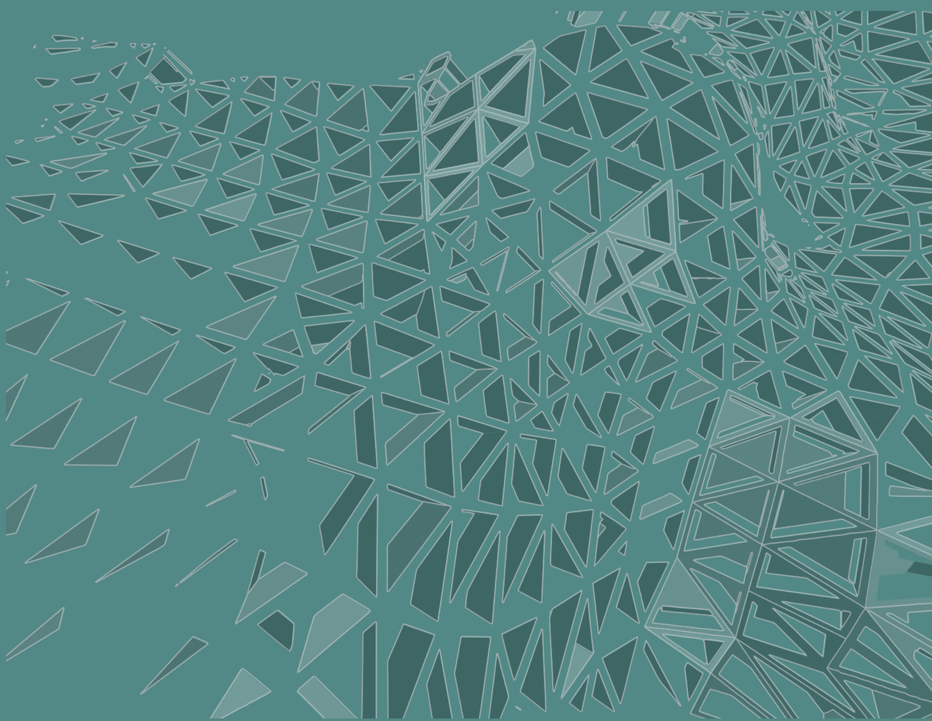
# Densi-Greenation

**Exploring the integration of nature and built environment**

Master's Theses in Architecture
Direction: Urban Challenges

Nour Fansa



CHALMERS

Master's Theses in Architecture
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### PREVIOUS WORK

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| Wåhlin Arkitekter | Stockholm/Sweden | 2015- |
| MD Arch Mimarlik | Istanbul/Turkey | 2014 |
| Studio Vertebra | Istanbul/Turkey | 2013-2014 |
| NDesign | Aleppo/Syria | 2011-2013 |
| Square Studio | Aleppo/Syria | 2010 |

### PERSONAL MOTIVATION

I grew up in the city of Aleppo in Syria, which had a population at the time of around four million inhabitants.

The city was pretty much dense and full of buildings with only 3-4 green public areas (parks), where they were often crowded.

After I moved to Sweden, I noticed how essential was nature and green areas for the people and the city planners in general which took my attention.

Despite that, I realised that not only people did not have good access to the green areas that were often very close to them, but also some green areas were removed during the building process and were not taken into account, which led to the inspiration of this master's thesis.

ABSTRACT

## TERMS AND DEFINITIONS

What are nature, Ecosystem services, and GYF?

Nature is a broad term, and it has many definitions. One definition of nature is “the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations” (Oxford dictionary, n.d.)
In this master’s thesis, the word nature is mainly used as a synonym to ecosystem and vegetation.

### Ecosystem services

Ecosystem services are the functions of the ecosystem that in some way benefit humanity, and improve the living conditions.

Cleaning the air we breathe, enhancing food, fuels, and pollination, the ecosystem has also intangible and emotional values that contribute to the quality of life and health.

Ecosystem services are often created in the interaction between people and nature.
Green areas and ecosystems, ranging from hardwood forests to green farms and green roofs, contribute many different ecosystem services.

They catch up, delay and purify stormwater, improve urban air, support pollination of fruit trees and berry bushes. Ecosystems also cool down high-temperature increases.

### GYF (The green surface factor)

The green surface factor is the ratio between the “eco-efficient surface” and the entire plot of land or property.
It is a working tool to ensure that green qualities are achieved in the site, and the purpose of it is to contribute to good living conditions for people, animals, and plants by creating air quality, good soil quality, water balance, and suitable free areas.
The green surface factor is above all an essential tool for a systematic dialogue between the municipality, and the building actor on greenery in the neighbourhood, and public spaces.



## ABSTRACT

“Today, around 55 percent of the world’s population is thought to be living in an urban area or city, with that figure set to rise to 68 percent over the coming decades” (United Nation, 2018)

What this fact illustrates is that more people are moving to the cities, making them more crowded and less green, we need to find solutions integrating nature more and more into the cities and reduce the rift between the green life in the countryside and the lack of the connection to nature in the cities.

The need of integrated nature in architecture has risen in the last few years, especially after experiencing direct effects of global warming in many areas around the world, unexpected flooding and an increase in the temperature.

Green cities (in this context cities with nature integrated in architecture) were well-known in the past, when as a result social relations were enhanced.
Nowadays, we are more capable of having this integration in better ways, thanks to the advanced technology we have achieved that can help us get more precise and better solutions.

In some ways, nature has the same effect as technology; it can enhance the living conditions, by protecting us from harmful solar radiation, and increase cooling, etc.

The purpose of this project is to explore how can natural systems be integrated into the built environment with the aim to create micro-ecosystems within the city that aspire to provide better methodologies and strategies in which we can integrate nature into buildings, and make everyday’s life more of a combination between the quality of the countryside and the city.

• Figure 0.1: Hanging gardens of Babylon (familyholiday.net)

# 1-INTRODUCTION

## 1-INTRODUCTION 08-10





## 1.1 AIM

This master thesis aims to explore using a combination of different methods, the possibilities of integrating vegetation to architecture, based on experiments, and other factors to create new ecosystems within the city and enhance the urban experience.

## 1.2 BACKGROUND

Architecture and nature have always been in a relationship; they formed an equilibrium that enhanced the spatial and urban experience. During the past decades, it seems that this relationship is falling apart due to the wrong focus and use of technology and development that we have achieved, possibly because of some rules limitations or because of our way of thinking in integrating nature to architecture.

The rules are given mainly to enhance our lives, but they also might not be adaptable in all cases.

As it seems, the architects try to adapt their designs to the rules even though it might limit their development of the project.

## 1.3 THESIS QUESTIONS

Nature has always been a central part of the architecture development even though it seems to be sometimes forgotten/ ignored in various contexts.

Therefore this thesis will attempt to answer these questions:

How can nature be integrated into architecture to enhance the urban experience?

How can an architect increase the percentage of green spaces into an architectural development?

## 1.4 RELEVANCE

Climate is changing, and Stockholm is expected to get warmer and softer climate. There will be more rainfall in winter, milder winters and shorter ones.

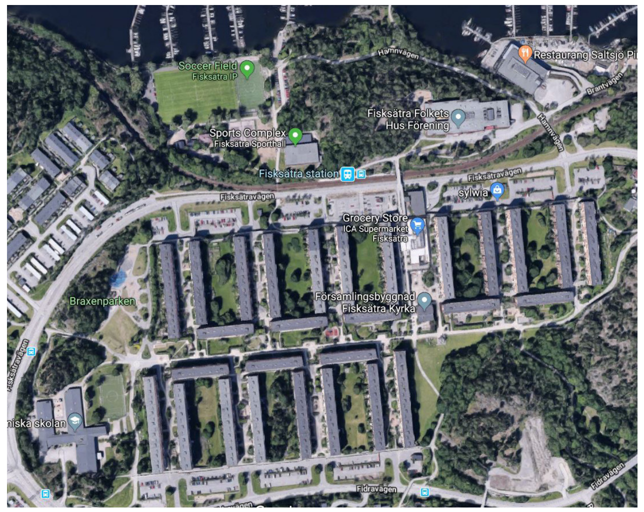
In addition, the chance of ice seasons, warmer and drier summers, heat waves, rainstorms, earlier spring floods and risk of flooding would increase. It also means stresses for vegetation in the city: more extended dry periods, reduced snow cover, earlier spring, and autumn, etc.

Many areas increased demands on building resilient green structures in the city that can recover after strains. (Stockholm city, 2015)

Sweden is one of the countries where the existence of nature and vegetation can be experienced almost everywhere.

Meanwhile, some areas in the cities mainly suburbs have still the possibility to enjoy "green" qualities more than any other part of the city.

Figure 1.1 is a site plan picture from google maps where it is showing the existence of nature in the suburbs.



• Figure 1.1: Fisksätra (Google maps)

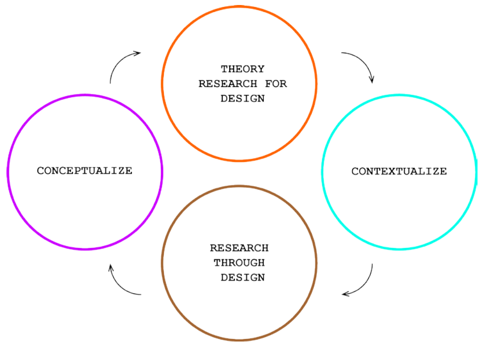
## 1.5 METHODS/TOOLS

The master thesis design method is divided into three parts, based on researching for design and researching through design.

•Starting from previous case studies and research, where there was an integration of nature into architecture.

•Understanding Ecosystem services.

•Experimenting through the design elements and parameters that can help to have better conditions to integrate nature.




• Figure 1.2: Method diagram

## 1.6 METHODOLOGY

The type of research conducted would be research for design and research by design. The second, third, and fourth chapters of the thesis are based on research for design method. Meanwhile, the fifth chapter of the thesis is based on research by design method to formulate a design proposal to reflect on the design itself.

The information in this thesis would be collected from books, articles, and previous developments suggestions.

The first phase would be: understanding the correlation between nature and architecture, sketching ideas and define the solutions, based on the information collected in the project.
Fitting in the context, and making a design proposal would be the second phase.
On the final presentation, there will be a design proposal, based on research, experiments, and the collected information.

## 1.7 DELIMITATIONS

The main focus of the project is to explore how nature could be integrated into architecture.

The exploration is limited based on some parameters and factors (Green Surface Factor).

Due to the time limitation, the system will not be applied to other sites and areas. However, it could be adaptable in other sites.

The current "Detaljplan" for the chosen site would be ignored, (heights requirements, type of buildings, and the allowed built area), considering that "Detaljplan" could be changed in future.

The design proposal in this master thesis will not tend to focus on the structure, nor the circulation of the design proposal, the focus will be on the system in general.

## 1.8 CONTEXT

**Where?**
The project would take place in the Swedish million program areas, more specifically in Stockholm, Fisksätra area.

**Why?**
The Million program project is one of Sweden biggest developments in its modern history, where it could be seen in most of the major cities of Sweden.

The Million program is built in areas full of nature. However, under the development of the program, a part of the nature of the site was removed in order to fulfil the requirements of the development. Some areas of the program are nowadays under ongoing development, which gives the chance of investigating new approaches to integrating nature into architecture.



# 2-BACKGROUND AND RELATED WORK

## 2.1 CASE STUDIES

There are many projects that integrate nature into architecture. Through the research process, three projects were selected to be studied. The selection was based on the different approaches of integrating nature into architecture that each project has, and these projects are:

**1-PARKROYAL on Pickering in Singapore by WOHA architects:**
In this project, nature is integrated into architecture as in Hanging gardens.

**2-1000 trees in Shanghai by Heatherwick Studio:**
In this project, nature is integrated into architecture in a way that each tree has its own separate structure isolated from the main structure.

**3-Vertical Forest in Milan by Boeri studio:**
In this project, nature is integrated into architecture in a repetitive system.

**1-PARKROYAL on Pickering in Singapore by WOHA architects**

It is a hotel building by WOHA architects, where nature is integrated into architecture.

Different types of planting methods were used in this project, as plants were planted vertically and horizontally, and creepers were planted along with the building.

It has more than 15000 m2 of green areas which are doubled than the total land area, it has the look of hanging gardens where nature is hanged in some parts of the hotel, makes it accessible through specific places.

The gardens contain shading trees, palm trees, and creepers. They attract not only people but also birds and insects.


• Figure 2.1: PARKROYAL on Pickering in Singapore by WOHA architects (Archdaily)



Parkroyal is a self-sustaining building with all the systems, and the technologies that are used and integrated into the building, like harvesting rainwater in the upper floor, and a system to recycle the NEWater (treated wastewater), making it Singapore's first zero energy sky garden.

In this approach, the greenery exists only in specific areas of the building which leads to limited accessibility towards nature.

**2-1000 trees in Shanghai by Heatherwick Studio.**

"1000 Trees is conceived not only as a building but as a piece of topography and takes the form of two tree-covered mountains, populated by hundreds of columns," (Heatherwick Studio, n.d.)

The development is arranged in an orthogonal grid forming a typology shaped mountain sloping down the edges, the development covers an area of 300000 m2.

The integrated planting acts as a natural balancing elements, where fully grown trees are hanged on separated structured columns that carry all the loads of the trees and the soil.

In this approach, the integrated nature is concentrated on separate structured columns and has no accessibility from the building.

• Figure 2.2: 1000 trees in Shanghai by Heatherwick Studio (Heatherwick Studio)

**3-Vertical Forest in Milan by Boeri studio**

"It is a model of vertical densification of nature within the city that operates in relation to policies for reforestation and naturalization of large urban and metropolitan borders."
(Stefano Boeri Architetti, n.d)

The propose of the project is to create a microclimate within the city.

Vertical Forest has a repetitive system to integrate nature, where vegetation is placed on hanged balconies that shift in each level making space for vegetation to grow. These balconies are accessible from each apartment. Thus, each apartment has its own nature.

Furthermore, the vegetation could be seen in all the different levels of the building.

As noticed, the first two case studies touched the concept of integrating nature into architecture. However, the greenery in PARKROYAL on Pickering project was accessible from specific parts of the building but not repetitive.

Meanwhile, in 1000 trees project the greenery is repetitive but not accessible.

In contrast, the Vertical Forest project approach of nature was both repetitive and accessible. Thus the project would be studied further.

• Figure 2.3: Vertical forest in Milan (Stefano Boeri Architetti)



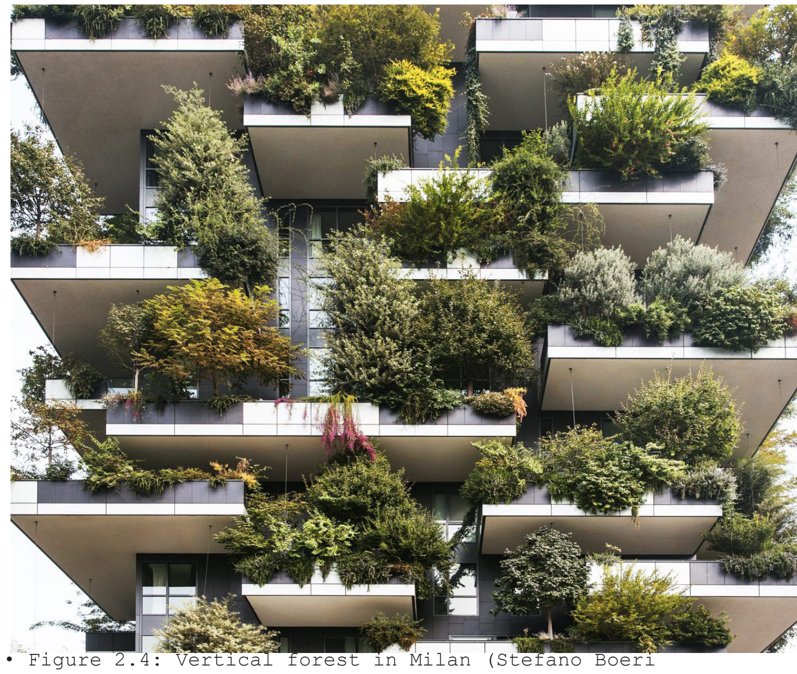
## 2.2 VERTICAL FOREST

• Key Concept: Ecosystem diversity, Nature, Urban Biodiversity, Vertical Forests

• Project: Bosco Verticale

• Location: Milan, Italy• Who: Stefano Boeri Architetti

• What: Ecosystem diversity



• Figure 2.4: Vertical forest in Milan (Stefano Boeri Architetti)

### ECOSYSTEM DIVERSITY

The purpose of the project:

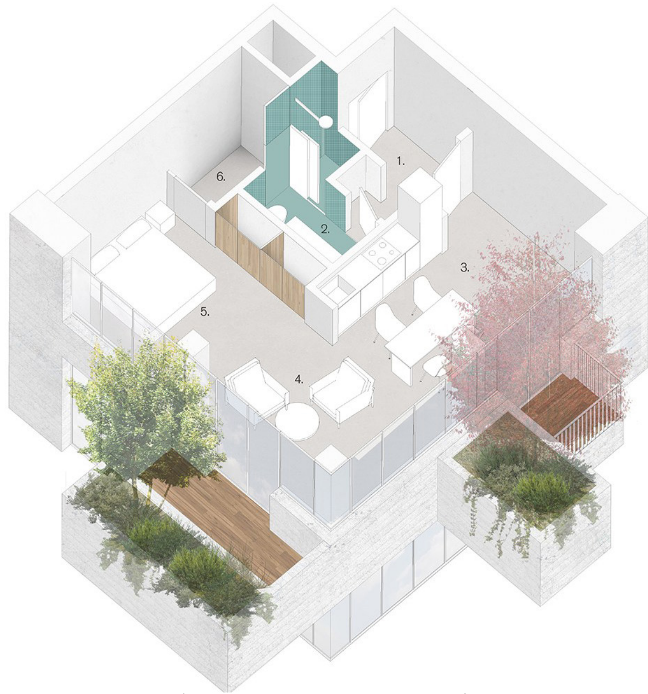
"A project for metropolitan reforestation contributing to the regeneration of the environment and urban biodiversity without the implication of expanding the city upon the territory.

It is a model of vertical densification of nature within the city that operates in relation to policies for reforestation and naturalization of large urban and metropolitan borders.

Hosting 800 trees (each measuring 3, 6 or 9 meters), 4,500 shrubs and 15,000 plants from a wide range of shrubs and floral plants distributed according to the sun exposure of the facade" (Stefano Boeri Architetti, n.d).

By looking more closely to the plan drawing understanding the relation of the footprint between the built area and the "green area", where did the architect intend to place the vegetation, and see how it affected the space and the growth of vegetation.

• Figure 2.5: Vertical forest, plan drawing (Stefano Boeri Architetti)

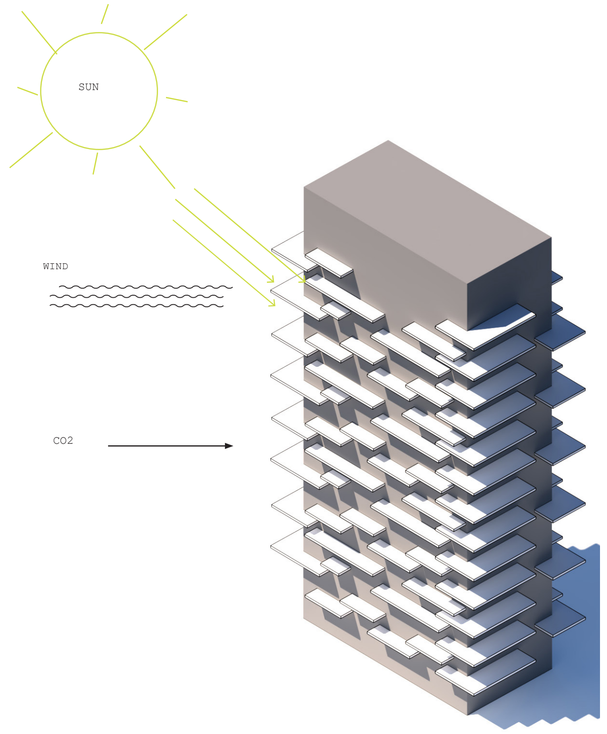


• Figure 2.6: Vertical forest, axonometric (Stefano Boeri Architetti)

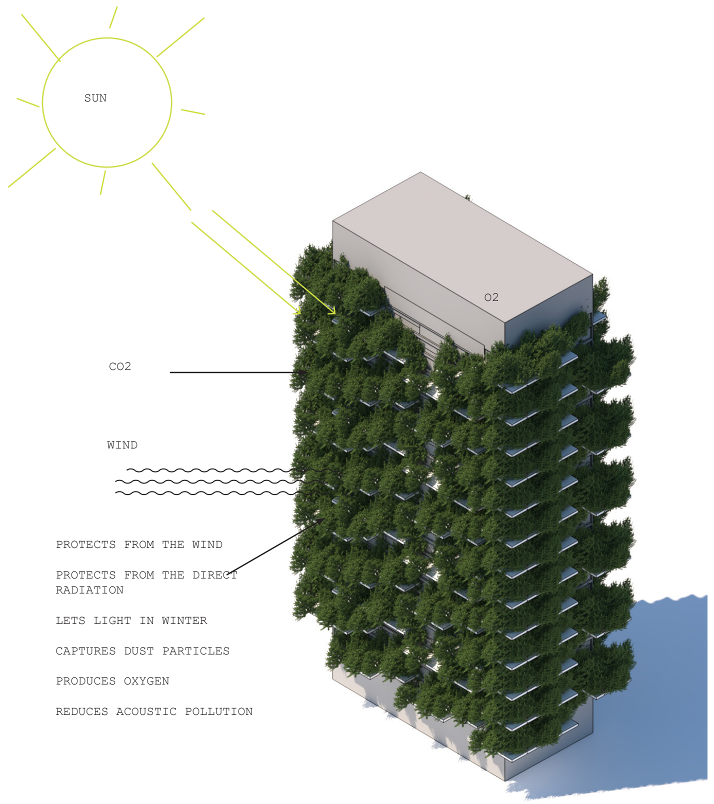
## 2.4 WITHOUT VEGETATION AND WITH VEGETATION

Vegetation integrated to architecture creates within the urban environment a green habitat for the development of biodiversity, a real ecosystem with over 70 different plant species able to combat air pollution, the capacity of trees to absorb over 50 tons of carbon dioxide every year.

Vegetation aligned on the facade helps to protect the building from the harmful solar radiation in summer, and it lets sunlight to get inside in winter. Vegetation helps to absorb Co2 and release O2, it works as a wind shelter, it captures the dust particles make the air cleaner, and it reduces the acoustic pollution.




• Figure 2.7: A building without vegetation




• Figure 2.8: A building with vegetation



## 2.5 ORIENTATION OF SPACE

Trees and different plants are essential components of prompt open-air spaces.

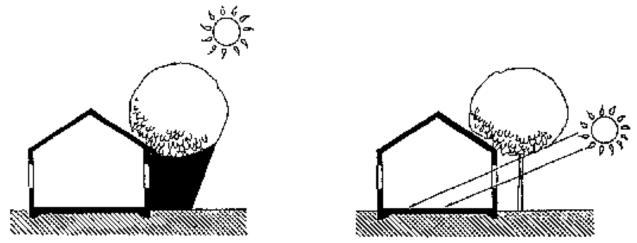
They are modest components which manage and improve the atmosphere.

When planting trees, some essential principles ought to be remembered:

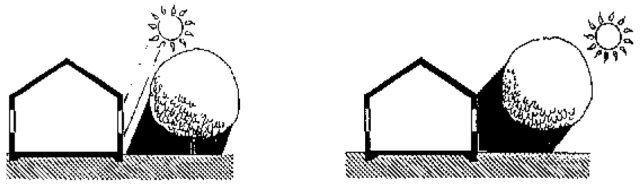
At what time and at what periods of the year is shade needed?

• A tree planted near a building, even with the crown covering the rooftop, gives the best assurance from the extraordinary late morning sun, however, enables access to the sun in noontime hours, when in specific circumstances this is welcome.

• A tree planted in a specific distance of a building gives shade just during the day or morning hours, yet not at noontime, the most blazing time.



• Figure 2.9: A tree planted near a building (Climate responsive building)



• Figure 2.10: A tree planted in a specific distance of a building (Climate responsive building)

## 2.6 UNDERSTANDING THE SYSTEM

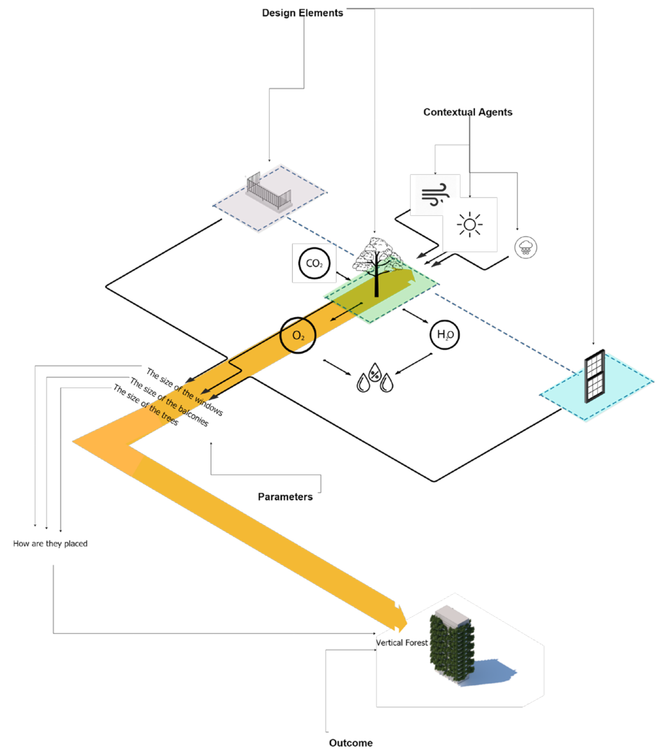
The focus was to explore what system was used for the vegetation in Vertical Forest, understanding the relationship between trees, balconies, and windows and their parameters, the size of them and how are they placed.

How they intend to maintain the vegetation and how long can the trees grow.

What volumes had been used to plant the vegetation.

In this case, the types of trees were chosen by their height and their positioning on the facade; some of the trees were 3, 6, and 9 meters long.

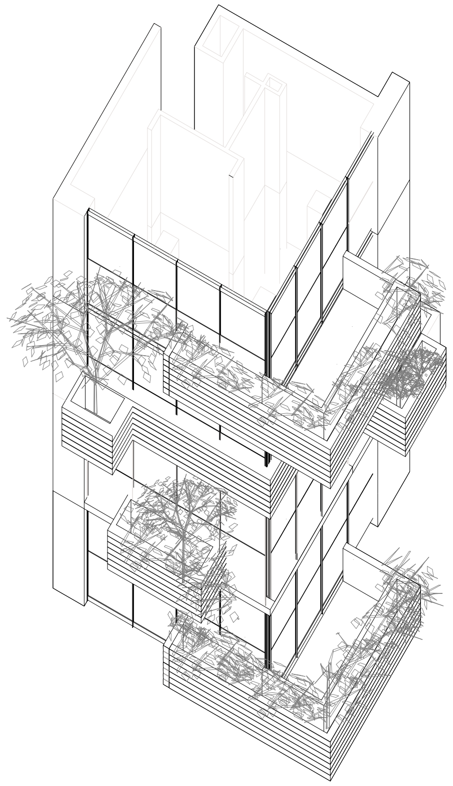
One critical problem in the project was that the hanged soil basins along the façade had a depth of less than 1 meter of soil, therefore, trees would require way more water than an average tree, thus their roots would not grow deeper.




• Figure 2.11: System analysation

Therefore, there was a problem regarding the relationship between the size of the trees, and the soil basin that hosted them.

There's an essential part of a vertical approach which is **CORRELATION WEIGHT AND VOLUME**, and there is a measurement that is used to measure a property of soils and other masses of particulate material divided by the total volume kg/ m³, which is called Bulk Density.



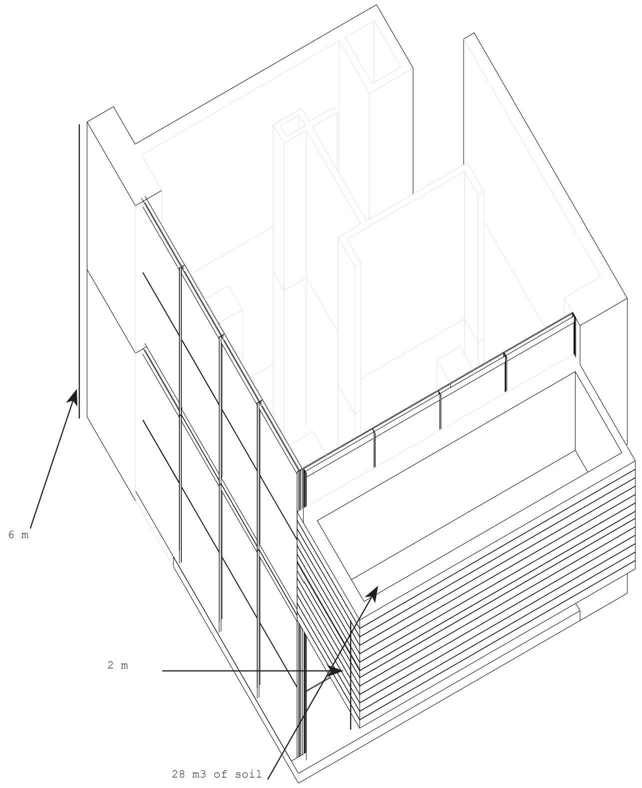
• Figure 2.12: The relation between balconies and vegetation

## 2.7 CORRELATION WEIGHT AND VOLUME

"Soils with a bulk density higher than 1.6 g/cm3 tend to restrict root growth" (soilquality.org.au)

It is different how much soil does a tree need, on the other hand, there is a ratio between the available amount of soil and the size of the tree.
The recommended amount of soil is 28 cubic meters per tree in case they were planted individually unless more than one tree share the same soil, then the amount of soil can be decreased, However, it is not clear how much less. (Green Infrastructure)

Figure 2.13: An illustration showing the approximate volume needed of soil to plant one tree.




• Figure 2.13: The approximate volume needed of soil to plant one tree.

## 2.8 MAINTENANCE

The maintenance of the trees in Vertical Forest is through an integrated system that controls the needs of each tree and plant through sensors and provides them with the needed water, and scheduled gardeners to maintain the trees and trim them, (Figure 2.14)

The system might have flaws such as the lack of accessibility, and the need for consistent maintenance, which requires a dependency on human intervention for the vegetation to be alive.



An approach of these criteria would be to explore a different kind of plants, and the maintenance they need, and understanding the possibilities of placing the greenery differently.

Trees integrated into many floor buildings need to be watered and maintained, which would not be needed if they were on the ground since their roots grow deeper to get underground water naturally.

However, green roofs and shrubs are easier to maintain, and water, possibly through a simple watering system "indirect gravity system" together with harvesting rainwater system (Figure 2.16), rainwater will be stored in water tanks and provide the green surfaces with water through the watering system. The system will keep working even without power.

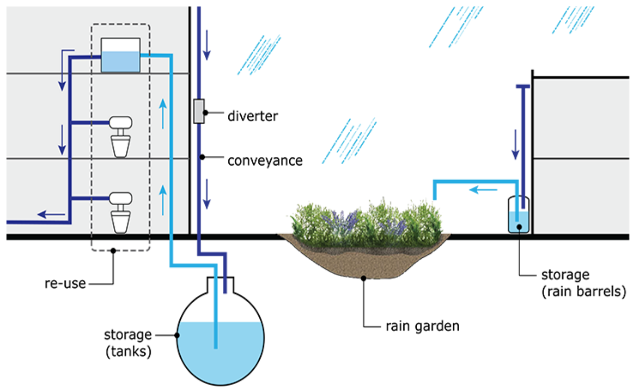
The same irrigation system would work vertically with the need of installing a pump that will pump the collected water in the water tanks to a higher level where water can go through the "indirect gravity system".

Based on the previous case studies, there are some essential points which are needed to be considered to integrate vegetation into the built environment properly. First, soil correlation weight and volume are critical since the architectural design has to be approached in a way that fulfils the vegetation needs. Second, the architectural design should provide easy access to facilitate the maintenance process of the green areas. Finally, using a methodology to determine the relationship between the footprint of the built area and the green surfaces. As noticed from the previous case studies, there was no clear methodology explaining this relationship.

Since this thesis is conducted in Sweden, a standardised methodology called GYF "grönytefaktor" will be applied in the process to both determine the relationship between the green and built areas, and to also accommodate the developed proposal to fit the municipality's requirements.

• Figure 2.14: Integrated maintaining systems (Stefano Boeri Architetti)

• Figure 2.15: Maintenance of Vertical foret (Archdaily)




• Figure 2.16: Indirect gravity system(Save Greenery)

# 3-THE GREEN SURFACE FACTOR

**3-THE GREEN SURFACE FACTOR** 20-29





## 3.1 WHAT IS THE GREEN SURFACE FACTOR

During the 90s the concept was developed in Berlin, Germany under the term "BAF, the biotope area factor" A tool for urban planning to increase green space in the city. The "BAF" can calculate the biodiversity of an area or a plot. i.e. the factor will be represented by the size of land used for plants and ecosystem functions, in relation to the total plot size.

This methodology is not dependent on site-specific condition related to the city, which means, it could be applied in other cities.

The tool was introduced in Sweden, at the "Bo01 fair" (housing fair) in Malmö in 2001, and it is used under the term "GYF" in Sweden. It is designed to allow vegetation and water collections to be housed in the urban environment, and are aimed to promote biodiversity.
Urban Biodiversity and Design book (2008, Norbert Muller, John G. Kelcey)

As mentioned earlier, The Green Surface Factor is the ratio between the "eco-efficient surface" and the entire plot of land or property. It is a tool that is used by Swedish municipalities to ensure that green qualities are achieved in the site.

The Green Surface Factor in the detailed planning process gives the opportunity of planning the greenery in an early stage of the process.

The requirement on which green area factor to be achieved can vary between different projects, depending on the proportion of the neighbourhood that is built or going to be built.

For the GYF (The green surface factor) to be functional as intended, the factor may need to be regulated concerning the proportion of undeveloped ground surface in relationship to the green areas.

The more significant the proportion of undeveloped ground surface means a higher GYF factor, and vice versa.

## 3.2 THE REQUIREMENTS FOR THE GREEN SURFACE FACTOR

In most of the municipalities, The Green Surface Factor must be at least 0.6.
A factor of 1.0 means low exploitation of the plot and 0.4 means there is a massive part of the block is built.

Different municipalities design their working methods with a green surface factor based on local needs and conditions.

Several developers can occur in one neighbourhood, they need to work together to achieve the green area factor jointly. (Stockholm city, 2015)

The green surface factors consist of approximately 70 different factors, and these factors are divided into four categories:

Biological diversity (B), Social values (S), Climate adaptation (K) Sound quality(L).

At least 60% of these factors should be achieved, in order for the development to be approved.

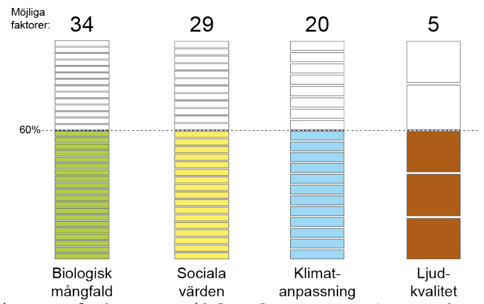
Each of these four categories is divided into secondary factors: Biological diversity (B): it consists of 34 factors.

Social values (S): it consists of 29 factors.

Climate adaptation (K): it consists of 20 factors.

Sound quality (L): it consists of 5 factors.

Figure 3.1: an illustration showing that 60% needs to be achieved in each of the four categories in order to get approved. (Boverket)




• Figure 3.1: Possible factors, (Boverket)

## 3.3 How IS THE GREEN SURFACE FACTOR CALCULATED

The green surface factor is calculated in the relation between functional green surfaces and hard surfaces. Functional green surfaces are for example surfaces covered by trees, lawns or green roofs. On the other hand, Hard surfaces are the solid surfaces that have no vegetation, nor permeability for stormwater such as concrete.

The following steps can be used to calculate Green surface factor (GYF):

• Hard, vegetation-free surfaces usually get the value 0.

• The area of each functional surface is multiplied by the function value to get a measure of the surface's eco-efficiency. For example, a large tree on the ground generates many ecosystem services. Therefore, it gets a higher value than the corresponding surface on a green roof covered with shrubs and green cover.

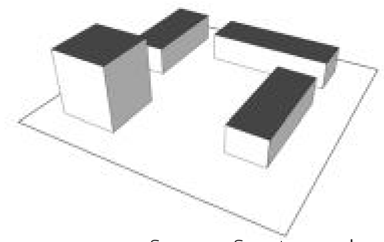
Some of the factors can be in more than one category, for example, a green roof or greenery installed on balconies can help the biological diversity (B), social values (S), and climate adaptation (K)at the same time. (Figure 4.2/5)

• The next step of the calculation would be summarising the eco-efficiency of the green areas and dividing the total eco-efficient area by the total area. The ratio of these becomes the area's green surface factor (GYF).

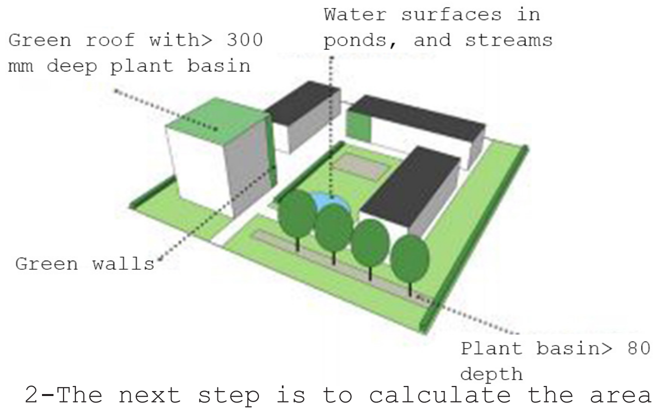
A calculation template is used to automatically calculate The Green Surface Factor. Areas, numbers of different green objects and functions are used as an input, and The Green Surface Factor would be the output of the template.

Figure 3.2: An example of GYF calculation process (Stockholm City)

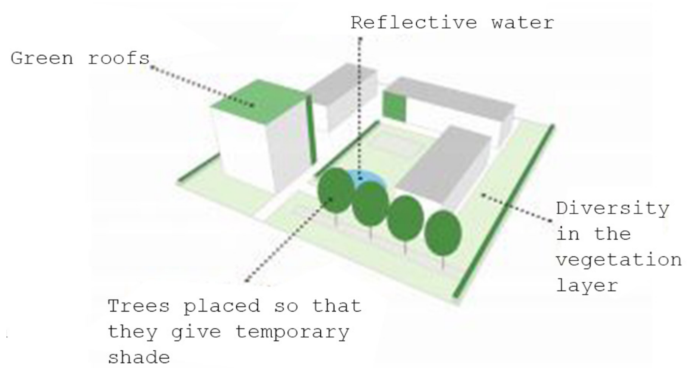
Figure 3.3: GYF calculation template.



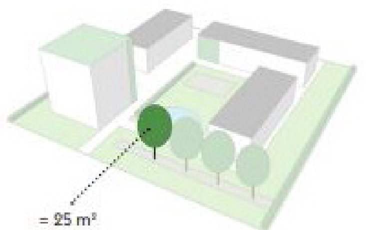
1-The green surface factor is based on the entire plot area.



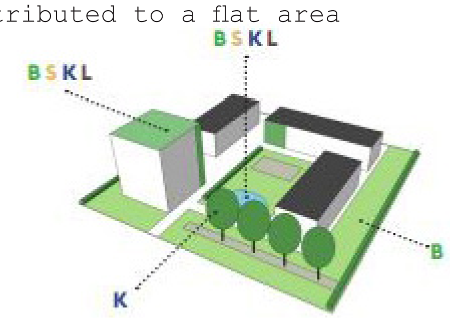

2-The next step is to calculate the area of the green "eco-efficient" surfaces.




3-Additional factors that add extra points are added to the "eco-efficient" surfaces.




4-Some objects such as trees lack a clearly defined surface and are therefore attributed to a flat area




5-The balancing is checked

• Figure 3.2: An example of GYF calculation process (Stockholm City)



| | YTA: | FAKTOR: | ANTAL: | AREA: | FAKTORBERÄKN. AREA: |
|---|---|---|---|---|---|
| | **Delfaktorer grönska** | | | | |
| BSK | Bevarad naturmark | 1,5 | - | 0 | 0 |
| BSK | Ej underbyggd markgrönska | 1,5 | - | 0 | 0 |
| BSK | Växtbädd >800 mm djup | 1,4 | - | 0 | 0 |
| BSK | Växtbädd 600-800 mm djup | 0,3 | - | 0 | 0 |
| BSK | Växtbädd 200-600 mm djup | 0,1 | - | 0 | 0 |
| BSK | Grönt tak med > 300 mm djup växtbädd | 0,3 | - | 0 | 0 |
| BSK | Grönt tak med 110-300 mm djup växtbädd | 0,1 | - | 0 | 0 |
| BSK | Grönt tak med 50 - 110 mm djup växtbädd | 0,05 | - | 0 | 0 |
| BSK | Grönska på väggar | 0,4 | - | 0 | 0 |
| BSK | Grönskande balkonger | 0,3 | - | 0 | 0 |
| | **Tilläggsfaktorer grönska/biodiversitet** | | | | |
| B | Diversitet i fältskiktet | 0,05 | - | 0 | 0 |
| B | Naturligt arturval | 0,5 | - | 0 | 0 |
| B | Diversitet på gröna tunna sedumtak | 0,1 | - | 0 | 0 |
| B | Grönskande balkonger med häng- eller klätterväxter | 0,3 | - | 0 | 0 |
| B | Fjärilsrabatt | 1,0 | - | 0 | 0 |
| B | Buskar generellt | 0,2 | - | 0 | 0 |
| B | Bärande buskar | 0,4 | - | 0 | 0 |
| B | Karaktärsträd | 3,0 | 0 | 0 | 0 |
| B | Befintliga träd | 3,0 | 0 | 0 | 0 |
| B | Nya stora träd (stam >30 cm) | 2,4 | 0 | 0 | 0 |
| B | Nya mellanstora träd (stam 20-30 cm) | 1,5 | 0 | 0 | 0 |
| B | Nya små träd (stam 16-20 cm) | 1,0 | 0 | 0 | 0 |
| B | Bärande träd | 0,4 | 0 | 0 | 0 |
| B | Holkar, bikupor | 0,5 | 0 | 0 | 0 |
| B | Baggholkar | 2,0 | 0 | 0 | 0 |
| B | Faunadepåer | 2,0 | 0 | 0 | 0 |
| B | Biologiska gestaltningselement/habitatstärkande åtgärder | 2,0 | 0 | 0 | 0 |
| | **Tilläggsfaktorer grönska/rekreativa & sociala värden** | | | | |
| S | Ytor för social aktivitet | 1,2 | - | 0 | 0 |
| S | Odlingsytor | 0,5 | - | 0 | 0 |
| S | Tak, balkonger, terrasser och växthus för odling | 0,5 | - | 0 | 0 |
| S | Gemensamma takterasser | 0,2 | - | 0 | 0 |
| S | Synliga gröna tak | 0,05 | - | 0 | 0 |
| S | Blomsterprakt i fältskiktet | 0,2 | - | 0 | 0 |
| S | Buskar upplevelsevärden | 0,1 | - | 0 | 0 |
| S | Buskar med ätliga bär och frukter | 0,2 | - | 0 | 0 |
| S | Träd, upplevelsevärden | 0,4 | 0 | 0 | 0 |
| S | Fruktträd | 0,2 | 0 | 0 | 0 |
| S | Pergolor o.dyl. | 0,3 | - | 0 | 0 |
| S | Habitatstärkande åtgärder, upplevelsevärden | 0,2 | 0 | 0 | 0 |
| | **Tilläggsfaktorer grönska/klimat - temperaturreglering** | | | | |
| K | Träd placerade så att de ger lövskugga | 0,4 | 0 | 0 | 0 |
| K | Pergolor, lövgångar mm som ger lövskugga | 0,5 | - | 0 | 0 |
| K | Gröna tak eller flerskiktad markgrönska | 0,05 | - | 0 | 0 |
| | **Tilläggsfaktorer grönska och ljudkvalitet** | | | | |
| L | Vegetationsklädd mark | 0,1 | - | 0 | 0 |
| L | Grönska på väggar, växtsubstrat på väggen | 0,3 | - | 0 | 0 |
| L | Grönska på väggar, klätterväxter | 0,1 | - | 0 | 0 |
| L | Gröna tak | 0,05 | - | 0 | 0 |
| | **Delfaktorer vatten** | | | | |
| BSK | Vattenytor i dammar, bäckar och diken | 1,0 | - | 0 | 0 |
| BSK | Öppna hårdgjorda ytor | 0,3 | - | 0 | 0 |
| SK | Halvöppna hårdgjorda ytor | 0,2 | - | 0 | 0 |
| SK | Hårdgjorda ytor med fogar | 0,05 | - | 0 | 0 |
| - | Täta ytor | 0,0 | - | 0 | 0 |
| | **Tilläggsfaktorer vatten/biodiversitet** | | | | |
| B | Biologiskt tillgängliga permanenta vattenytor | 4,0 | - | 0 | 0 |
| B | Fuktstråk med tillfälligt kvardröjande vatten | 2,0 | - | 0 | 0 |
| B | Förd. av dagvatten från hårdgjorda ytor i ytvattensamlingar och fuktst: | 0,2 | - | 0 | 0 |
| B | Avvattning av hårdgjorda ytor till omgivande grönska på mark, regnbädd: | 0,2 | - | 0 | 0 |
| B | Förd. av dagvatten från hårdgjorda ytor i magasin | 0,1 | - | 0 | 0 |
| | **Tilläggsfaktorer vatten/rekreativa & sociala värden** | | | | |
| S | Vattenspeglar | 0,5 | - | 0 | 0 |
| S | Biologiskt tillgängliga vatten - upplevelsevärden | 1,0 | - | 0 | 0 |
| S | Fontäner o.dyl. | 0,3 | 0 | 0 | 0 |
| | **Tilläggsfaktorer vatten/klimat - temperaturreglering** | | | | |
| K | Vattensamlingar för torrperioder | 0,5 | - | 0 | 0 |
| K | Uppsamling i magasin av regnvatten för bevattning | 0,05 | - | 0 | 0 |
| K | Fontäner o.dyl. | 0,3 | 0 | 0 | 0 |
| | **Tilläggsfaktorer vatten och ljudkvalitet** | | | | |
| L | Fontäner o.dyl. | 0,3 | 0 | 0 | 0 |
| | ***Total summa (eko-effektiv yta):*** | | | | 0 |
| | ***Hela tomtens yta:*** | | | 0 | |
| | **Uppnådd faktor:** | | | | #DIV/0! |
| | Balansräkning: | Max antal: | Jppnått antal | % : | |
| | B = Biologisk mångfald | 34 | 0 | 0% | |
| | S = Sociala värden | 29 | 0 | 0% | |
| | K = Klimatanpassning | 20 | 0 | 0% | |
| | L = Ljudkvalitet | 5 | 0 | 0% | |

• Figure 3.3: GYF calculation template (Stockholm City)

## 3.4 CRITERIA

**Greenery sub-factors**

• **Preserved natural land. (1,5)**
Existing trees can be used as an additional factor.

• **Greenery on the ground level. (1,5)**
Trees and bushes can be used as an additional factor.

• **Plant basin> 800 mm depth. (1,4)**
Trees and bushes can be used as an additional factor.

• **Plant basin 600-800 mm deep. (0,3)**
Trees and bushes can be used as an additional factor.

• **Plant basin 200-600 mm deep. (0,1)**
Smaller shrubs can be used as an additional factor.

• **Green roof with> 300 mm deep plant basin. (0,3)**
In this plant basin depth, smaller trees and shrubs can be used as an additional factor.

• **Green roof with 110-300 mm deep plant basin. (0,1)**
It is particularly suitable to construct more varied roofs with sedum, herbs and grass.

• **Green roof with 50-110 mm deep plant basin. (0,05)**
Thin plant basin with drought-resistant vegetation, usually consisting of moss.

• **Greenery on walls. (0,4)**
The surface counts for that part of the wall up to a maximum of 10 meters height, as within 5 years can be expected to be covered by greenery. The sub-factor should be reported with a sketch of the vertical surface and expected coverage after 5 years.

• **Lush balconies. (0,3)**
Even on balconies, plant basin can be created with the conditions for wall-covering vegetation that contributes to deciduous (climate adaptation) and cultivation joy. The sub-factor is calculated from the horizontal surface of the plant bed. The plant bed must be at least 500 mm deep. Plant beds of 200 mm can be approved if the soil surface is present throughout the balcony.

**Biodiversity**

• **Diversity in the vegetation layer. (0,05)**
Diversity in the vegetation layer within a certain green surface provides additional points but at the same time places higher demands on maintenance.

• **Natural species selection. (0,5)**
In general, naturally-occurring species should be chosen over exotic, as they favour the local plant and animal life better. To obtain points, at least 50% of the surface is covered by naturally occurring vegetation.

• **Diversity on green thin sedum roofs. (0,1)**
A variety of species on the green roofs can attract butterflies and other insects.

• **Lush balconies with hanging or climbing plants. (0,3)**
How much of the wall the vegetation is expected to cover within 5 years, with starting from the location of the plant basin.

• **Flowers that attract Butterflies. (1,0)**
Planting with herbs or perennials intended to attract butterflies. Herbs with nectar-rich flowers. The factor must not be counted on meadow surfaces.

• **Shrubs in general. (0,2)**
Additional factor applies to all shrubs.

• **Bearing shrubs. (0,4)**
Shrubs that provide berries that are estimated by bird life provide additional supplemental factors.

• **Natural trees. (3,0)**
Which tree species are natural trees and give points in the project are specified in the GYF template.

• **Existing trees. (3,0)**
Trees with a diameter> 30. Old pine trees, oaks and other precious trees are especially valuable to preserve.

• **New large trees (stem> 30 cm). (2,4)**
Additional factor applies to all tree species; however, hardwood and bearing trees are preferred from a biological point of view.

• **New medium sized trees (stem 20-30 cm). (1,5)**
Additional factor applies to all tree species; however, hardwood and bearing trees are preferred from a biological point of view.

• **New small trees (stem 16-20 cm). (1,0)**
Additional factor applies to all tree species; however, hardwood and bearing trees are preferred from a biological point of view.

• **Bearing trees. (0,4)**
Tree species with berries appreciated by birds, such as rowan, and, Cherry.

• **Birdhouses, nests, hives. (0,5)**
Should be of different models that fit different bird species.

• **Bug feeders. (2,0)**
Specially made wooden pockets with food should be placed in relative proximity to existing natural environments.

• **Fauna depots. (2,0)**
Dead branches from old trees are important for among, wood-borne insects and fungi.

• **Biological design elements. (2,0)**
Traffic safe passage designed appropriately so that the breeding animals can get under the road or the street.

**Recreational and social values**

• **Areas for social activities. (1,2)**
Green surfaces designed so that they are useful for playing surfaces and ball games. Points are counted for usable grass area that is greater than 75 square meters.

• **Cultivation Areas. (0,5)**
Surfaces intended for cultivation at ground level is an important social quality.

• **Roofs, balconies, terraces, and greenhouses for cultivation. (0,5)**
Cultivation in connection with the home is great social quality.

• **Common roof terraces. (0,2)**
The ability to come up to the roof and enjoy the views and evening sun have great qualities. In order to count the additional factor, there must be at least 50 sqm green roofs with> 300 mm deep plant basin.

• **Visible green roofs. (0,05)**
Green roofs placed so that they can be seen from the surroundings and / or from windows in the neighborhood's building lines and thus contribute to a "green" view may be counted as an additional factor.

• **Flowers in the vegetation layer. (0,2)**
Flowering plants provide beauty and garden character to the surface.

• **Bushes impression values. (0,1)**
Shrubs and hedges contribute to spatiality, impression of seasonal changes etc.

• **Shrubs with edible berries and fruits. (0,2)**
Edible berries and fruits are greatly appreciated, especially by children. Flowers and berries attract insects, butterflies and birds, which contributes to a variety of impressions.

**Trees, impression values. (0,4)**
Trees are very important for the character of the garden. Trees contribute in many different ways to increase the impression value of the gardens.

• **Fruit trees. (0,2)**
Fruit trees and flowers attract insects, butterflies and birds, which contributes to a variety of experiences. Edible fruits and berries are greatly appreciated, especially by children. Points are given for fruit trees, planted as older than 6

years, and for other flowering trees with stem size> 20-22 cm.

**• Pergolas. (0,3)**
Pergolas and other structures for vertical and horizontal greenery contribute to spatiality and visual shielding. The additional factor is calculated per square meter of pergola or equivalent construction.

**• Habitat-enhancing measures. (0,2)**
A rich biological life improves the garden environment. Here the children can closely follow the different phases of nature. The farm is supplied with natural educational values.

**Climate - temperature control**
**• Trees placed so that they give temporary shade. (0,4)**
The need for coolness and shade increases with more and longer heat waves. Trees such as (oak, beech, lime, ash, maple etc.) are adapted to a warmer climate. The shade should cover 40-60% of the playground and/or common patio.

**• Pergolas that give temporary shade. (0,5)**
The need for coolness and shade increases with more and longer heat waves. The additional factor may only be counted if the pergola is placed in a sunny position.

**• Green roofs or multi-layered greenery. (0,05)**
Multi-layered vegetation seems to reduce the risks for local heating. shading from leaves contributes to coolness and moisture (levelling the temperature). If a green roof is irrigated, in some cases it may also reduce the need for indoor cooling systems. The additional factor is counted as sqm green roof or ground surface with multi-layered vegetation consisting of more than two layers.

**Greenery and sound quality**
**• Vegetation-covered land. (0,1)**
The surface counts for the actual surface of a plant basin with vegetation. The vegetation must be on the ground level.

**• Greenery on walls. (0,3)**
The surface is counted for the part of the wall/screen that can be expected to be covered by vegetation in 5 years.

**• Climbing plants. (0,1)**
The surface is counted for the part of the wall/screen that can be expected to be covered by vegetation within 5 years.

**• Green roofs. (0,05)**
The surface is counted for the part of the roof that is covered with green roof.

**Subfactors of water**
**• Water surfaces in ponds, and streams. (1,0)**
Refers to water surfaces that hold water for most of the year (also during dry season).

**• Open hard surfaces. (0,3)**
Concrete or natural stone tiles that have grass between them.

**• Semi-open hardened surfaces. (0,2)**
Open asphalt, gravel, sand and other surfaces with high permeability for stormwater.

**• Hard surfaces. (0,05)**
Concrete slabs, paving stones and tiles, with normal joints such as sand would give a certain permeability to the stormwater.

**• Dense surfaces. (0,0)**
Roof surfaces, and concrete that does not have any form of plant basin or other opportunities to develop a biological environment for vegetation.

**Water / biodiversity**
**• Biological water surfaces in ponds, streams and the ditches inside the yard. (4,0)**
Water surfaces that exist during spring and summer, totalling at least 6 months. The installation of permanent small water contributes to richer wildlife (insects, birds and other species).

**• Moisture inside the yard. (2,0)**
Vegetation surfaces inside the garden that holds water temporarily during parts of the summer months, up to 6 months. Applying moist vegetation surfaces contributes to richer wildlife (insects, birds and other species).

**• Delay of stormwater. (0,2)**
Drainage from dense surfaces (factor 0) and hardened surfaces (factor 0.05) that are collected in ponds or moisture paths, provide an additional factor for the dewatered surface, provided that the surface water collection holds at least 20 l / sqm of dewatered surface. This stormwater management helps to create local water environments with ponds, moisture stretches, etc., which have a direct impact on local plant and animal life. The surface water collection can be outside the district land, but the dewatered area should be on the neighbourhood land.

**• Dewatering hard surfaces to surrounding greenery on ground level. (0,2)**
This stormwater management is of primary importance for the water cycle in the local ecosystem, for equalization of flows and indirectly for the local animal and plant life.

**• Delay of stormwater from hard surfaces in reservoirs. (0,1)**
Drainage from dense surfaces and hardened surfaces collected in reservoirs where the water cannot be used by vegetation provides an additional factor for the dewatered surface, provided that the reservoir holds at least 20 l / sqm of dewatered surface.

**Water / recreational and social values**
**• Reflective water. (0,5)**
Open water surfaces that reflect light and mirrors have great aesthetic values.

**• Bioavailable water. (1,0)**
In order to meet the requirements for child safety, the water environments need to be designed in a way that minimizes the risk of accidents, but at the same time makes them available for animal and plant life.

**• Fountains and the like. (0,3)**
Sound of water contributes to the park's attractiveness. Circulation of the water also contributes to oxygenation.

**Water / climate - temperature control**
**• Water collections for dry periods. (0,5)**
The need for cooling increases with more and longer heat waves. Water in various forms contributes to the coolness of parks.

**• Collection of rainwater reservoirs for irrigation. (0,05)**
Extended heat waves with drought have a negative impact on people, vegetation and wildlife. Collecting stormwater for later use in drought provides additional points.

**• Fountains and the like. (0,3)**
Higher humidity and the sound of water contribute to both real and anticipated coolness during hot summer days.

**Water and sound quality**
**• Fountains. (0,3)**
Water sounds can cover unwanted noise and contribute to a better sound environment in gardens.

## 3.5 SELECTION CRITERIA

Approaching the mentioned factors in architecture development does not necessarily lead to nature integrated into architecture. Since there is a possibility of ending up having a multi-story building surrounded with areas that meet the factors.

In order to both meet the green surface factor requirements and also guarantee a well-integrated nature to architecture, the criteria of the green surface factor could be categorised based on what type of planting approaches, preserved areas, and social surfaces.

These categories were chosen as follows:

- Planting approaches (Horizontal, vertical, climbing plants, indoor trees and, indoor farming.)
- Preserved greenery and land.
- Social and public surfaces.

• **Planting approaches**:
- Horizontal approach.
Understanding the advantages and disadvantages of horizontal approach, what kind of vegetation could be used in a horizontal approach, and what kind of maintenance does it need.

- Vertical approach.
Understanding the advantages and disadvantages of vertical approach, what kind of vegetation could be used in a vertical approach, and what kind of maintenance does it need.

- Climbing plants.
Understanding the advantages and disadvantages of climbing plants, what kind of climbing plants could be used, where, and what kind of maintenance does it need.

- Indoor forests and indoor farming.
Understanding the advantages and disadvantages of having indoor trees, and indoor farming, what kind of vegetation could be used, and what kind of maintenance does it need.

• **Preserved greenery and land.**
It would be considered from the site fitting.

• **Social and public surfaces.**
It would be considered from the site fitting.

The green surface sub-factors are shown in the template (Figure: 3.4)

Blue colour refers to: Horizontal approach.

Green colour refers to: vertical approach.

Dark blue colour refers to: Climbing plants.

Red colour refers to: Indoor trees and indoor farming.

Turquoise colour refers to: Preserved greenery and land.

Yellow colour refers to: Social surfaces.



| SUB-FACTOR | FACTOR | HORIZONTAL APPROACH | VERTICAL APPROACH | CLIMBING PLANTS | INDOOR TREES AND INDOOR FARMING | PRESERVED GREENERY AND LAND | SOCIAL AND PUBLIC SURFACES |
|---|---|---|---|---|---|---|---|
| Greenery sub-factors | | | | | | | |
| Preserved natural land. | (1,5) | | | | | ✓ | |
| Greenery on the ground level. | (1,5) | ✓ | | | ✓ | | |
| Plant basin> 800 mm depth. | (1,4) | ✓ | ✓ | | | | |
| Plant basin 600-800 mm deep. | (0,3) | ✓ | ✓ | | | | |
| Plant basin 200-600 mm deep. | (0,1) | ✓ | ✓ | | | | |
| Green roof with> 300 mm deep plant basin. | (0,3) | ✓ | | | | | |
| Green roof with 110-300 mm deep plant basin. | (0,1) | ✓ | | | | | |
| Green roof with 50-110 mm deep plant basin. | (0,05) | | | | | | |
| Greenery on walls. | (0,4) | | | | | | |
| Lush balconies. | (0,3) | | ✓ | ✓ | | | |
| Biodiversity | | | | | | | |
| Diversity in the vegetation layer. | (0,05) | ✓ | ✓ | ✓ | ✓ | | |
| Natural species selection. | (0,5) | ✓ | ✓ | ✓ | ✓ | | |
| Diversity on green thin sedum roofs. | (0,1) | ✓ | | | | | |
| Lush balconies with hanging or climbing plants. | (0,3) | | ✓ | ✓ | | | |
| Flowers that attract Butterflies. | (1,0) | ✓ | ✓ | ✓ | | | |
| Shrubs in general. | (0,2) | ✓ | ✓ | | | | |
| Bearing shrubs. | (0,4) | ✓ | ✓ | | | | |
| Natural trees. | (3,0) | ✓ | ✓ | | ✓ | | |
| Existing trees. | (3,0) | | | | | ✓ | |
| New large trees (stem> 30 cm). | (2,4) | ✓ | ✓ | | | | |
| New medium sized trees (stem 20-30 cm). | (1,5) | ✓ | ✓ | | | | |
| New small trees (stem 16-20 cm). | (1,0) | ✓ | ✓ | | | | |
| Bearing trees. | (0,4) | ✓ | ✓ | | ✓ | ✓ | |
| Birdhouses, nests, hives. | (0,5) | ✓ | ✓ | | ✓ | ✓ | |
| Bug feeders. | (2,0) | ✓ | ✓ | | ✓ | ✓ | |
| Fauna depots. | (2,0) | ✓ | ✓ | | ✓ | ✓ | |
| Biological design elements. | (2,0) | ✓ | ✓ | | | ✓ | |
| Recreational and social values | | | | | | | |
| Areas for social activities. | (1,2) | ✓ | ✓ | | ✓ | | ✓ |
| Cultivation Areas. | (0,5) | ✓ | ✓ | | ✓ | | ✓ |
| Roofs, balconies, terraces, and greenhouses for cultivation. | (0,5) | ✓ | ✓ | | ✓ | | ✓ |
| Common roof terraces. | (0,2) | ✓ | ✓ | | | | ✓ |
| Visible green roofs. | (0,05) | ✓ | ✓ | | | | |
| Flowers in the vegetation layer. | (0,2) | ✓ | ✓ | | ✓ | | ✓ |
| Bushes impression values. | (0,1) | ✓ | ✓ | | ✓ | | ✓ |
| Shrubs with edible berries and fruits. | (0,2) | ✓ | ✓ | | ✓ | | ✓ |
| Trees, impression values. | (0,4) | ✓ | ✓ | | ✓ | | ✓ |
| Fruit trees. | (0,2) | ✓ | ✓ | | ✓ | | ✓ |
| Pergolas. | (0,3) | ✓ | ✓ | | | | ✓ |
| Habitat-enhancing measures. | (0,2) | ✓ | ✓ | | | | ✓ |
| Climate - temperature control | | | | | | | |
| Trees placed so that they give temporary shade. | (0,4) | ✓ | ✓ | | ✓ | ✓ | |
| Pergolas that give temporary shade. | (0,5) | ✓ | ✓ | | | ✓ | |
| Green roofs or multi-layered greenery. | (0,05) | ✓ | ✓ | | | | |
| Greenery and sound quality | | | | | | | |
| Vegetation-covered land. | (0,1) | ✓ | | | | ✓ | |
| Greenery on walls. | (0,3) | | | ✓ | | | |
| Climbing plants. | (0,1) | | | ✓ | | | |
| Green roofs. | (0,05) | ✓ | | | | | |
| Subfactors of water | | | | | | | |
| Water surfaces in ponds, and streams. | (1,0) | ✓ | | | | ✓ | ✓ |
| Open hard surfaces. | (0,3) | ✓ | | | | | |
| Semi-open hardened surfaces. | (0,2) | ✓ | | | | | |
| Hard surfaces. | (0,05) | ✓ | | | | | |
| Dense surfaces. | (0,0) | | | | | | |
| Water / biodiversity | | | | | | | |
| Biological water surfaces in ponds, streams and the ditches inside the yard. | (4,0) | ✓ | | | | | |
| Moisture inside the yard. | (2,0) | ✓ | | | | | |
| Delay of stormwater. | (0,2) | ✓ | ✓ | | | | |
| Dewatering hard surfaces to surrounding greenery on ground level. | (0,2) | ✓ | ✓ | | | ✓ | |
| Delay of stormwater from hard surfaces in reservoirs. | (0,1) | ✓ | ✓ | | | | |
| Water / recreational and social values | | | | | | | |
| Reflective water. | (0,5) | ✓ | | | | | ✓ |
| Bioavailable water | (1,0) | ✓ | | | | | ✓ |
| Fountains and the like. | (0,3) | ✓ | | | | | ✓ |
| Water / climate - temperature control | | | | | | | |
| Water collections for dry periods. | (0,5) | ✓ | ✓ | | ✓ | | |
| Collection of rainwater reservoirs for irrigation. | (0,05) | ✓ | ✓ | | ✓ | | |
| Fountains and the like. | (0,3) | ✓ | | | ✓ | | ✓ |
| Water and sound quality | | | | | | | |
| Fountains. | (0,3) | ✓ | | | ✓ | | ✓ |

• Figure 3.4: GYF template

# 4-GYF PLANTING APPROACHES

**4-GYF PLANTING APPROACHES** 30-45





## 4.1 HORIZONTAL APPROACH

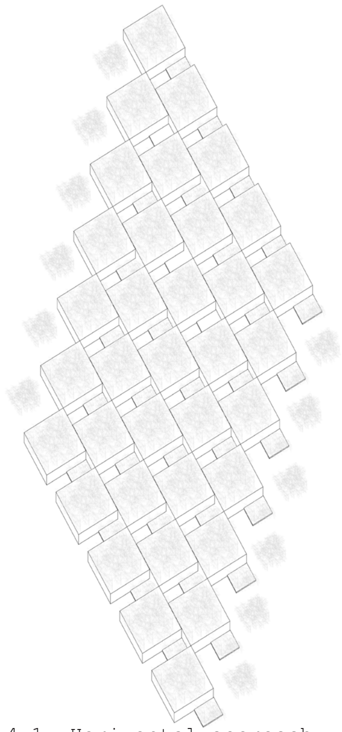
### 4.1.1 EXPLORATION I

This is a possible approach when there is a big area to develop, and when there is a possibility to build horizontally, the result would be getting more surfaces, that could be used as green roofs to be a place for small, medium-size plants and grasses.

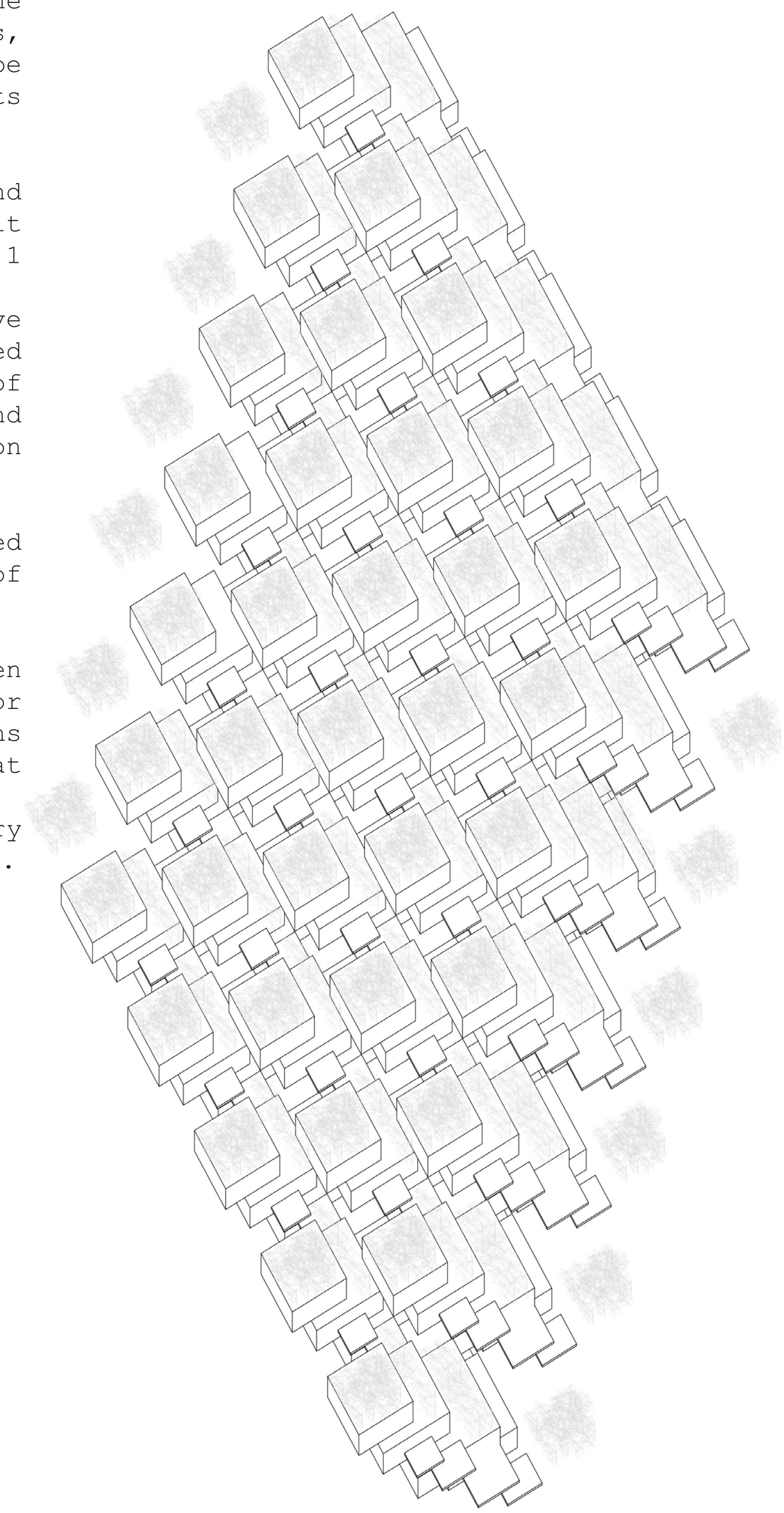
Considering as well that green roofs and bigger surfaces on the top would make it easier to harvest rainwater.(Figure 4.1 and Figure 4.2)
Green roofs have many types, they have different depths, and they could be used in different ways, depends on the need of accessibility to the roof, and what kind of vegetation are going to be planted on them.

What kind of vegetation could be used on green roofs? Moreover, what kind of maintenance do they need?

The types of greenery would be chosen based on the green surface factor criteria, for example, different depths of green roofs, berries, and plants that attract bees like Lilac.
More details about the chosen greenery are discussed and shown in pages 32-33.



• Figure 4.1: Horizontal approach.



• Figure 4.2: Horizontal approach.

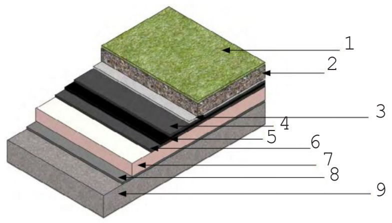
### 4.1.2 GREEN ROOFS TYPE VERSUS MAINTENANCE

| | Name | Maintenance |
|---|---|---|
| GREEN ROOFS | Extensive green roofs. (Figure 4.3) | *These have shallow ( 70mm) soils and it can support greenery, and grasses. This type is used when it is not required to get to the rooftop. It is the lightest sort of green rooftop. It must be watered often in the first year. |
| | Semi-intensive green roofs. (Figure 4.4) | *These kinds of roofs have a deeper layer of soil (150mm) more than extensive green roofs, it enables more kinds of shrubs, and plants to be planted on it. Seasonal maintenance is required. |
| | Intensive green roofs. (Figure 4.5) | *These kinds of roofs have a deeper layer of soil (150mm) more than semi-extensive green roofs, a regular maintenance, and an irrigation system are required. |
| PLANTS | Berries. (Figure 4.6) | *It can planted on rocky ground. |
| | Lilac. (Figure 4.7) | *Cultivated in gardens and parks. |
| | Fläder. (Figure 4.8) | *Often planted near farms and houses. |
| SHRUBS | Amsonia. (Figure 4.9) | *It can be used in place of shrubs in the landscape. This easy care, heat and humidity tolerant. |
| | Matteuccia struthiopteris . (Figure 4.10) | *Needs plenty of space to grow since they are rapid spreaders. Quickly forming colonies. |
| | Polygonatum odoratum. (Figure 4.11) | *It is a charming plant for the shade. |



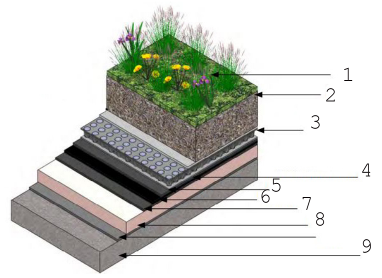
GREEN ROOFS

1-Vegetation
2-Single-course growth media
3-Protection layer/ moisture management fabric
4-Root-barrier membrane
5-Waterproofing membrane
6-Separation layer
7-Insulation layer
8-Vapor barrier
9-Deck



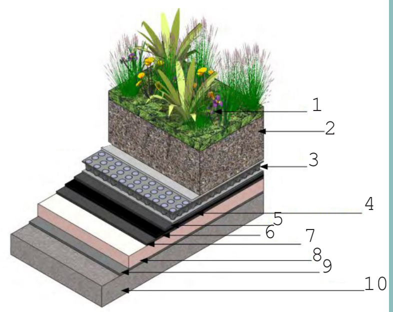

• Figure 4.3: Extensive green roofs (GSA GREEN ROOF BENEFITS AND CHALLENGES)

1-Vegetation
2-Single-course growth media
3-Protection layer/ moisture management fabric
4-Root-barrier membrane
5-Waterproofing membrane
6-Separation layer
7-Insulation layer
8-Vapor barrier
9-Deck



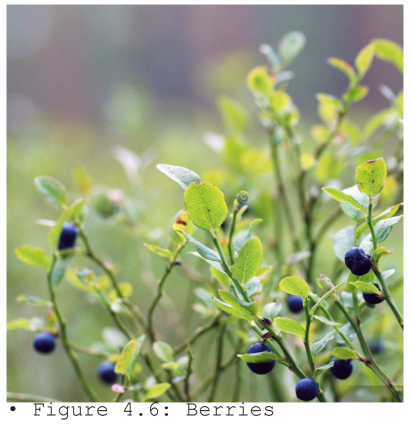

• Figure 4.4: Semi-intensive green roofs (GSA GREEN ROOF BENEFITS AND CHALLENGES)

1-Vegetation (variety of plant species)
2-Multi-course growth media
3-Geocomposite or granular mineral drainage layer
4-Protection layer/moisture management fabric
5-Root-barrier membrane
6-Waterproofing membrane
7-Separation layer
8-Insulation layer
9-Vapor barrier
10-Deck




• Figure 4.5: Intensive green roofs (GSA GREEN ROOF BENEFITS AND CHALLENGES)

PLANTS



• Figure 4.6: Berries (skogsskafferiet.se)

• Figure 4.7: Lilac (skogsskafferiet.se)

• Figure 4.8: Fläder (skogsskafferiet.se)

SHRUBS

• Figure 4.9: Amsonia (skogsskafferiet.se)

• Figure 4.10: Matteuccia struthiopteris (skogsskafferiet)

• Figure 4.11: Polygonatum odoratum (skogsskafferiet.se)

## 4.2 VERTICAL APPROACH

It is a possible approach when there is a small or limited surface, area to develop.

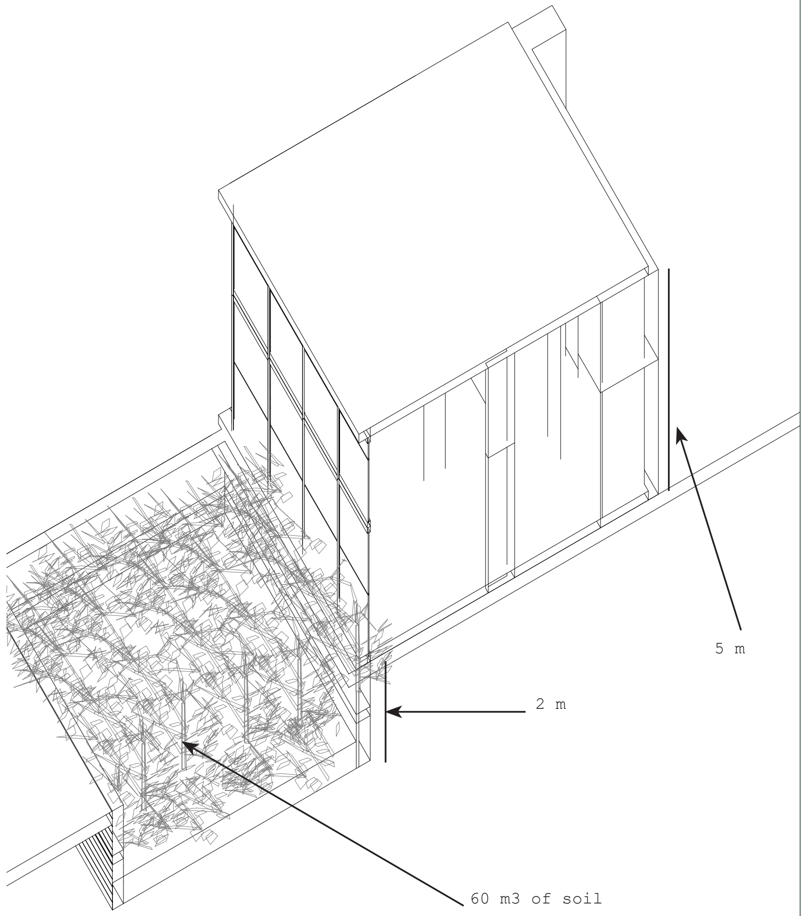
An essential part of the vertical approach is to understand the possibilities where soil basin could be placed.

**ALTERNATIVE 1**

A possible approach is to place the soil basin in the ground.

It would make it easier for trees to establish their roots, and there will be hypothetically no need for massive support beneath the basin.

However, it will not be possible to have a basin on the site ground in case of higher floors. (Figure 4.12)



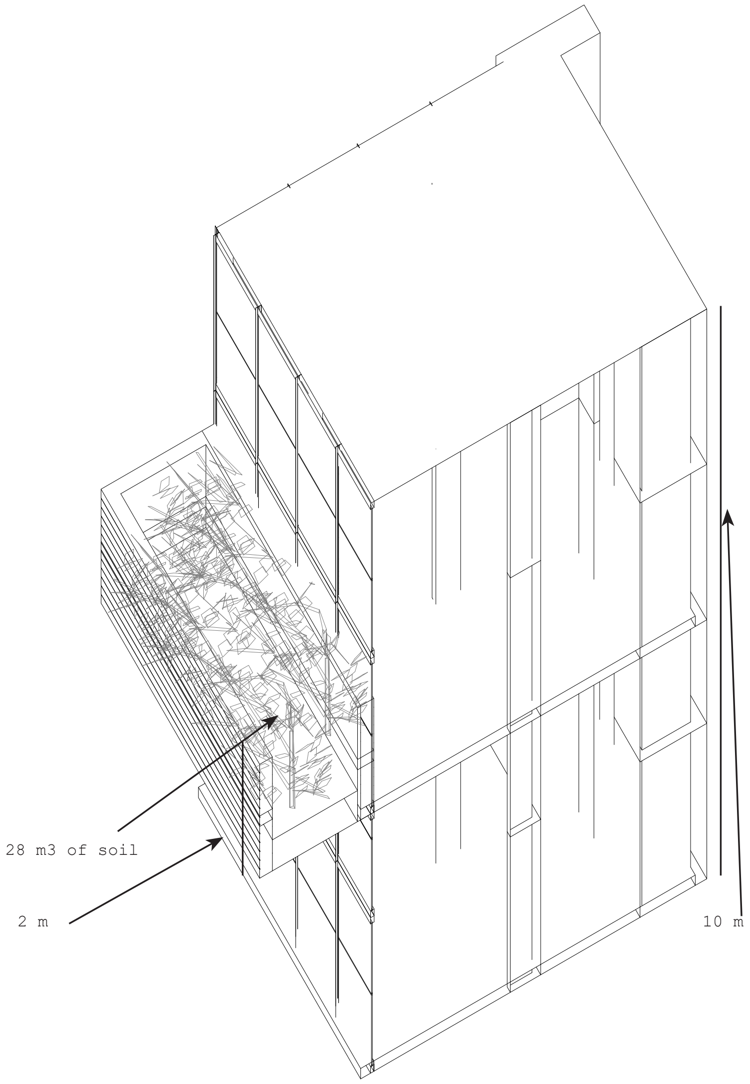

• Figure 4.12: The needed volume of soil to plant 2 trees, small plants, and grass cover on the ground

**ALTERNATIVE 2**

Another possible approach is to place the soil basin on balconies.

It would make it easier for trees to be placed in vertical buildings in different heights and levels.

However, there would be a need for support depending on the size of the basin, and the weight of the soil and trees that it would carry.(Figure 4.13)




• Figure 4.13: The needed volume of soil to plant 1 tree, small plants, and grass cover on a hanging balcony

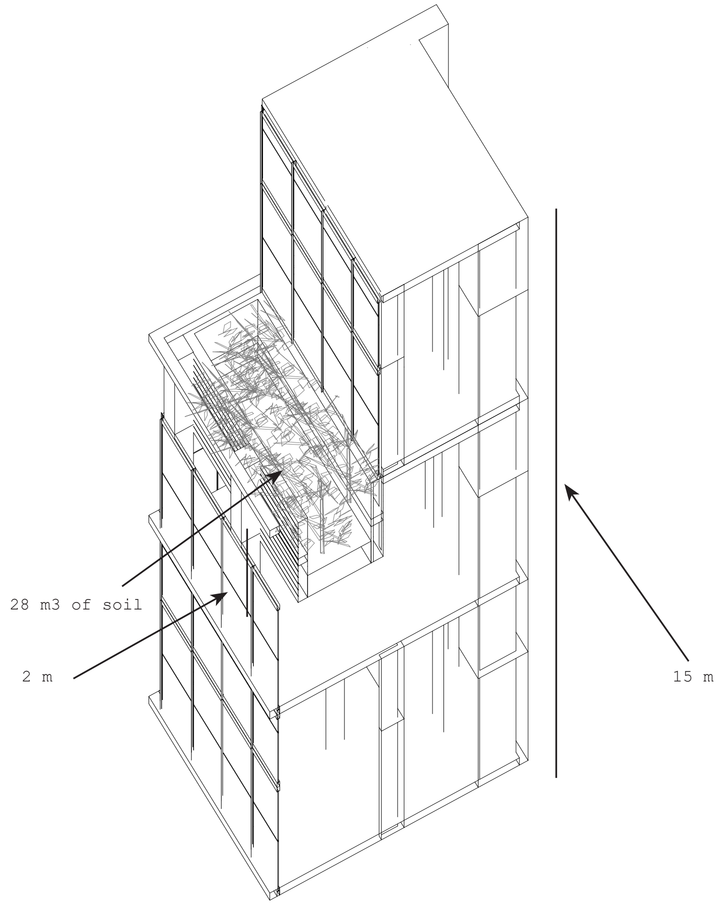


**ALTERNATIVE 3**

Placing the soil basin to be part of a room space on the roof would make it easier for trees to be placed on the roofs of a vertical building if some parts of the building were divided to different levels.

However, there would be a need for support depending on the size of the basin, and the weight of the soil and trees that it would carry.

Figure 4.14: is showing the needed volume of soil needed when planting two trees, small plants, and grass cover on a rooftop.




• Figure 4.14: Soil basin to be part of a room space

**ALTERNATIVE 4**

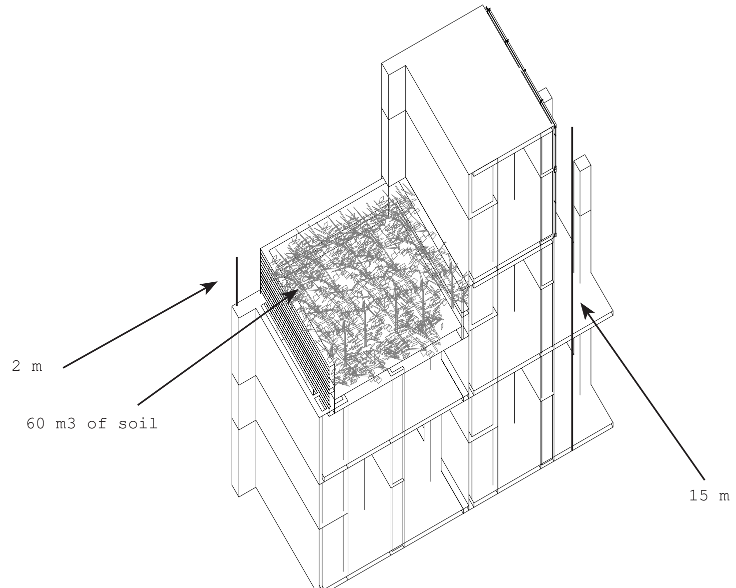
Another possible approach is to place the soil basin on the roof.

It would make it easier for trees to be placed on the roofs of a vertical building if some parts of the building were divided to different levels.

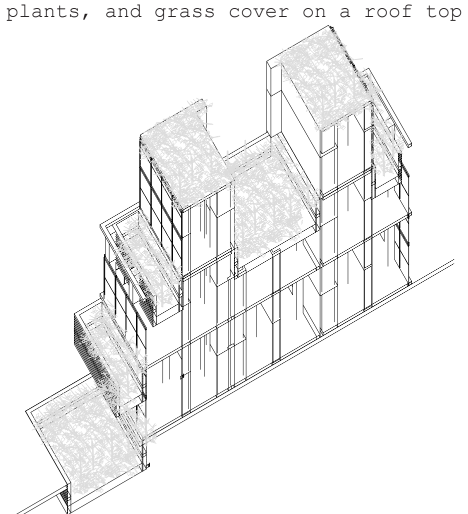
However, there would be a need for support depending on the size of the basin, and the weight of the soil and trees that it would carry.

Figure 4.15: is showing the needed volume of soil needed when planting two trees, small plants, and grass cover on a rooftop.

Figure 4.16 is showing a combination of a vertical and horizontal approach together.




• Figure 4.15: The needed volume of soil to plant 2 trees, small plants, and grass cover on a roof top



• Figure 4.16: A combination of vertical and horizontal approach

## 4.2.1 EXPLORATION II

Approaching integration of vegetation in architecture in a traditional way such as in Vertical Forest could be achieved by placing trees on hanging balconies. As a result, this would affect the growth of trees, because of the limited free space around them, and therefore, they have to be trimmed rapidly to limit their growth. (Figure 4.17)

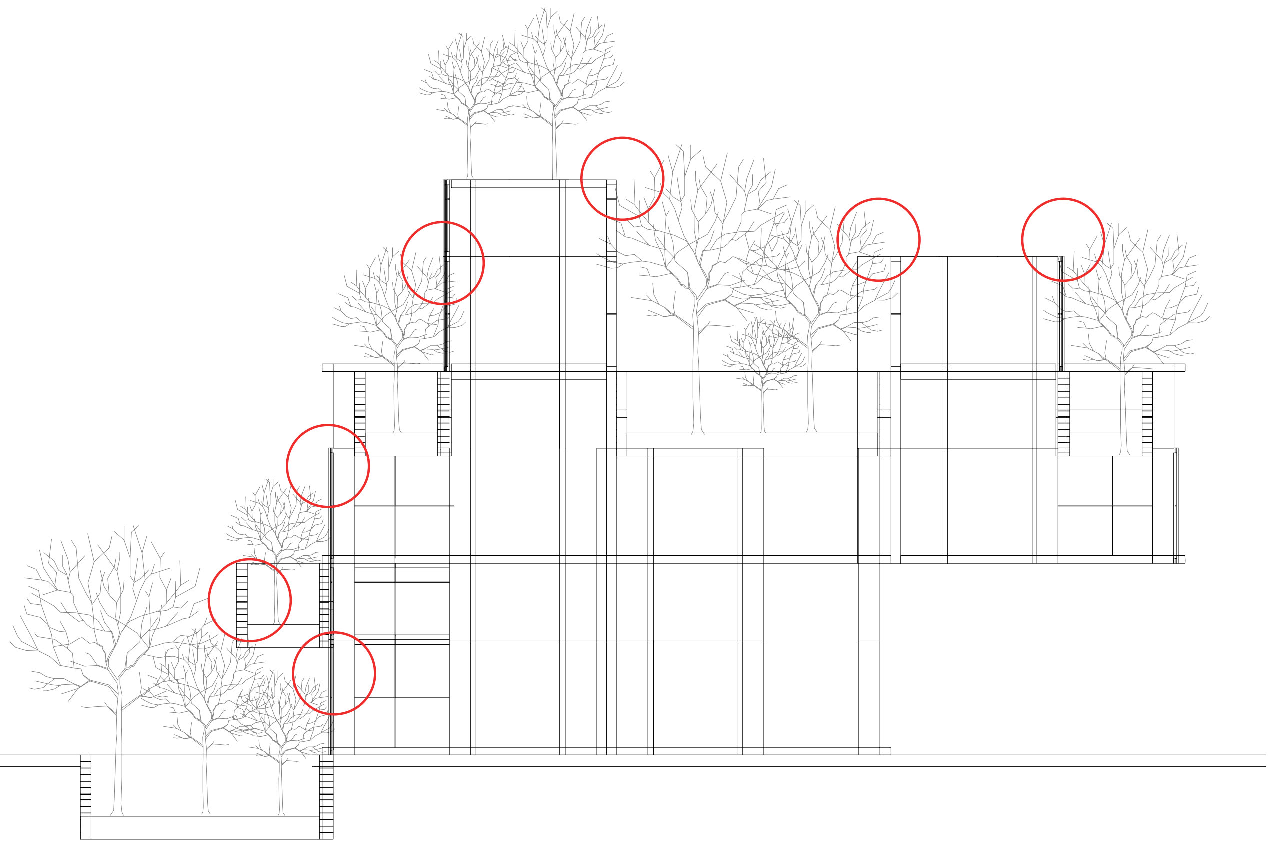
As a solution, building facades could be designed to adapt to the shape of the tree. Which means that the built area would be defined by the estimated growth of the chosen trees.

A possible approach would be tilting parts of the facade 60° both in section and plan so trees can get enough space to grow fully. (Figure 4.18)

In addition, roots would be able to grow deeper due to the resulted shape, which is designed to fit the estimated growth of the roots. (Figure 4.19)

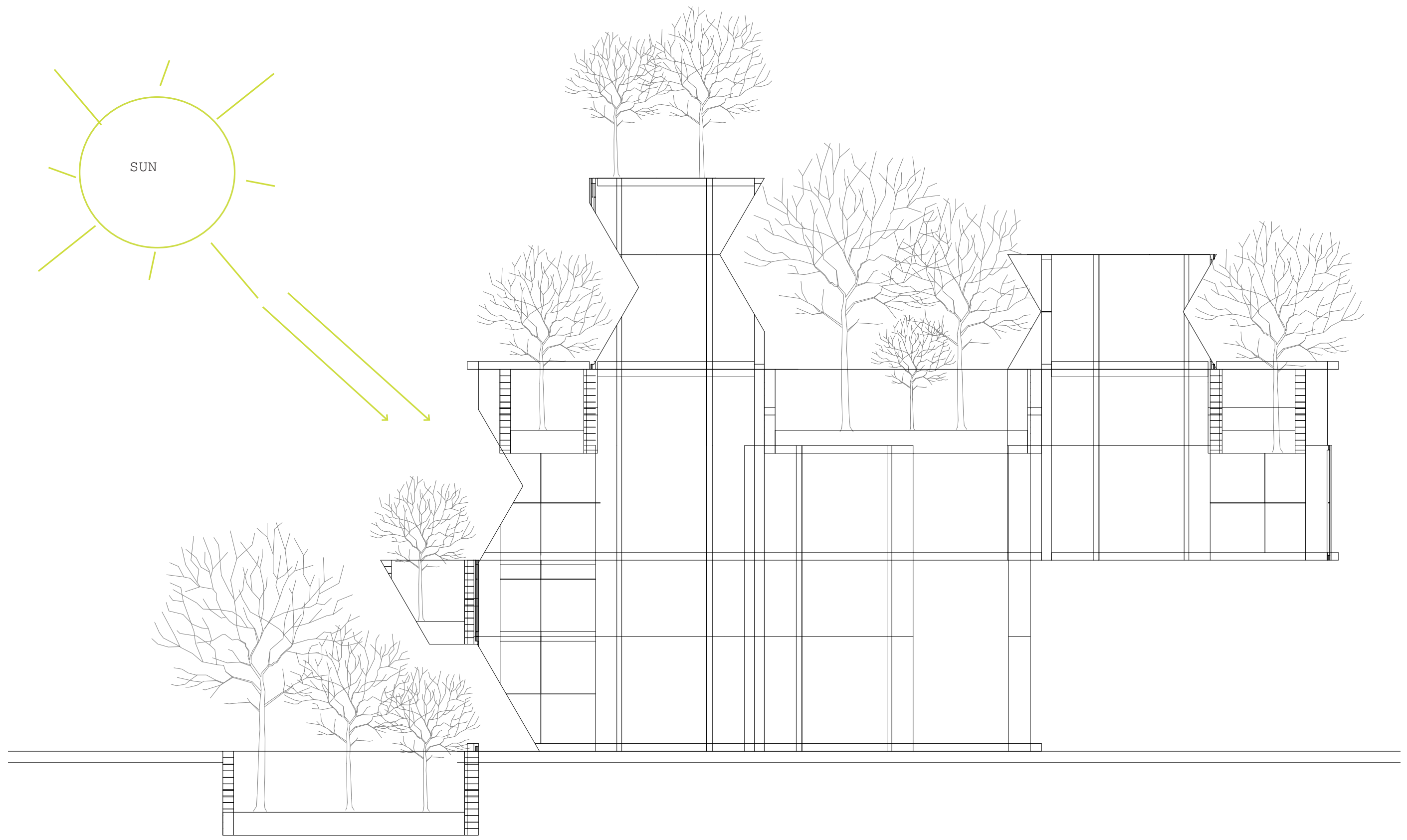
Furthermore, leaving an opening between the soil basins would let light to go through to the levels below. (Figure 4.20)

The types of greenery in vertical approach would be chosen based on the green surface factor criteria, for example, bearing trees such as apple trees, native trees such as Maple trees, plants that attract bees like Lilac, and diversity of the greenery. More details about the chosen greenery are discussed and shown in pages 38-39.

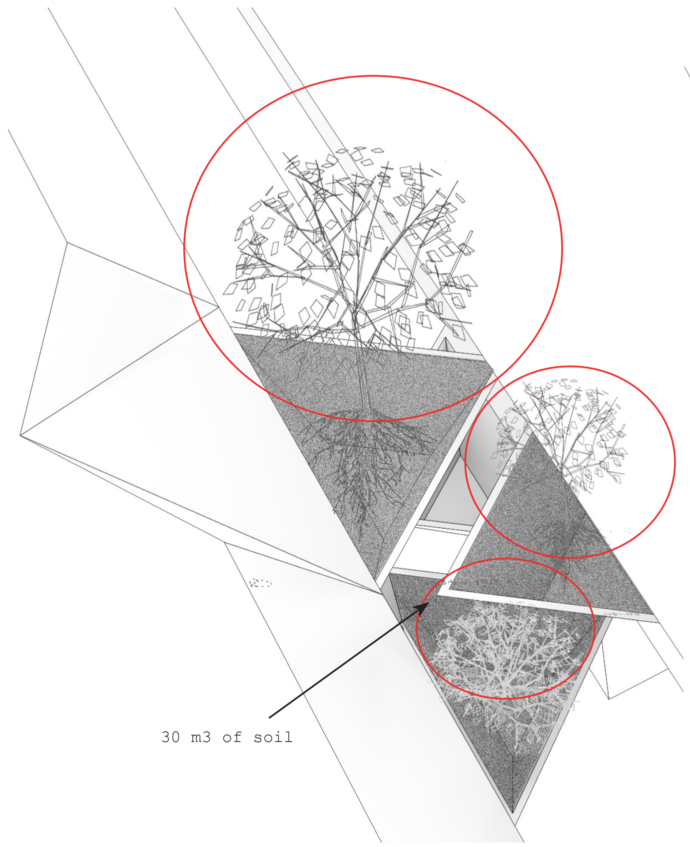


• Figure 4.17: Trees can not sufficiently grow in small space

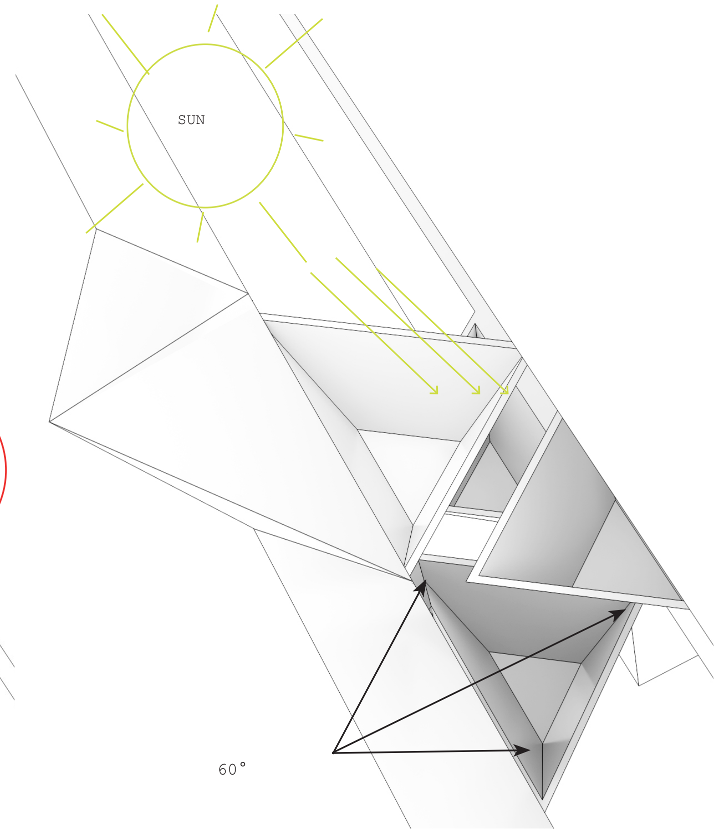





• Figure 4.18: Tilted parts of the facade 60°




• Figure 4.19: pyramid shaped-soil basin




• Figure 4.20: Opening between the soil basins would let light to go through

### 4.2.2 TREES AND PLANTS TYPE VERSUS MAINTENANCE

TREES

| Name | Maintenance |
|---|---|
| Hornbeam maple (Figure 4.21) | *Good for use as a solitary tree or in groups in gardens and parks. It can be used as a hedge thanks to its naturally slender growth pattern. |
| Amur maple (Figure 4.22) | *This often stands out much better in a sunny site. The fibrous root growth is flat and shallow. A very hardy plant, well resistant to air pollution. |
| Styphnolobium japonicum (Figure 4.23) | *It is a good plant for bees and blooms at an early age, often even after 6 to 8 years. Is not very prone to diseases or problems. |
| Carpinus betulus (Figure 4.24) | *Root growth is relatively close to the surface. Very suitable for use in (narrow) streets and housing estates. |
| Pinus parviflora (Figure 4.25) | *Tolerates sea wind, and it is often grown in private gardens. |
| Apple tree (Figure 4.26) | *Needs to be watered regularly in the beginning.<br>Not recommended to be placed in gusty area. |

PLANTS

| Name | Maintenance |
|---|---|
| Berries (Figure 4.27) | *It can planted on rocky ground. |
| Lilac (Figure 4.28) | *Cultivated in gardens and parks. |
| Fläder (Figure 4.29) | *Often planted near farms and houses. |

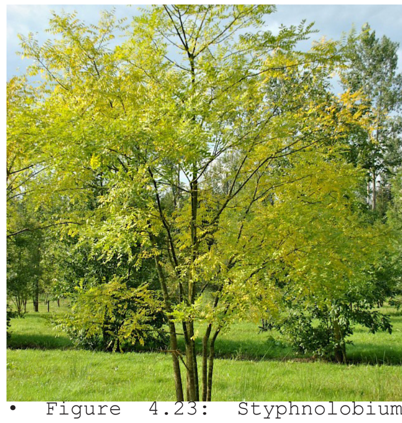
SHRUBS

| Name | Maintenance |
|---|---|
| Amsonia (Figure 4.30) | *It can be used in place of shrubs in the landscape. This easy care, heat and humidity tolerant. |
| Matteuccia struthiopteris (Figure 4.31) | *Needs plenty of space to grow since they are rapid spreaders. Quickly forming colonies. |
| Polygonatum odoratum (Figure 4.32) | *It is a charming plant for the shade. |




• Figure 4.21:Hornbeam maple (vdberk.com)


• Figure 4.22: Amur maple (vdberk.com)

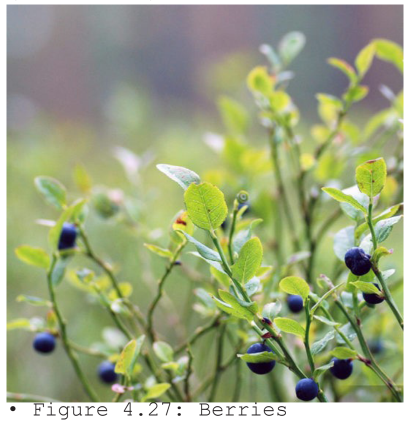

• Figure 4.23: Styphnolobium japonicum (vdberk.com)

TREES


• Figure 4.24: Carpinus betulus (vdberk.com)


• Figure 4.25: Pinus parviflora (vdberk.com)


• Figure 4.26: Apple tree (skogsskafferiet.se)


• Figure 4.27: Berries (skogsskafferiet.se)


• Figure 4.28: Lilac (skogsskafferiet.se)


• Figure 4.29: Fläder (skogsskafferiet.se)

PLANTS


• Figure 4.30: Amsonia (skogsskafferiet.se)


• Figure 4.31: Matteuccia struthiopteris(skogsskafferiet)


• Figure 4.32: Polygonatum odoratum (skogsskafferiet.se)

SHRUBS

## 4.3 CLIMBING PLANTS

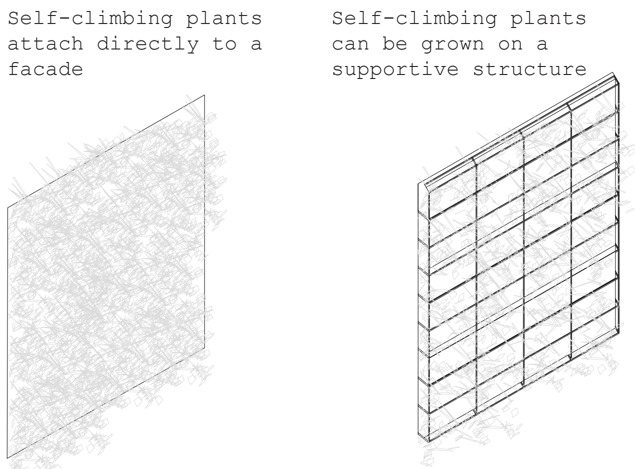
A possible way of integrating vegetation to deal with solid surfaces is to plant climbing plants.

Climbing plants enhance the quality of the air and reduce the noise pollution, they can spread horizontally and vertically, and and in general they can survive in the shade.

On the other hand, they could be harmful to the facade in the long term. In case climbing plants grow freely, they may be hard to control. They stick to the surfaces and grow between cracks, and can damage the surface if tried to be removed from it.

However, planting them on a separate structure like a shell or an installation attached to the original facade or a separate structure that is erected separately would help to maintain the facade, and would make it easier to control them.

Figure 4.33: showing how creeping plants could grow directly on a wall or a separate structure attached to the facade.
Figure 4.34 showing how creeping plants can grow on an isolated structure attached to a solid wall.




• Figure 4.33: Climbing plants growing directly and isolated from a wall

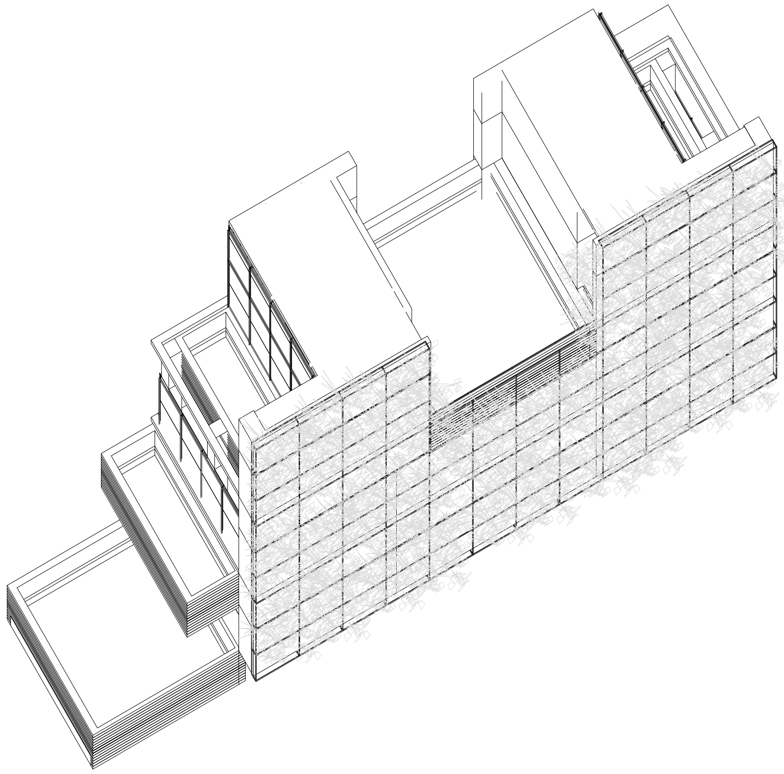
## 4.3.1 EXPLORATION III

Climbing plants can grow in all directions X, Y, and Z which could be used to make a particular type of designs to cover the areas with vegetation that are difficult to cover in different approaches like green roofs, plants, or trees (Figure 4.35).

There are many possibilities of using climbing plants, due to their ability to grow in all directions, they could be used as shading in summer.

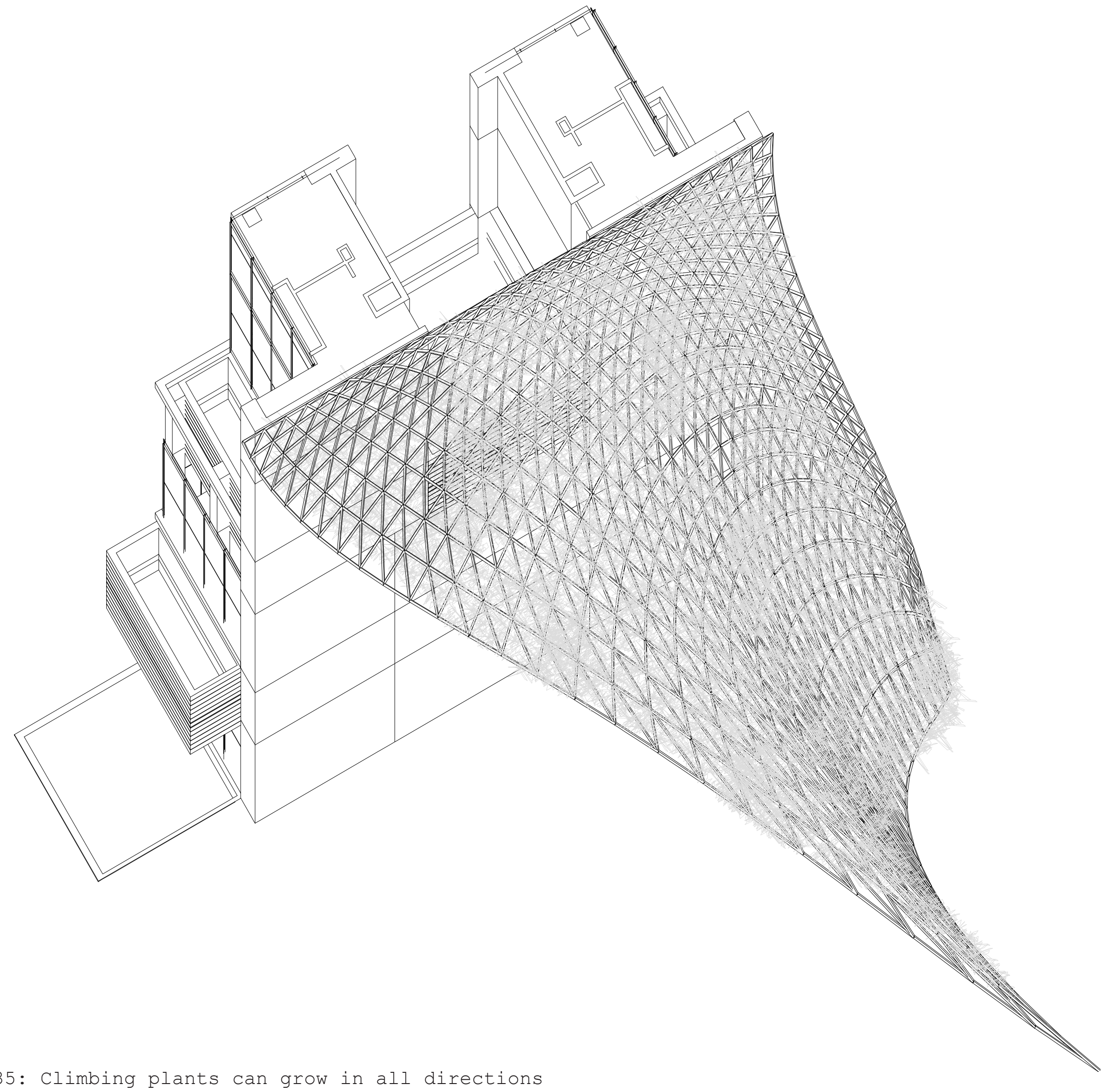
Departing from exploration I, 60° triangular grid is used to conceptualise a structure where creeping plants can grow. (Figure 4.36)

The types of greenery in climbing plants would be chosen based on the green surface factor criteria, for example, bearing plants and diversity of the greenery. More details about the chosen greenery are discussed and shown in pages 42-43.

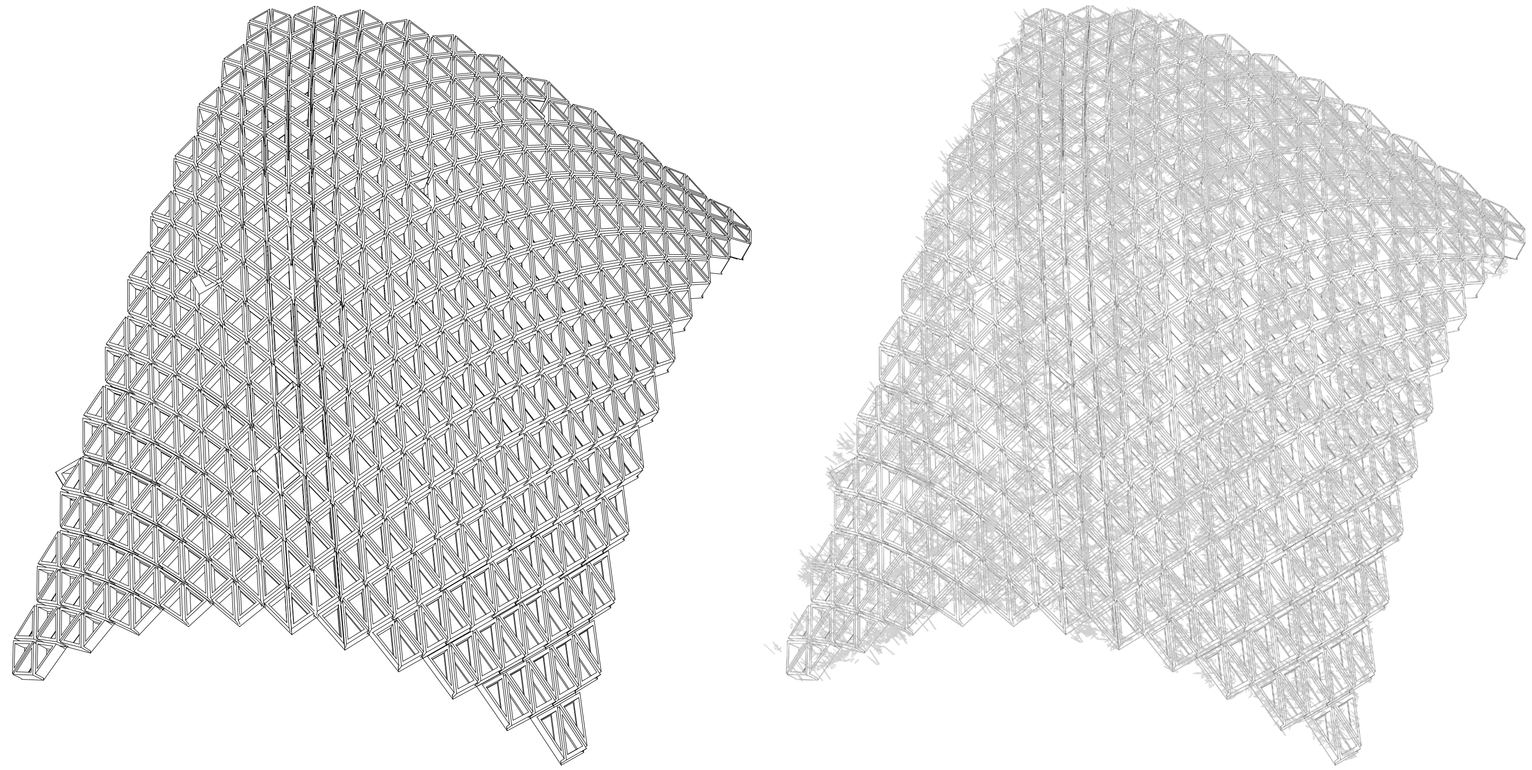


• Figure 4.34: Climbing plants can grow on an isolated structure attached to a solid wall.





• Figure 4.35: Climbing plants can grow in all directions



• Figure 4.36: Climbing plants can grow on separated structures

### 4.3.2 CLIMBING PLANTS TYPE VERSUS MAINTENANCE

CLIMBING PLANTS

| Name | Maintenance |
|---|---|
| Devil’s Ivy | *It requires little attention and it is quickly developing evergreen climber. |
| Confederate Jasmine | *Most appropriate for balcony and patio. |
| Mandeville | *Most appropriate for big and long walls. |
| Morning Glory | *Most appropriate for fences. |
| Trumpet Vine | *It requires little watering |
| Clematis | *Most appropriate for shady structures like pergolas |
| Bougainvillea | *It requires just initial consideration. |
| Wisteria | *It improves soil quality as it has nitrogen-fixing properties. |
| Moonflower | *It requires no unique soil or watering and develops effectively. |
| Flame vine | *It blossoms in winter and spring. |



• Figure 4.37: Devil’s Ivy (treemendous.in)

• Figure 4.38: Confederate Jasmine (treemendous.in)

• Figure 4.39: Mandeville (treemendous.in)

• Figure 4.40: Morning Glory (treemendous.in)

• Figure 4.41: Trumpet Vine (treemendous.in)

• Figure 4.42: Clematis (treemendous.in)

• Figure 4.43: Bougainvillea (treemendous.in)

• Figure 4.44: Wisteria (treemendous.in)

• Figure 4.45: Moonflower (treemendous.in)

• Figure 4.46: Flame vine (treemendous.in)

CLIMBING PLANTS

## 4.4 INDOOR FORESTS AND INDOOR FARMING

**INDOOR FORESTS**

Indoor forests would be a possible approach, especially in cold countries like Sweden, where winter is usually harsh.

It is a way to keep green trees green in winter and make it possible for people to be around an indoor forest.

Indoor forests could help to integrate new types of trees, and plants from different parts of the world and enhance the indoor living conditions.

It is the equivalent of creating a massive greenhouse for vegetation where they can be in a warmer atmosphere, where the climate could be controlled.

By having an indoor vegetation structure, it would make it also possible to have indoor farming and to grow indoor plants.

However, indoor farming could be done in a smaller scale without the need of having a massive structure.

• Figure 4.47: Indoor forest (Courtesy of Safdie Architects)



## 4.5 INDOOR FARMING

**HYDROPONIC FARMING**

It is a growing method, where vegetables grow without soil. Adding just as much nutrition as the plants need in each growth phase.

The air gap left between the plant and the water causes the root system to get enough oxygen all the time.

In hydroponic systems, it is possible to grow chilli, tomato and other fruit-bearing plants, and it is easy to grow lettuce.

On the other hand, they require a little more space as they need to become larger plants in order to become bigger and carry fruits. This method leads to higher yields on small surfaces.

Furthermore, It could be used in both horizontal, and vertical farming approaches.

• Figure 4.48: Hydroponic farming (foodandcity.org)

# 5-DESIGN PROCESS

**5-DESIGN PROCESS** 46-69





## 5.1 SITE/PROGRAM

The chosen site is located in Fisksätra to apply the development plan since there is an ongoing development in that area that could be improved.

Fisksätra is a suburb in Nacka municipality in Stockholm region, and has a population of about 8,000 inhabitants, with its 7 227 inhabitants/km², it is Sweden’s most densely populated urban area. (Fisksätra.se)

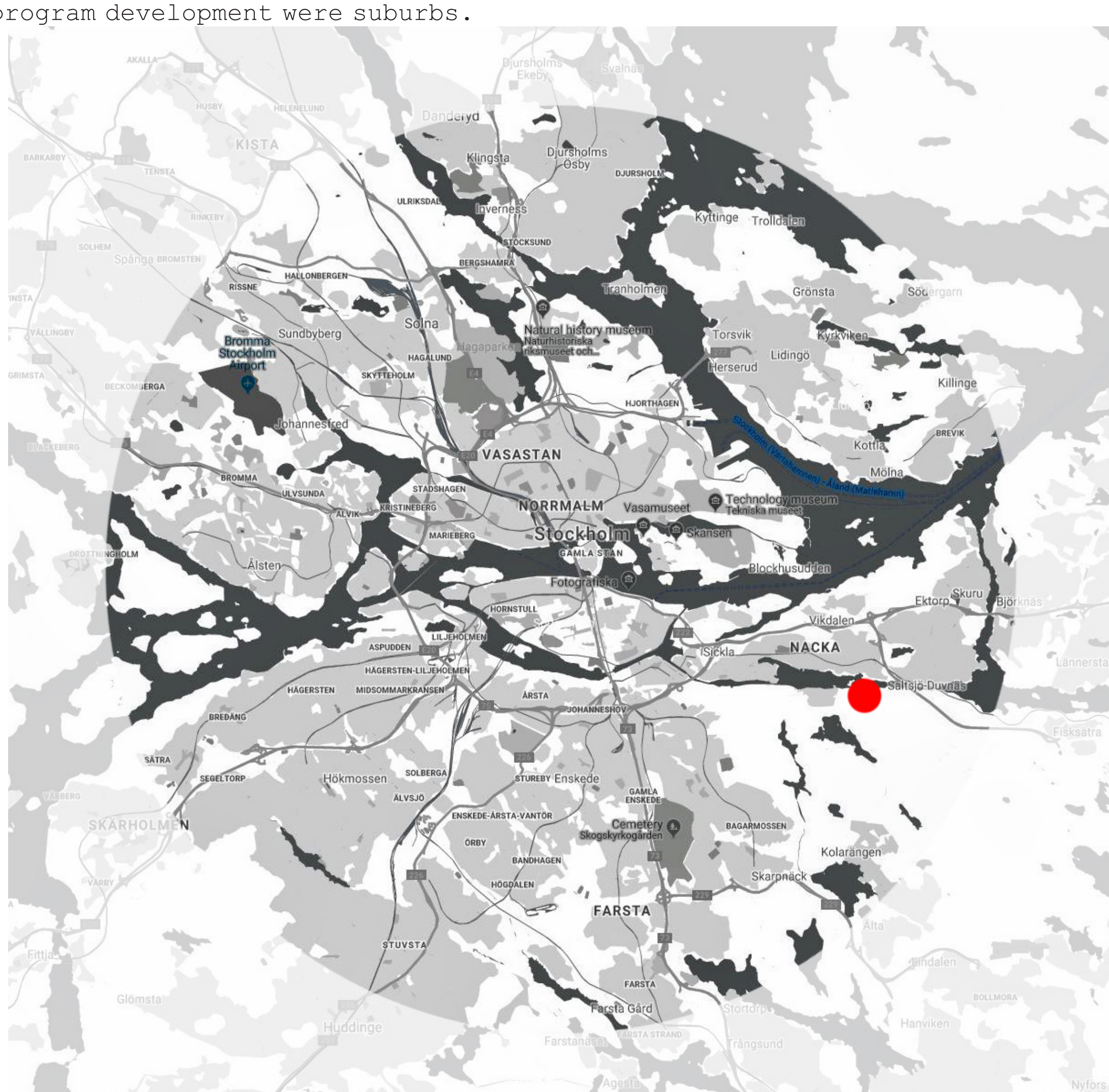
The area was mainly built during the million program era, in the late 60s and beginning of the 70s.

Most of the selected regions of the million program development were suburbs.

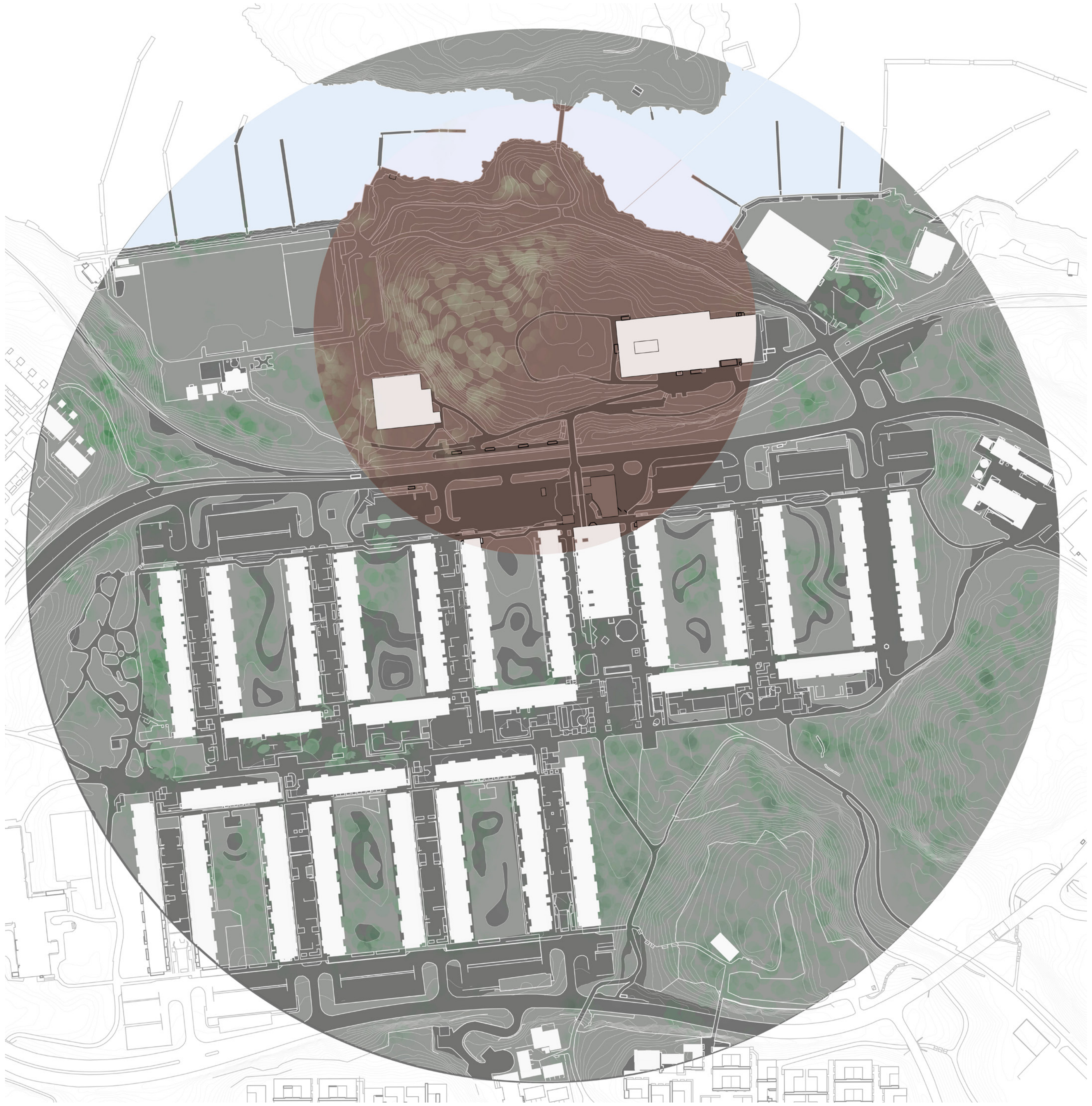
As it seems, the main approach in the million program was building mainly eight-floor building blocks, with a gap between them that usually has a garden in it.

The chosen site is located on the opposite side of the residential area of Fisksätra, where nowadays a football field ,Folketshus, and a yacht club are located.

The size of the chosen site for this master’s thesis development is approximately 4 Hectare.




• Figure 5.1: Site location in Fisksätra



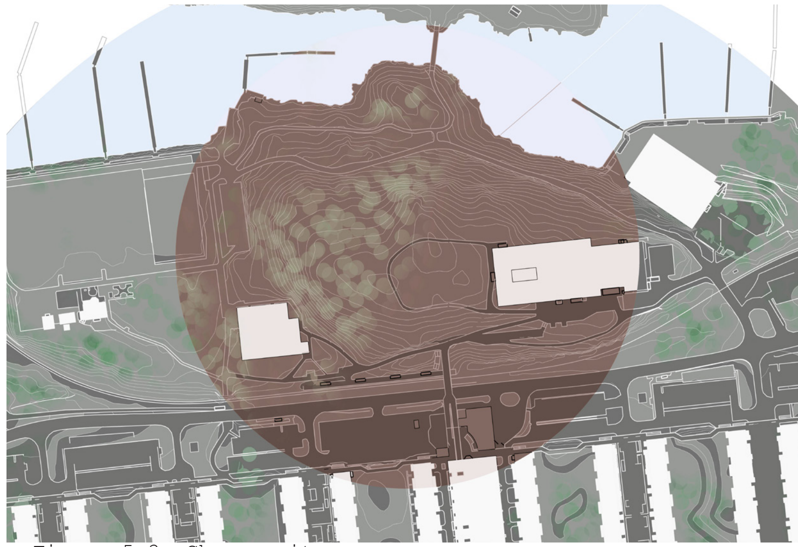
• Figure 5.2: Site plan



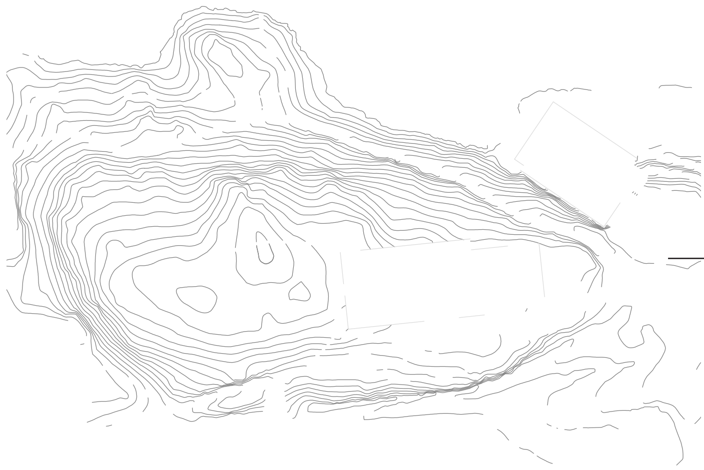
## 5.2 DISGEN PROPOSAL

The site development was started by using the existing terrain of the site. To preserve the existing green areas from the site (Figure 5.6), category number 2 (preserved greenery and land) from the simplification of the green surface factor was applied.

The new shape would be a combination of a terrain map subtracted by the existing greenery.
(Figure 5.7)

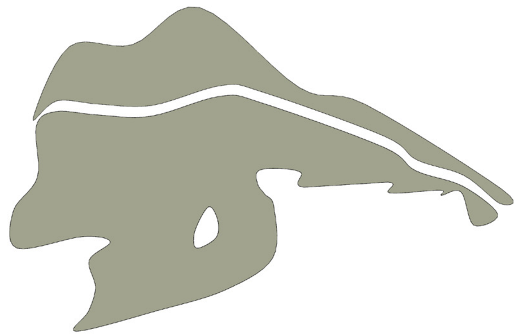


• Figure 5.3: Chosen site

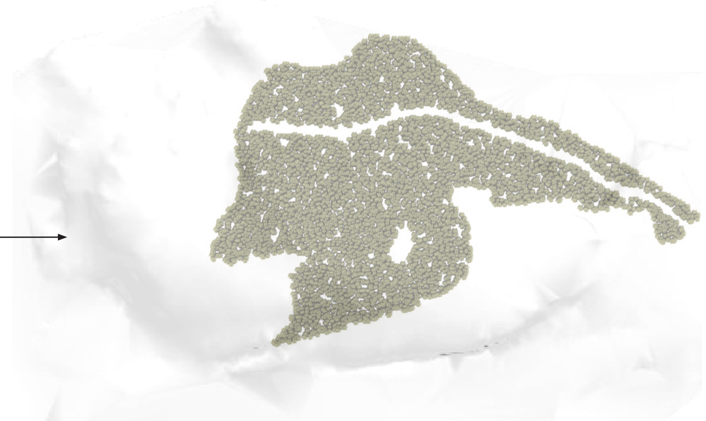


• Figure 5.4: Contour lines

• Figure 5.5: Existing terrain



• Figure 5.6: Existing green areas



• Figure 5.7: Existing green areas

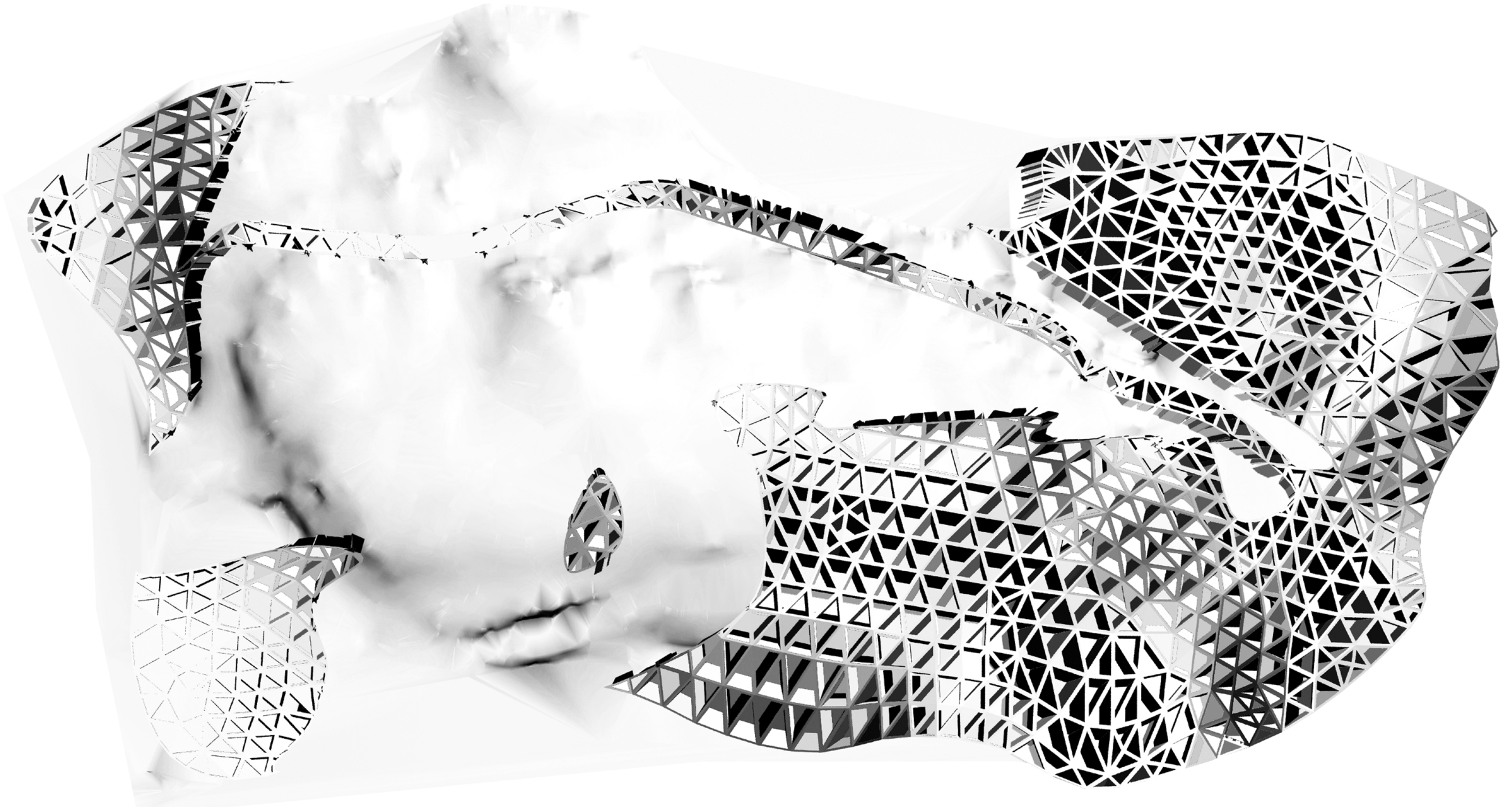
Two shapes of module system were taken into account; triangle module system, and square module system.

A Triangle-shaped module system would provide more stability to the structure, in contrast to a square-shaped module system since when forces are applied to a square, a square is more prone to lose its shape.

In addition, triangular shapes would provide more design options and flexibilities during the development process.

Applying a grid of triangles that have 60 degrees angles (it was taken from exploration II) to the resulted shape (Figure 5.8).

The resulted shape would be used as a module system to place a variety of units in it.(Figure 5.9).



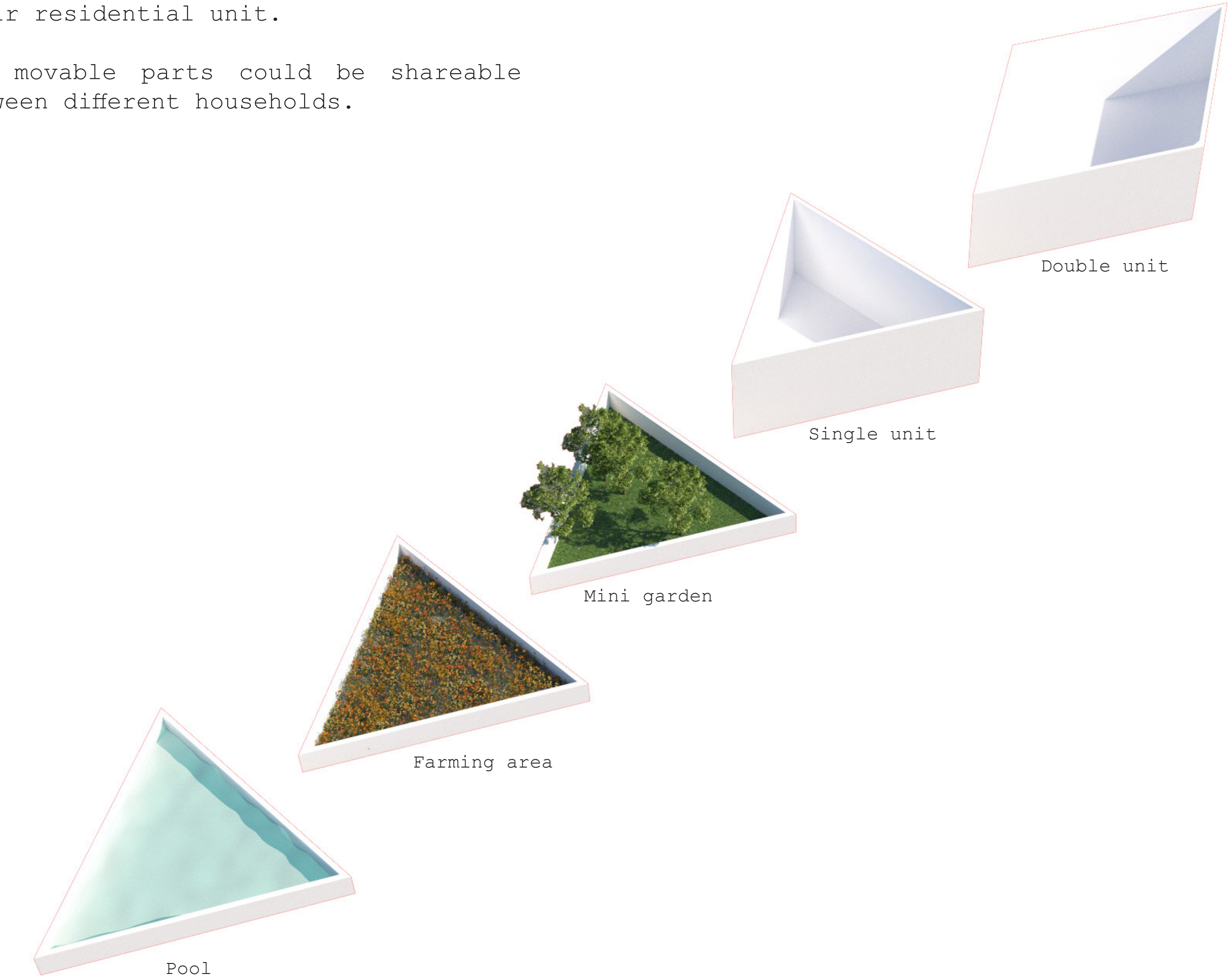
• Figure 5.8: Module system



A possible approach is to use the system to work as a base as Lego pieces, some parts would be crucial and placed permanently in the system (residential units and their cores), and some other parts would be movable and changeable (pools, gardens, and farming areas).

The residents would have the opportunity to choose the size of the unit they want which would be permanently placed; meanwhile, they can decide upon which pieces they would like to add next to their residential unit.

The movable parts could be shareable between different households.




• Figure 5.9: An example of samples that could be used in the module

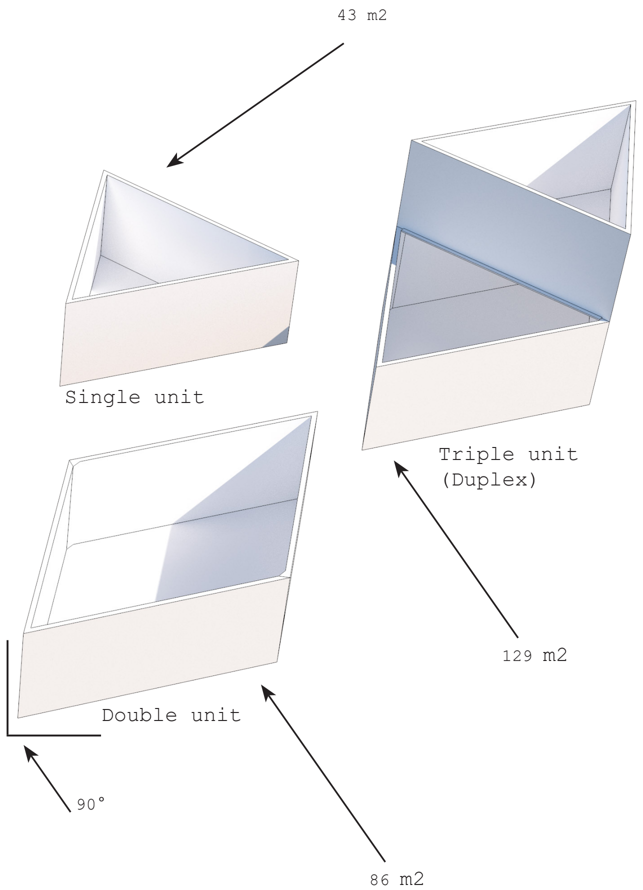
The statistic of the Swedish population could be used to understand the needed size of the units that would be used in the system.

The statistic might give a clarification of How many percent of people live alone, how many percent of people live collectively or in a family.

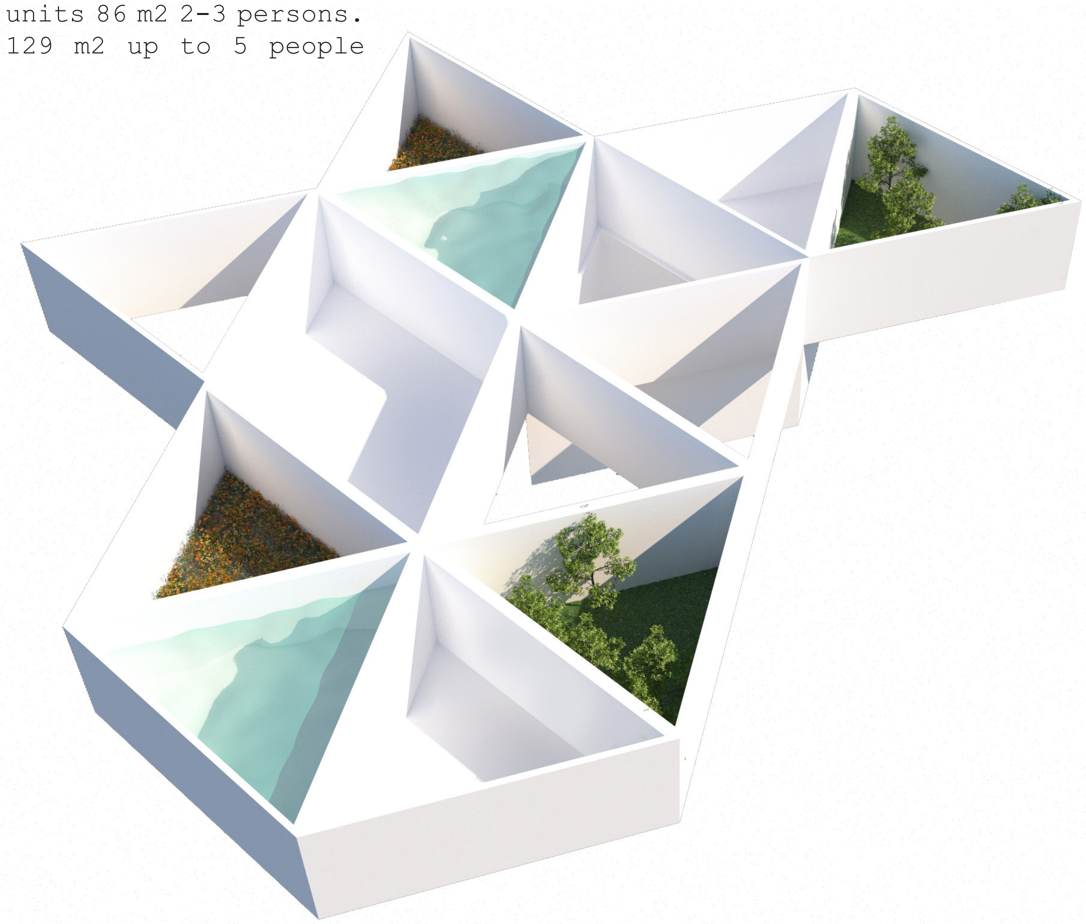
According to SCB (statisk centralbyrån, the population statistics unit)
37.8% of the population are single people who live alone.
28.9% of the population are people with children.
33.3% of the population are people with no children.

According to the previous information, three sizes of units would be used to define the units that represent the residential area.

37.8% small units 43 m2 1 person.
33.3% medium size units 86 m2 2-3 persons.
28.9% big units 129 m2 up to 5 people (Figure 5.10).




• Figure 5.10: An example of different sized apartments



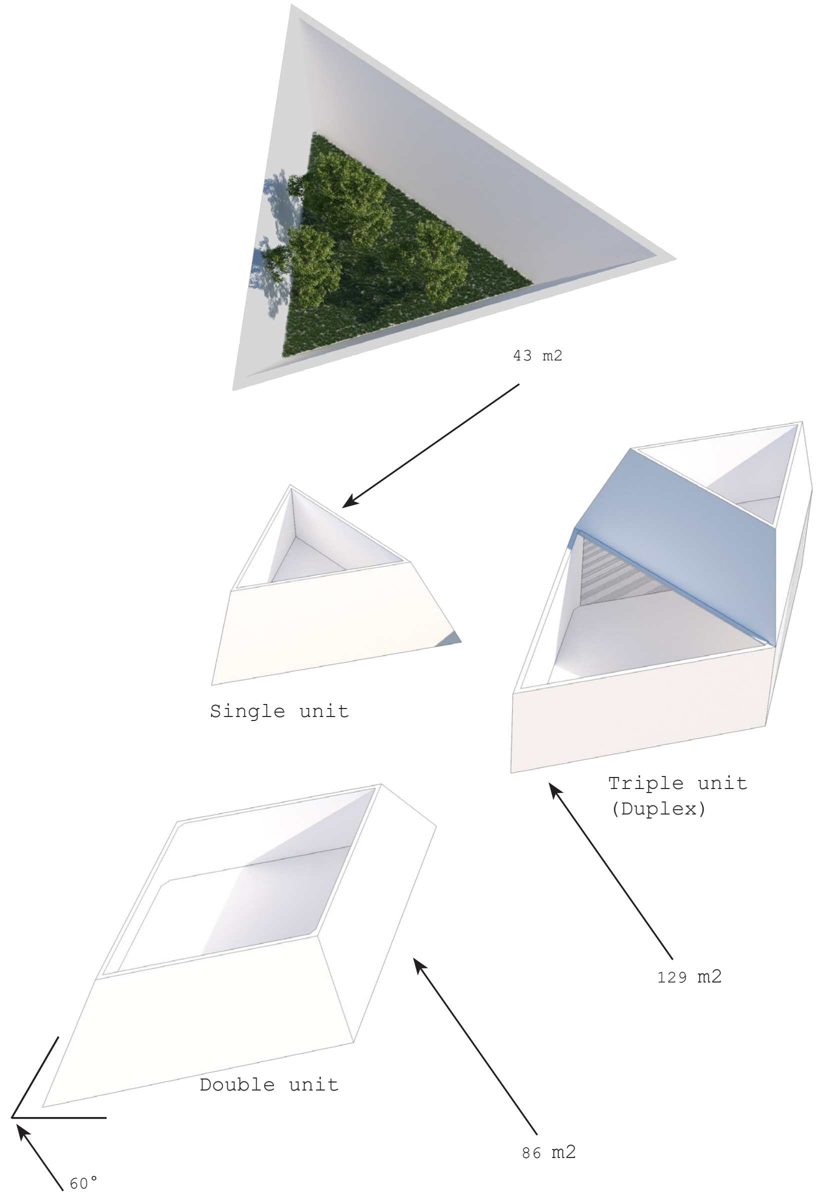
• Figure 5.11: Fitting in the module



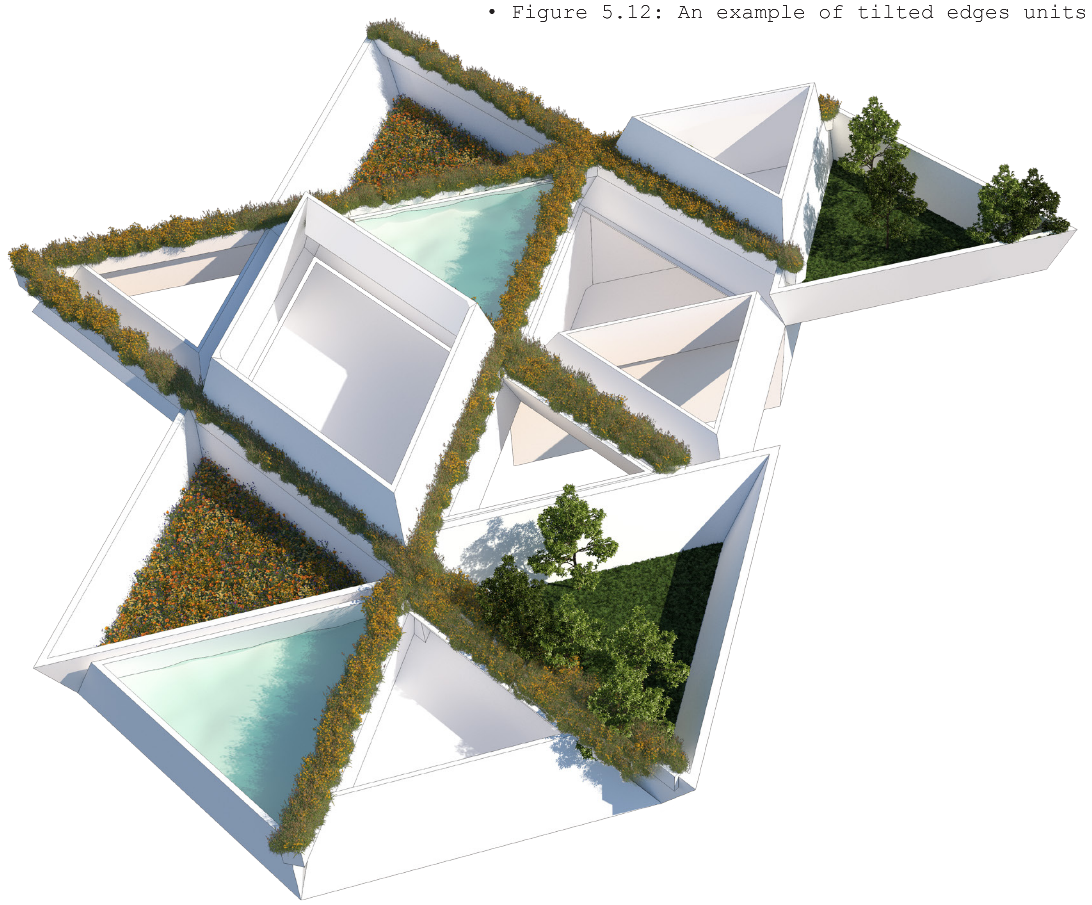
To ensure the quality of biodiversity, there should be a connection between the green areas; to make it easier for insects and small animals to move freely and not to be trapped.

A possible approach to achieve the biodiversity would be by tilting the side edges of the units to the inside, and tilting the edges of the gardens basin to the outside(Figure 6.12); it would make more significant volumes for vegetation to grow.

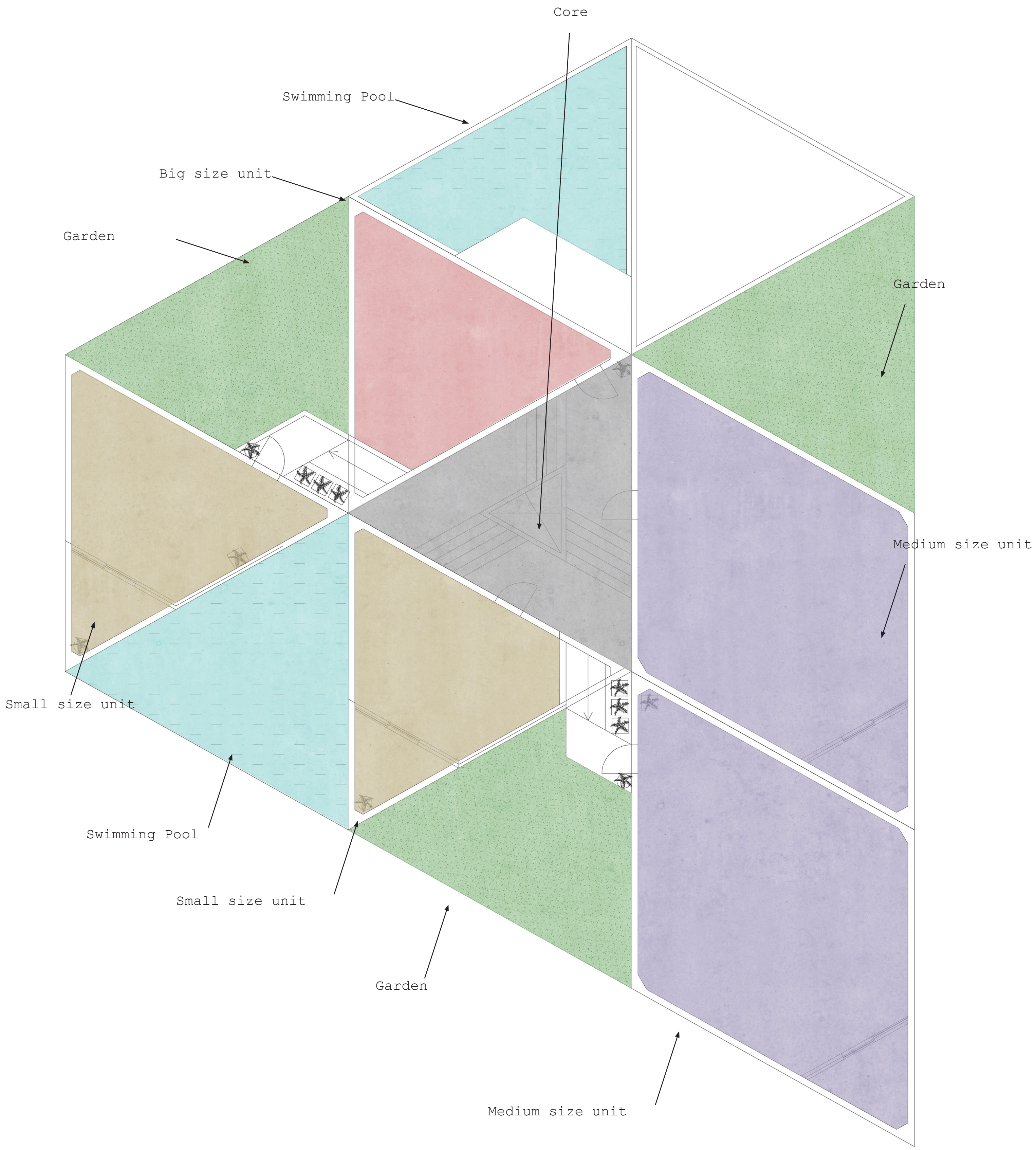
The gaps between the units and the other pieces of the module system would be used as green surfaces which will work as a connection between the different green areas to achieve a better quality of biodiversity. It would also work as a collector to harvest rainwater.
(Figure 5.13)




• Figure 5.12: An example of tilted edges units

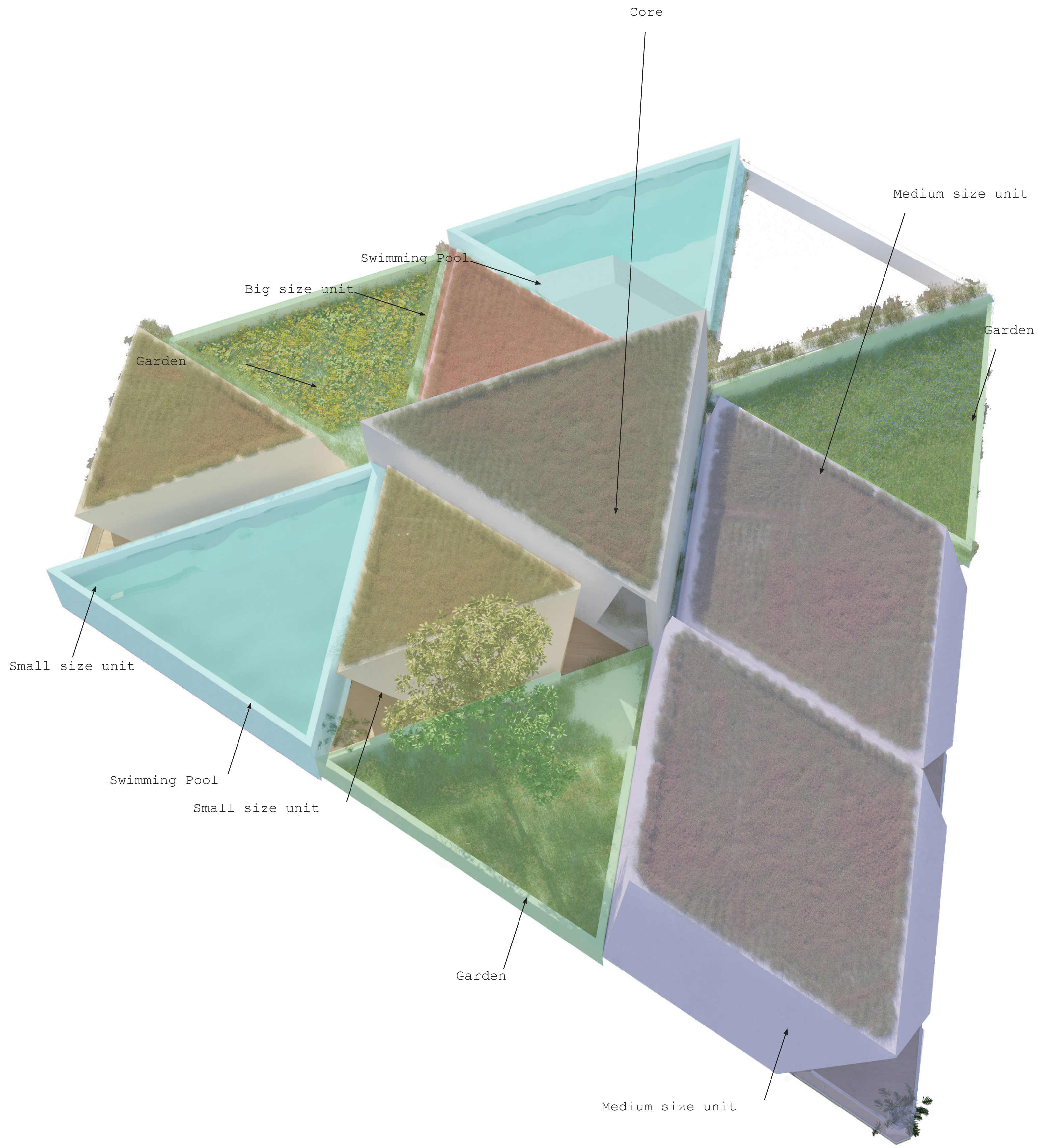


• Figure 5.13: Fitting in the module




• Figure 5.14: An example of samples that could be used in the module





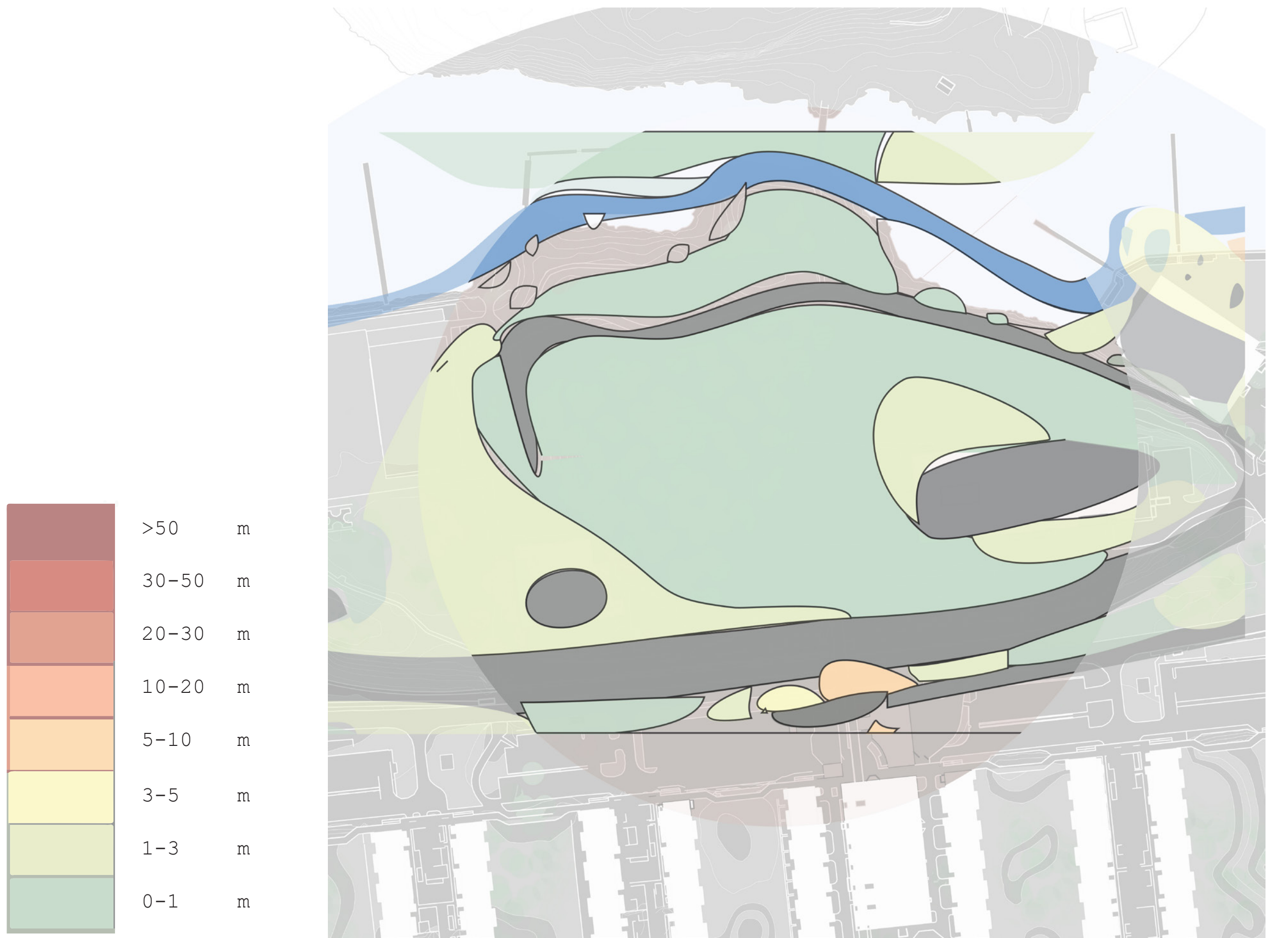

• Figure 5.15: An example of samples that could be used in the module

The module system would be expanded to be represented by 3 layers (an upper layer, a lower layer, and a between layer). This could be done by transforming the area of development from a 2D-layer to a 3D-layer. A 3D-layer would be approached through following the site geological map. (Figure 5.16).

The estimated depth of soil from the geological map would be used to define an estimated height limitation that could be used for the development. Such an approach means, the shallower the depth of soil is, the higher could be built, and the deeper the soil is, the lower could be built.

Reversing the numbers of the estimated depth of soil (Figure 5.17), to be used as a height limitation, when the depth of soil is between 0-1 m, the maximum height would be up to 50m, and when the depth of soil is between 50-10 m, the maximum height of the development would be around 10 m, etc.

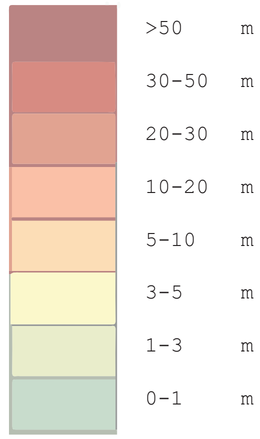
This method could be applied to the chosen site to generate the development heights of the selected site based on the geological map. The result is a new terrain map showing the possible heights that could be used in the process (Figure 5.20).



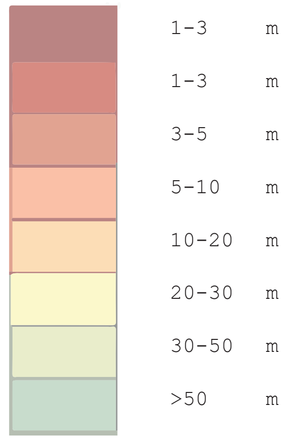

• Figure 5.16: Estimated depth of the soil (Geosigma AB, 2017)



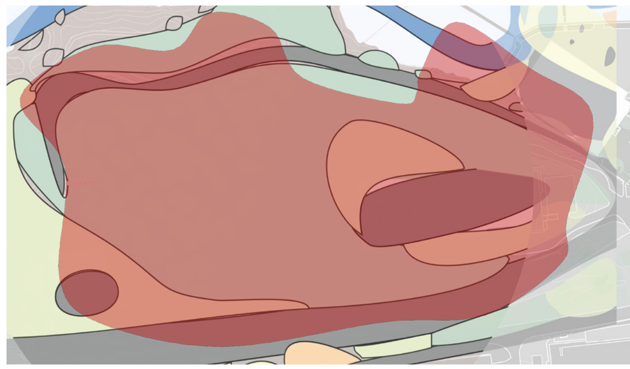
As in the previous trial, preserving the existing green areas from the site (Figure 5.21) was applied through category number 2 (preserved greenery and land) from the simplification of the green surface factor.



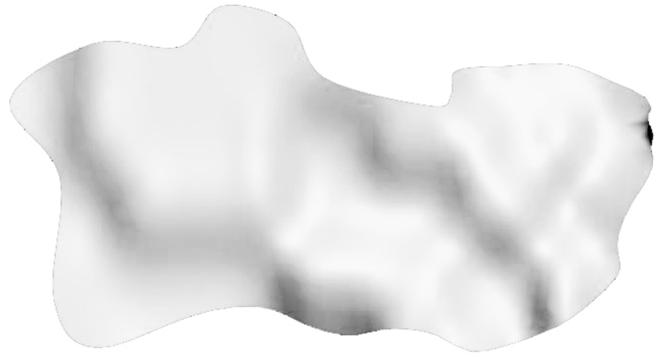

• Figure 5.17: Estimated depth of the soil



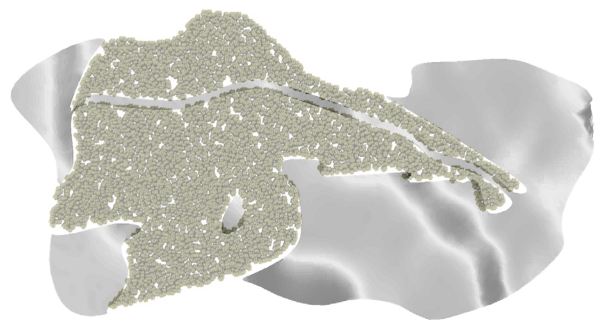

• Figure 5.18: Estimated possible heights



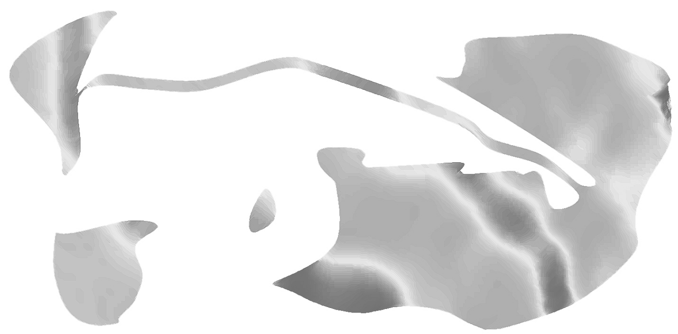
• Figure 5.19: Chosen site



• Figure 5.20: Terrain map of the possible heights



• Figure 5.21: A combination of a terrain map generated by the geology of the site, and subtracted by the existing greenery

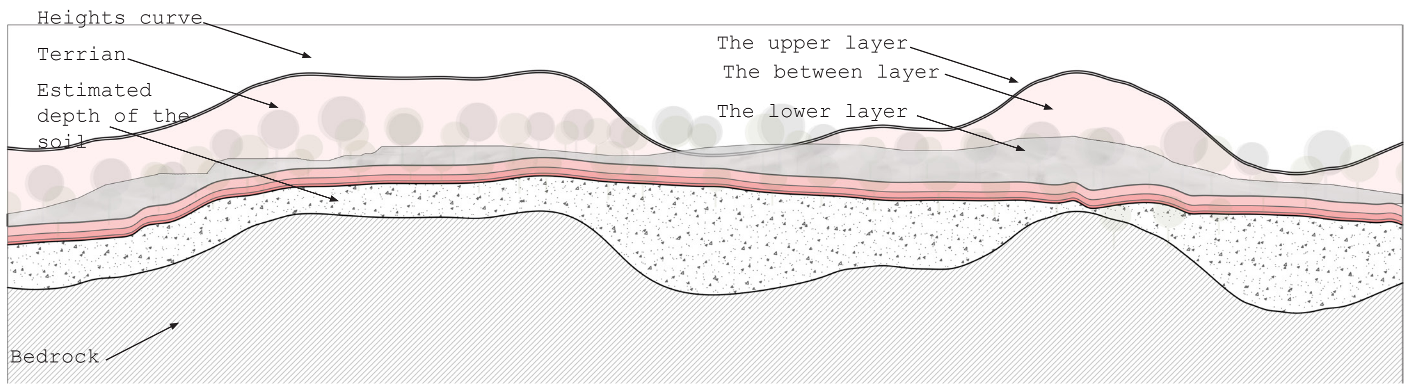


• Figure 5.22: Resulted shape

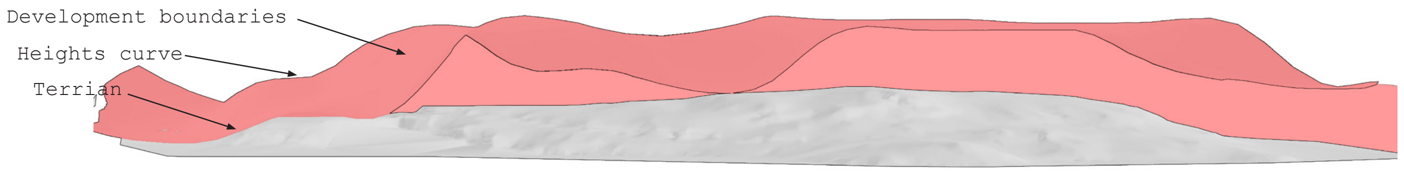
In order to apply the third category of the Green Surface Factor(Social and public surfaces), the lower part of the module system would be used as public and social areas. These areas would be open for the public, and it would contain a market where people could sell their crops directly.

Some parts of the lower part would be used as an indoor forest, where new types of trees and plants could be planted in the area where it usually cannot be exposed to the outside.

Meanwhile, the upper layer would be private, where residential units would be located. The between layer would consist of circulation, social areas, service and maintenance units, and facilities such as parking lots.




• Figure 5.23: A section of the terrain, the height limitation curve, and the estimated depth of the soil



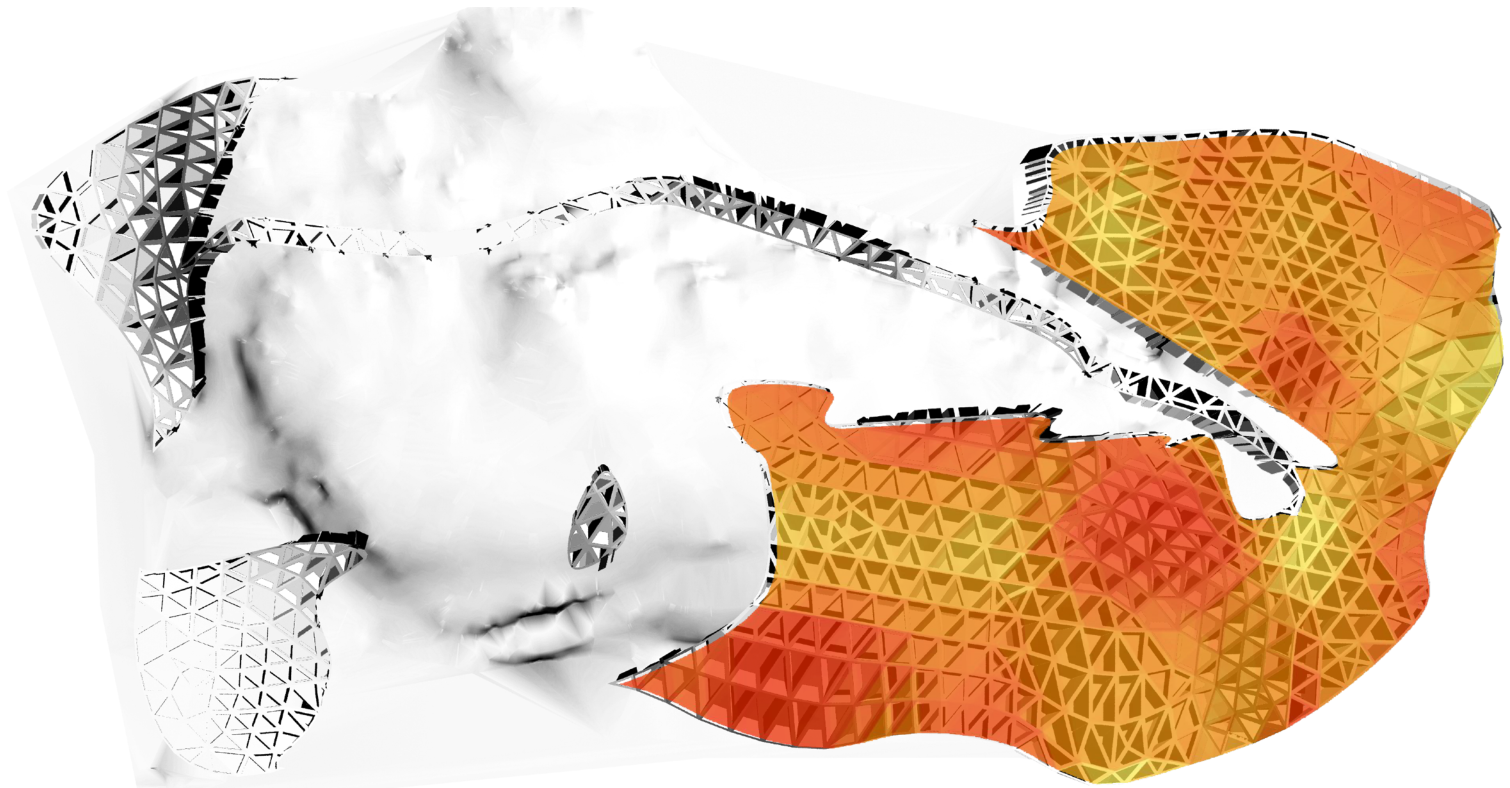

• Figure 5.24: A section of the existing terrain and the height limitation curve



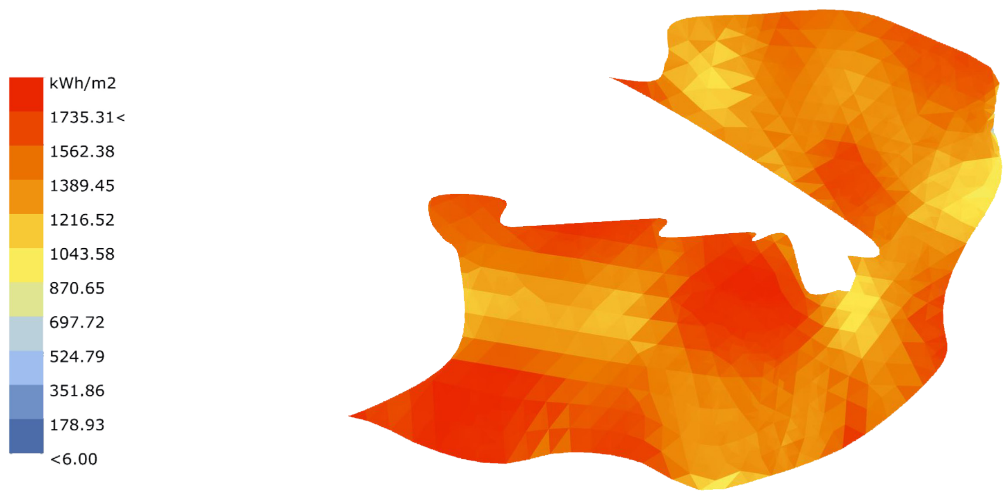
A limitation for the indoor forests is that they exist in the lower part, which means they may have limited resources of light and heat. A solution for this limitation could be through applying exploration II, which provides openings in the module to guarantee that the light and heat would reach the indoor forests.

A solar study of the module system was used to define where the openings would be placed. (Figure 5.25)

In addition, the parts of the existing roads and the football field would be excluded from the current development of the project.

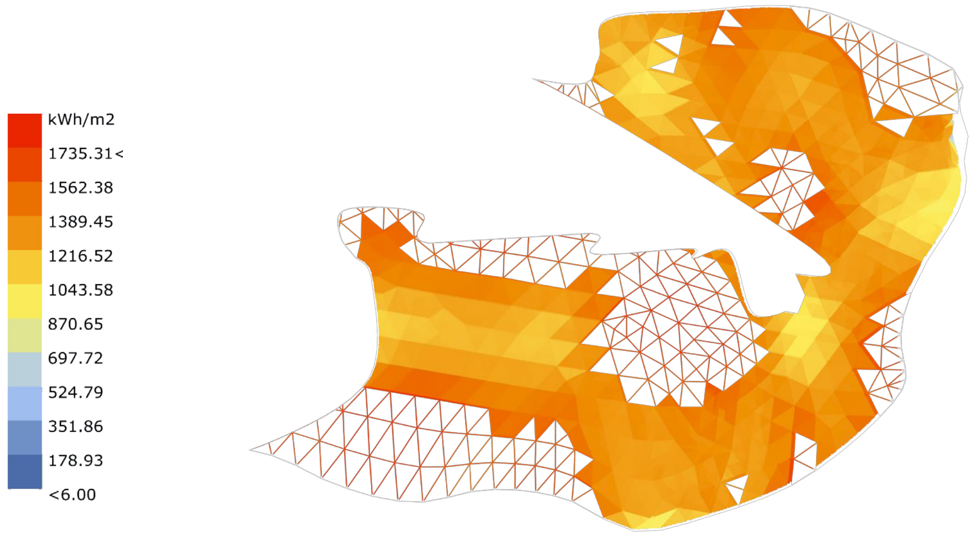


• Figure 5.25: Solar study

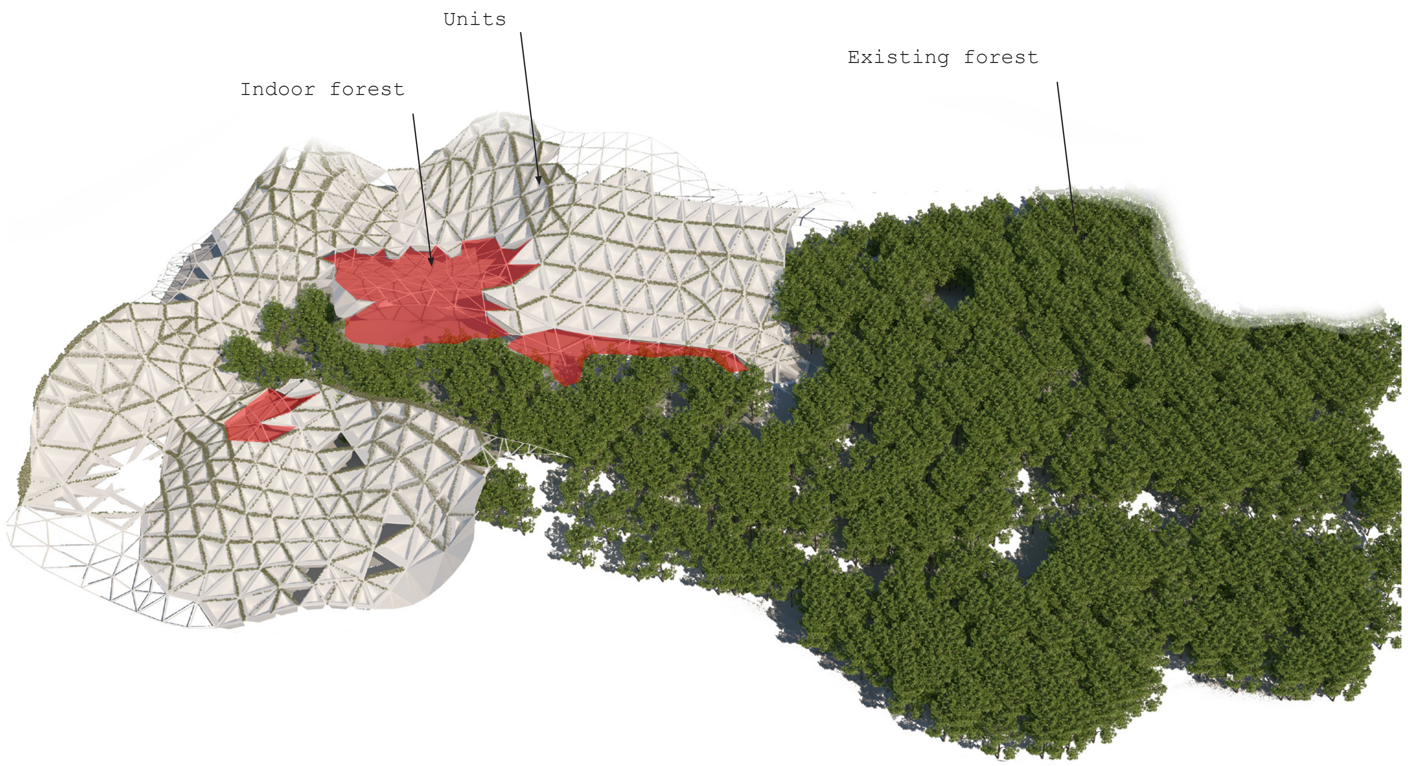



• Figure 5.26: Solar study, Year round

The openings would be placed in the warmest areas, and would be covered by a transparent roof. Thus, the lower level can get more light and heat. (Figure 5.27)

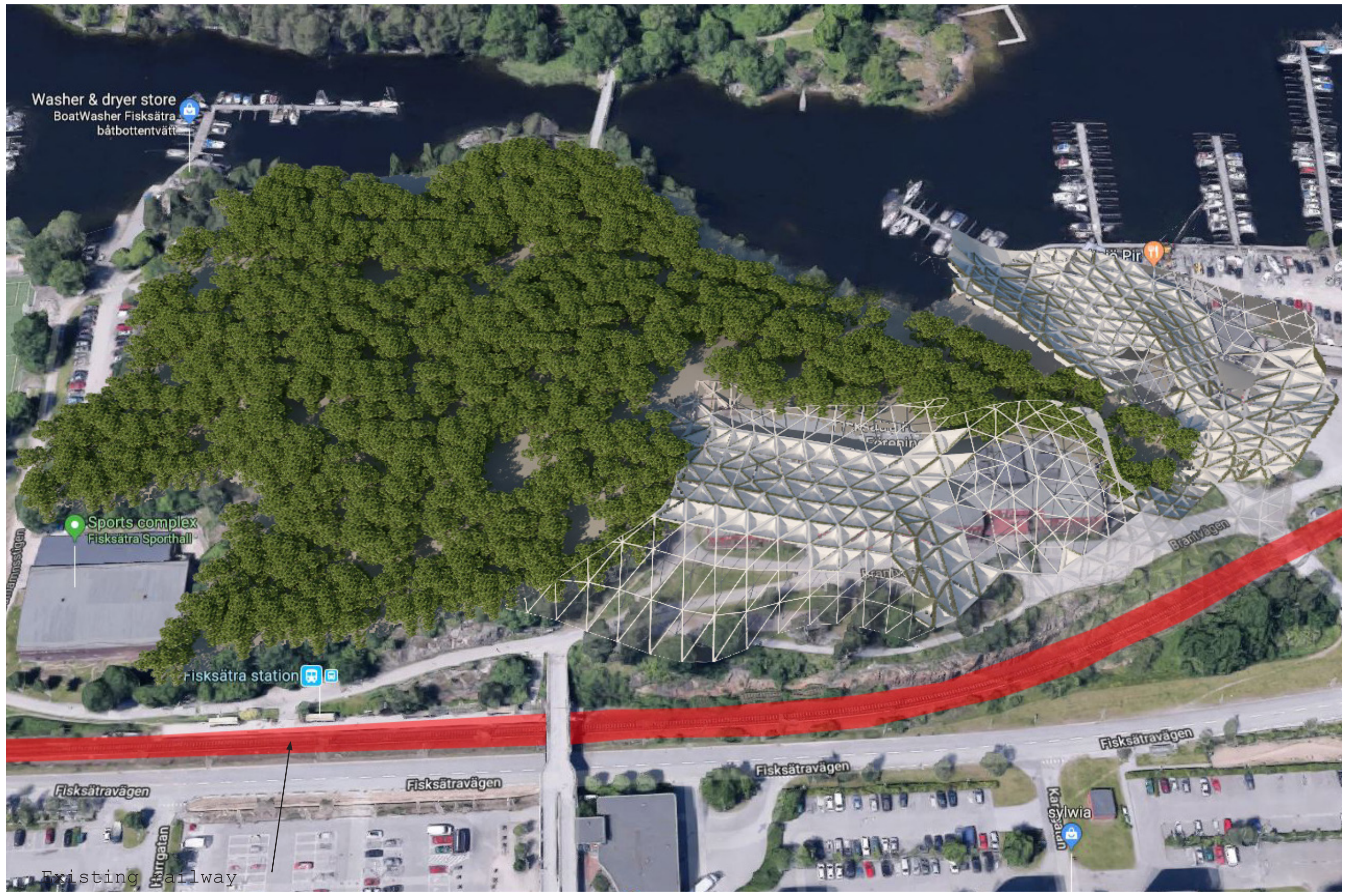



• Figure 5.27: The openings in the module




• Figure 5.28: Module system






• Figure 5.29: Fitting in the context North view


• Figure 5.30: Fitting in the context South view

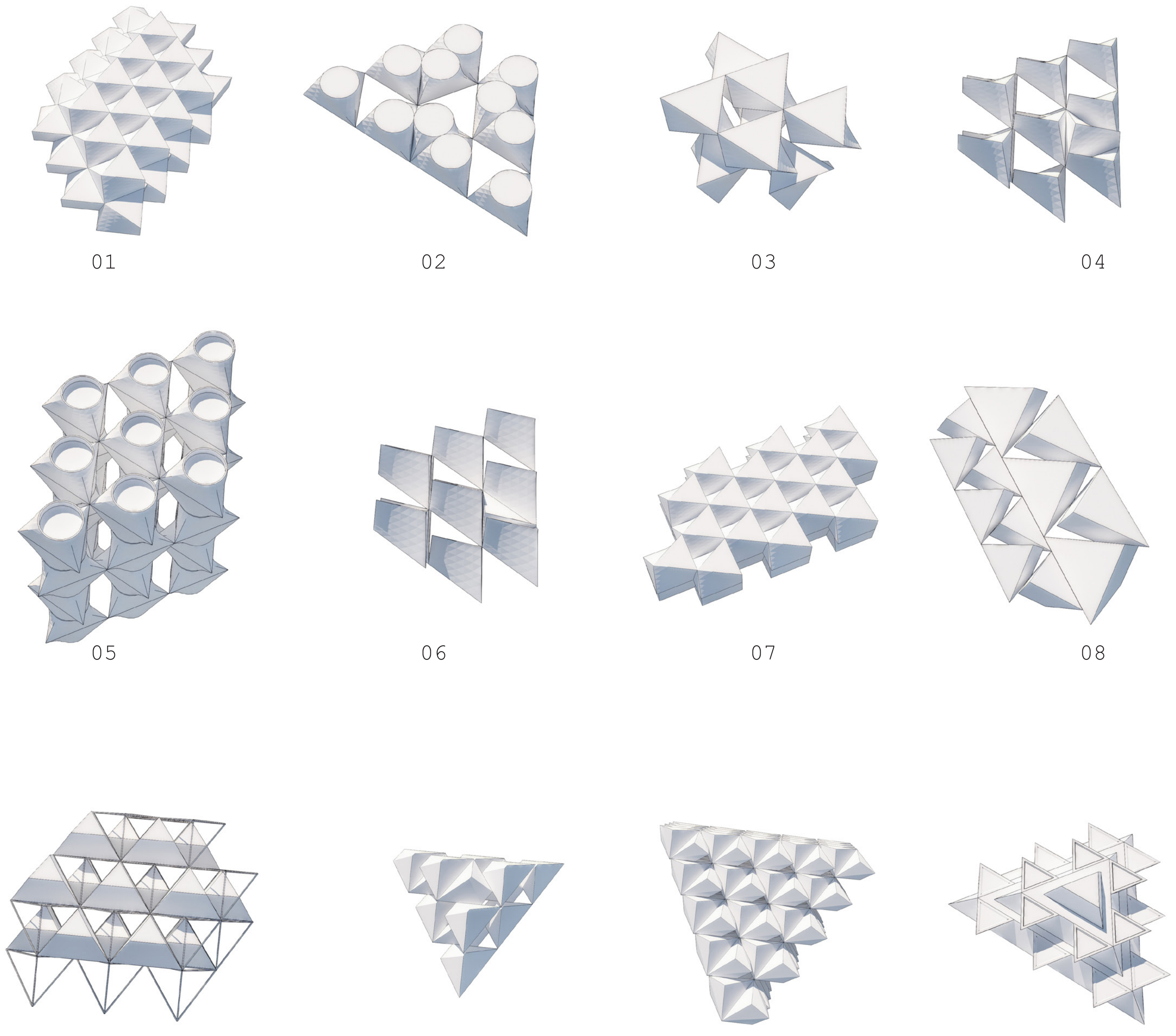
## 5.3 DESIGN EXPERIMENTS

The previous design was difficult to be approached vertically in the module system. The problem was that the surfaces that are representing the green areas would have limited resources (light, rainwater, heat, etc.) due to the limitation of the floor height.

To find a solution to the problem, new design experiments were made. The experiments would provide the system with the ability to be repeated not only vertically but also horizontally.

Several trials were made in order to identify the shape and alignment of the units. Due to the time limit, only 12 trials were made. (Figure 5.31)

Trial number 12 was selected to develop further, for the reason that it has the light and space qualities that are needed for vegetation.

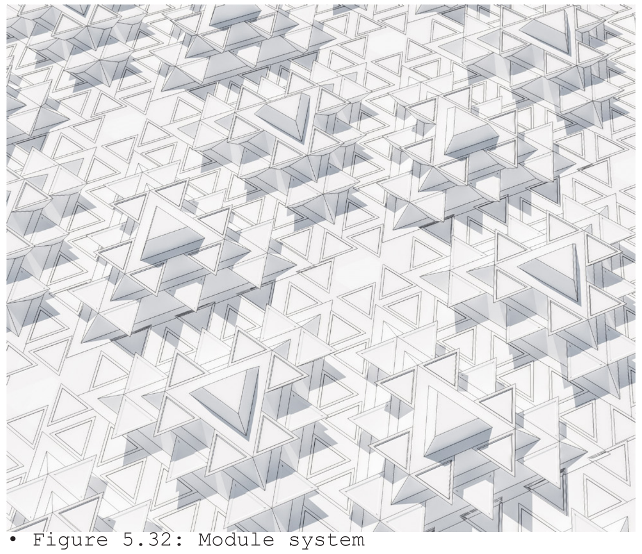



• Figure 5.31: Design experiments

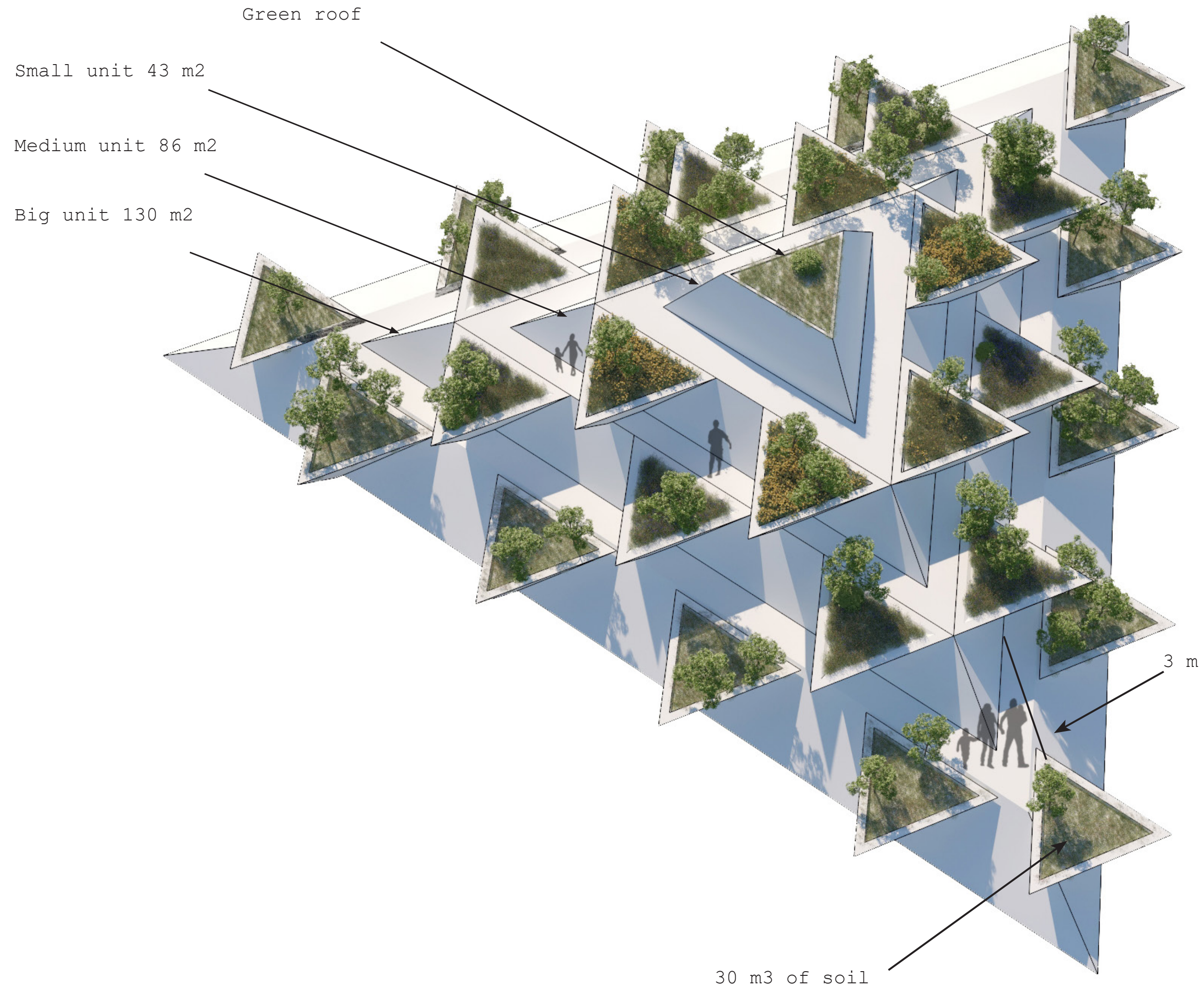


In the selected trial, the main idea was that soil basins could be attached separately to the units, and also have a depth that is exactly as the floor's height. This would give more space for trees to establish their roots deeper. Furthermore, the pyramid-shaped units would make more space for trees to grow. (figure 5.32).

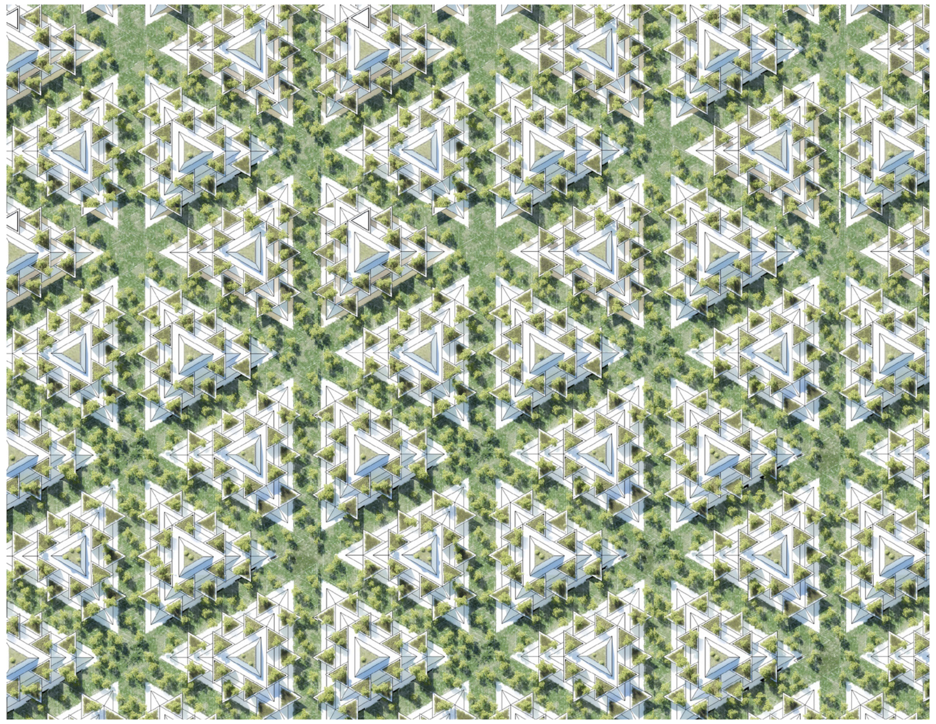
The module system could be used in a small scale (small, medium, and big units), or in a bigger scale (each floor might contain multiple units/apartments).



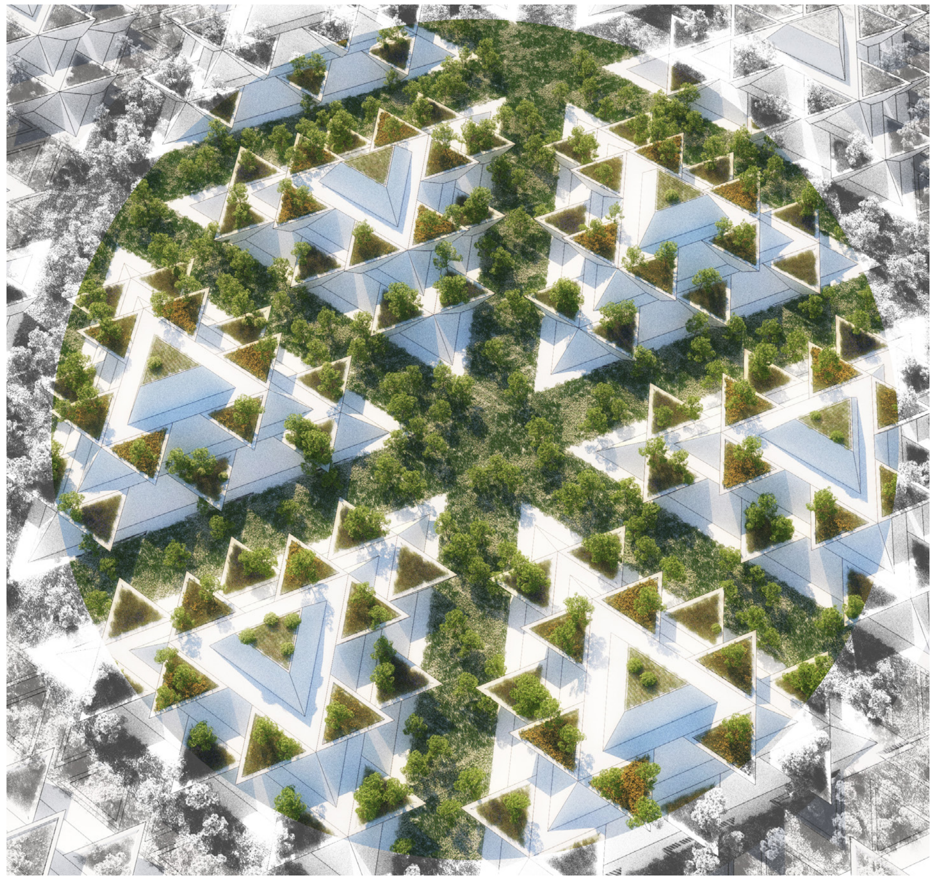
• Figure 5.32: Module system




• Figure 5.33: Selected design



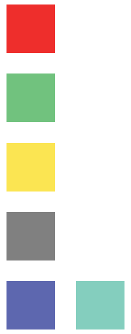
• Figure 5.34: An illustration of the module system (Upper layer)

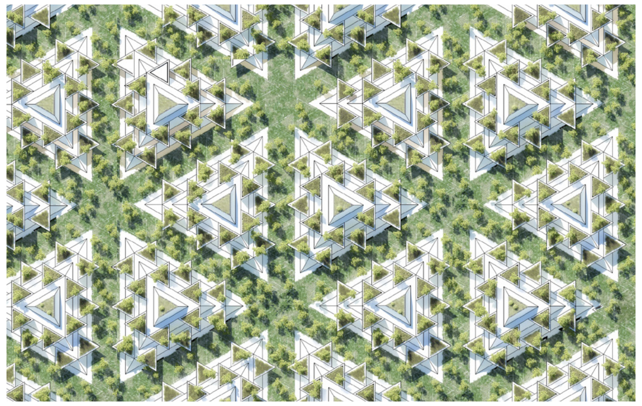


• Figure 5.35: An illustration of the module system (Upper layer)

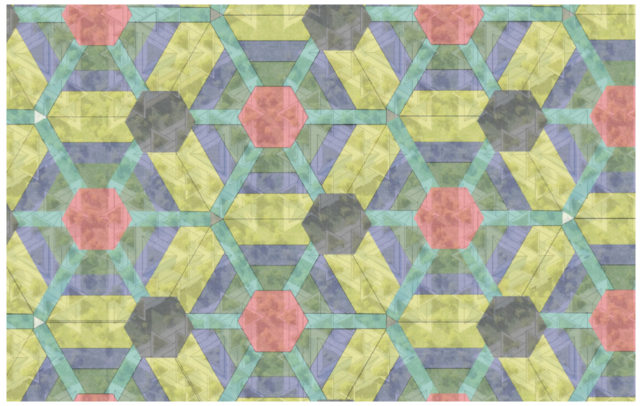


The between layer is divided into 5 zones, these zones would consist of: A service area that includes a water tank that would be used to collect rainwater. The second zone is the farming area, and it would be used as hydroponic planting facility. The third zone would have a social and public program. Meanwhile, the fourth and the fifth zones would be used for the circulation (stairwells, roads, and parking lots) to connect the previous zones together, and to connect the lower layer with the upper layer. (Figure 5.37) (Figure 5.38)

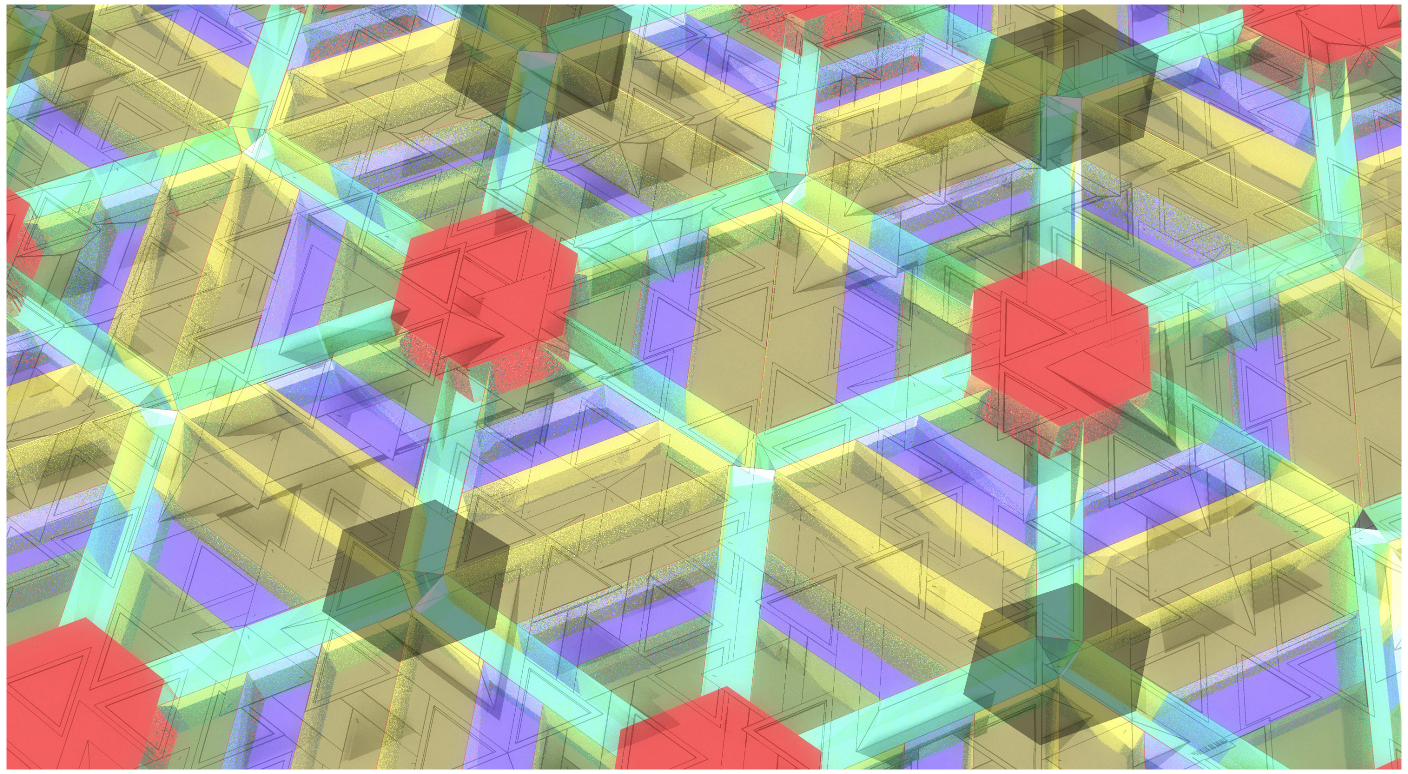


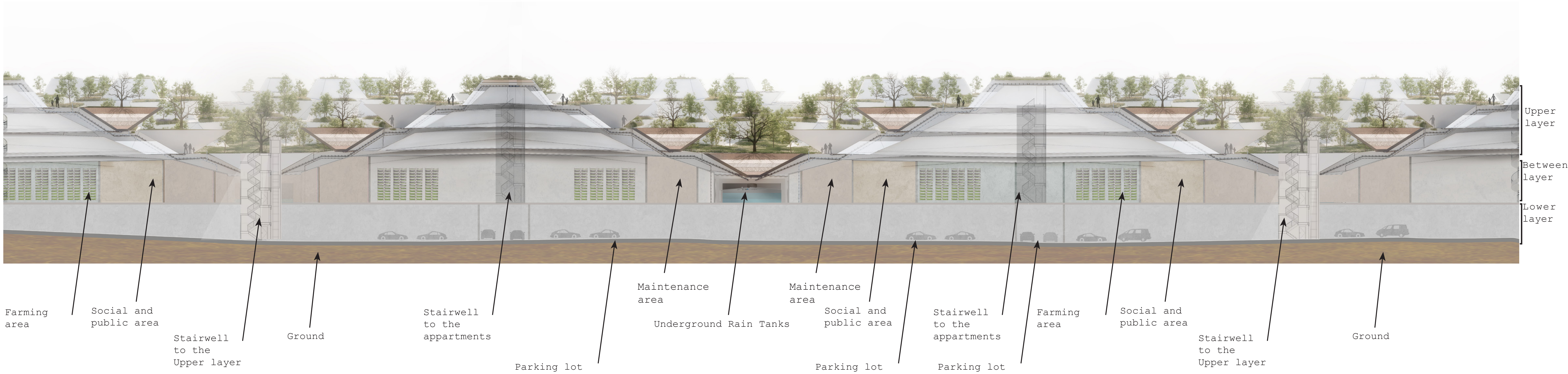
• Figure 5.36: An illustration of the module system (Upper layer)



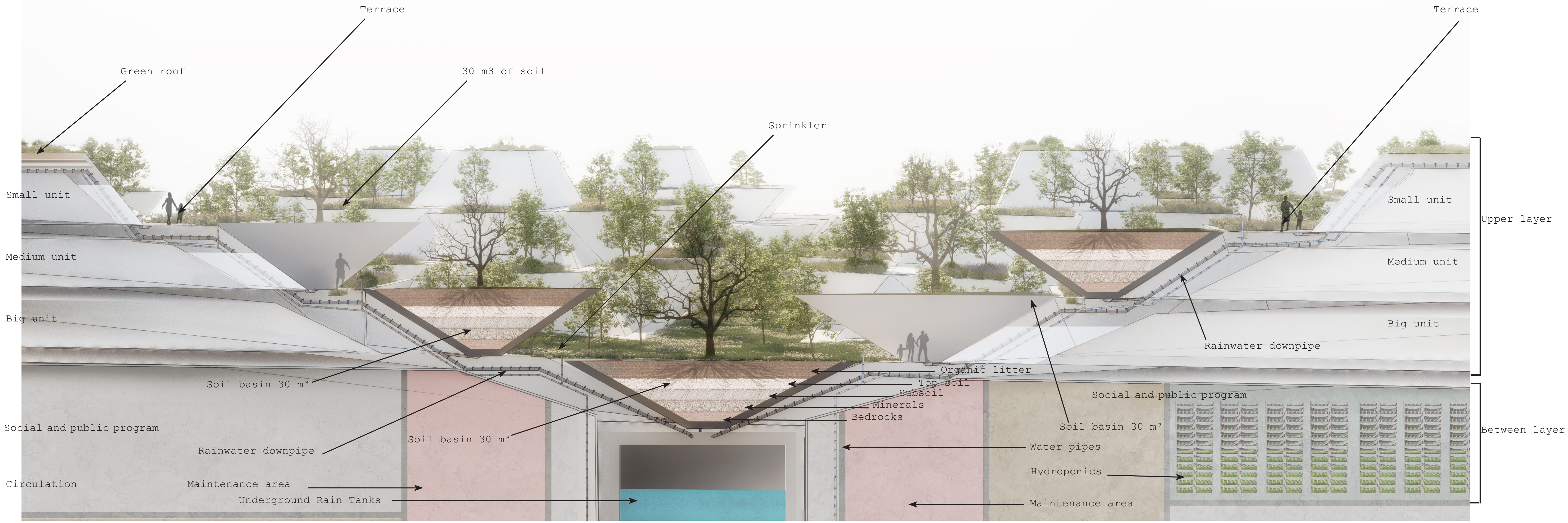
• Figure 5.37: An illustration of the module system (Between layer)



• Figure 5.38: An illustration of the module system (Between layer)




• Figure 5.39: Section perspective of the different layers and levels of the module

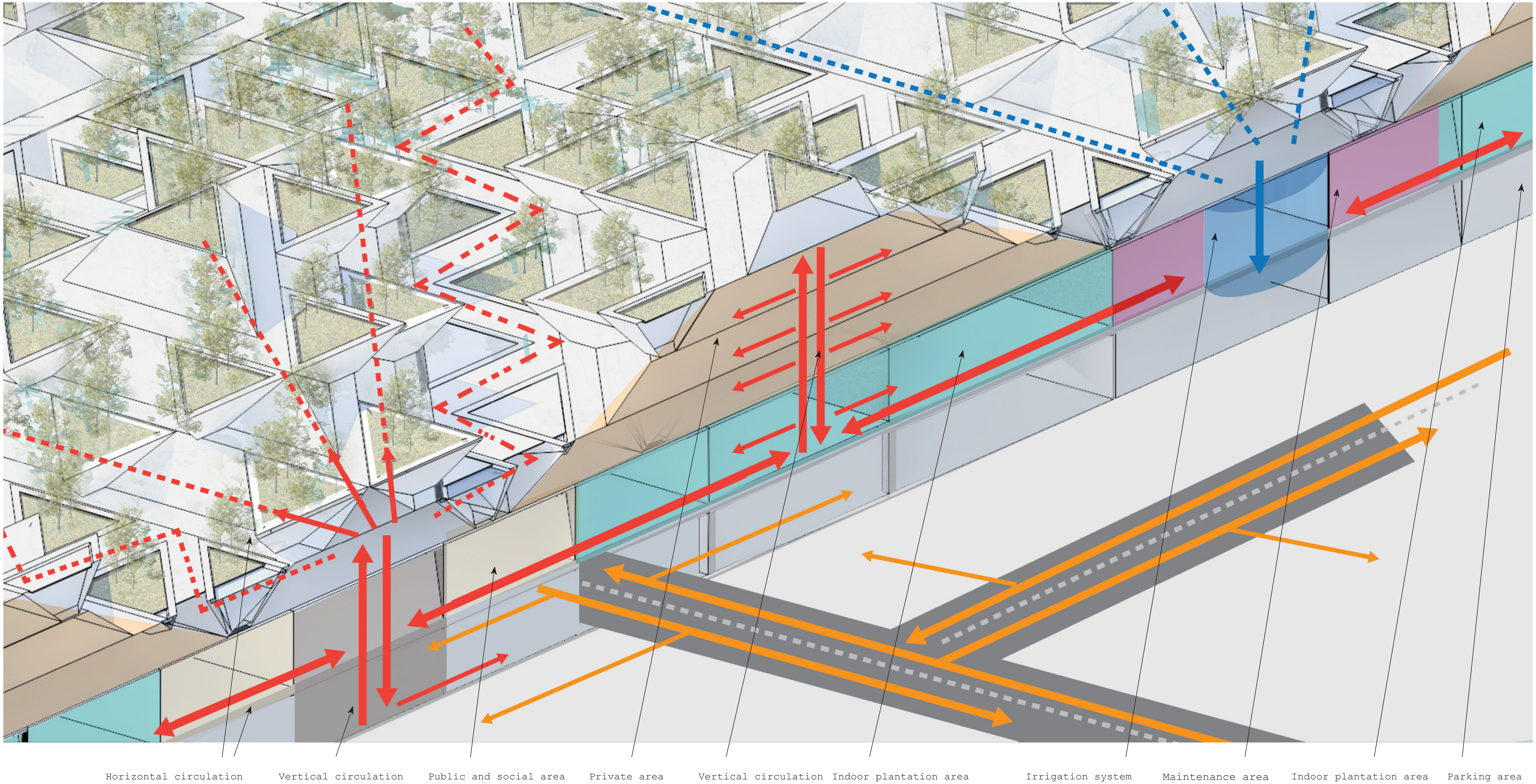



• Figure 5.40: Section perspective of the different layers and levels of the module

Pedestrian circulation

Vehicles circulation

Irrigation system




• Figure 5.41: Diagram showing the connections between the 3 different layers

• Figure 5.42: Fitting in the context North view

# 6-DISCUSSION AND CONCLUSION

The proposal in this thesis gives an overview of how to integrate nature into architecture, however, it does not include a detailed phase. A detailed phase could, for example, include more sub-factors from The Green Surface Factor such as beehives, birdhouses, fountains, social areas, and some other elements.

In addition, social areas were taken into account in the proposal as social and public surfaces with no specific details, assuming that they would be more defined in the detailed phase. Since the detailed phase is not performed, the green surface factor could not be calculated in the final proposal of this thesis.

This proposal of integrating nature into architecture was full of obstacles, such as the difficulties of achieving the needed requirements of integrating plants and trees (soil volume, maintenance, etc.) into the architecture development.

The resulted approach of the thesis gave a definition of the architectural development process by introducing a new method, which mainly focused on designing for nature. This approach would open the way to enable local nature and its ecosystems to thrive alongside architectural interventions; it would also restore the parts of forest and nature that had been always there in the past.

Finally, nature was there way before the architecture development, as a result, I arrived at the conclusion that the structure of the thesis question should change from

***"How can nature be integrated into architecture to enhance the urban experience?"***

to ***"How can architecture be integrated into nature to enhance the urban experience?"***



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