vegetables. The vegetables are grown in containers filled with aggregate. These are placed in big waterbeds that cover the entire floor of the greenhouse. A pump periodically fills the waterbed with nutrient solution and then it is drained into a nutrient tank to replenish the nutrients and give the vegetable roots access to oxygen. The cycle is repeated depending on the conditions and the crop type. Some challenges of this system are the weight which makes it inappropriate for rooftop agriculture.[21]

This system is relatively low cost in comparison to many other hydroponic systems. The plants can be planted directly in the aggregate, however, planting them in containers is beneficial because it allows for relocation if necessary. The flood-and-drain system is easy to maintain. The reservoir has to be periodically changed and a new batch of the nutrient solution has to be created.[22]

	Place: Indoor
	Typlogy: Greenhouse, ground level, basement
	Crop: Roots, legumes, leafy greens, vine plants, fruit plants
	Yield: 40 - 50 kg/m^2
	Water needs: 15 - 20 l/kg
KG	***Weight:*** 100 - 120 kg/m^2
	Construction cost: High

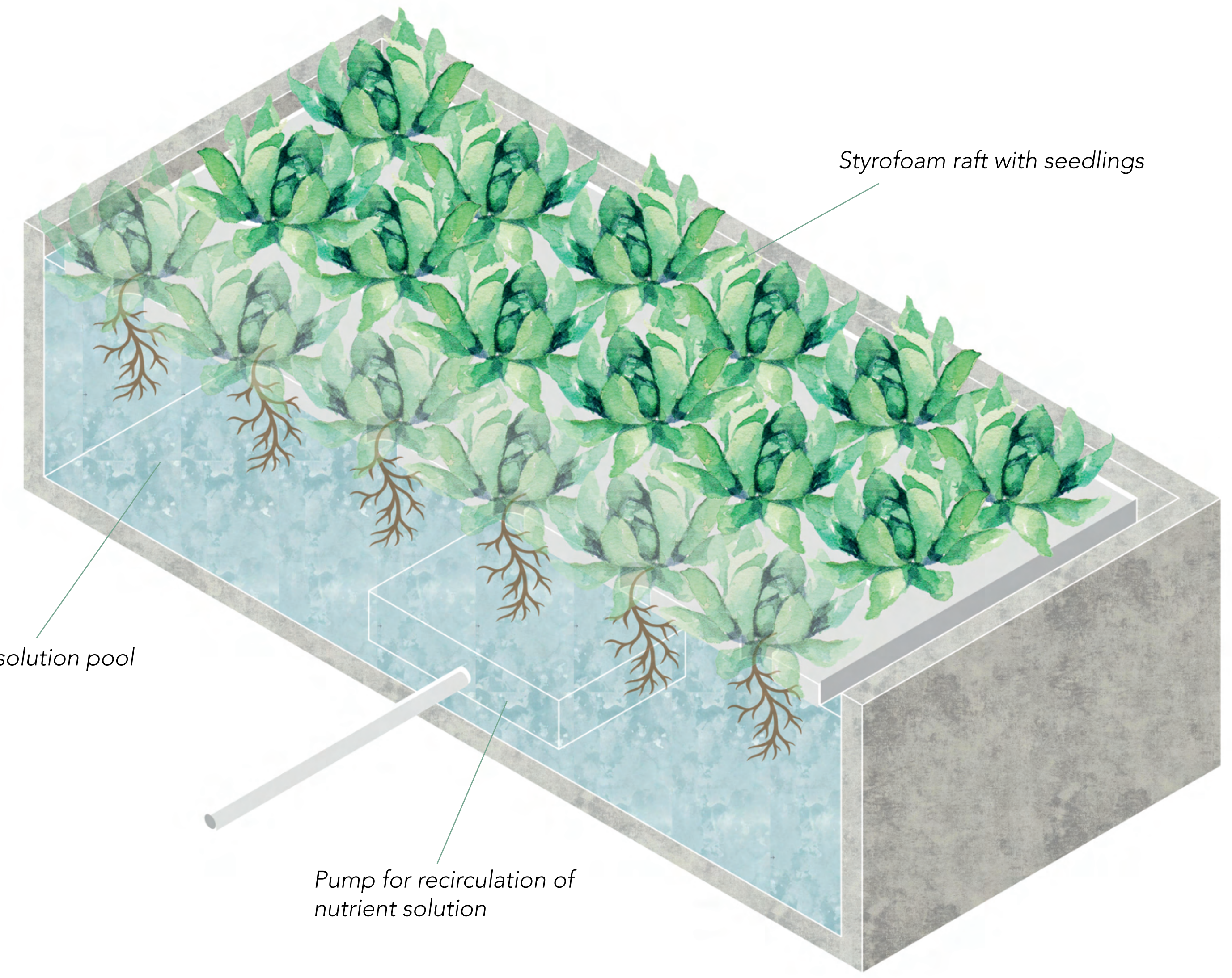


Raft Culture

In the raft culture system, the roots of the plants are submerged in a deep bed of nutrient solution (waterbeds). This method is mostly used commercially to grow lettuce and herbs on rafts made out of perforated styrofoam and it efficiently uses the floor space of the greenhouse. The nutrient solution is circulated to a tank where it is sterilized, aerated, replenished, and then pumped back into the system. Similar to other systems, the raft culture system is not suitable for rooftop farming due to the weight of the system. However, it can be implemented on the basement or ground floor level.[23]

The plants receive oxygen by creating the nutrient solution. The temperature of the solution is important for the plant's retention of oxygen. Another important factor is the pH level which is dependent of the need of the plant. A benefit to this system is the possibility to change the spacing between the plants depending on the growth stage. The distance can be increased in later stages to account for growth and light needs.[24]

	Place: Indoor
	Typlogy: Greenhouse, ground level, basement
	Crop: Leafy greens, fruit plants
	Yield: 40 - 50 kg/m^2
	Water needs: 15 - 20 l/kg
KG	***Weight:*** 100 - 120 kg/m^2
	Construction cost: High

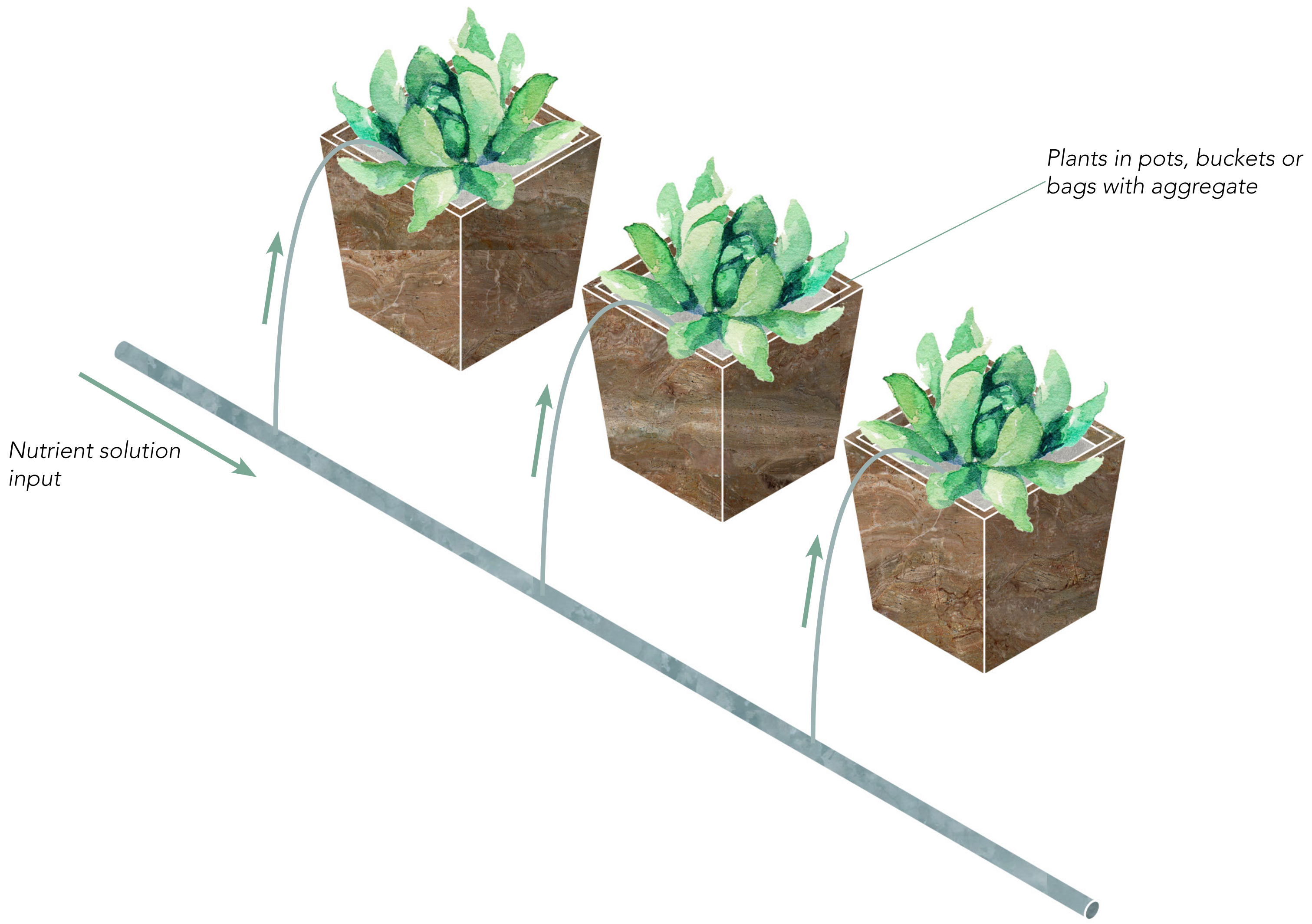


The Drip System

The Drip System is lightweight and thus suitable for rooftop farming. It is the preferred system for growing vine crops like tomatoes, cucumbers, and peppers. They are planted in containers with growth medium and the nutrient solution is carried through irrigation lines. Each plant has a personal emitter and the drip rate is determined by crop, conditions, and stage of growth. Some of the benefits of this system are the high yield due to the level of control, the roots are aerated as the nutrient solution mixes with air, it is water-efficient and there is no overflow since the plants absorb all of the nutrient solutions. The challenges with this system are the dependence on a pump where the plants can easily die if it breaks and clogging in the irrigation lines due to the minerals. They need regular cleaning.[25]

The drip system allows the plants to produce more fruit than traditional agriculture, although there is a downside to the shared reservoir that increases the risk for diseases to spread to all the plants. There is also a learning curve to understanding the nutrient needs of each plant, the drip rate, and how to support the plants as they grow. When the system is up and running, it is easy to increase capacity by adding more pots or buckets to the system.[26]

Place:	Outdoor/indoor
Typlogy:	Rooftops, greenhouses, ground level
Crop:	Roots, leafy greens, vine plants, fruit plants
Yield:	50 – 70 kg/m²
Water needs:	15 l/kg
Weight:	25 kg/m²
Construction cost:	High

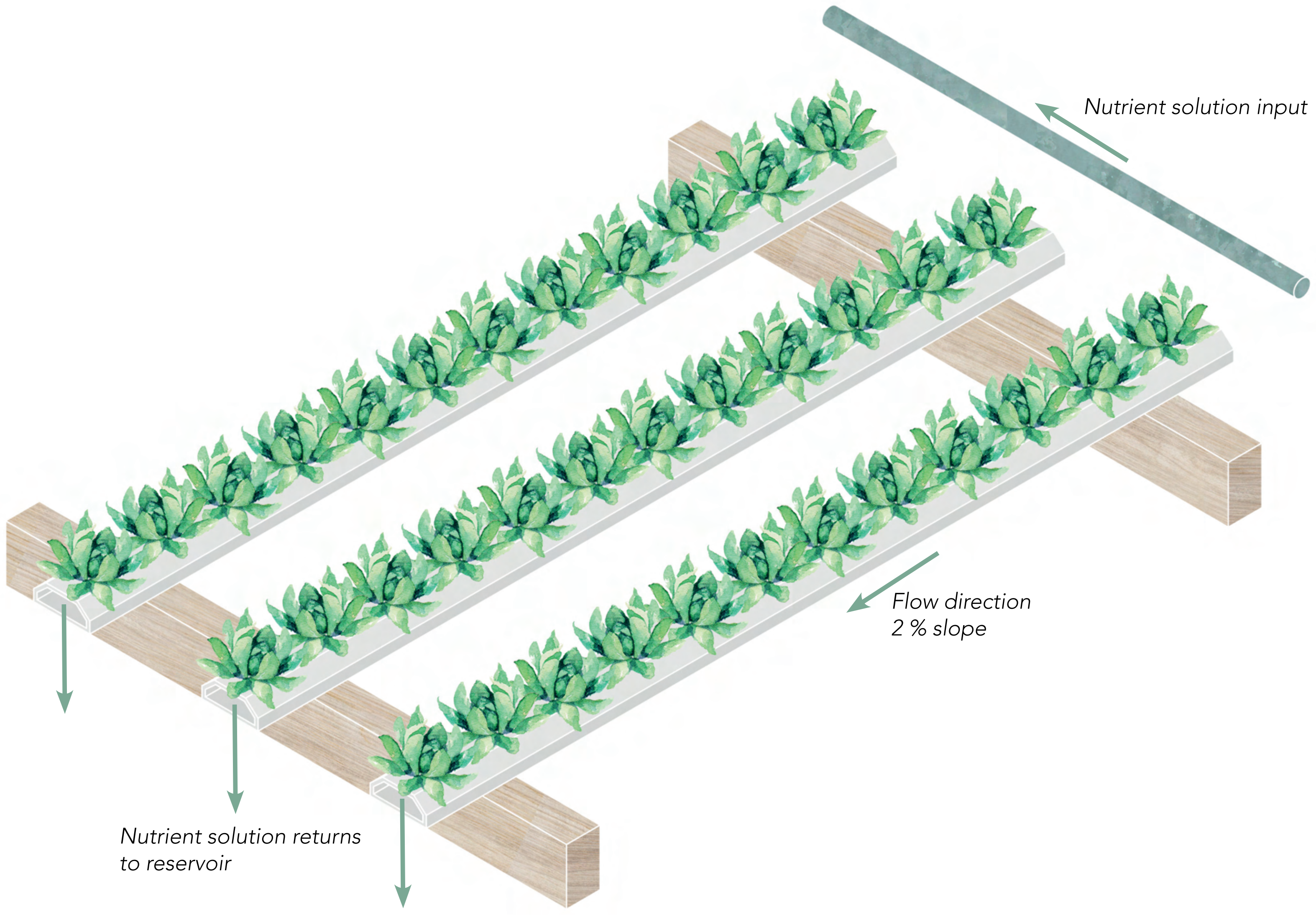


Nutrient Film Technique

The Nutrient Film Technique (NFT) is most frequently used for growing leafy greens. The roots of the plants are suspended in a long trough. The nutrient solution is trickled down this trough and is then recirculated, sterilized, aerated, replenished, and pumped back into the system. There is a small inclination in the trough to allow the solution to flow downwards.

The benefits of this system are the relatively low setup and construction cost. It is a lightweight construction which makes it flexible and space-efficient, thus ideal for rooftop integration. It is also the highest-yielding growing method. Some challenges are that the nutrient solution depletes in concentration further down the trough due to the first plants extracting the nutrients. Another challenge is that growing roots can divert water from the plants further down. This method is labour-intensive and requires monitoring and calibration.[27]

Place:	Outdoor/Indoor
Typlogy:	Vertical systmems, rooftops, greenhouses
Crop:	Legumes, leafy greens, fruit plants
Yield:	45 – 80 kg/m^2
Water needs:	15 l/kg
Weight:	5 – 10 kg/m^2
Construction cost:	High

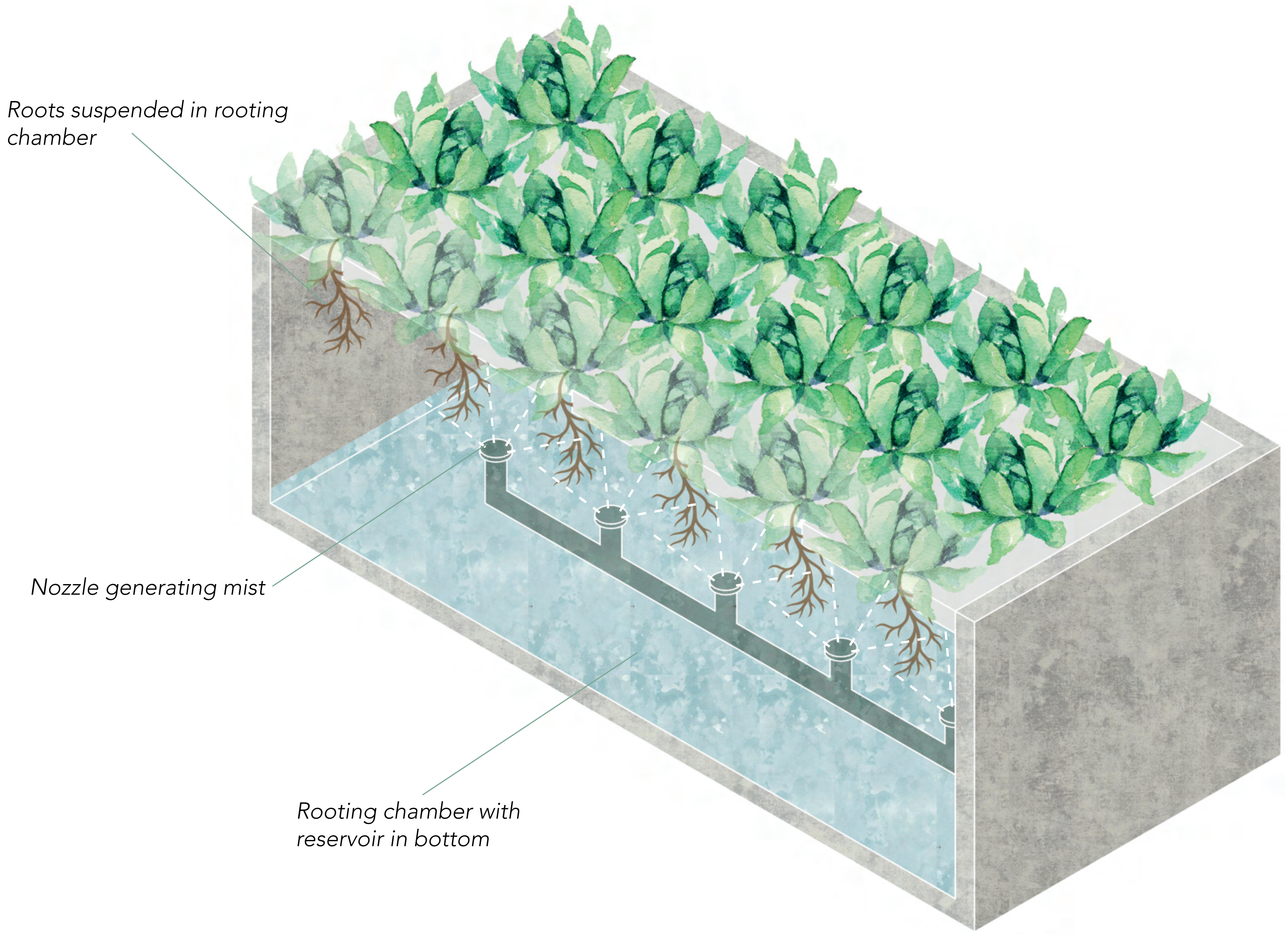


Aeroponics

Aeroponics is a version of hydroponics but it differs in the way that the plants don't grow in water or aggregate. The roots are uninterruptedly sprayed with a fine mist of nutrient solution which is more easily absorbed by the roots. This allows a higher yield than recurrent spraying. One version of this system consists of vertical structures that are about 1,5-2 meters with a water reservoir in the base. The aeroponic system requires high-pressure pumps and nutrient filtration to prevent the nozzles from clogging.[28]

The benefits of this system is that it is more profitable, easier to monitor, has many opportunities for building integration and uses 70 percent less freshwater compared to hydroponics. Additionally, the process of aeration is not necessary because the roots are essentially grown in air. Some of the challenges and limitations are the risk of clogging in the nozzles spraying the roots which are only suitable for smaller plants.[29]

Place: Indoor
Typlogy: Vertical systems, rooftops, greenhouses
Crop: Leafy greens, vine plants, fruit plants
Yield:
Water needs: 5 l/kg
Weight:
Construction cost: High



Aquaponics

Aquaponics is a symbiotic relationship between aquaculture (fish farming) and hydroponics that produces both fish and plants.[30] The system consists of a loop of three living organisms: the fish, the plants and microbial communities. The microbial communities transform fish excrement into plant fertilizer for the nutrient solution. The ammonia from the fish urine is broken down and filtered through a bacterial process to create nitrates. These are used in the nitrogen cycle that allows the plants to extract nutrients from the water as well as clean it. The water is then used for the fish. Food for the fish is practically the only addition to the system, but also the missing nutrients for the plants.

Ideally, the system should be in an equilibrium of the plant's nutrient needs and the fish excrement so that no additions have to be made. This system needs monitoring of the temperature and oxygen level of the fish tank as well as the nutrient concentration of the plant water. A well-balanced aquaponic system produces a higher yield than a hydroponic system and uses a sustainable source of nutrients for the plants.

The aquaponics system can be connected to any of the hydroponic systems described above.[31]

Place:
Indoor, outdoor, usually CEA

Typlogy:
Ground level, greenhouses

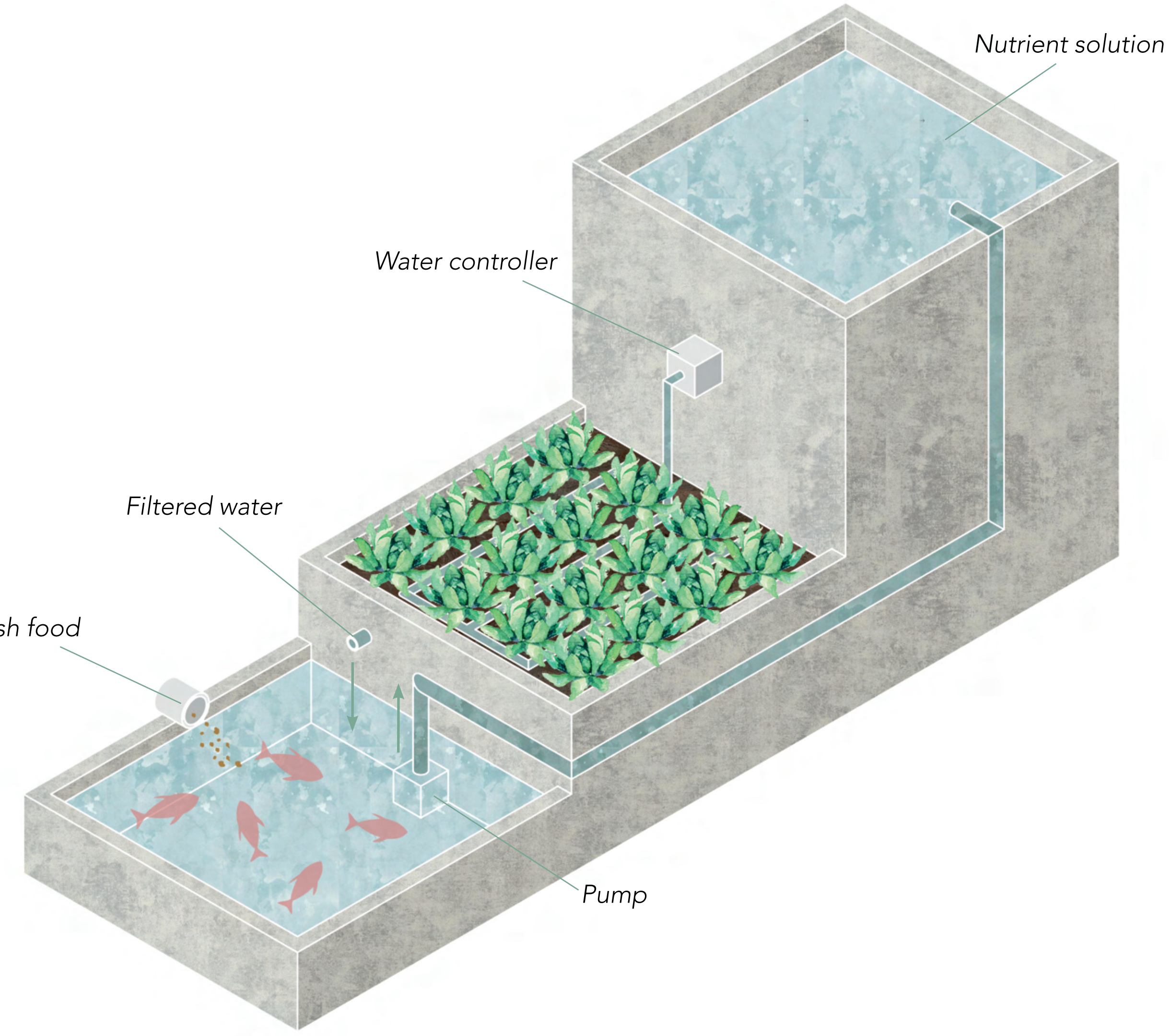
Crop:
Depends on which hydroponic system it's connected to

Yield:
45 – 80 kg/m²

Water needs:
15 l/kg

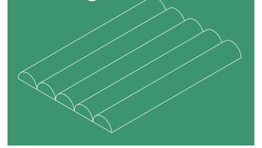
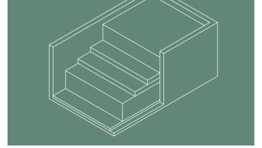
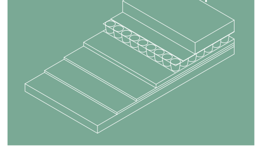
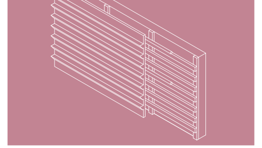
Weight:
25 – 150 kg/m²

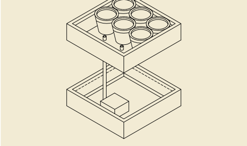
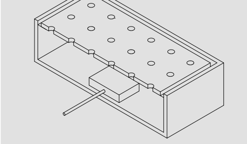
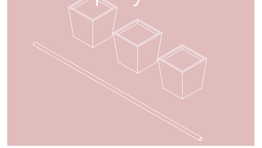
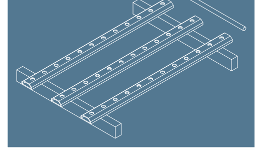
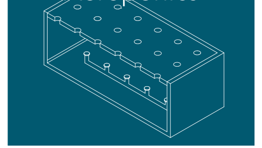
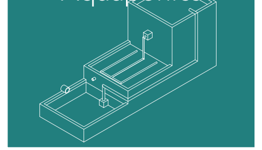
Construction cost:
High



Comparison Matrix

The matrix is a compilation of data from the used sources.

Geoponics	Place	Typology	Crop	Yield	Water need	Weight	Cost
Agriculture 	Outdoor	Parks, court yards, ground	Vegetables, fruits	1,5 - 2,5 kg/m^2	60 l/kg	–	Low
Soil bed 	Outdoor	Parks, court yards, roofs, balconies	Legumes, leafy greens, vine plants, fruit plants	2 - 3 kg/m^2	> 20 l/kg	340 - 730 kg/m^2 (point load)	Low
Green Rooftop 	Outdoor	Rooftops	Vegetables, fruits (depends on soil depth)	2 - 3 kg/m^2	> 20 l/kg	50 - 200 kg/m^2	Medium
Green Wall 	Outdoor/ Indoor	Facades	Leafy greens, vine plants, legumes	2 -3 kg/m^2	> 20 l/kg	90 - 110 kg/m^2	Medium

Hydroponics	Place	Typology	Crop	Yield	Water need	Weight	Cost
Flood & Drain 	Indoor	Greenhouse, ground level, basement	Roots, legumes, leafy greens, vine plants, fruit plants	40 - 50 kg/m^2	15 - 20 l/kg	100 - 120 kg/m^2	High
Raft Culture 	Indoor	Greenhouse, ground level, basement	Leafy greens, fruit plants	40 - 50 kg/m^2	15 - 20 l/kg	100 - 120 kg/m^2	High
Drip System 	Outdoor/ Indoor	Rooftops, greenhouse, ground level	Roots, leafy greens, vine plants, fruit plants	50 - 70 kg/m^2	15 l/kg	25 kg/m^2	High
NFT 	Outdoor/ Indoor	Vertical systems, rooftops, greenhouses	Legumes, leafy greens, fruit plants	45 - 80 kg/m^2	15 l/kg	5 - 10 kg/m^2	High
Aeroponics 	Indoor	Vertical systems, rooftops, greenhouses	Leafy greens, vine plants, fruit plants	60 - 100 kg/m^2	5 l/kg	10 - 20 kg/m^2	High
Aquaponics 	Outdoor/ Indoor	Ground level, greenhouses	Depends on which hydroponic system it's connected to	45 - 80 kg/m^2	15 l/kg	25 - 150 kg/m^2	High

WHERE?

3

The city contains a wide variety of places and structures. The type of ownership, location in the city, intermediate function and context of these locations vary. This chapter briefly introduces the potentail spaces, with a focus on the intermediate city: the link between dense cities and rural areas.

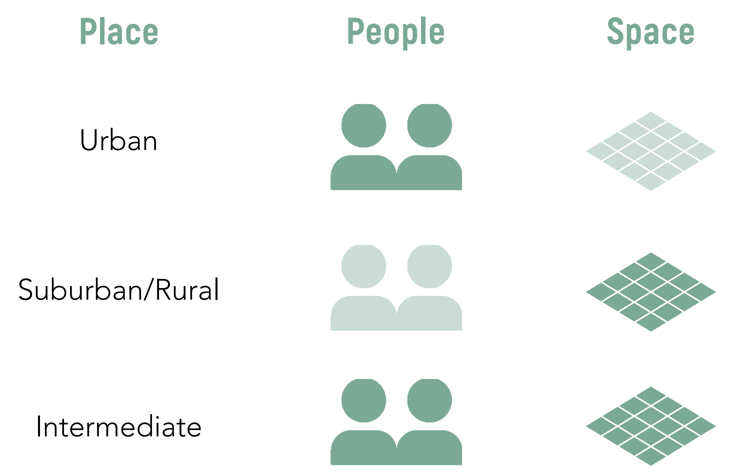
Potential Places

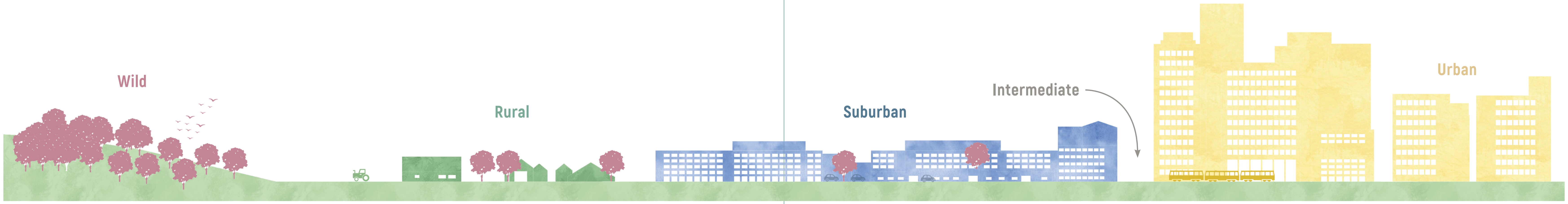
Urban development is an irreversible global trend. The abandonment of agricultural areas has led to a decrease in food production and the ageing of rural communities. Likewise, there is more and more urban pressure exerted on farmland and forests.[32] The need to analyse structural and comprehensive solutions is required to overcome the problems associated with these issues. At the same time, while urban land is expensive, cities have a large amount of abandoned or unused land. What possibilities do these locations have to serve their communities more effectively? The solution may appear self-evident: we can modify these unoccupied areas to address growing concerns about food insecurity.

When studying the city, there are numerous opportunities for urban agriculture to boost sustainable food production. Rooftops, facades, streets, parks, infills, and underdeveloped sites are all possible locations for urban agriculture. Each of these has distinct advantages and disadvantages. Agricultural ideas for various typologies and locations can be scaled up or down depending on the surface area.

Every aspect of urban development is predicated on three core components: buildings, open spaces and streets. By combining these different components, diverse urban settings with their own individual traits and conditions can be formed. The transect from wild to urban can further be divided into rural and suburban spaces. Somewhere between the suburban and the urban lies the intermediate city, maintaining an in-between character with a lot of potential.[33] For example, in the suburban city, there is space but not enough people, in the urban city there are people but not enough space and the intermediate city has both people and space.

Intermediate parts of cities can be defined as links between dense cities and rural areas,[34] and are therefore chosen as a reference for upcoming design opportunities.





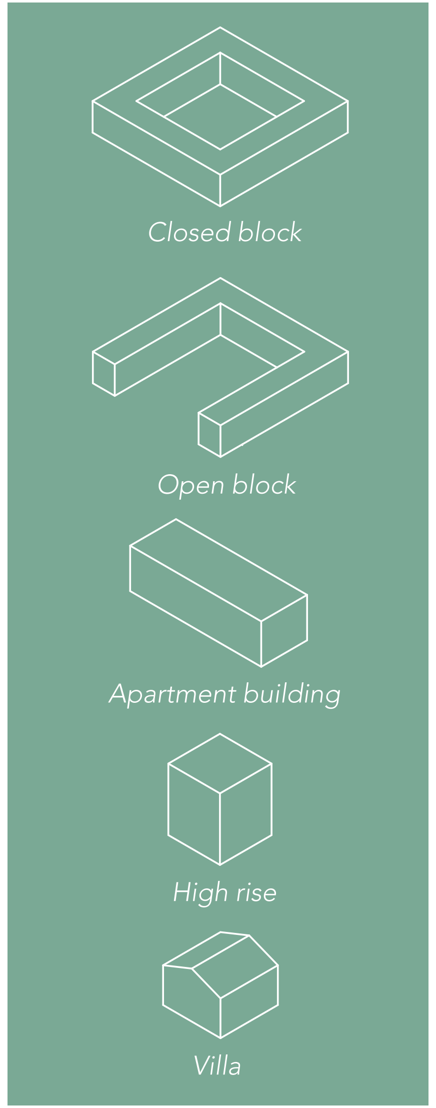
The Intermediate City

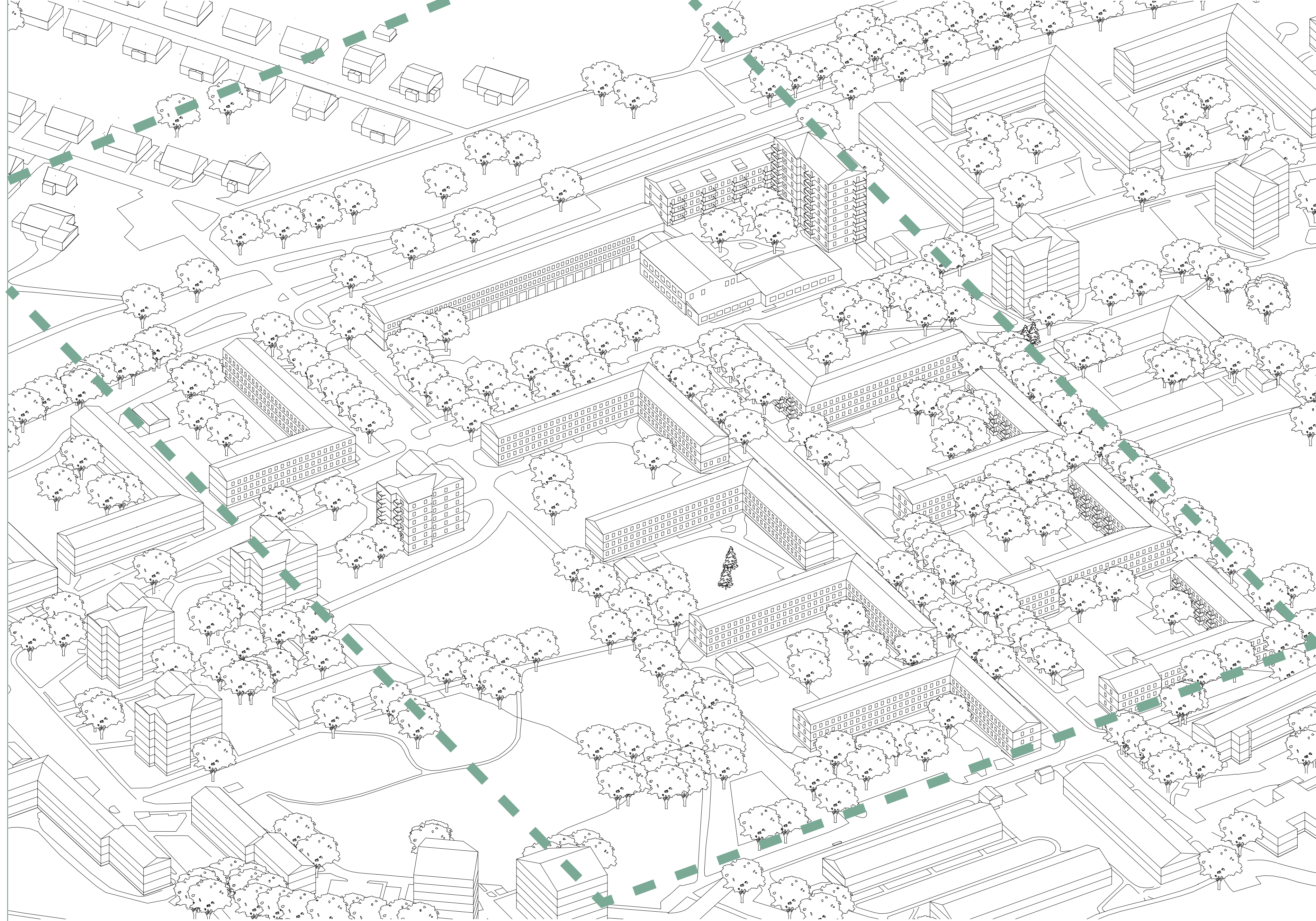
The term *intermediate city* refers to the place that exists between dense urban areas and rural areas. Unlike the urban and compact city, the intermediate city is more associated with an in-between character, connecting important rural and urban locations.[35]

Nowadays the intermediate part of cities is often judged to be too sparse, but that does not mean that they are without qualities. In some situations, openness is central to the architectural experience. Still, there is a great need for housing around the world and the compact city has been established as an ideal urban model to address the increasing urbanisation and associated pressures on cities.[37] However, in times of a construction boom, small-scale values risk being forgotten, and it is hardly desirable with further distortion of the contact of nature and greenery. Questions get raised such as, how do you convert sparse car-dependent residential areas based on houses-in-parks into a traditional dense city and will the densification result in new high-rise buildings being squeezed into places that were initially chosen to be open, so that the areas would not become dark and cramped?

In the best of worlds, the intermediate city is supplemented and refined so that new values are created without existing ones disappearing. The intermediate city entails a lot of potential and here we address the possibility of it implementing urban agriculture as well as some densification solutions.

The perspective to the right showcases a typical intermediate area in Gothenburg City, called Kyrkbyn. It will be used for explorations in chapter four.

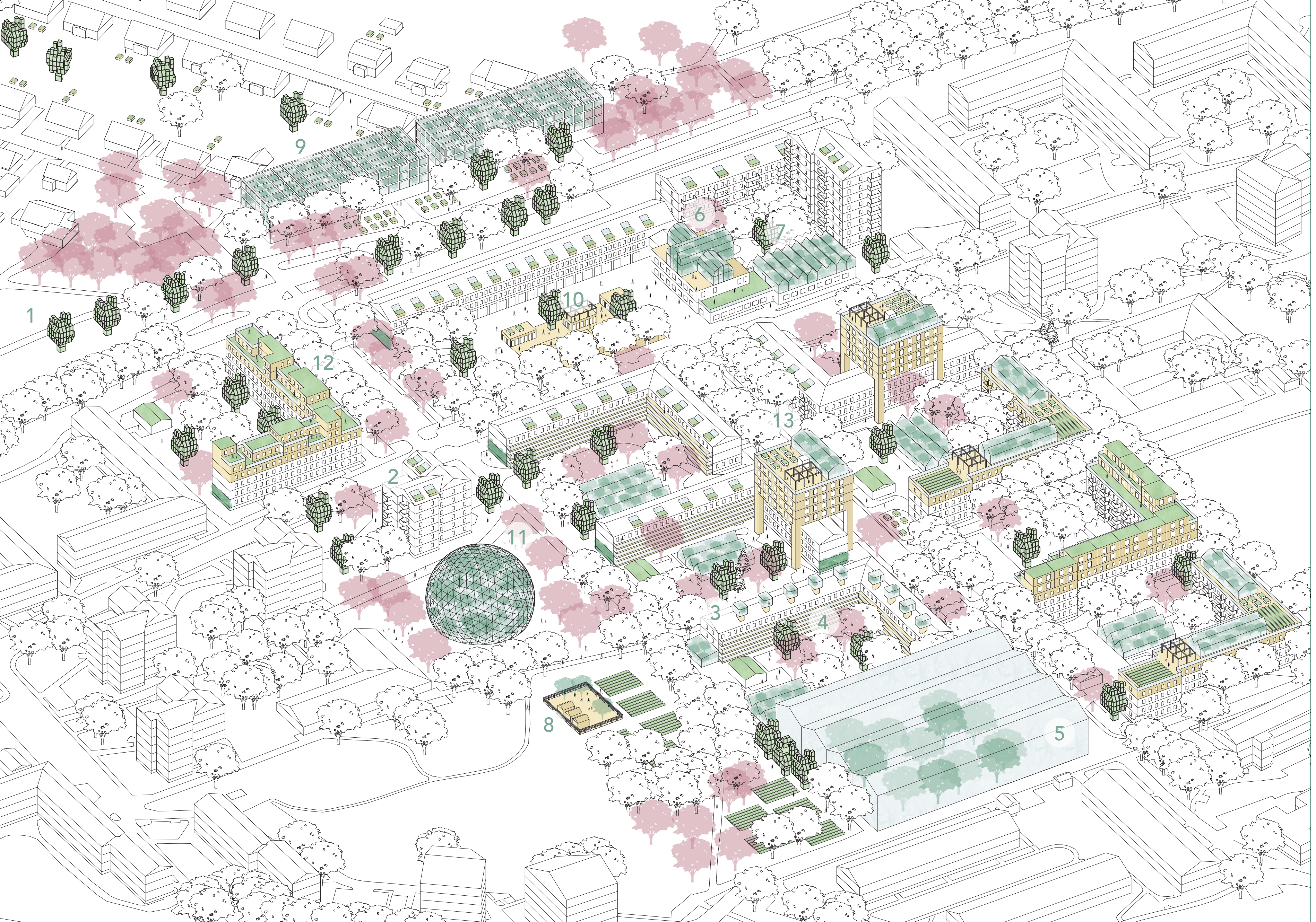




4

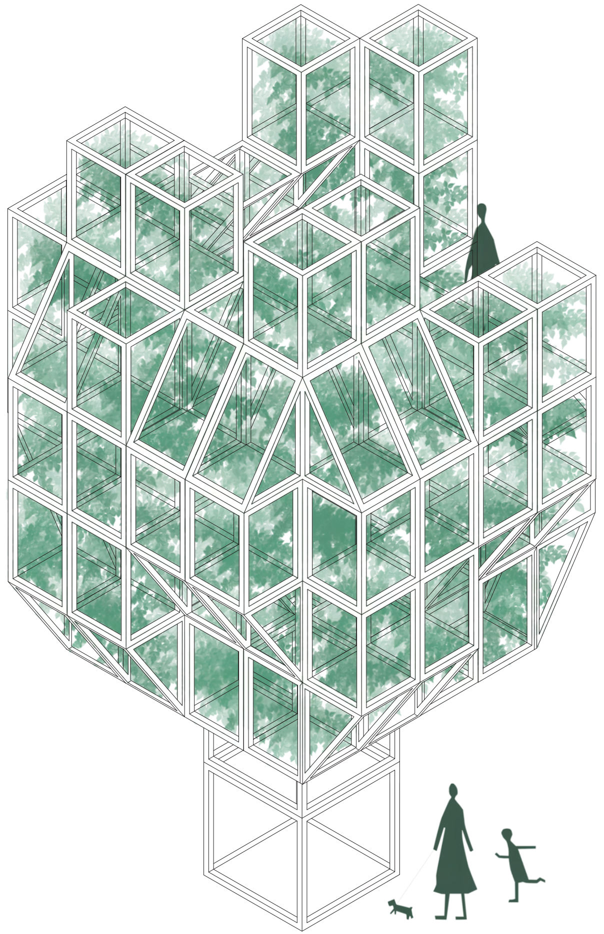
WHAT?

The previous two chapters introduced the agricultural systems and the potential spaces to implement them in a city. This chapter presents some design opportunities of how these can be implemented and is a source of inspiration for the possibilities when integrating urban agriculture with design. Some of the presented designs are derived from reference projects.



Aero-Tree

1



This tree structure is based on the Brooklyn-based project Glasir. It consists of a modular design and uses an AI to grow, relocate, deliver and communicate with other trees. The food is produced through a aeroponic system, encapsulated in each module of the tree, and can be delivered via drones to the subscribers of the service.

A full grown Glasir can produce around 21 800 kg of food per year in total. The tree also includes functions like energy saving that can be used to charge devices and water collection and purifying that is pumped back up to the aeroponic system.

Reference Project

Glasir: A Tree Assembles in Brooklyn
Designer: Framlab
Read more: https://www.framlab.com/glasir

Rooftop Soil Bed

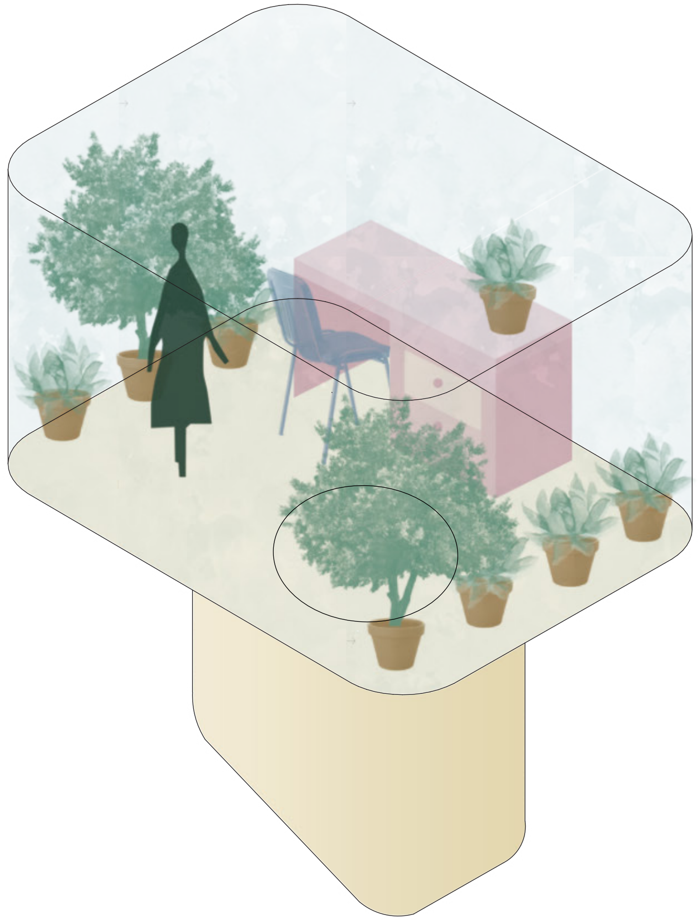
2

This is a play on the soil bed presented in chapter two. It is built into a pitched rooftop with an access point through the window. The soil beds are placed in the directions with the best sunlight quality and have a decent soil depth, approximately 0,5 meters, which allows for a big variety of vegetables, and even some fruits to be grown.

The soil beds are for personal use in the connected household. Since it is not placed in a climate-controlled room, there are some limitations to the harvest season and what is possible to grow. However, the daylight quality and easy access will allow for a more efficient harvest.

Flexroom

3

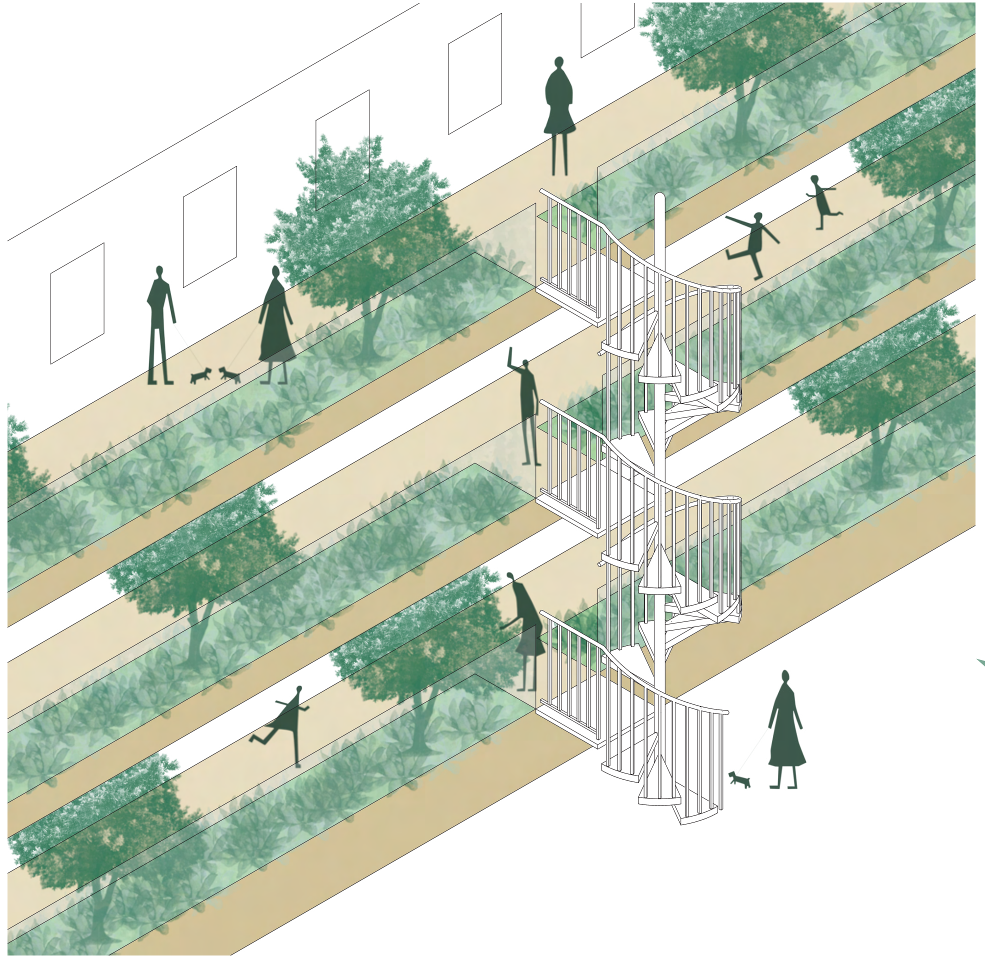


This is a private room on the rooftop, connected to the housing unit underneath, that can be used for work, studying, reading, exercising or gardening. This structure can be placed on pitched or flat rooftops and offer the residents an extra room with privacy and distance from the rest of the home, while simultaneously creating visibility access to the outside world.

During the COVID-19 pandemic, we noticed the need for a quiet space to work or relax, disconnected from the rest of the home. The Flexroom provides that space while creating a new experience surrounding the activities that usually occur in a home

Corridor Garden

4



The Corridor Garden utilises external communication corridors on buildings by integrating a soil bed directly in the floor. This creates a green exterior to the building while promoting food production in close proximity to housing. The corridor can still be used as a means for communication, both vertically and horisontally, and also as social spaces for interactions and relaxation.

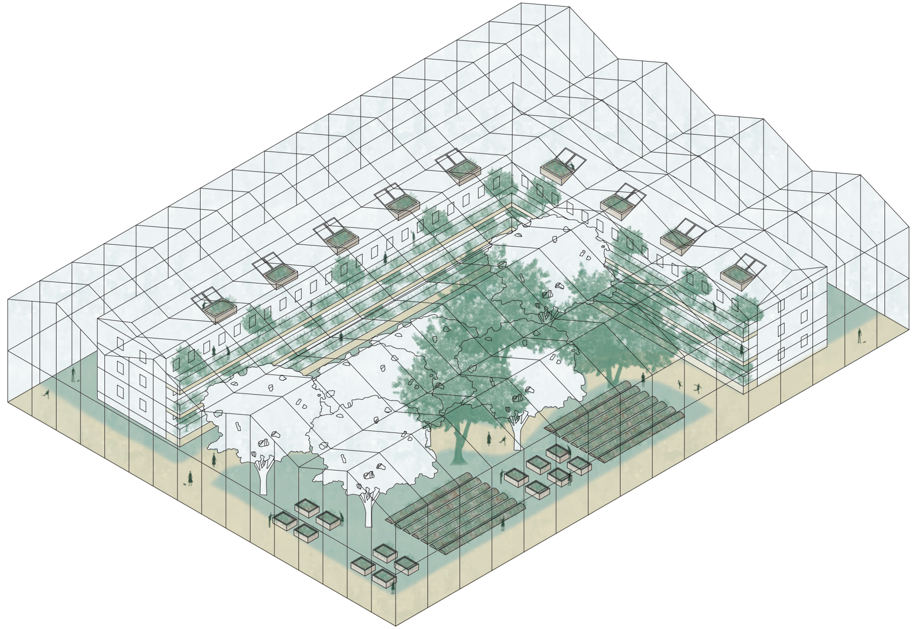
Each household is allotted a partition of the green corridor that is cultivated and harvested for personal use. Due to the nature of the corridor there is room for collaboration, interaction and knowledge-sharing between neighbors.

Reference Project

Urbana Villor, Malmö
Designer: Siegel Architecture
Read more: https://www.siegel.nu/home/urbana-villor/

Grand Glass House

5



This is a greenhouse that covers a dwelling and its courtyard which creates a big climate-controlled environment that allows for more exotic cultivation as well as year-round harvest. The building also houses some of the other designs that have been presenter, for example, the Corridor Garden and the Rooftop Soil Bed, with the difference that these are now inside a greenhouse.

This place attracts residents that value urban agriculture and wants to experience an exotic environment on a daily basis, in their personal residence. The neighbours collaborate on farming and reap the benefits of their work.

Reference Project

Bovieran, Svedala
Designer: Liljewall Arkitekter
Read more: https://bovieran.se

Palm House

6

The main function of the Palm House is to attract visitors for recreational purposes and knowledge sharing, and is thus placed on a public building. In the Palm House you find more exotic plants, and perhaps get to harvest a few dates from the trees during your visit. It's connected to a rooftop with raised soil beds that can be used for education and promotion of urban agriculture.

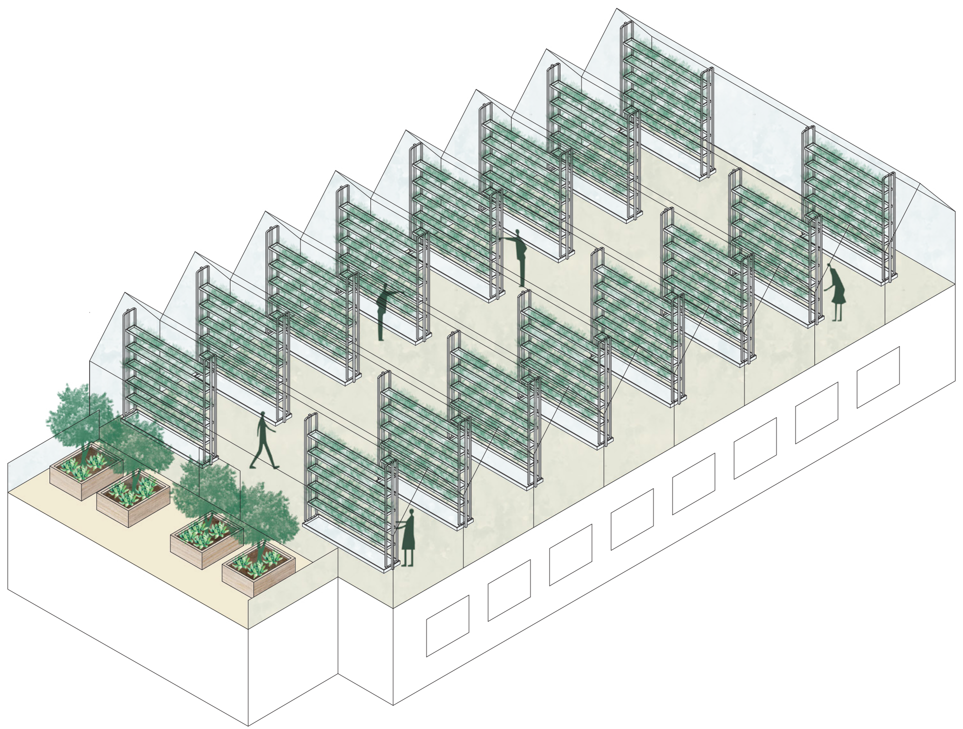
A building of this importance should be placed in close promixity to public spaces in order to attract visitors. A flat rooftop of decent size is benefecial in order to fit as much as possible. In this case, a slightly pitched rooftop has been adjusted and flattened to fit the Palm House and the adjacent rooftop allotment garden.

Reference Project

Palmhuset, Göteborg
Designer: Alexander Shanks & Son
Read more: https://goteborg.se/wps/portal?uri=gbglnk%3A201662875824940

Production House

7

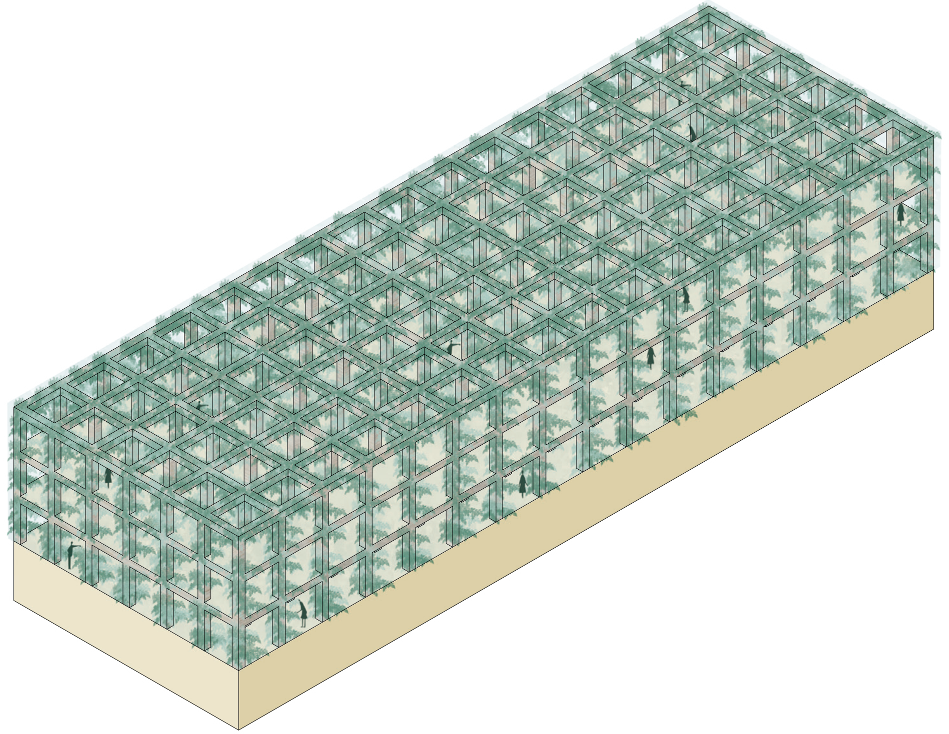


This greenhouse is mainly for production of food. It is placed on top of a public building with a flattened roof and is commercially operated for the total food production of the city. It utilises vertical farming structrures and hydroponics agricultural systems for optimal production yield and minimal resources consumption. Since it is a greenhouse, the production and harvesting can be done throughout the entire year by using artificial lighting and heating.

The production house is not accessible to the public, however, it is placed in a location that creates visibility surrounding urban agrictulture and adds greenery to the city.

Vertical Garden

8

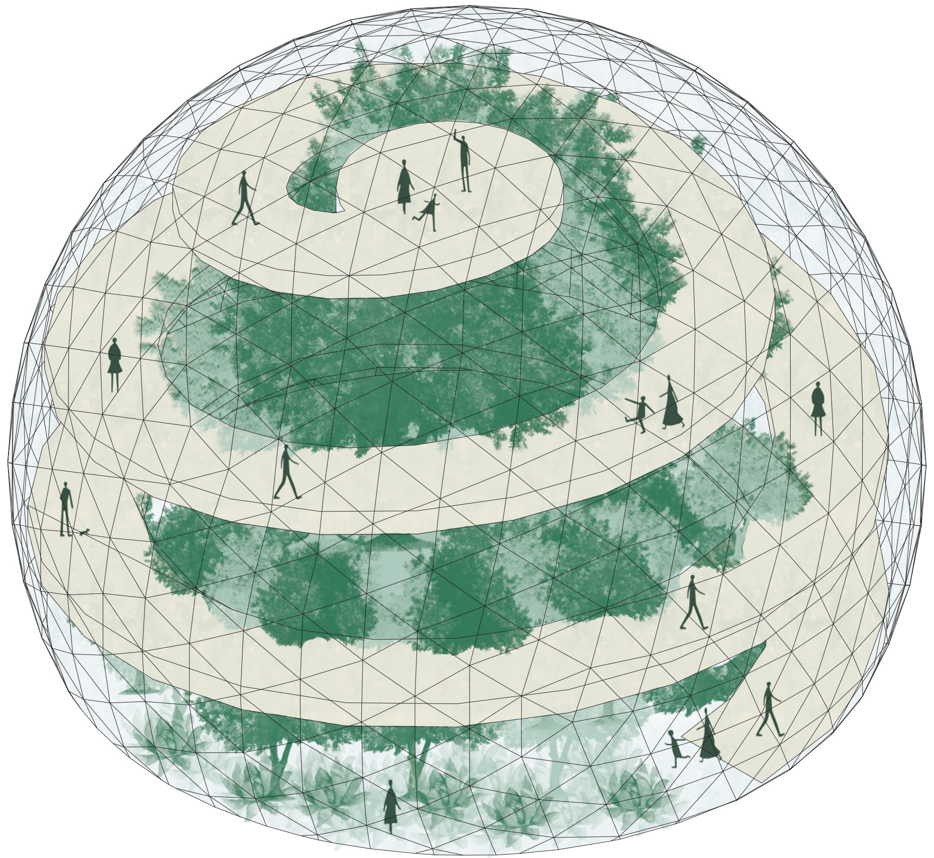


Buildings for storage and water management can be placed on the outskirts of the neighbourhood. The flat rooftops can be utilised for a vertical garden that can be used to plant and harvest climbing plants, as well as dry fruits and vegetables. The facility also has a basement floor for colder storage of food which allows for storage with low energy consumption. This will cover the food needs during the colder seasons when the harvest is lower.

The garden is accessible to the public, creating social spaces for interaction and education about the processing part of the food system. The transparency creates visibility about urban agriculture which increases interest in the general population.

Green Dome

9

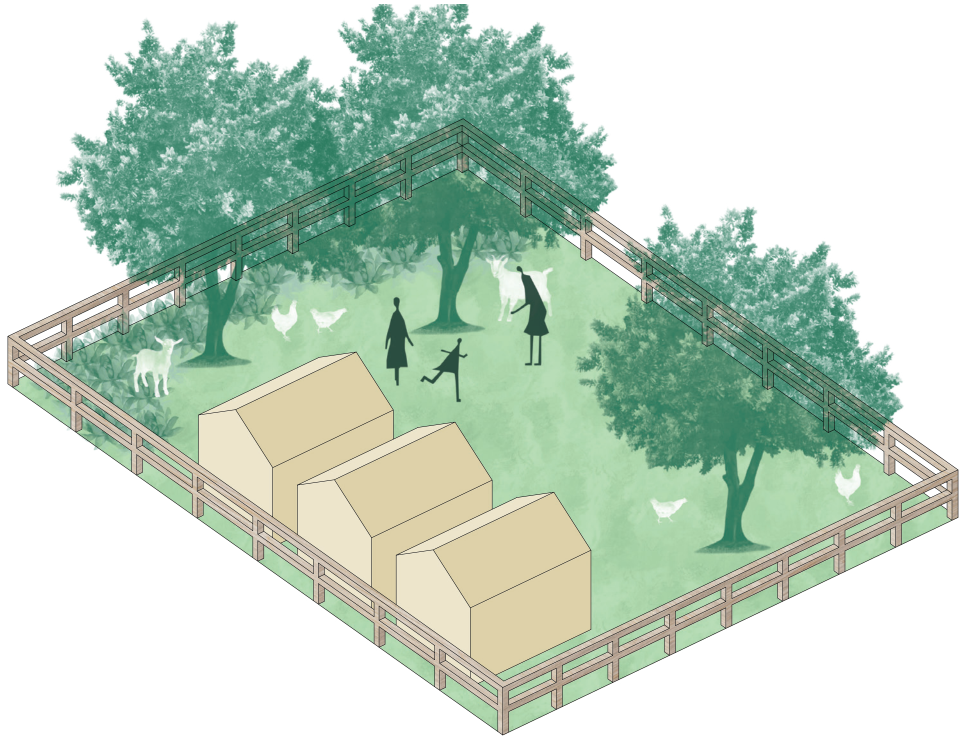


The Green Dome is a landmark and a vantage point. It is placed in an open field and is visible from many directions. The purpose of the dome is to attract visitors and create visibility around urban agriculture. The dome doubles as a greenhouse and the bigger scale of it allow bigger tree structures to grow inside.

Visitors move along a ramp to the top where they find a vantage point that overlooks the neighbourhood, and in the meantime, they find themselves at the same level with treetops, something uncommon amongst the general population. In other words, the Green Dome offers an experience, visibility and vantage point.

Petting Zoo

10

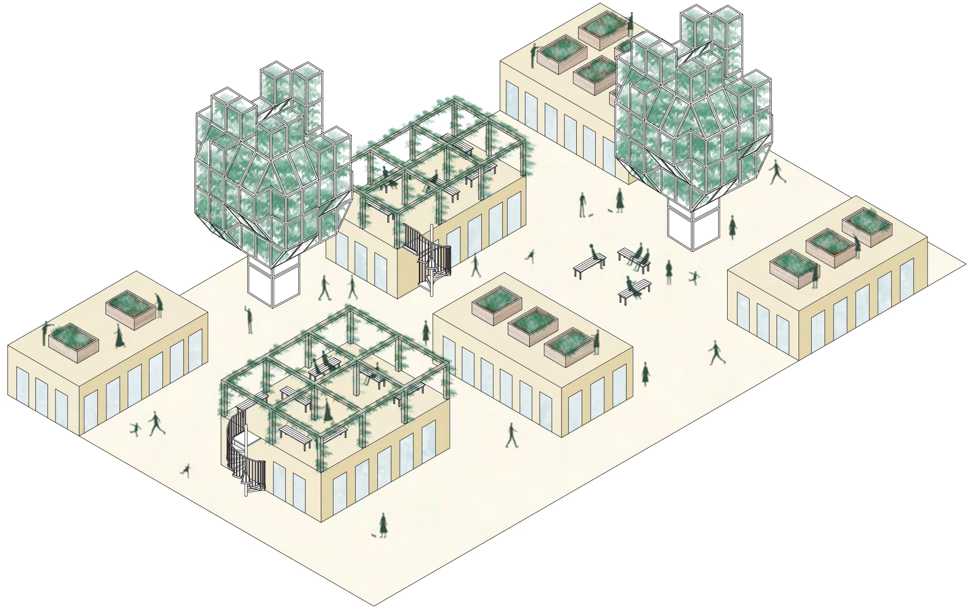


Most people love animals. The close proximity of the petting zoo to the housing units will make it popular both with children and adults. Other than being an attraction, the petting zoo promotes education and knowledge about the food system. Manure is an important part of food production as it contributes with nutrition.

The petting zoo is placed in an open field, partially for the wellbeing of the animals, but also to counteract unwanted smells from reaching the homes. It can house animals native to Sweden such as chickens, goats, pigs, rabbits and some birds.

Start-Up Market

11

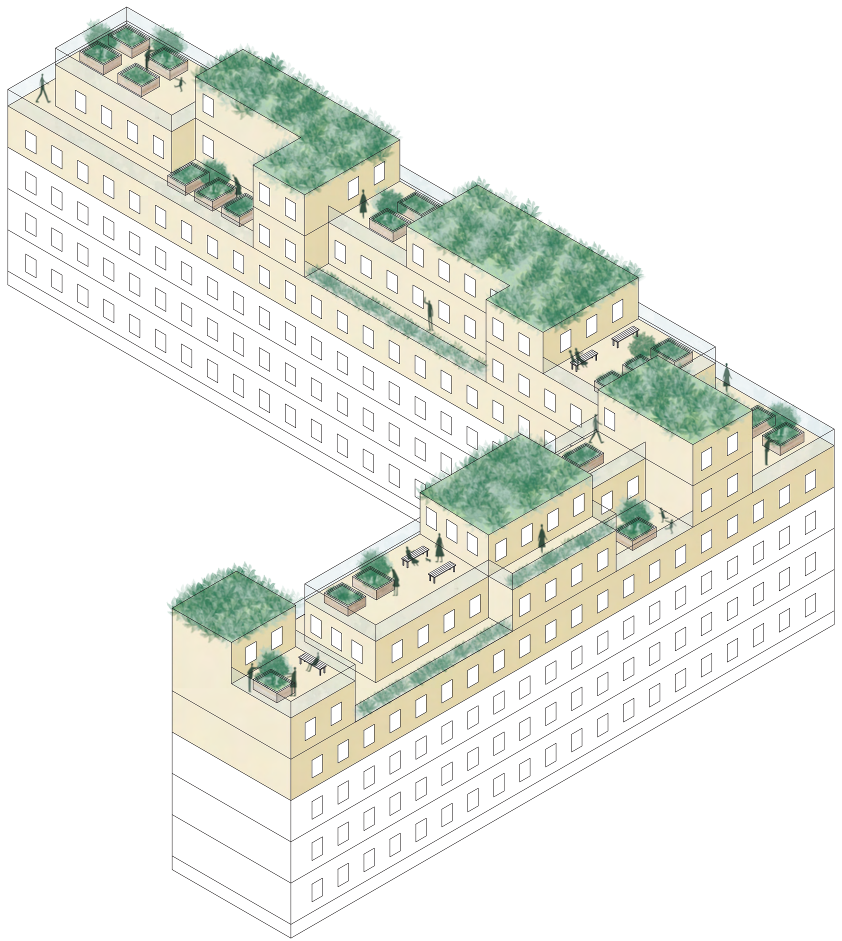


Buildings for storage and water management can be placed on the outskirts of the neighbourhood. The flat rooftops can be utilised for a vertical garden that can be used to plant and harvest climbing plants, as well as dry fruits and vegetables. The facility also has a basement floor for colder storage of food which allows for storage with low energy consumption. This will cover the food needs during the colder seasons when the harvest is lower.

The garden is accessible to the public, creating social spaces for interaction and education about the processing part of the food system. The transparency creates visibility about urban agriculture which increases interest in the general population.

Rooftop Accommodation

12



Densification is an important problem that most cities are faced with. Adding a floor to an existing building is a way to combat the problem. By making the roof on the new floor flat, it can be used for further urban agriculture, or as in this case, more densification. This example showcases apartment buildings with varied terraces that can be used for private cultivation through raised soil beds, or built-in soil beds (see Corridor Garden).

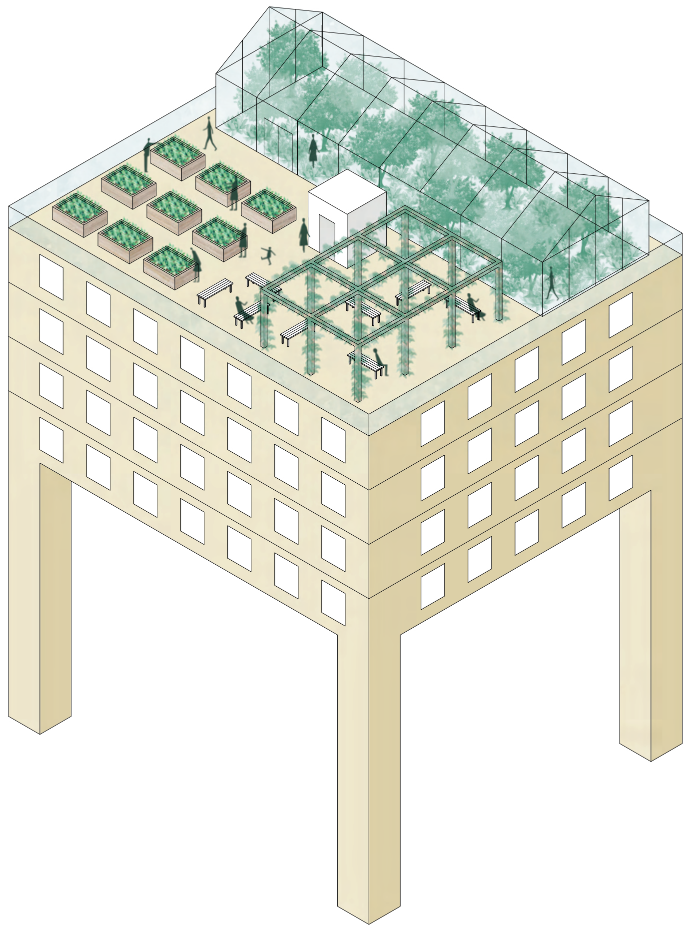
Other variations, as can be seen in the main perspective, include added densification through rowhouses or using the new flat rooftop for urban agriculture in greenhouses, soil beds or the traditional way.

Reference Project

Didden Village, Rotterdam
Designer: MVRDV
Read more: https://www.mvrdv.nl/projects/132/didden-village

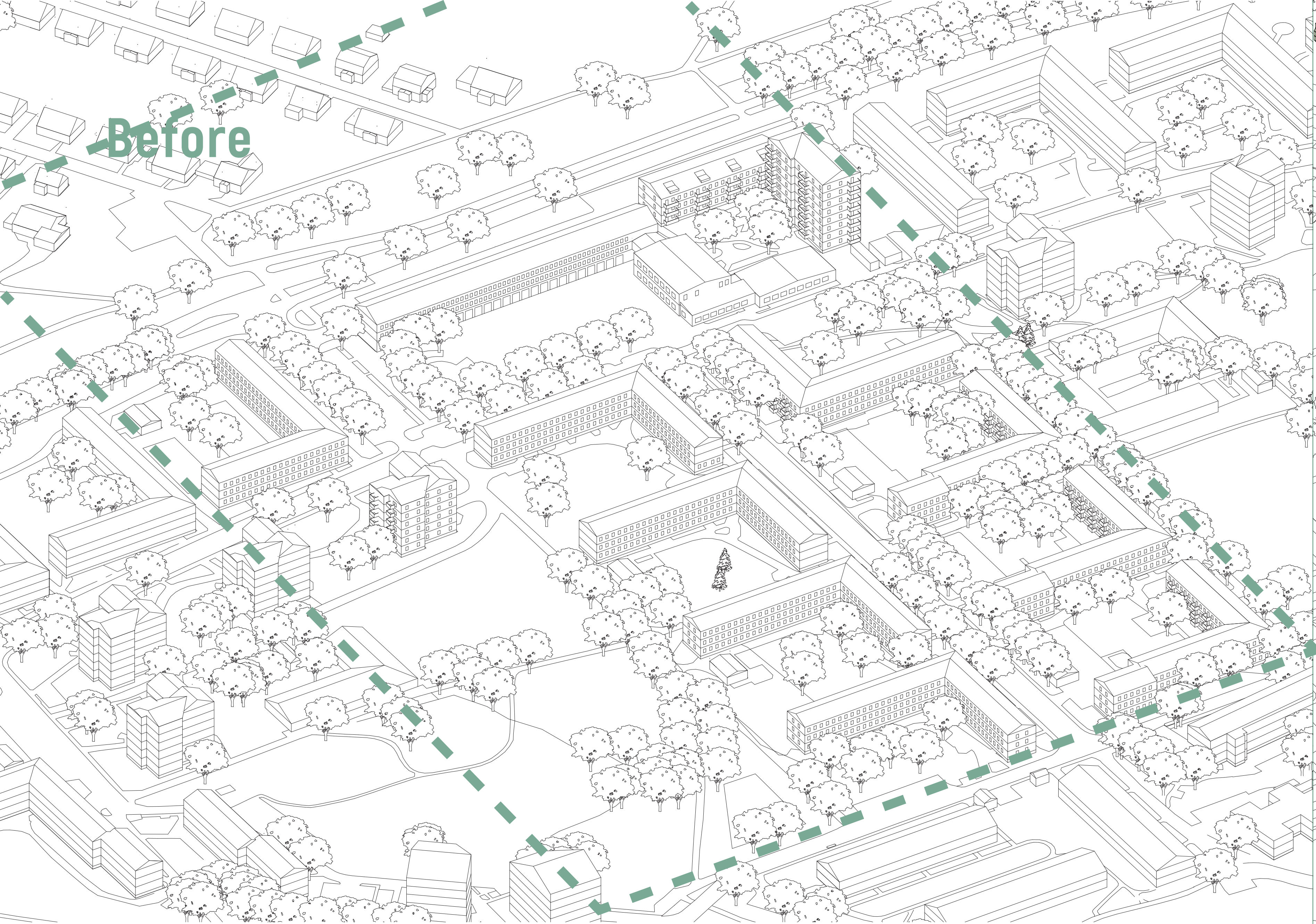
The Elephant

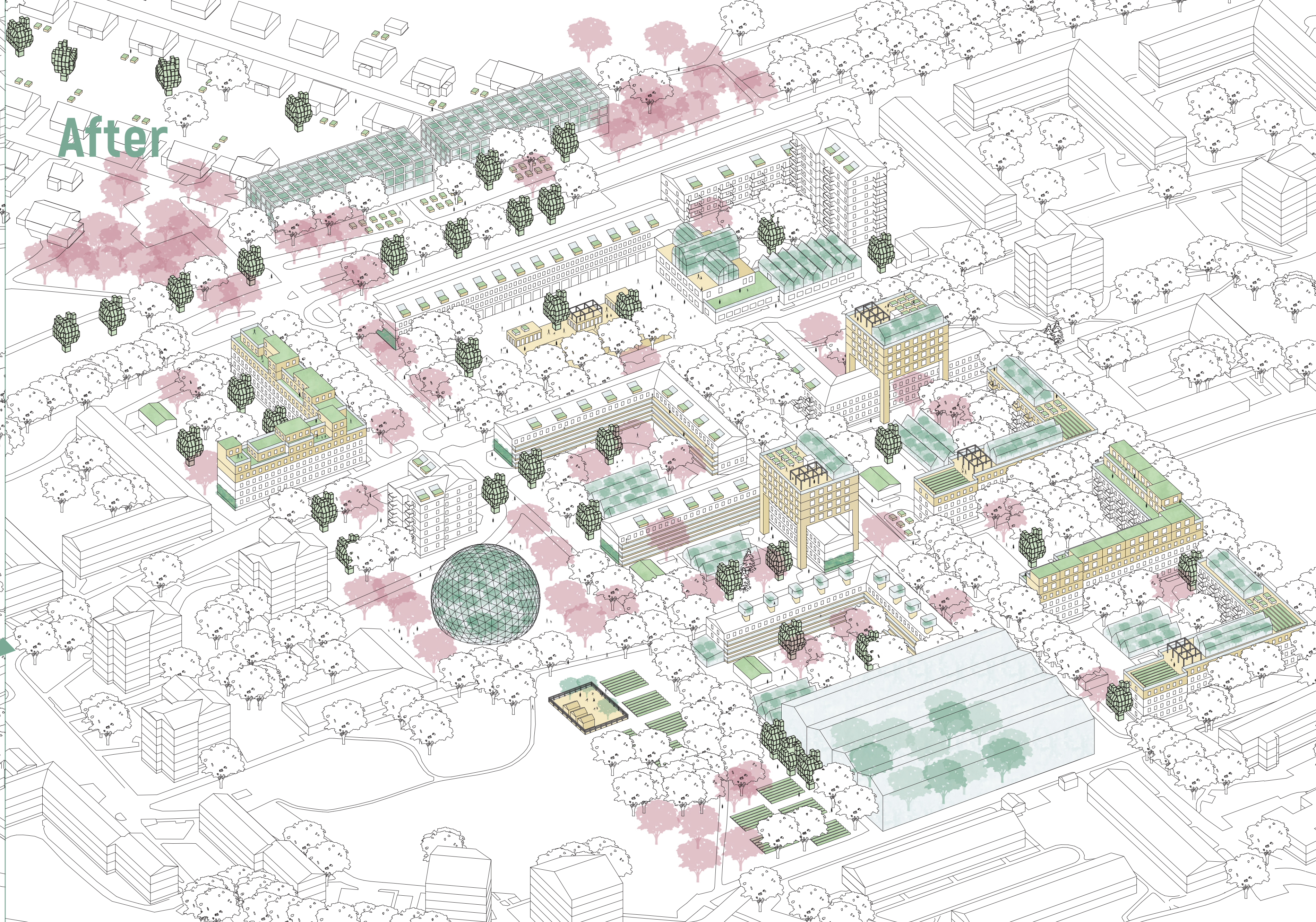
13



The Elephant is a densification project that minimizes the land use by lifting up the structure on four big pillars. It can be placed around and above existing buildings and connected to them for movement. The rooftop is flat and contains a greenhouse that can either use geoponics or hydroponics farming methods. There are also raised soil beds and trellis for further growing. Additionally there are some social spaces shared by the residents of the building.

The gardens can either be taken care of communally by the residents that later share the harvest, or, an exeternal partner can take care of them and divide the harvest between the residents in exchange for a price.


Before


After

Afterword

It is a late afternoon in August and you are fleeing the city's hectic life by having a stroll in the Green Dome, finding yourself at the same level as the treetops. Or imagine watching your kids break out in laughter as they curiously observe the goats playing in the neighbouring petting zoo.

Urban agriculture is a wide term that can mean many different things depending on the context. This handbook indicates that it has huge potential. As a reader, it is important to understand that these design principles are merely a source of inspiration. In reality, the complexity of a design project has to be taken into consideration, rendering some of the suggested designs less likely to be realized. However, we still believe many of these designs can be of value when considering how to further develop an existing area or start development on a new area as they pose questions and answers about the optimization of space to make room for urban agriculture.

What is achievable on and between existing and newly constructed buildings? Not only do we need to alter our thinking about policy, but also about space. Possibly it is no longer adequate to create two-dimensional maps. We need to think about the city in layers, which may necessitate the use of additional tools. This implies that we must change our way of thinking. How are we to accomplish that? Governments should begin developing their policies, construction- and architectural professionals could begin developing their projects and finally, landlords should begin considering their contributions to sustainable urban agriculture. What is your next move?

About the Authors

Lina El-Rifai | Architect

I have a great interest in urban farming and prior to this thesis, I developed a deeper understanding of the ecological and social effects in the studio Social-Ecological Urbanism. I feel that the combination of what historically has been a rural action with the configuration of the modern city can create an interesting interaction to explore further.

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Gothenburg, spring 2020

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Linnéa Seevers | Architect

I believe that the transition zone between the city and its suburbs is perfect for urban farming interventions. As can be seen in this handbook, urban agriculture can make a rooftop or a courtyard more alive with greenery and create spaces for collaboration, work, and social engagement surrounding farming, all while solving the issues with food production.

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Chapter Four

Application on the Gothenburg Context

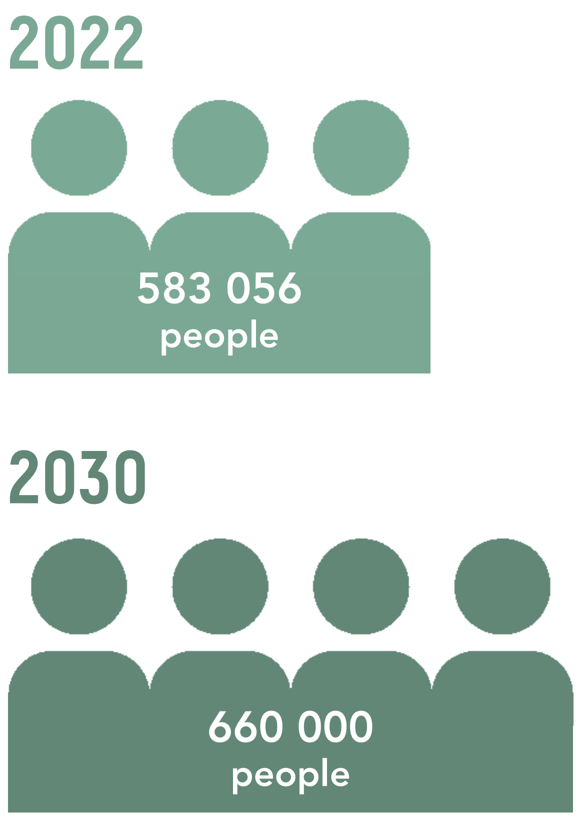
4

Can Gothenburg Become Self-Sufficient in Vegetables and Fruits?

Today the population in the city of Gothenburg is 583 056 people (Göteborgs Stad, 2022) and by 2030 that number is expected to rise to 660 000 people (Göteborgs Stad, n.d.). According to Livsmedelsverket, every person should consume 500 grams of vegetables and fruits every day (Livsmedelsverket, 2021). The following calculation shows an approximation of the amount that needs to be produced by 2030, in order to supply the whole population of Gothenburg for one year:

660 000 (residents) x 365 (days) x 0,5 (kg vegetables & fruits) = **120 450 000 kg** vegetables and fruits per year.

As the thesis aims to explore if the intermediate city can supply the whole municipality of Gothenburg with vegetables and fruits, the calculation above sets the goal for the intermediate parts to make Gothenburg self-sufficient. This investigation is done by picking a site, a smaller section of the intermediate city, which represents the overall intermediate city's typology and urban pattern quite well. The section is then used as an example of how to program urban agriculture, using the different agriculture systems described in the handbook. The programming is based on a farming framework in order to properly position agricultural systems while taking the quantity of each vegetable and fruit group into account, to ensure a varied diet with full nutritional content.



Zones in Gothenburg City

Gothenburg's geography can be simplified and divided into the inner city, the intermediate city (mellanstaden) and the outskirts. The outskirts include:

1. Large-scale industry, ports and logistics
2. Coastal areas and the archipelago
3. Development areas
4. Nature areas

(Göteborgs Stad, 2014)

This thesis will mainly focus on the investigation of whether the large rurban fringe, also called the intermediate city, of Gothenburg, can make the whole municipality self-sufficient when it comes to vegetables and fruits.

As previously mentioned the greenery in Gothenburg's municipality is declining and the city has lost 4,5 percent of greenery between 1986 and 2019. The study shows that the industrial-city (large-scale industry, ports and logistics) has accounted for the largest reduction in green space, followed by the inner-city and the intermediate city.

The reason for the decline of greenery differs between the areas. In the industrial city, the decrease has been due to the expansion of industries and large companies. In the intermediate city, the proportion of green space has decreased due to residential areas and shopping centres built on old arable land, forest areas and grasslands. Furthermore, in the inner city greenery has disappeared when institutions such as universities and amusement parks expand. A trend for all areas is that the establishment of roads, public transport, cycle paths and footpaths has taken up a large proportion of green space (Blinge, 2020).

The total land area of Gothenburg City is 447,8 km2 (Statistiska Centralbyrån, 2019). Approximately half of the area of Gothenburg city consists of forests (Göteborgs Stad, n.d.):

Inner city: 12,8 km^2
Intermediate city: 92,4 km^2.
Industrial city: 26,5 km^2
Countryside: 66,9 km^2
Forest and open ground: 249,2 km^2

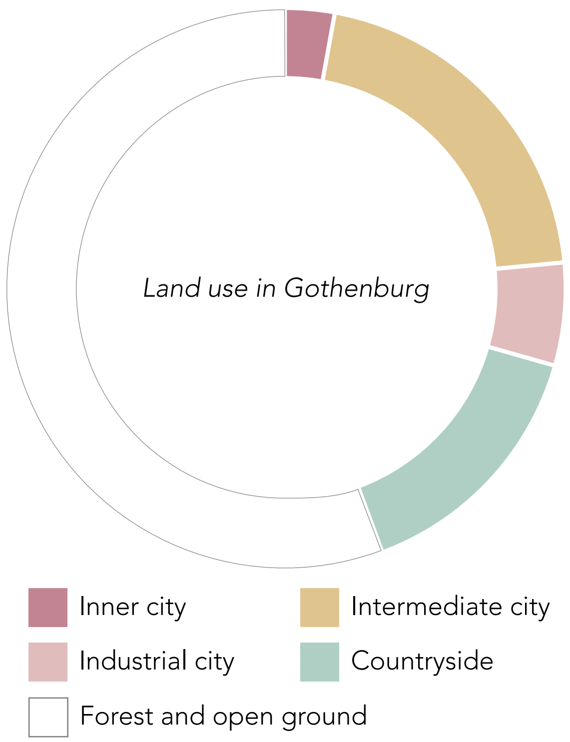


Figure 4.1: The cultivation ground seen in the map to the right is part of the countryside

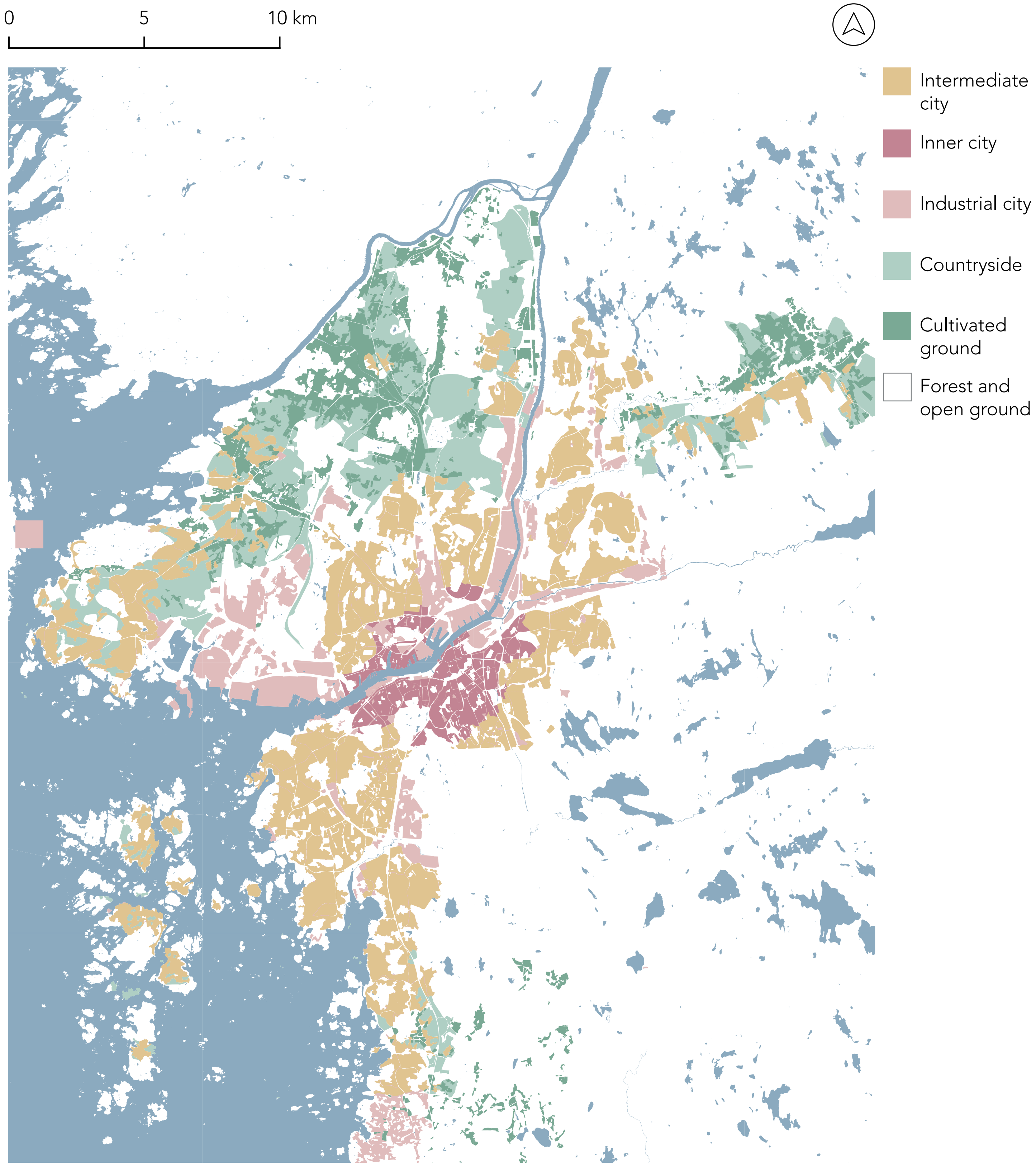


Figure 4.2: The different zones in Gothenburg city

1 : 200 000

The Intermediate City

Positioning the Intermediate City in the Densification and Housing Politics in Gothenburg

There is a great need for housing in Gothenburg, as well as elsewhere. A growing city is important to give more people the opportunity to settle in Gothenburg and the goal for housing construction is set at 4000–5000 homes per year until 2030 to meet future needs and reduce the current shortage of housing (Göteborgs Stad, 2022). A strategy that is being tested is the possibility of an expansion to build 45 000-55 000 new homes in the intermediate city until 2035 (Göteborgs Stad, 2014).

The compact city has been established as an ideal urban model to address the increasing urbanisation and associated pressures on cities (Adelfio et al., 2020). Urbanisation itself has been going on since the beginning of industrialism. Even older is the mindset of country/city, polarized as idyll/destruction, or conversely backwardness/progress. However, Claes Caldenby questions the urban norm, as today more people are moving out of the big cities than into them (Caldenby, 2021). Still, the city of Gothenburg gives a clear mandate in the Development Strategy Gothenburg 2035 to use a new master plan as a starting point for UN Habitat's principles for density and to create block structures with active facades on the bottom floors (Göteborgs Stad, 2014).

Due to the geographical location of the intermediate city, it is expected to have certain urban qualities, such as a stronger social cohesion and a higher grade of activity. Unlike the urban and compact city, the intermediate city is more associated with an in-between character, connecting important rural and urban locations (Adelfio et al., 2020).

Picturing the Intermediate City

Urban development is an irreversible global trend. The abandonment of agricultural areas has led to a decrease in food production and the ageing of rural communities. Likewise, there is more and more urban pressure exerted on farmland and forests (The Veolia Institute, 2019). The need to analyse structural and comprehensive solutions is required to overcome the problems associated with these issues. The urban fringe, also called the intermediate city, can be defined as links between dense cities and rural areas (UCLG, n.d.).

Gothenburg is generally known as a relatively sparse city, and to meet the needs of urbanisation and a growing population requires expansion in both central and intermediate parts in the coming years. The latter is in the comprehensive plan for Gothenburg called the intermediate city. The Development Strategy of the City of Gothenburg highlights the importance of the intermediate city for the future development of the city, those parts of the city located just outside the city centre (Göteborgs Stad, 2013). The desire for a more dense city is, therefore, to be realised in environments that today are more or significantly less naturally urban. As a result, the comprehensive plans raise several questions. How do you convert sparse car-dependent residential areas based on houses-in-parks into a traditional dense city? Will the densification result in new high-rise buildings being squeezed into places that were initially chosen to be open so that the areas would not become dark and cramped? In times of a construction boom, small-scale values risk being forgotten, and it is furthermore hardly desirable with distortion of the contact of nature and greenery.

The intermediate city often consists of well-designed environments. Nowadays they are often judged to be too sparse, but that does not mean that they are without qualities, in some situations openness is central to the architectural experience. In the best of worlds, the intermediate city is supplemented and refined so that new values are created without existing ones disappearing.

Figure 4.4: Open blocks, Västra Frölunda

Figure 4.5: High rises, Västra Frölunda

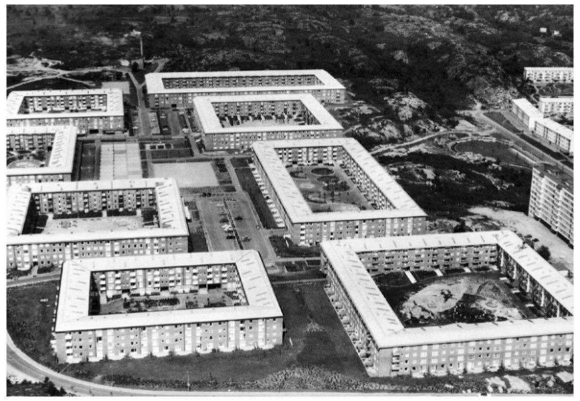


Figure 4.3: Closed blocks, Norra Biskopsgården

Figure 4.6: Apartment buildings, Lundby

Urban Fabric

Every aspect of urban development is founded on three fundamental components; buildings, open spaces, and streets. Courtyards, squares, parks, and car parking lots are all examples of urban open spaces. How residents and visitors access, perceive and experience various urban spaces has a significant impact on how they are used (Göteborgs Stad, 2008).

The most common figuration of building typologies in the intermediate city of Gothenburg consists of closed blocks, open blocks, apartment buildings, high rises and villas. These typologies give rise to different conditions when it comes to urban space and can be simplified into five categories; private space, semi-private space, semi-public space, public space and residual space.

By combining buildings, open spaces, and streets in different manners, distinct urban environments with their own unique characteristics and conditions are created. This section presents some typical urban patterns in Gothenburg's intermediate city, along with a brief description of their spatial design characteristics.

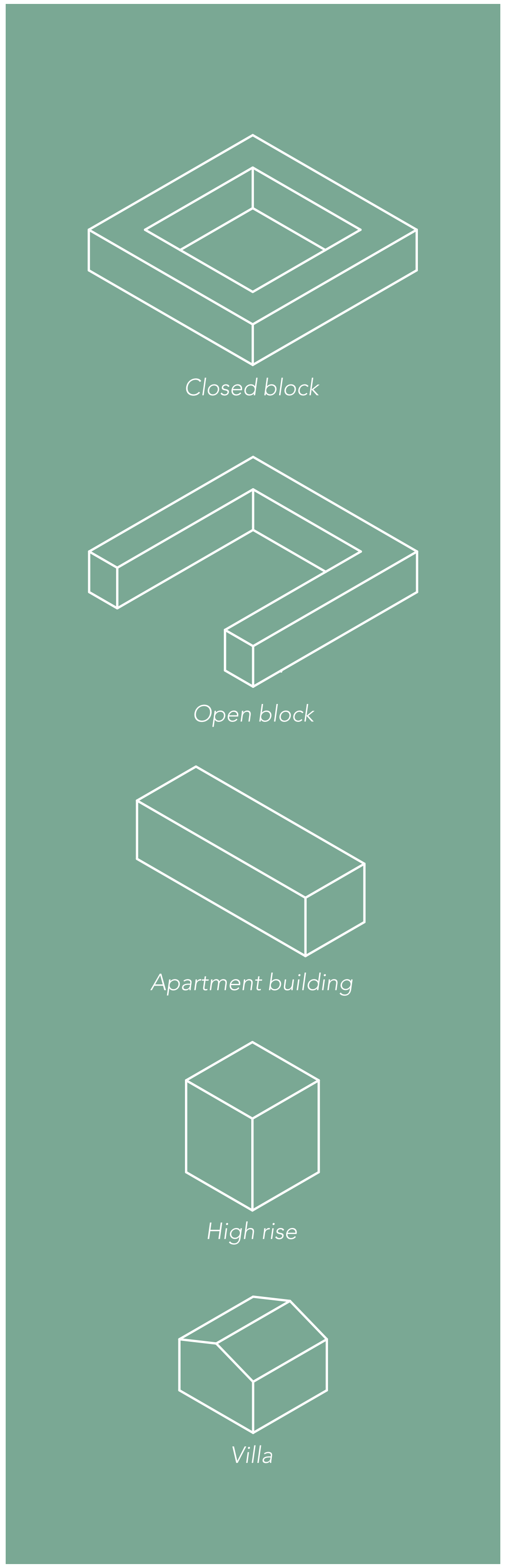
Private: for individual use

Semi-private: shared by several households

Semi-public: neighborhood land open to the public

Public: open and accessible to everyone

Residual: space without a clear function

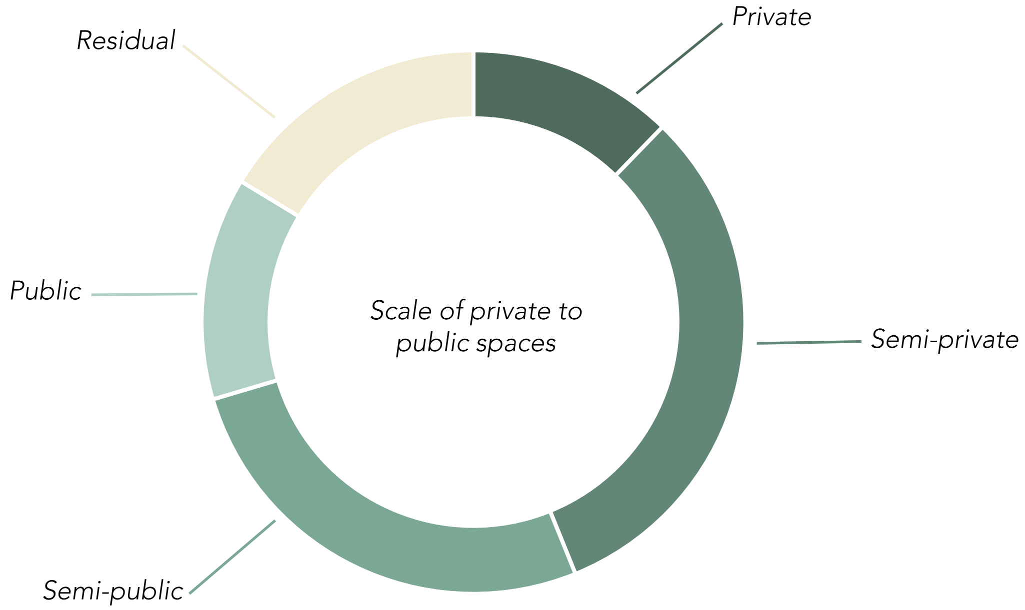


Closed blocks

- *Entrances to the street or courtyard*
- *Semi-private courtyards*
- *Function-separated streets*
- *Few non/residential functions*
- *Obscure public urban spaces*
- *Number of floors 3–6*
- *Floor Area Ratio (FAR) = 1.0–2.0*

(Göteborgs Stad, 2008)

Figure 4.7: Typical urban pattern of the closed blocks typology in Norra Biskopsgården

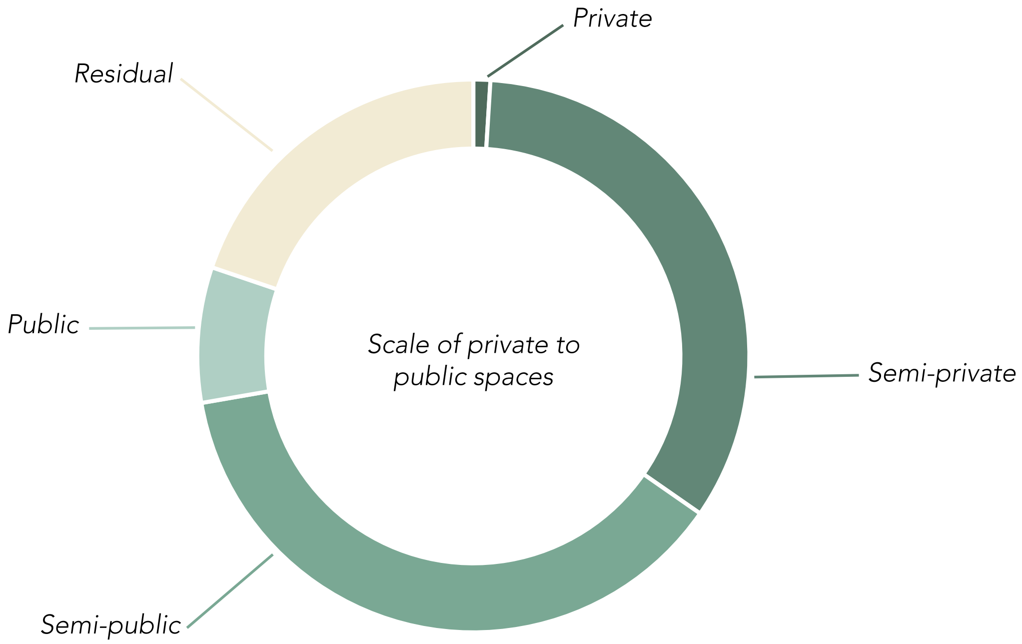


Open blocks

- Entrances to to the street or courtyard
- Semi-private courtyards
- Unclear boundaries between semi-public and public urban spaces
- Few non/residential functions
- Number of floors 4–5
- Floor Area Ratio (FAR) = 0.6–1.2

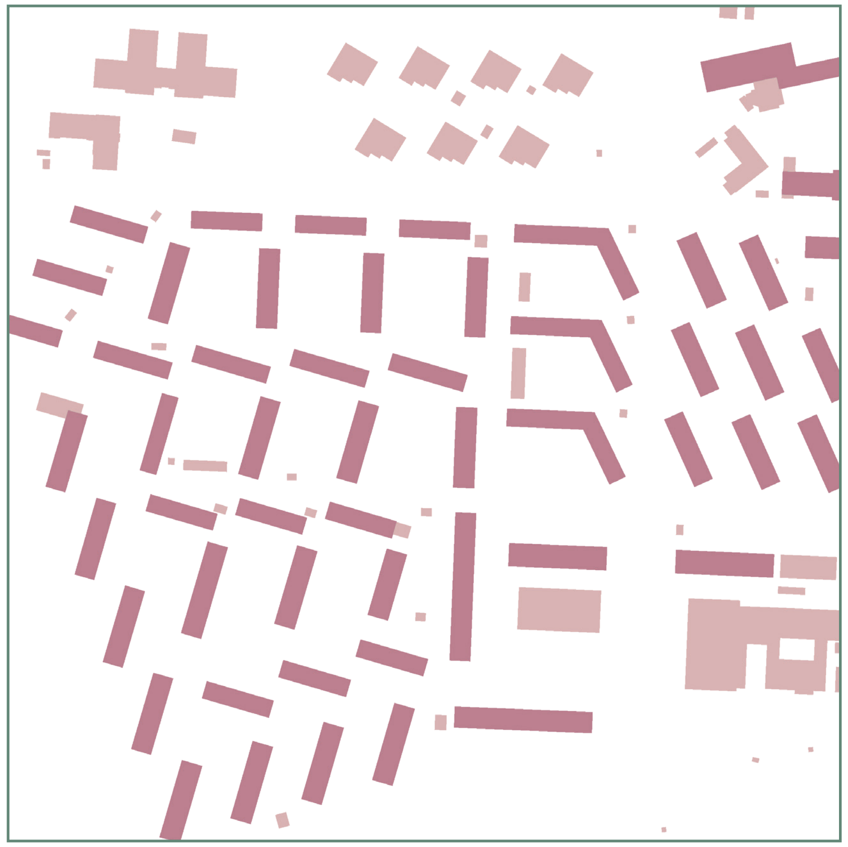
(Göteborgs Stad, 2008)

Figure 4.8: Typical urban pattern of the open blocks typology in Västra Frölunda



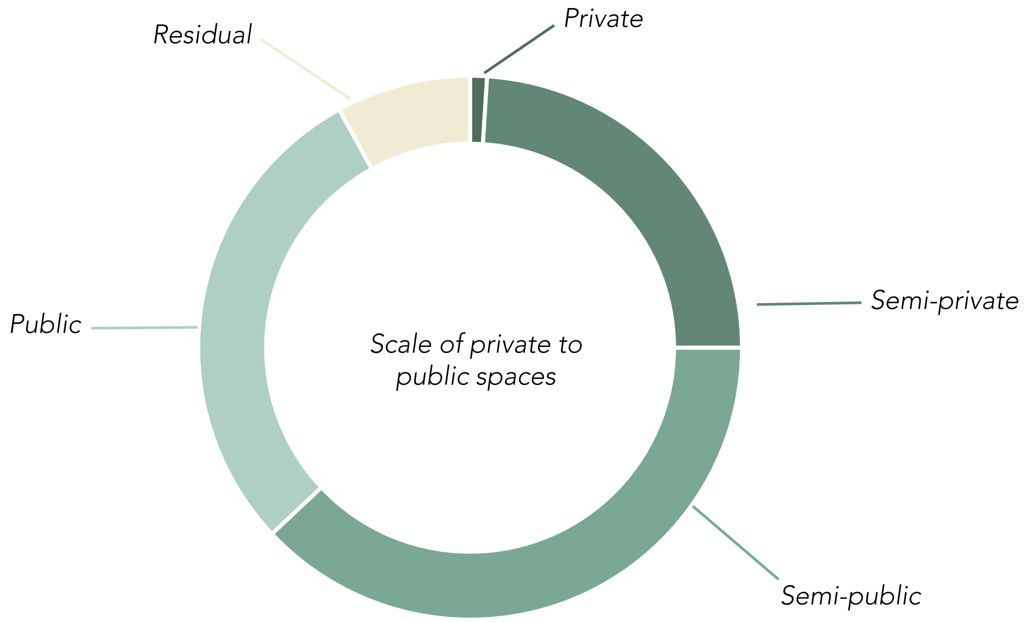
Apartment buildings

- Entrances to the street or courtyard
- Semi-public courtyards
- Unclear boundaries between semi-private and semi-public
- Possible locations for retails against the streets
- Number of floors 3–4
- Floor Area Ratio (FAR) = 0.5–0.8



(Göteborgs Stad, 2008)

Figure 4.9: Typical urban pattern of apartment buildings typology in Kvillebäcken



High rises

- Entrances to the park
- Unclear boundaries between semi-private and semi-public spaces
- Few non/residential functions
- Obscure public urban spaces
- Number of floors 8–15
- Floor Area Ratio (FAR) = 0.6–1.2

(Göteborgs Stad, 2008)

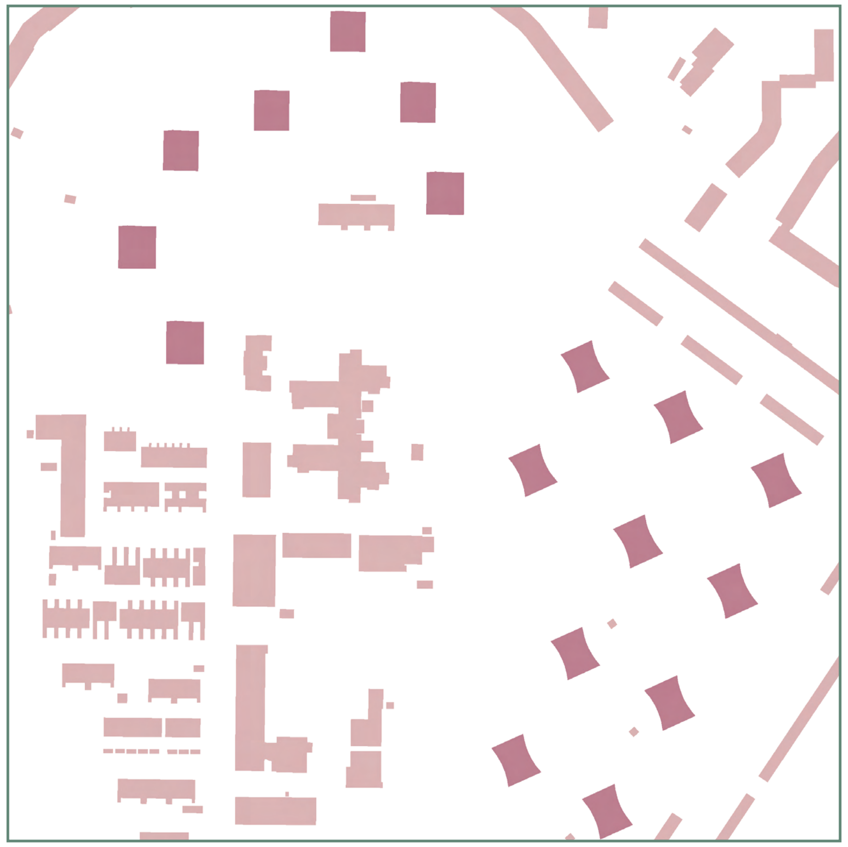
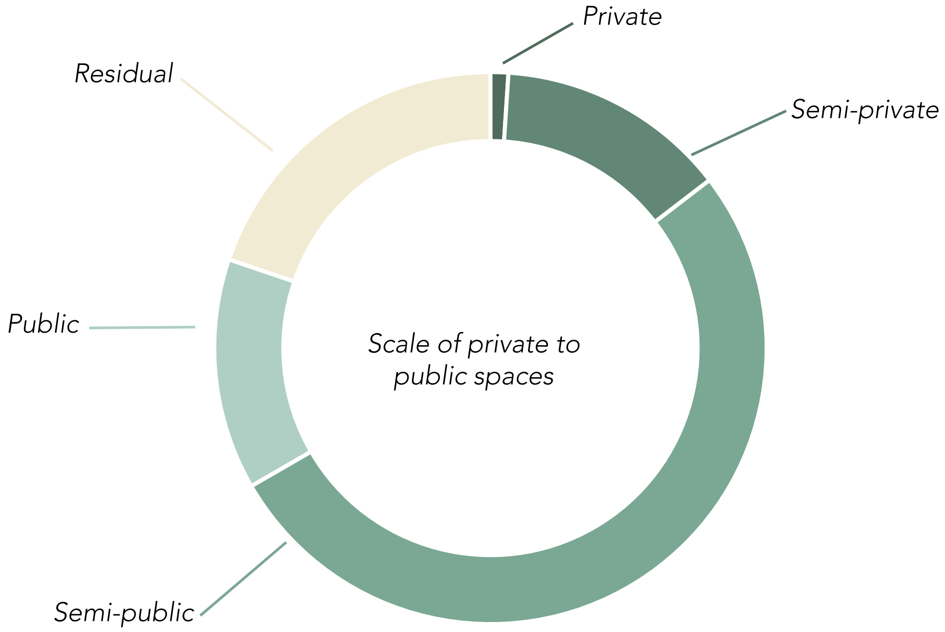


Figure 4.10: Typical urban pattern of high rises typology in Västra Frölunda



Villas

- Entrances to the street or garden
- Individual gardens with clear borders
- The street functions as the public space
- Few semi-private and semi-public urban spaces
- Number of floors 1-3
- Floor Area Ratio (FAR) = 0.1–0.3

(Göteborgs Stad, 2008)

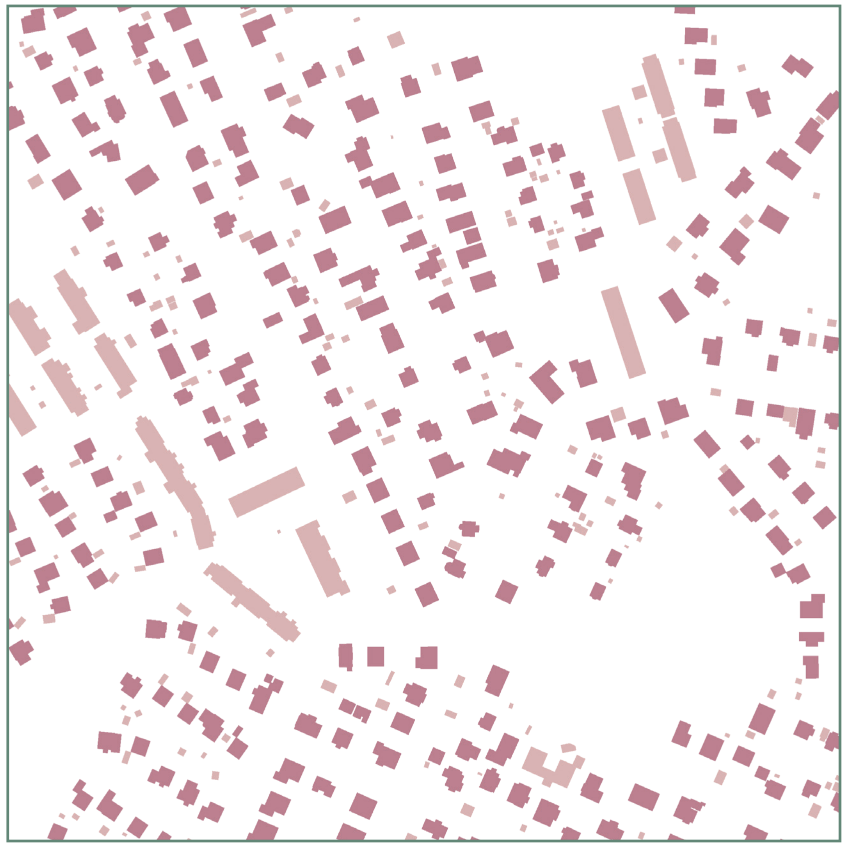
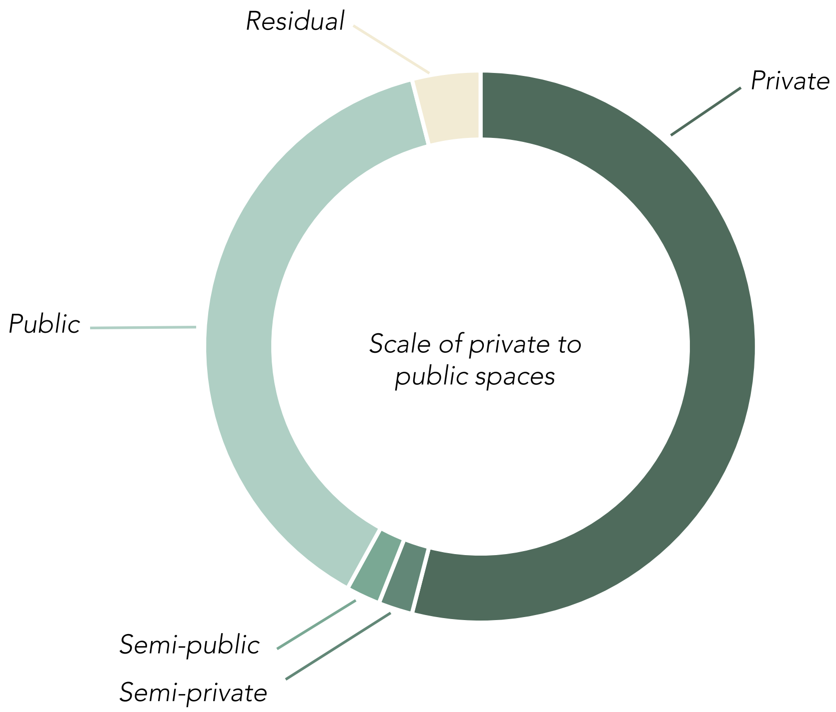


Figure 4.11: Typical urban pattern of the villa typology in Lundby.



Site Analysis

Functions and Soil

The chosen site is called Kyrkbyn and is placed north of the Göta-Älv river in the Hisingen district. The typology looks like a typical intermediate-city area of Gothenburg: 3-4 floor apartment buildings or open blocks, 2-floor villas and row-houses, 6-floor high-rises, and some public buildings. There is a public square with a grocery store, barbershop, kiosks, pharmacy, second-hand boutique, a restaurant, and a library. The rest of the area consists of apartment buildings and open green courtyards and a couple of pre-schools. There is a big number of trees and greenery in the area.

The open green spaces have the potential to become spaces for urban agriculture. In order to know where the possibility to farm exists, the soil types have been mapped. The rock is from the ground beneath and is not possible to farm on. The filling has been done during the construction of the area and is also not possible to farm on. The soil types glacial clay and post-glacial sand are nutritious and thus can be farmed on (Naturskyddsföreningen, 2022). It is not possible to farm next to the buildings due to the soil being compressed during construction (Jordbruksverket, 2003).

Figure 4.12: The spacious public square

Figure 4.14: The park and open green courtyards

Figure 4.13: Smaller, green residual spaces

Figure 4.15: Vacant land close to the main street

Figure 4.16: Mapping of soil type

1 : 4000

Figure 4.17: Mapping of building functions on the ground floor

1 : 4000

Site Analysis

Sun Studies

The sun studies were made using a SketchUp plugin called *SunHours*. The dates picked were the brightest (June 21st), the darkest (December 21st), and the date in between (Mars 21st). The plugin calculates the hours of sunlight that the surface is reached by every day. On June 21st, most of the site is reached by sunlight during most of the day. On December 21st only the southern parts of the site are reached by an adequate amount of sunlight. Most spaces north of a building are barely reached by sunlight. On Mars 21st, the southern spaces have a good amount of sunlight and the northern parts are darker but still reached by a few hours each day.

Using this data, the crop placement can be determined based on the crop's need for daylight and sunlight. Similarly, the placement of bigger agricultural systems and greenhouses can be determined depending on the intended outcome. Some agricultural systems can use artificial lighting and heating making them more resilient to the outside environment and light conditions.

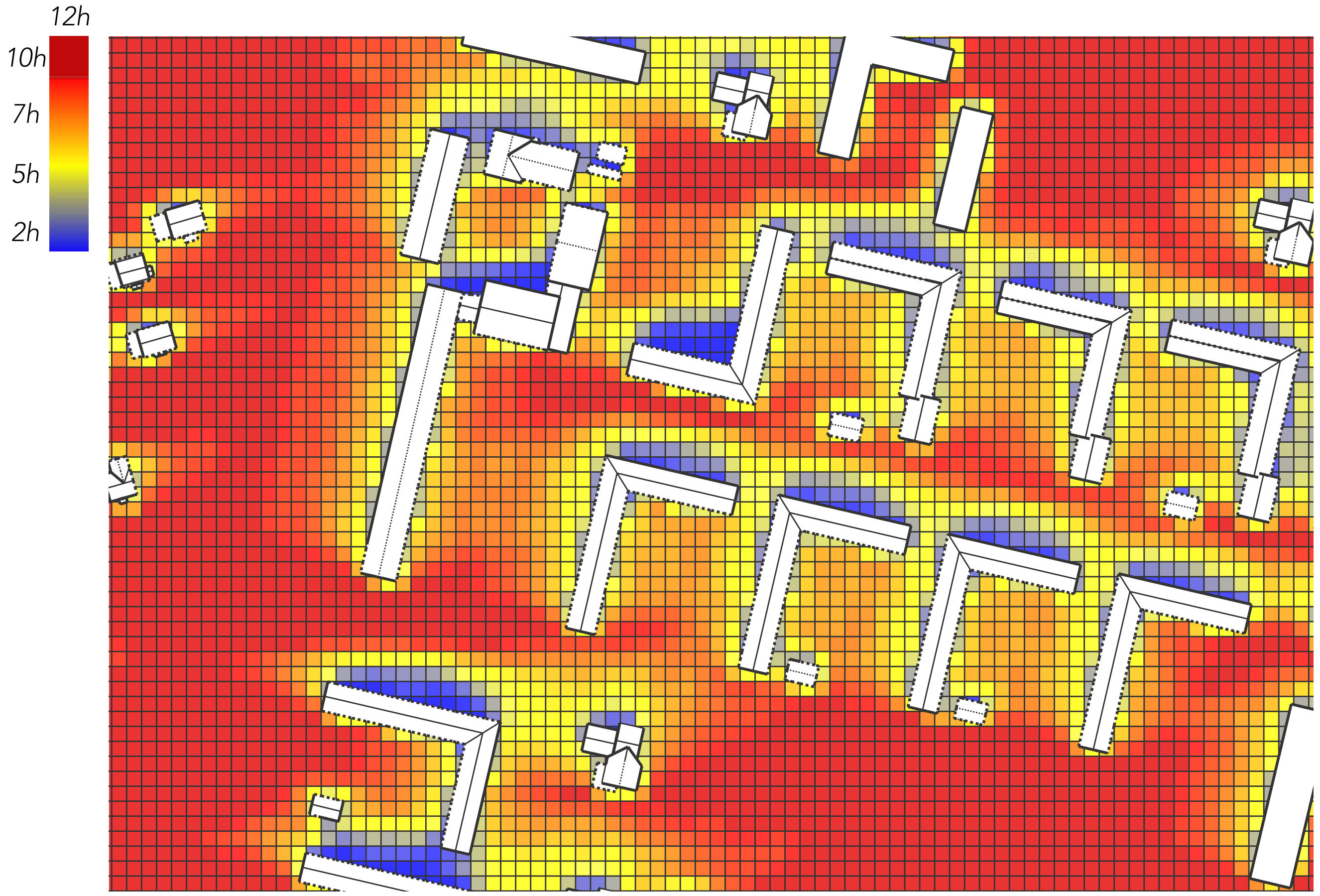


Figure 4.18: Sun study, Mars 21th

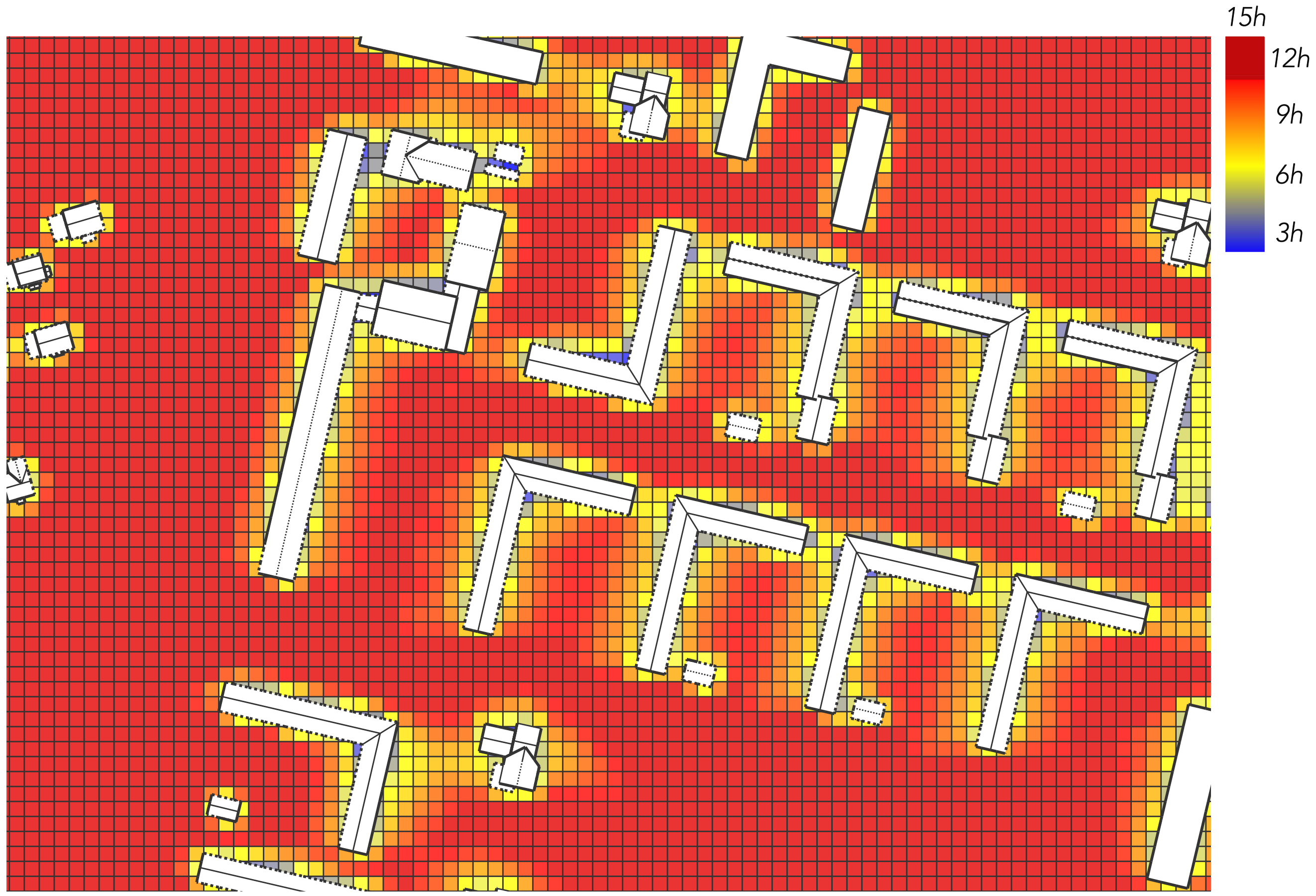


Figure 4.19: Sun study, June 21th

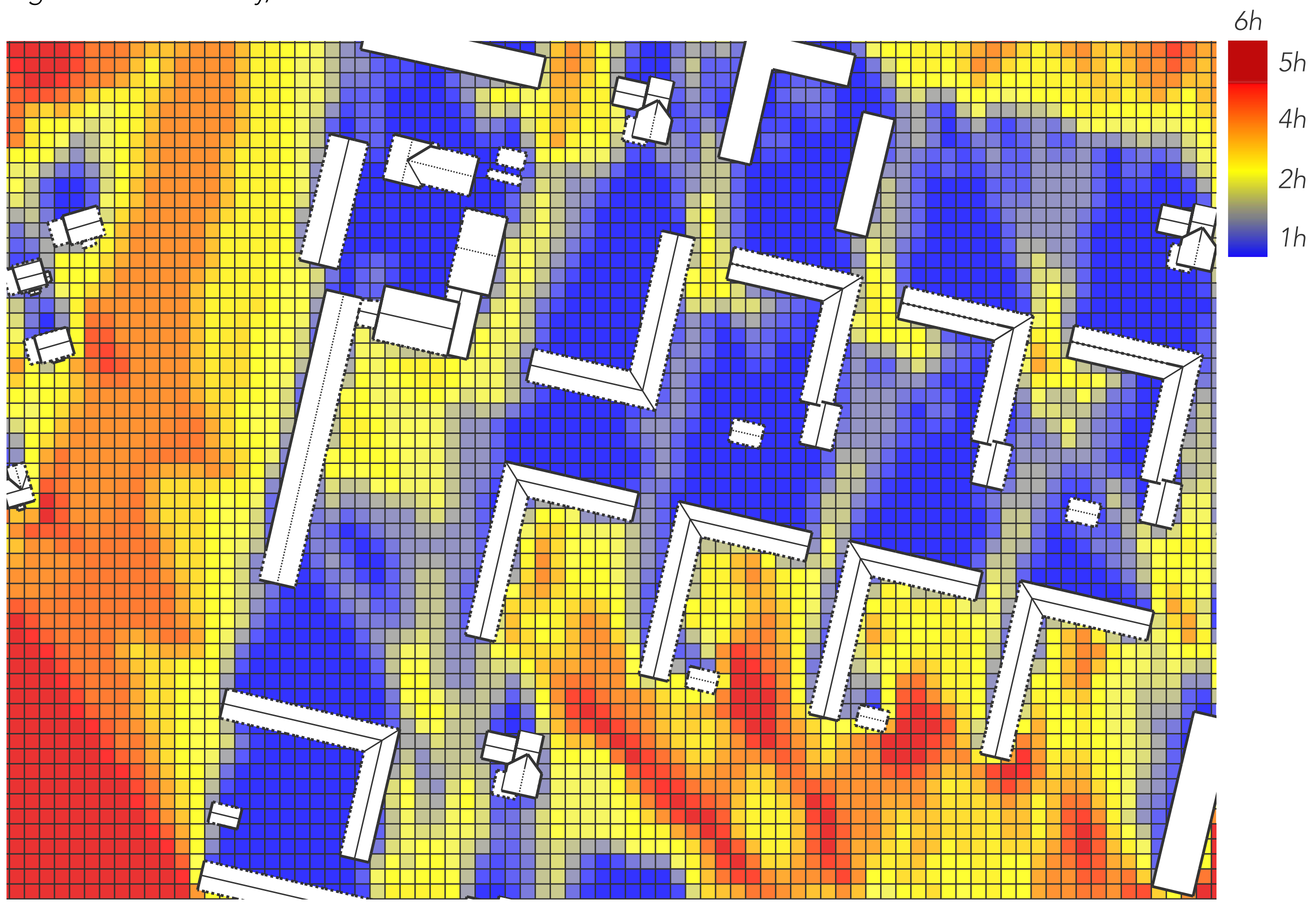


Figure 4.20: Sun study, December 21th

Framework

For Positioning of Agricultural Systems

In order to optimally position the agricultural systems while taking into consideration the quantity of each group of vegetables and fruits, the framework was created. It shows the sunlight needs, the harvest season and in which agricultural system each group can be grown. The harvest season does not take into consideration climate-controlled systems such as greenhouses with artificial lighting, which can prolong the harvesting to all year round. This information can also be found independently in the handbook with an additional showcase of design opportunities and implementation of the agricultural systems.

The framework also shows a percentage of how much is to be cultivated in each group. This does not necessarily translate into the agricultural area used for each group, but to the amount that is harvested in total which depends on the system yield.

The knowledge in the framework combined with the sun, soil and function analysis as well as the general knowledge about the intermediate city is used to program the area of the chosen site, Kyrkbyn, to optimize the placement of the agricultural systems.

Plant Type	Light	Harvest Season	Agricultural System	% of Total Cultivation
Roots	Sunny Partial shade	All year around	Flood & Drain, Drip System, Traditional Agriculture, Roofs	15
Legumes	Sunny	Late Spring Summer Fall	Flood & Drain, NFT, Soil bed, Traditional agriculture, Roofs, Green walls	10
Leafy Greens	Partial shade	Summer Fall	All systems	10
Vine Plants	Sunny	Summer Fall	Flood & Drain, Drip System, Aeroponics, Soil bed, Traditional agriculture, Roofs, Green walls	15
Fruit Trees	Sunny	Summer Fall	Traditional agriculture, Roofs	30
Fruit Plants	Sunny	Summer Fall	All hydroponics systems, Soil bed, Traditional agriculture, Roofs	20

Figure 4.21: Compilation of data from the used sources

Programming & Calculations

As mentioned in the introduction to chapter four, the production goal to make the Gothenburg municipality self-sufficient in vegetables and fruit is 120 450 000 kg per year. To address this goal, the chosen site in Kyrkyn is programmed with different agricultural systems to get a general estimation of possible production.

The pitched roofs are used for green roofs due to the limitations of those surfaces. In the southern part of the section, the flood and drain system, the raft culture system and traditional agriculture are placed, due to the sunlight quality.

The aquaponic system is placed in the slightly more shaded courtyards due to the fish in the tanks. The lighter hydroponic systems (NFT, aeroponics and drip system) are placed on some of the rooftops. Soil beds are placed in close proximity to other agricultural systems, near the courtyards and on some of the rooftops.

The pitched roofs with a combination of the drip system and soil beds (pink and green) are part of a densification effort. The buildings are extended with additional floors with new flat roofs that house agricultural functions.

System	Area (m²)	Average Yield (kg/m²)	Production (kg/year)
Agriculture	10 000	2	20 000
Soil Bed	10 000	2,5	25 000
Green Rooftop	8 000	2,5	20 000
Green Wall	60	2,5	150
Flood & Drain	2 000	45	90 000
Raft Culture	2 000	45	90 000
Drip System	2 000	60	120 000
NFT	2 000	65	13 000
Aeroponics	1 000	80	80 000
Aquaponics	1 500	65	97 500
Total	38 560	-	672 650

Figure 4.22: The table shows the production of each agricultural system based on an approximation of the area and the average yield of each system

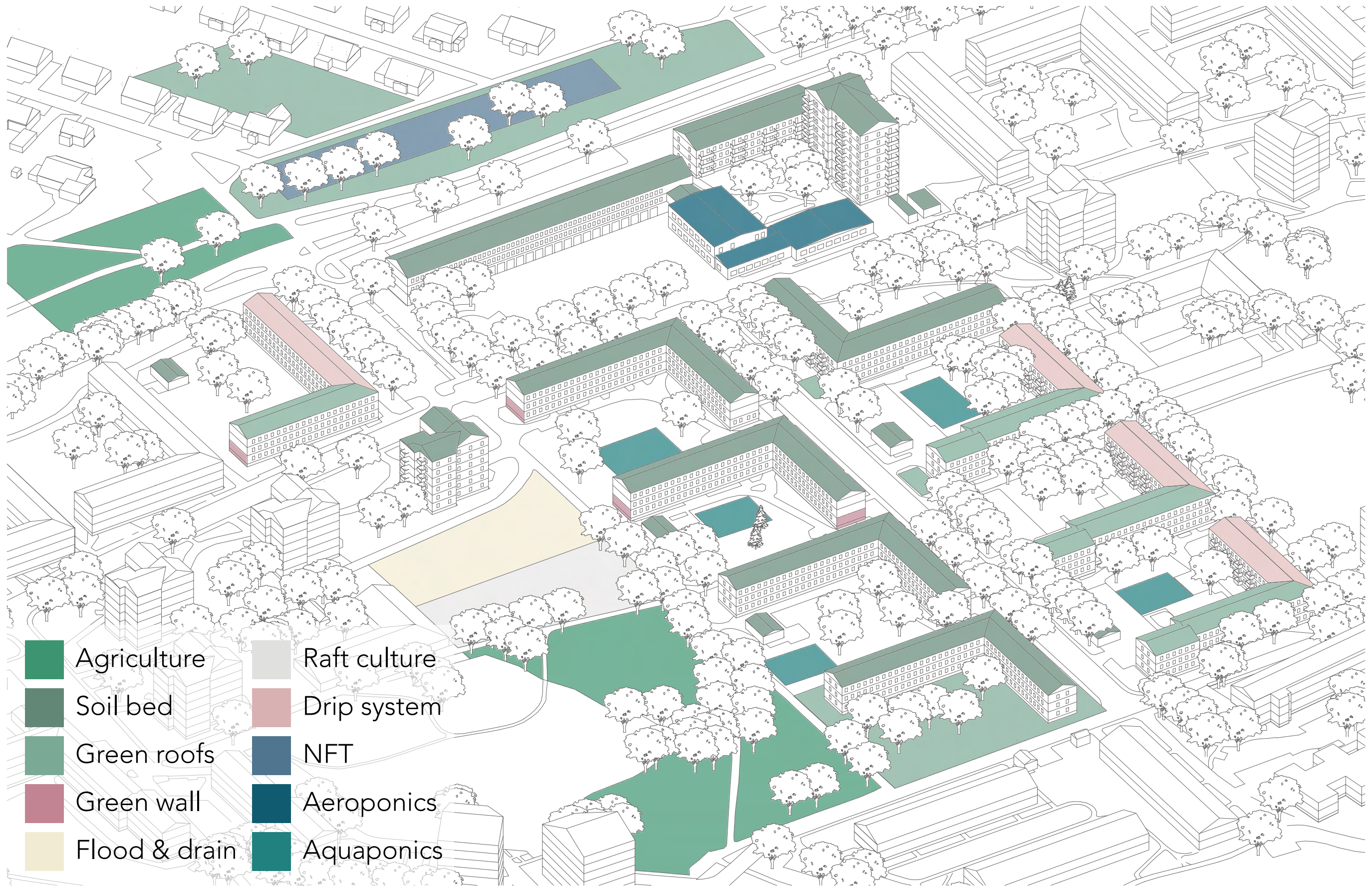


Figure 4.23: Progamming of agricultural systems in the chosen area Kyrkbyn

To take into consideration that the area is also occupied with additional agriculture infrastructure, areas that may have a lower yield, soil quality, and other unidentified circumstances, the total production is reduced by 50 percent. This gives a final production of 336 325 kg vegetables and fruits per year. The following calculation shows an estimate of the total production of the intermediate city, under the assumption that the other areas have an equal production as Kyrkbyn:

Area of exploration: 120 000 m2 (0,12 km2)
Intermediate city area: 92,4 km2

Production estimate: 92,4 / 0,12 (km) x 336 325 (kg) = **258 970 250 kg**

This is more than twice the intended goal of 120 450 000 kg per year.

Production goal

Production outcome

Production of Fruit From Trees

Making a generalisation, a fruit tree produces approximately 40 kg of fruits per year. According to the framework (see page 47), fruit trees are should cover 30 percent of the total food production, meaning 0,3 x 120 450 000 (kg) = 36 135 000 kg. Translating this to Kyrkbyn, the production would be 0,12 / 92,4 (km2) x 36 135 000 (kg) ≈ 46 900 kg. The amount of trees that would need to be planted to cover for the production is 46 900 (kg) / 40 (kg/tree) ≈ 1170 trees. There is not enough ground space to plant that amount of trees in Kyrkbyn, thus, even if the total production need of Gothenburg is covered, the fruit need most likely will not be covered.

Production Unaccounted For

In the design area, a total of 36 Glasir-trees (see chapter three in the handbook) have been placed. According to the reference project Glasir, one tree can produce approximately 21 800 kg of food through the aerponic system. If all the areas of the intermediate city had an equal density of Glasir-trees, the total production outcome would be 604 296 000 kg which is five times as much as the goal. However structure has not been included in the calculations because it has yet to be a proven method of food production.

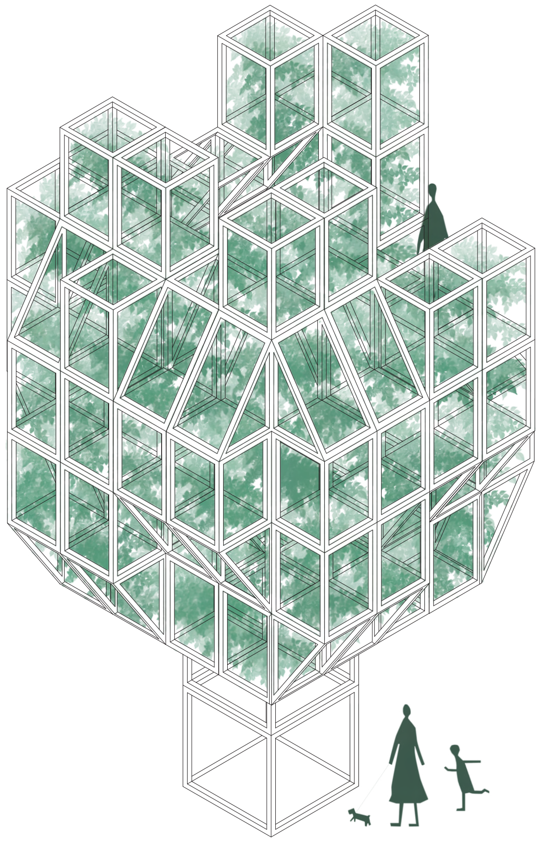


Figure 4.24: An illustration of the Glasir-tree

Reference Project

Glasir: A Tree Assembles in Brooklyn
Designer: Framlab
Read more: https://www.framlab.com/glasir

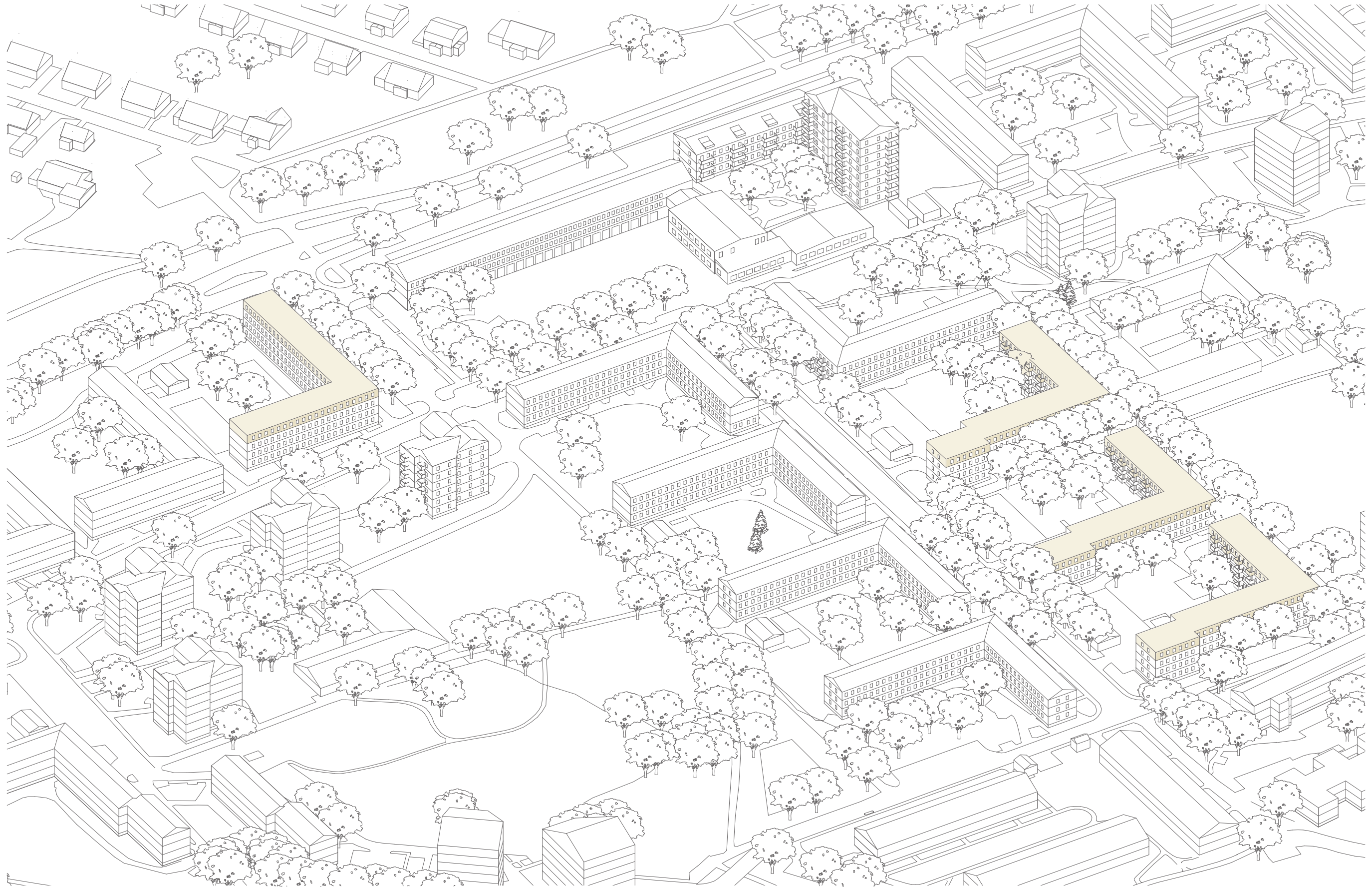


Figure 4.25: Densification by adding a floor to four of the open blocks

Densification

Four of the open blocks are part of a densification effort to cover the housing needs of Gothenburg city by adding a floor. As stated in the section *Densification and housing politics in Gothenburg*, the city needs to build 4000-5000 homes per year until 2030. Averaging 4500 new homes per year, with the start year 2022, a total of 9 (years) x 4500 (homes) = 40 500 homes need to be produced by 2030.

A plan view of one of the open blocks in Kyrkbyn can be found in Appendix A, showing the number of apartments per floor. Each new floor contains 18 new apartments, totalling 72 for the entire area. The following calculation shows an estimate of the densification of the entire intermediate city:

Densification: 92,4 / 0,12 (km2) x 72 (homes) = **55 440 homes**

An addition of one floor on just a few buildings can cover the need of the entire city, while minimally altering the densified areas. For design opportunities on how this can be done, see Rooftop Accommodation in chapter four of the handbook.

Chapter Five

Discussion & Conclusions

Discussion and Conlusions
Bibliography

5

Discussion and Conclusions

The first part of the thesis answered the question of **what design opportunities can be found for scaling up urban agriculture in Gothenburg**. Urban agriculture is a wide term that can mean many different things depending on the context. Finding design principles to scale this operation up in Gothenburg city consisted of exploring the existing technical systems for agriculture and their productivity as well as exploring possible design principles and solutions. The resulting product is a handbook that describes the existing agricultural systems divided into two categories: geoponics and hydroponics, and some design principles to showcase the possibilities within the intermediate city. As a reader, given they are a designer or a city planner, it is important to understand that these design principles are merely a source of inspiration. In reality, the complexity of a design project has to be taken into consideration, rendering some of the suggested designs less likely to be realized. However, we still believe many of these designs can be of value when considering how to further develop an existing area or start development on a new area as they pose questions and answers about the optimization of space to make room for urban agriculture.

The handbook is not meant to be read as a final product, but rather to be seen as an ongoing process of our understanding of urban agriculture and design.

The second part of the thesis answered the question of **whether urban agriculture in the intermediate city of Gothenburg can produce enough vegetables and fruits to make Gothenburg self-sustaining**. The exploration of this question consisted of utilising the knowledge gathered about the agricultural systems and their productivity for the first part of the thesis. Combining this knowledge with the sun, soil and functional analysis of the chosen area Kyrkbyn allowed us to program the area according to the optimal agricultural functions. The simple answer to the question is: yes, urban agriculture in the intermediate city can produce enough vegetables and fruits to make Gothenburg self-sustaining. However, there are a few complexities that we have not taken fully into consideration.

The chosen area is a typical area of the Gothenburg intermediate city. To make the calculations of the entire intermediate city, we made an assumption that all the intermediate city areas of Gothenburg can generate as much produce as Kyrkbyn. We believe that is a fair assumption to make because of the similarities between the different parts of the intermediate city, however, we can't deny that the accuracy of this prediction may be wrong. For example, we can't take into consideration the soil type, daylight quality, and exact building configuration of the entire intermediate city. If the differences are big enough, the answer to the self-sufficiency question may vary.

Optimization of design for urban agriculture

When designing the section of Kyrkbyn we noticed a predictable trend - flat surfaces are vital for making room for urban agriculture. This can be translated into courtyards without height differences, generally flat terrain, and flat rooftops. The only thing out of the designer's control is the general terrain of an area. One can argue for the spatial qualities in the variation of terrain or the beauty of a city silhouette with pitched rooftops, however, in the face of climate change, natural disasters, and food shortage, these qualities come secondary to the optimization of food production. That is not to say that urban agriculture does not bring spatial qualities. As can be seen in the handbook, urban agriculture can make a rooftop or a courtyard more alive with greenery and create spaces for collaboration, work, and social engagement surrounding farming, all while solving the issues with food production.

The majority of rooftops in Gothenburg city are pitched, and though there is beauty in that, we argue that there is no point in further building this type of rooftop. Flat rooftops simply have more to offer in terms of space for urban agriculture as well as social space and are thus more beneficial to the development of the city. However, this opens a debate about the prioritisation of roof spaces for solar panels versus urban agriculture. Solar gain is evolving in terms of technological features but still, the integration of solar panels onto the façade is becoming the norm. It is preferable to build facades for energy consumption and roofs for food and recreation.

The complexity of the food system

The food system as a whole is described in the thesis background and contains land and space for agriculture, farming and food production, processing and distribution, trading, consumption and food waste and recovery. The research and design have been focused on land and space for agriculture as well as farming and food production while taking minimal consideration for the rest of the system. To develop a new agricultural system, the complexity of the whole system has to be understood and designed. We have created spaces for storing food and water, as well as a space for trading, but we have not explored the systems in depth.

Local production is more sustainable than importing goods because it cuts down on transportation which is a major contributor to emissions. Combining that with trading on site can be a major cutdown on the climate impact of food production. Domesticating the food production would mean a bigger consumption of fertilizer, or in the case of hydroponics, nutrient solution. An exploration of the production, transportation and environmental impact has to be done. One possible solution is domesticating the production of this as well, for example, nutrient solution through aquaponics. Added emissions due to fertiliser production have to be taken into consideration when considering a sustainable food system.

The Swedish climate is often too cold to produce vegetables and fruits during the winter months which generates the question of self-sufficiency during the colder seasons. The calculations are based on a yearly yield per square meter, and though some of the systems don't produce during the colder months, the total production is still enough to sustain Gothenburg city. It is a question of storing the food for later consumption. The climate-controlled systems can utilise artificial lightning and heating to continue production during the colder months. This poses a question of environmental impact and emissions due to the added energy consumption. The expense of heating and lighting is a major obstacle for modern greenhouse vegetable farming. Prices have recently reached an all-time high, which has significantly diminished the economic gain for businesses. This equation must be solved for local production to be economically viable.

Development of Gothenburg City

Going into this master thesis, our main focus was to find agricultural systems and design principles to implement in the intermediate city. This thesis has generated many other questions about the general development of Gothenburg city and the sustainability of it all. The policy in Gothenburg city has been to densify most urban areas and create block structures with active facades on the bottom floor. When densifying spaces in the intermediate city, a similar approach has been utilised which has created an unsustainable design. The context has been ignored in favour of the idealized idea of the dense, active block structure, while completely overlooking the qualities of spaciousness, light, and greenery that the intermediate city has to offer.

We argue that building more residences does not necessarily have to lead to a dramatic increase in densification at the expense of daylight, space, and green qualities. We can clearly showcase this in the design principles in Kyrkbyn. Even while adding more residences, enough to cover the need of Gothenburg city if implemented on the intermediate city scale, the daylight quality is still sufficient. The spaces are reconfigured into agricultural functions, however, the social spaces are not reduced, but rather enhanced to create a community around farming. Additionally, the greenery has increased in the area, both in quantity and quality, thus counteracting the general reduction of green spaces that is been occurring while simultaneously densifying the area. There is no question of green versus dense or light versus dense. We believe we can solve both issues when developing the intermediate city by being prudent in the usage of land. As a rule, do not add BYA - plots on the ground. Always expand and extend BTA within the existing fabric. These interventions and ways of thinking can solve both issues of densification and food security for future population growth.

Some of the design principles create economic and social sustainability as well. For example, the start-up market consists of small spaces that can be rented by new start-up companies. The market can also be used to sell and distribute vegetables and fruits that have been produced in the area which creates a new local economic loop. Similarly, the palm house and the globe create new public spaces for interaction, thus promoting social sustainability. These spaces can also be used for education.

As with everything else, there is a question of financial feasibility, and while we have chosen not to focus on that in the thesis process, it is worth a mention because of its importance in a real-life application. One of the suggested design principles is building an additional floor on existing buildings. This has been done many times before and is thus a realistic solution, especially considering the general spaciousness of the housing structure in the intermediate city. The resistance may come from the potential cost of construction, which is a topic that needs to be further explored. Another option is conversions of attics which are not as costly.

Can the added revenue from the new residences and agriculture cover the cost of construction? Can the municipality of Gothenburg subsidise the cost as a means to promote sustainable development?

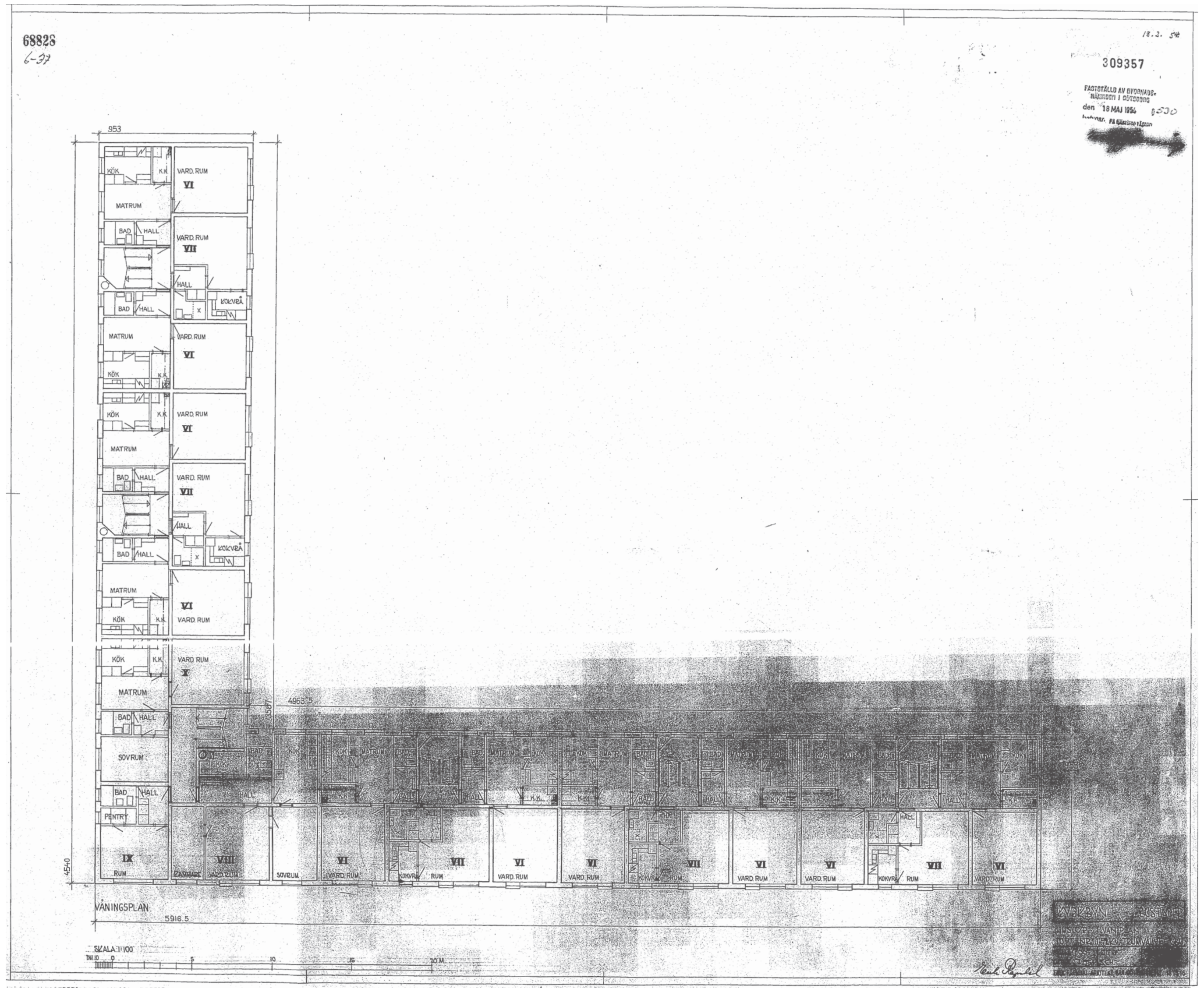
Chapter Six

Appendix & Bibliography

Appendix A
Bibliography

Appendix A

This is a plan of one of the open blocks in Kyrkbyn.



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