Personal portfolio Luuk Winters

DEEPENING AND PROJECT SKETCHES

12/7/2020

CLASS OF 2023

SEMESTER 1

Deepening rubric

Introduction

To complement our initial research and our design process, I'll focus my deepening on permaculture and (urban) farming methods. First I will look into what a permaculture is, how it is set up and some examples including their pros and cons. Since our project is about food security, I will look into setting up a permaculture foodwise, not necessarily a permaculture as a whole.

Furthermore, I will look into farming and new, innovative farming methods that make farming in hard-to-farm areas like cities possible. I will also list their pros and cons, which will give me a list of what farming methods are useful for our design and context. Farming methods will range from simple solutions, like burning the land, to more complicated, hightech solutions like hydroponics and aquaponics.

Combining these two subjects I'll write a conclusion stating what the best farming method is for our context and how this could help set up a permaculture, defining possible difficulties we could encounter and should overcome and stating why this is the best solution for our context.

I will display my deepening in written format, since it will be like an advisory report combined with research to explain the given advice. The written report will include research about permaculture, urban farming and farming methods and an advice on what farming method is the best for our context.

Intended learning outcomes

1. I want to conduct research about what a permaculture is and how it could be set up
2. I want to conduct research in the field of farming in difficult areas, exploring different methods
3. Lastly, I will combine the topics of my research and make a report about how a permaculture can be set up regarding food and what is the best solution for our context.

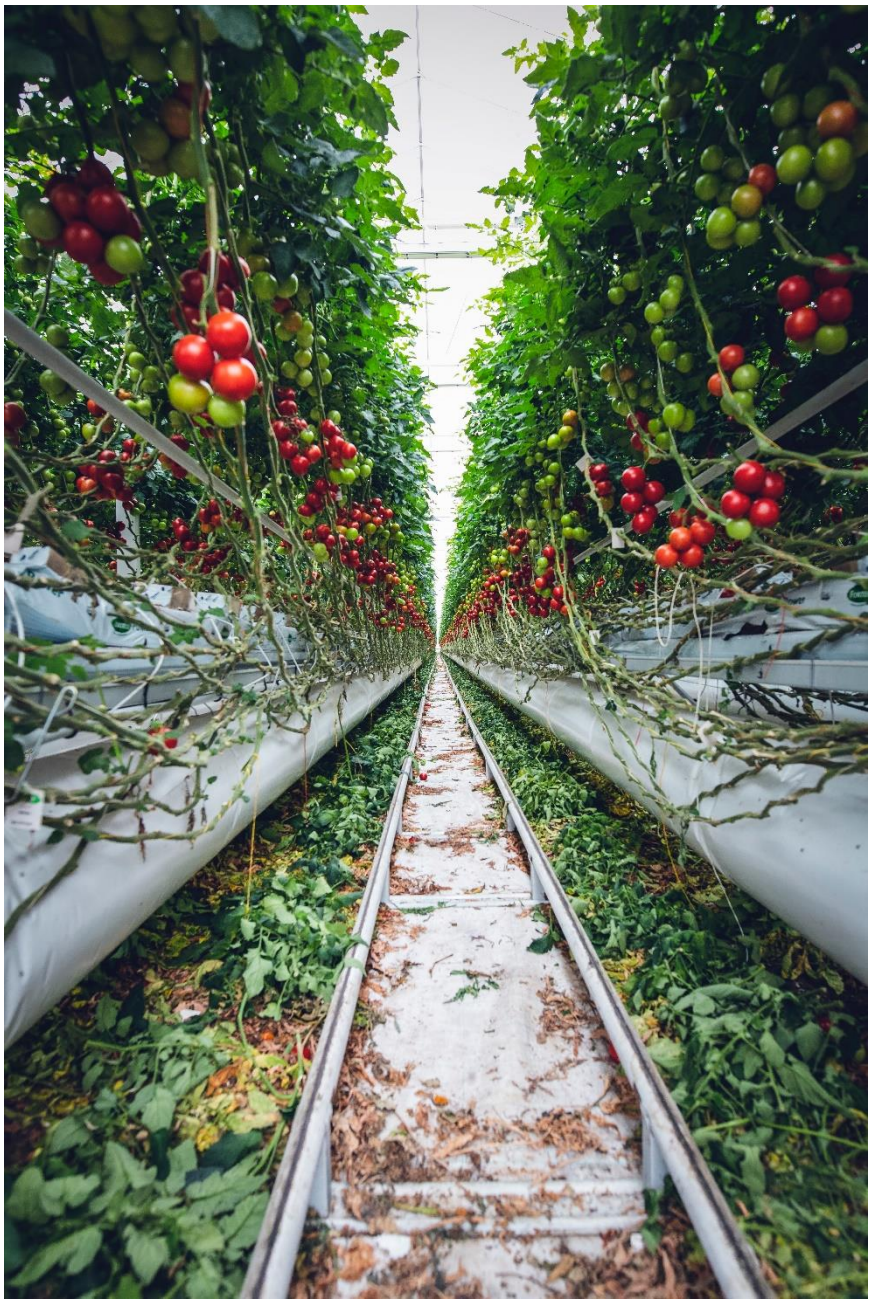
These learning goals are mainly related to learning goals 2 and 4 in the syllabus.
Goal 2: Gather and integrate information from different sources and academics, on the same topic, in order to communicate about the subject knowledgeably
Goal 4: Create informative/explanatory resources to communicate a topic and convey ideas, concepts, and information through the selection, organization, and analysis of content. Use relevant facts to support main ideas or themes; and organize them appropriately according to task, purpose, and audience

Relevance

I think my deepening is very relevant and quite important for our project, since our solution will be based on the farming methods I will find and advice. Furthermore, we want our design to be sustainable and fit into a permaculture, to ensure it will be a long-term solution and not have any bad side effects on the long term. We are already exhausting the natural resources of our earth at a very fast pace, so in order to not fasten this process, we will have to ensure a sustainable design and need some more information about what techniques a permaculture uses.

Sustainable farming

An advisory report on sustainable farming methods



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Atlas class of 2023

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1 Abstract

The world is undergoing a big food crisis, there are increasingly more people dying of hunger and with the growing population, this won't stop anytime soon. Therefore, new techniques and methods need to be developed and implemented in order to keep up with the ever growing demand. First this report will look into what a permaculture is and how it is set up, since this can help with ideas of how sustainable farming is achieved. Then, this report will look into farming, urban farming and the farming techniques that are currently being developed or are already being used. The farming methods will be evaluated, considering what is good and what still needs to be improved. In the conclusion of this report two plans are drafted to implement the discussed farming methods in the context of the slums of Mumbai, India.

2 Permaculture

Global warming is one of the biggest challenges humanity is facing today, without any sign of improvement. A more sustainable society is necessary and thought needs to be given to the influences of certain actions on the planet and environment in the long run. Therefore, setting up a global permaculture is of the utmost importance and should be a main priorities to ensure the survival of the human race. In this section of the report the term permaculture will be explained and some examples that are already implemented worldwide will be discussed.

2.1 What is a permaculture

> *'Permaculture is a global grassroots development, philosophy and sustainability movement that encompasses a set of ethical principles and design guidelines and techniques for creating sustainable, permanent culture and agriculture*. '
>
> (James R. Veteto & Joshua Lockyer 2008)

James R. Veteto & Joshua Lockyer (2008) described a permaculture not as a concrete concept, but as a collection name for idea's, philosophies and movements that focus on living in a more sustainable way. Instead of focusing on human creations, permaculture focuses on the balance between these creations, humans and the natural world. The term permaculture was first introduced in 1974 by Bill Mollison and David Holmgren, which resulted in a book; *Permaculture One* (1978). This book is still considered to be the bible of permaculture, where most of the permaculture ideas are based upon.

In essence a permaculture is a permanent culture, 'a self-sustaining culture preserving and extending natural systems' (Mollison, 1988). It is basically a culture that 'works with, rather than against nature' (Mollison, 1988). Permaculture is quite a broad term which takes into account multiple concepts like the social and economic dimensions. Or as the magazine *Permaculture activist* said:

'Permaculture is a holistic system of design, based on direct observation of nature, learning from traditional knowledge and the findings of modern science. Embodying a philosophy of positive action and grassroots education, Permaculture aims to restructure society by returning control of resources for living: food, water, shelter and the means of livelihood, to ordinary people in their communities, as the only antidote to centralized power.'

(quoted by Veteto & Lockyer, 2008, p. 48)

Furthermore, permaculture focuses on regeneration of the environment as well as preservation. Regeneration is essential when trying to set up a permaculture, since some sustainable solutions become unsustainable over time. Therefore instead of trying to preserve all the nature, focusing on restoring nature might be easier from time to time. A regenerative system has more output than input, is resilient and adaptive. Adding onto that, a regenerative system also has, besides its ability to feed itself, the potential to improve and restore itself.

Permaculture is based upon three ethical principles: earth care, people care and fair share. Earth care encompasses the health of the planet and how certain practices influence its health. It stresses the importance of a healthy earth for our own wellbeing and human environments. People care mainly says that people should have all resources important for their wellbeing and basic needs easily accessible. Its philosophy is that through collaboration and companionship we can achieve a healthier life for all. The ethics behind fair share are about limited resources which should be equally distributed among humans, plants and animals, among this and all future generations. Therefore, fair share proposes we should limit our usage and population growth to ensure we can achieve these goals.

There are 12 more basic principles, which are all related to the three ethical principles and were presented by Holmgren (2002). They are explained beneath in the context of Earthaven, an ecovillage.

1. *Observe and interact*

   The founders of Earthaven spend over a year observing the place for their ecovillage. They observed the flows of energy (wind, solar and water) in the landscape, before they even started on developing their village. Even now that the village is built, they

still learn from their mistakes and keep observing their surroundings while interacting with it to improve wherever they can.

2. *Catch and store energy*

   Earthaven's energy is produced in renewable energy systems, like solar array and micro-hydro generating system. Inhabitants capture and store that energy, all without making use of any earth destroying products like fossil fuels. Furthermore, they make use of gravity to provide everyone with water instead of a pump which would require energy.

3. *Obtain a yield*

   Earthaven's citizens are very good in producing necessities locally. Inhabitants have established a very strict, long term forest management plan, where they can gather wood for construction but replant those trees. Earthaven also has some agroecological systems to enable citizens to grow their own food.

4. *Apply self-regulation and accept feedback*

   As said in point 1, inhabitants of Earthaven are constantly reflecting and improving while they are developing and learning more about being ecological and sustainable. They have regular meetings to discuss a possible change of course or whether they should go with other, more suitable systems. For example, they stopped the expansion of Earthaven until its centre was fully functional. They did this to ensure outer parts will not copy the unsustainable design that the city centre is right now, they first want to make sure that what they have right now is completely sustainable and self-sufficient.

5. *Use and value renewable resources and service*

   This is also discussed in point 2, where Earthaven's sustainable energy systems were discussed. Furthermore, inhabitants also use compost and human waste to make fertilizer for the crops, completing a closed nutrient-loop.

6. *Produce no waste*

   The use of compost and human waste is an excellent example of this principle in action. Inhabitants of Earthaven, however, are taking it to the next level. A large house, that serves as a bed and breakfast, was constructed with parts of a broken bridge and other waste material that was meant to go to a local landfill.

7. *Design from patterns to details*

A pattern that is quite often a guiding pattern for architects is the earth revolving around the sun. In Earthaven, buildings have to be built using passive solar orientation, meaning that they should catch sunlight in the winter when the sun is almost down to get some natural heating for the houses, but it has to reflect sunlight on hot summer days. Although every house is based upon this principle, they all differ and are designed specifically for their unique location and occupants.

8. *Integrate rather than segregate*

Most big, industrial farms are characterized by their gigantic monocrop farms where the focus is on production rather than sustainability. Earthaven approaches farming in a very different way, they use inter- and multi cropping methods, enhancing their pest control and soil regeneration. Furthermore, they are combining farming with the existing, somewhat cut down forest, by setting up so-called *forest gardens*, where food grows in existing forests.

9. *Use small and slow solutions*

Earthaven itself is small and slow, it was founded in 1994, meaning it has been in progress for 26 years and only consists of 75 adults and 25 children. What they've built so far is minimal infrastructure, energy systems, some farms, Council hall, kitchen and dining room, many small dwellings and some common wall houses. This differs from the normal, fast pace, urban construction, which is less open for self-regulation and harder to directly implement experience and newly found improvement points.

10. *Use and value diversity*

Most members of Earthaven know their surroundings by heart, meaning they know what species of plants are near and what they can collect to eat. They regularly went out for *plant walks* in which they identify as many species as possible, one time they returned with over 20 eatable mushroom species.

11. *Use edges and value the marginal*

Earthaven's buildings are sometimes built on places architects would consider marginally appropriate. Citizens however decided to turn this challenge into an opportunity, by building passive solar orientated houses on south-facing slopes. Furthermore, where there are edges to fields, they plant aesthetically pleasing flowers to improve their pest control.

12. Creatively use and respond to change

A big change that has taken place in Earthaven is the increase of young people joining the community. When it was founded, most members were of an older age, since they had a significant amount of financial resources. Joining the community originally required a big financial investment, therefore, most people that joined were quite wealthy. In order to create more diversity and open their ideas and philosophy up to more people, they decided that labour contributing to the community can compensate the financial investment. This enabled more people to join, creating a more diverse community.

2.2 The ecovillage

The permaculture movement has already spread throughout the world, with similar movements and spin offs popping up everywhere. For example, the ecovillage, often a small community of people that want to change the world and try to setup an eco-friendly town. This is one of the most common examples of a permaculture in practice.

There are a lot of different ecovillages in the world, but they all slightly differ in views and structure. They all started the same, a group of people had an idea for a more sustainable way of living and decided to put it into practice.

> *' The most commonly quoted definition of the term ecovillage is indicative of the lofty goals that motivate the people and communities that comprise the movement: "Ecovillages are human-scale, full-featured settlements in which human activities are harmlessly integrated into the natural world in a way that is supportive of healthy human development, and which can be successfully continued into the indefinite future" '*
>
> (Dawson 2006, quoted by James R. Veteto & Joshua Lockyer 2008)

An ecovillage is an often small settlement housing a small amount of people that try to perfect their community to establish full sustainability. It is a tight community, where the people are living in harmony with nature, trying to become a sustainable entity. They all have their own principles and rules, but the same goal; try to improve their community by

implementing creative, sustainable ways to produce energy / cultivate crops / restore nature and in general live.

2.3 A permaculture in India

The permaculture movement in India started in 1986, not much later the first permaculture demonstration farm was established in the South of Andhra Pradesh. In 2016 the first NPC (national permaculture convergence) was organised, bringing together thousands of farmers interested in permaculture practices, biodiversity and sustainable forms of agriculture. In 2017 the IPC (international permaculture convergence) was organised in India, bringing together even more interested people. These convergences gave farmers opportunities to connect with one another and discuss new technologies or discoveries in the field of agriculture and permaculture. A member of a NGO that focuses on permaculture says the following:

> *Permaculture is first of all about the sustenance. Farmers are at the moment very much into mono cropping because they think this is the way they can make money. I don't say they should stop cultivating cotton. But if you are only growing cotton and it fails … you know there has to be some substitute for it. So, permaculture can help people understand they can go beyond mono-cropping and remain self-subsistence. There is also water scarcity. Lots of states and regions experience drought. So, permaculture can help solve the water crisis at least for small scale farmers to guarantee food security. According to your area, to your problem, permaculture can help improve your life.*
>
> (quoted by Veteto, J.R. and Lockyer, J. (2008))

Another activist stresses the importance of permaculture in urban areas by saying:

> *Urban areas need more intense attention than any other place. Because in the urban areas population is more and farmers are less. Also our food comes from far away and for this they require a lot of spray to preserve the food. After the vegetable arrives to*

super market then they add more spray … This food creates obesity, cancer and diabetes.

(quoted by Veteto, J.R. and Lockyer, J. (2008))

A permaculture project got set up in a satellite city of Delhi, Gurgaon, which transformed a house complex into a water harvesting, crops growing complex where kitchen waste is mostly converted to compost.

In order for to setup a sort of permaculture in the slums of India, a sustainable design should be made from waste, avoiding the use of fossil fuels. People in the slums are innovative, so making it out of waste shouldn't be a problem. However, the people might prioritize food over sustainability, so they could for example use a lot of natural resources to maintain the crops (water, nutrients, soil) without giving back to nature. This is something we have to be aware of.

3 Farming

Everyone knows that in order to make crops grow and farm you need water, soil, nutrients and light. It requires a lot of hard work, good soil and fertilizer and lots of water for the standard form of agriculture that is widely implemented in the world right now. In the following section I will discuss what exactly is necessary for farming and what is the most important.

3.1 Requirements

Plants have some standard requirements that need to be met in order for the plant to grow. Of course there are optimal resources and additional could be added to ensure more growth, however all plants need the following.

3.1.1 Water

Just as for humans, water is a vital resource for plants in order to grow. They use it for photosynthesis, more on this in *3.1.2 Light*, which is a vital process to keep the plant alive. They get most of their water intake from their roots, by absorbing ground water, but some water is retrieved by their leaves. Leaves also absorb a small amount of water, however, this is not enough to provide the plant with enough water to sustain itself.

3.1.2 Light

Light is very important for plants, it is their source of energy. They make glucose out of water and CO2 under the influence of light, which they use as energy. During this process they also make oxygen, which is released into the atmosphere and used by us. This process is more commonly known as photosynthesis. In a natural setting the necessary light is provided by the sun, however in vertical farming most of the light is created artificially, since sunlight is mostly blocked. If a plant doesn't get enough light, it can't produce enough glucose to sustain itself and will die. However, a plant can also get too much light, which makes the leaves dry out as well as the soil it grows in. Not all plants have the same optimal light condition, they all

differ. There are even some parasitic plants that don't need light at all, but they need other plants for energy.

3.1.3 Nutrients

Plants needs nutrients, such as nitrogen, phosphorus and potassium to grow. These nutrients are normally available in good soil, which is why normal farming can't be done in every area. But nutrients can also be added into the water supply, in which it will dissolve and then the roots of the plants can absorb the water and nutrients together. When the nutrients aren't available in the soil, fertilizer is added, which includes the nutrients. In order to keep things cheap for the stakeholders, fertilizer might not be the ideal solutions. The main nutrients are listed below.

3.1.3.1 Nitrogen

Nitrogen is found almost everywhere in the plant, making it one of the most important building blocks. Nitrogen is commonly found in either soil or fertilizer. Nitrogen can be bought in stores and then added into the water.

3.1.3.2 Phosphorus

Phosphorus is a very important nutrient for the early growth of plants and their roots. Even after an initial growth period, phosphorus is very important to hasten maturity of the plant and to support the energy conversion of energy from sunlight into usable energy for the plants. There are very few soils around the world that contain enough phosphorus to sustain crop growth, that's why phosphorus is mainly added via manure.

3.1.3.3 Potassium

Potassium is mainly important for the immune system of the plant, it helps strengthen its resistance against diseases and it will overall increase the health of the plant. Furthermore, potassium supports the production and transport of sugars, oils and starches inside the crops. Potassium is found in some soils, but a big potassium deficiency is present in

places where there has been a lot of grazing or horticultural practices. Potassium is mostly provided by a salt called potash or a sulphate of it.

3.1.3.4 Calcium

To ensure a healthy root system, where new roots grow and roots are overall healthy, calcium is an important nutrient. There are multiple ways to ensure enough calcium is provided for the plants to upkeep an healthy root system. The four main resources to higher the calcium concentration are: lime, gypsum, dolomite (magnesium-calcium carbonate) and superphosphate (mixture of calcium phosphate and calcium sulphate). Dolomite is mainly useful because it also provides magnesium, however when used long term, it could mess with the magnesium/calcium ratio. Superphosphate is used when a shortage of calcium and phosphate appears.

3.1.3.5 Magnesium

Plants owe their green colour to chlorophyll, which is also an important component in the photosynthesis cycle. Magnesium is important for plants to ensure they have enough chlorophyll and is furthermore key for photosynthesis. Shortages mainly occur in sandy acid soils, in regions with a lot of rain. If a lot of fertiliser with potassium is used, a magnesium shortage can occur. Magnesium deficiency can be solved with dolomite, magnesite (magnesium oxide) or espum salts (magnesium sulphate).

3.1.3.6 Sulphur

Plants use proteins to regulate internal processes and these proteins consists of amino acids. Sulphur is an important building block for amino acids, but it also helps in energy production of the plant. It is also of importance for the taste and scent of certain plants, for example cabbage and onion. When there is a lack of organic matter, a sulphur deficiency appears. Superphosphate, gypsum, elemental sulphur and sulphate of ammonia are the main components of fertilizer providing sulphur.

3.1.4 Air

Air consists of many different gasses, for example nitrogen, carbon dioxide and oxygen. Plants need the carbon dioxide (CO2) for photosynthesis, which is described in *3.1.2 Light* as well. They use this carbon dioxide to produce glucose for themselves and oxygen which they release into the air. This is another reason why plants and trees our vital to the survival of the human race, they don't just provide us with food, but they also give oxygen and reduce the amount of carbon dioxide particles in the air. This helps us battle global warming.

3.1.5 Space

All organisms need space, not only for growth but also resource collection. Roots systems of plants need space to take the necessary nutrients and water, which cannot be provided if there are too many other plants around it. Also the top of the plants, its leaves, need space to catch enough sunlight. That's why in thick forests, there are not many plants in the shadows of the trees.

3.1.6 Mulch

Mulch is not a necessity, although really helpful. It can improve fertility, crop health, conserve moisture and reduce weed growth by adding a layer upon the soil, which is called mulch. Mulch can consist of many things; compost, straw, hay, wood chips, even cardboard or just leaves. When farming in poor, underdeveloped countries, cardboard would be the best option. The disadvantage is that you need to remove the tape of the cardboard first and it can easily be blown away by wind. A big advantage of cardboard is that it is a very effective way of trapping water, more effective than wood chips and straw, which is great during dryer periods or when farmers can't water their plants very often. Another very big plus for using cardboard is that worms love it, they literally eat it and they excrete *black gold*, which works as a fertilizer and is helpful for growing crops. Furthermore, if you add cardboard and some organic material to your farm you can also farm worms, which could help fertility and increase yield. However, if no soil is used, like in hydroponics, mulch isn't very useful, since

the plants get watered from the roots, not some sort of soil and weeds don’t grow in a soilless environment.

4 Urban farming

Scientists and engineers have been researching urban farming for the last couple of years to provide the ever-growing urban population with food. It's a concept to integrate farming into cities, making efficient use of space, light and water. Urban farming won't only help with food production, but it will also help with freshness of the crops and it will ensure less waste and emission. If the food is growing closer to where it's sold, transport costs and emissions will be lowered and the crops will be fresher at the selling point. These farms won't actually replace buildings, but the idea is building them on top of the roofs that can hold farms. There are also ideas to make big towers in which you make so-called vertical farms, stacking farms upon each other, which could provide thousands of people for a year. The problem with these skyscraper farms is that soil weighs a lot, especially if it is used in such big quantities. That's why designers are using a technique called hydroponics. The basic idea is to feed a plant all the nutrients via the water, so you only need a medium for the plant and not a lot of soil. Further information will be given on this subject in section *5.3 Hydroponics*

4.1 Challenges

There is already quite a lot of urban farming in place, there are rooftop greenhouses and high-tech cultivation systems in urban environments, sharing many features with standard greenhouses. However, most of the features (heating/cooling, structure and material) are specifically modified to fit the rooftops in an urban setting. Two main challenges when designing a farming setup for an urban area are available resources (heat use, rainwater, grey water, CO2, etc.) and building specifics in relation to greenhouse requirements (weight and wind load, compatibility, fire resistance and safety requirements).

Other challenges when introducing crop cultivation in cities on top of buildings are agronomical, ecological and environmental related. They are associated with supply of water and nutrients, conditions of context (amount of sunlight, wind and rain), the influence of surrounding fauna, safety measures and assure high quality products. Another branch of urban farming is container cultivation, which is basically a farm in a small structure about the size of a container house. It is like a greenhouse, just not made out of glass. When this

method is used in combination with hydroponics, nutrients solutions need to be mixed into the water. The biggest challenge is providing the basic necessities for plants whilst avoiding salinity, too much salt in the plants. Cities are densely packed with buildings; the air is filthy and in general it is not built for farming. Therefore, it is harder to meet the requirements for plants to grow regarding compost, light and nutrients. Furthermore, water from taps, although drinkable, is not optimal for plant growth, mainly because of high chlorine levels. It would even be harder to implement this in water-scarce areas, where there might not even be enough drinking water.

4.2 Possible solutions

This problem of water could be solved by using rainwater collection systems or by filtering grey water (waste water from houses or offices like toilet-, shower-, sink- or washing machines water). Rainwater is a good alternative because of its composition, it has optimal microbiological and biochemical conditions and its use isn't limited legally. The only downside of using rainwater is the extra weight of the rainwater, if it is stored on roofs which is likely in dense cities. The downside of using grey water is that the composition of grey water might not be ideal for farming, since there could be concentrations of chloride, sodium and carbonates.

4.3 Communal garden

In some urban settings, communal gardens are implemented instead of individual, at home farming. These communal gardens can be built on rooftops of public buildings, like libraries or schools. These farms could be either controlled by the government, employing people who farm the crops and then sell them locally or it could be a system where locals can grow their own food, just in a common area.

A communal garden won't only provide food, but might improve the social connections people have, which could be established in multiple ways. 'Gardens also perform a social function, restoring the associative mentality lost when emigrants leave their communities' (Francesco Orsini, Nicola Michelon, Giorgio Gianquinto, Scocozza, 2009). It can create a community of people that cultivate vegetables at home, a community in which

people share their ideas and experiences and help each other gaining yield. It could also be implemented on a bigger scale, where people can work in skyscraper farms, where food is produced vertically, on top of each other. This place could also function as a place to relax. Furthermore, urban farming will give people a basic understanding of biology, chemistry and agriculture. However, the main focus of this report will be on the technical implications, difficulties and opportunities that urban farming brings with it.

5 Farming methods

The world population keeps increasing exponentially, estimated to grow to 9.7 billion by 2050 and peaking around 11 billion in 2100 (United Nations, 2019). The growing population comes with a growing demand for food, meaning farmers need to increasingly farm more to feed everyone. A lot of people are already starving, especially since the COVID-19 pandemic arose and forced people into poverty.

Furthermore, a lot of people are moving into the cities, where only about 30% of the population was living in the cities in 1950, in 2018 over 55% was living in urban areas (United nations, 2018). It is estimated that around 2050 68% of the population will be living in cities. When people move from rural areas, they mostly end up in the suburbs, facing severe poverty and unbalanced nutrition (Francesco Orsini, Nicola Michelon, Giorgio Gianquinto, Scocozza, 2009). Therefore, while urban farming still has it challenges, introducing cultivation in urban settings is necessary to feed the growing population and keep up with the demand. However, since traditional farming is nearly impossible in dense cities, due to inaccessibility of fertile lands, new farming methods are being developed and need to keep being developed to ensure enough yield. Those farming methods will be discussed in this section.

5.1 Common methods

There are a couple of sustainable farming methods that are commonly referred to and already being implemented. These are relatively easy ways to make a farm more sustainable. Instead of making a new farming system, these are improvements on the traditional farming method. There are many common methods, but below are the most relevant ones. These farming methods mainly apply to the traditional form of farming, but could be used in any setup involving soil.

5.1.1 Crop rotation

Crop rotation is the practice where different crops get cultivated after each other. So where some farmers decide to grow the same crops over and over again due to the high price they can sell them for or because it is easy, this method suggests to switch crops. For

example after farming corn, which takes a lot of nitrogen, farming beans would be beneficial, since beans give back nitrogen. Crop rotation is beneficial for the soil quality, which could make it easier and cheaper in the long run for farmers.

5.1.2 Cover crops

Covers crops is a phenomenon where crops are planted between other plants or trees in order to improve the soil quality and protect the crops. Furthermore, cover crops reduce soil erosion, keep weeds and pests from growing, fix nutrient levels and improve soil fertility. The only downside of cover crops is that they can overgrow the plants, taking their water and leaving the crops with a lack of water. Cover crops are already being implemented in some ecovillages like Earthaven, but since big farming companies focus on production and have gigantic farm lands, it might not be feasible for them.

5.1.3 Nutrient management

Nutrient management is basically making sure to limit nutrient loss by managing the amount, timing, source and method of nutrient application. While limiting nutrient loss, farmers also maximize farming productivity. Nutrient management is done by getting to know what is already in the soil, knowing what needs to be added in order for the plants to grow and then deciding what source is the most optimal to add. Nutrient management makes sure there is not an excessive amount of nutrients in the soil, which can be flooded away when the soil gets really wet. This can be bad for the surrounding nature, which can get a sudden increase and therefore overflood of certain nutrients. Besides ecological advantages, nutrient management also has economic advantages. If you know exactly the amount of nutrients needed, it becomes possible to prevent buying too much nutrients and be more economical with added nutrients, wasting less.

5.2 Zero acreage farming

Whereas some urban farming techniques are trying to make big buildings to provide the city with the food, zero acreage farming (Z-farming) focusses on using spare, non-conventional spaces like rooftops, vertical wall farms and old, empty buildings. An example of

Z farming is micro gardens, which is exactly what it sounds like, it is a collection name for all small farming setups. Whether this is a small hydroponics system, a single pot or a boot transformed into a pot, it is all considered a micro-garden. Micro-gardens are very useful in urban farming, since another big problem is lack of space and micro-gardens can be fit about everywhere. They are not meant for great agricultural practices, but rather for individual use to supplement diets with fresh vegetables. However, to be implementable in poorer areas, like third world countries, where nutrition might be the worst, the micro-gardens need to be built from local, cheap material and use the least amount of resources possible.

5.3 Hydroponics

Hydroponics can be considered the 'art' of farming, since the goal of hydroponics is to come up with new techniques of soilless, cheap, sustainable farming. 'Soilless farming is economically sustainable. From the study, no limit appeared to the growth of this farming system. Moreover, labour and space do not present a constraint. Farming pays the investment back within a short time, so the availability of capital is not a constraint to production.' (Francesco Orsini, Nicola Michelon, Giorgio Gianquinto, Scocozza, 2009).

5.3.1 How it works

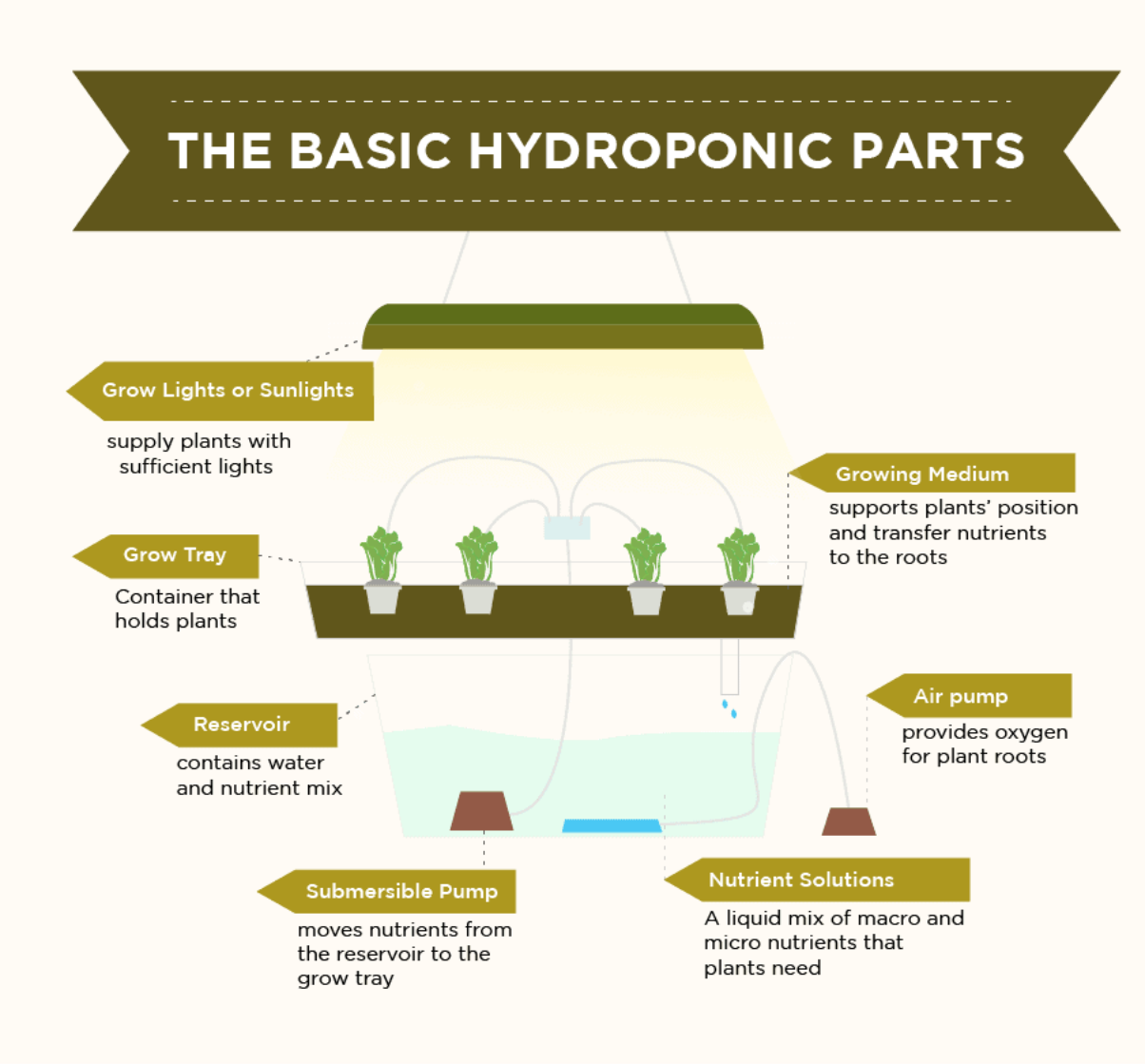
Hydroponics is a farming technique where you don't use soil and use a lot less water than with traditional farming. It is designed to fit in urban areas and be the most efficient way to farm. However, right now, it is really high tech and not available for poor areas.

For it to be economically stable and implementable in poorer areas it should abide to the following requirements:

1. It should be made from local, cheap material, preferably waste or recycled material, in order to cut the price
2. It should be a closed system, meaning it uses everything put in the system, near to no waste that can't be reused will be produced.

A hydroponic system is a system in which plants grow inside of a growing medium, while the roots hang in the water and get hydrated constantly. The water gets pumped

around to ensure constant hydration of the plants, which is essential. When the roots can't get water for some time, the plants die. Plants also need oxygenation, which is why the roots aren't fully submerged in water. Lastly, most hydroponics setup have some sort of nutrient intake in the main reservoir, because water alone isn't enough to make a plant grow.



5.3.2 Growing medium

Hydroponics systems mostly don't use soil, but most versions still use a replacement called a medium, which basically has the same functions as soil. In some ways it is even better than soil, since it doesn't produce weeds or pests, but it does transmit moisture, nutrients and oxygen to the roots. This growing medium can be really different substrates, natural ones (coconut fiber, gravel, etc.) as well as cardboard or other materials. As long as it satisfies the three requirements (transmits moisture, nutrients and oxygen) it can be used as

a growing medium. Since the focus is on the slums of Mumbai, an easy obtainable, cheap material should be chosen as growing medium.

5.3.2.1 Coconut

There are multiple ways of using a coconut as a growing medium. Either half a coconut with holes for the roots can be used or coco coir (a by-product of the coconut industry). Both ways ensure a solid retention of water while providing root oxygenation.

5.3.2.2 Gravel

Gravel is easy to obtain, cheap, available almost everywhere and easy to clean, which makes it a really good growing medium. However, gravel isn't very useful for absorbing and holding water and it's quite heavy, making it a decent growing medium when nothing else can be found in the area.

5.3.2.3 Sand

Since sand is available almost everywhere, it is really easy to get it and use it for hydroponics. Although, not all sands can be used, the ideal diameter would be around 2 mm. The water needs to be able to drain and not form a big puddle, making the sand muddy.

5.3.3 Why should we use it?

Hydroponics is known for its limited use of water and a non-soil medium. This may sound really weird, but it actually works better than traditional farming techniques, it has a 20%-30% increase in growth rate in comparison to normal farming in similar conditions. 'A study comparing different urban cultivation systems in Cleveland (Ohio, USA) showed that hydroponic systems produced an average of 19.5 kg m-2 year-1 versus 1.3 kg m-2 year-1 obtained in conventional on-ground urban gardens' (Grewal and Grewal, 2012, quoted by Francesco Orsini and Marielle Dubbeling and Giorgio Gianquinto, 2015)) Estimates say in the USA around 80% of the freshwater is used for agricultural practices (United states

department of Agriculture, 2019). With the world population still growing rapidly a lot more food needs to be available, which will require a lot more water and farmland when using current agricultural practices. Hydroponics could help with this problem, since the soilless growing method only uses about 10% of the water used by soil agriculture. It can do this because it reuses all the water that gets into the system. If you water crops on a traditional farm a lot of water will just go into the ground and will not be used by the crops. In hydroponics that water will be reused until it is used by the plants.

Water is not the only natural resource hydroponics uses barely, it also runs on little to no energy. Most traditional farms have big machines that all produce carbon emissions, which is bad for the environment. Hydroponics however could work completely without any carbon emissions or, when implemented on a bigger scale and in modern countries this is likely, it uses some electricity. But since electricity can also be generated without the use of fossil fuels, it is possible not to produce carbon emissions in the process. Hydroponics systems could use a lot of energy, depending on the farmed crops and the farmer's choices. If grown indoors, with big LED's and pumps to pump the water around, the energy usage will spike. However, with good isolation and LED management, this can be significantly reduced.

As said before, this farming method doesn't use soil, which comes with two great benefits.

1. Crops can be grown everywhere, meaning farmland is no longer a requirement. The area in which farming is desired could be contaminated or arable, a hydroponic system could still be setup. A hydroponics system could even be set up in a home or other smaller spaces.
2. Pests and diseases that live in soil or originate from soil won't be there. Also, there won't be any weed growing between your plants.

Last but not least, you control everything the plant gets, you can change the nutrients the plants will get. This way, you won't use too many or too less nutrients and you don't waste any nutrients.

5.3.4 Disadvantages

There are a lot of positive sides to hydroponics, making it a really good solution to the growing famine problem that the world is currently facing. However, there are some disadvantages, which need to be looked at before it can be implemented everywhere.

The main disadvantage of hydroponics right now is the initial expenses, which are pretty steep. The method is still quite new and therefore mainly build as a high-tech solution for first world countries. Also, it isn't as easy as normal farming, you should know how to farm with hydroponics and you should inform yourself a bit before starting with it. You can't just start farming with hydroponics, you really need to read into hydroponics. The information you need is widely accessible and actually easy to understand. Traditional farming, where you can just water your plants and look at them from time to time, is way different then hydroponics, where you need to control nutrient intake, water flow and root oxygenation. In order to make a good hydroponics system, the basis of hydroponics and why it works need to be understood. The user needs to know that a constant supply of water is necessary, nutrients might be needed and a good medium should be picked based on the context.

Furthermore, the plants really depend on you and your system, meaning they can die within hours if you have a power outage and they can't get any water. In normal farming, most plants don't rely on electricity and there is a lot of water in the ground, meaning they don't need a constant source. In most hydroponics setups, water gets pumped around constantly to ensure hydration of the plants. This could be lessened by installing a second reservoir of water, at the top, which will provide the plants with water. It could be refilled a couple of times a day by the reservoir at the end of the system.

Also, in order for the plants to survive, a constant pH concentration should be maintained. Most plants require a pH between 6 and 6.5 to ensure great intake of nutrients, although the optimal pH differs for each organism.

5.3.5 Kinds of hydroponics

There isn't actually one hydroponics system, hydroponics is a collective name for systems that use the same principles. All the systems that are defined as "hydroponic" can be

either active or passive, active meaning the nutrient solutions dissolved in water are moved with a pump, passive means there is a basin of water and the roots are watered by hanging in there.

Apart from passive or active versions, there are also (non-)recovery systems, based on whether the system reuses the nutrients (recovery) or not (non-recovery).

The six main hydroponic are described below.

- *The wick system*

  This is often considered the easiest hydroponic system out there, since it is just plants sitting in water. This system doesn't use electricity, pumps or other devices. The plants are placed in an absorbent material with nylon wicks going down in the water. The nylon will absorb water and nutrients and bring it up to the material which will then give it to the plant. This system requires no effort to maintain, but the plants don't get a significant amount of nutrients. It is therefore optimal for small garden plants or plants that don't require that much water. While in a system with pumps, the water and nutrients are mostly equally distributed, in the wick system, nutrients might be unequally absorbed, meaning a toxic amount of nutrients can be build up in some plants.

- *Deep water culture*

  This is an active, recovery system where the plants are floating in the water on styrofoam sheets, so the roots are in the water with nutrients. This helps the plants get nutrients easily and therefore they grow pretty fast. However, the roots are fully submerged in the water, meaning there is no space for oxygen to get to the roots. Therefore, air stones or diffusers are used to oxygenate the plants. This system is really easy to make and works well with almost every plant.

- *Nutrient film technique (NFT)*

  In this technique the plants are placed in channels, through which the water is pumped and then collected again in the large reservoir. The channels are slightly tilted down, so the water flows down without a pump, so the pump is only necessary to get the water from the reservoir to the top of the channels. The roots of the plants are getting hydrated by the flowing water and provide the plants with the right amount of nutrients. Although easily scalable, larger plants can't be grown in this system, because of the narrow channels.

- *Ebb and flow (flood and drain)*

  This system makes use of a timer to not overflow the roots, from time to time it will pump water from the reservoir to the plants, submerging the roots, and drain the excess water back to the reservoir. This system is very useful for growing a variety of crops, like certain vegetables, carrots and radishes. Only large plants are not recommended for this system, because it wouldn't fit. The drawback of this design is the timer, another component, like the pump, which can break and then the plants die.

- *Drip systems*

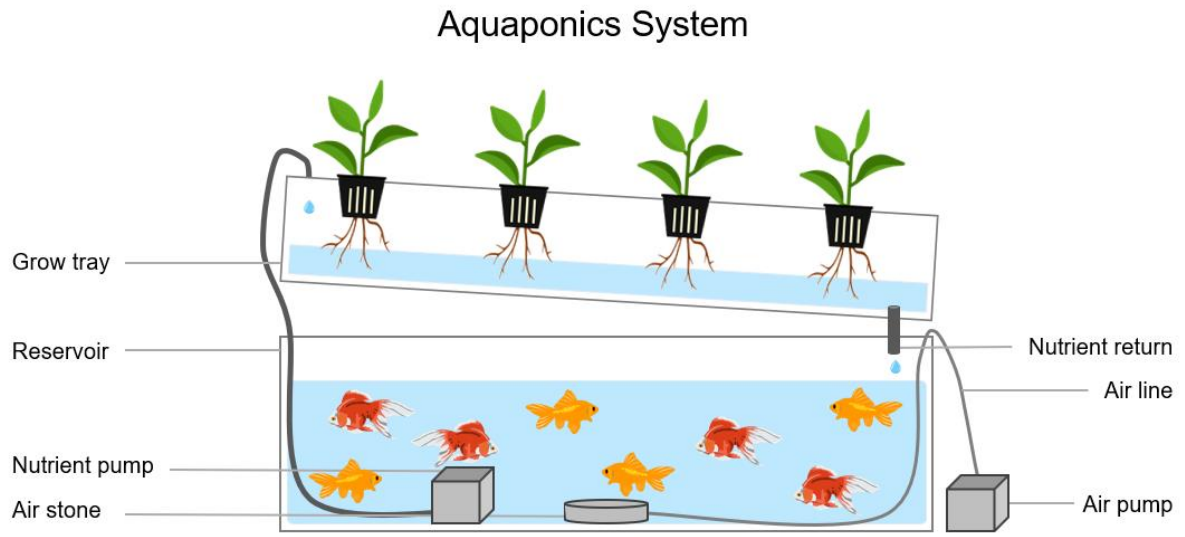
  This system uses a timer as well and pumps water from a reservoir to a drip manifold which drops the set amount of water onto the plants, collecting the excess water and reusing it. The drops consist of tiny amounts of water with nutrients. In this system it is easy to switch crops, being ideal for people wanting to farm different crops from time to time. There are two versions of this system, circulating and noncirculating, in a circulating system the water drops constantly.

- *Aeroponics*

  This type of hydroponic is probably the most high-tech version, where plants hang in the air, again without a medium. A timer controls a pump which sprays the water onto the roots quite often, since the roots are exposed by air and need proper moistures. Any excess water and nutrients will fall in the reservoir below and get collected again. This is the most efficient hydroponics system waterwise, it uses less water than other systems. However, it is harder and more expensive to build.

5.4 Aquaponics

5.4.1 How it works



Aquaponics is the method of cultivating plants as well as growing aquatic organisms. It basically puts a hydroponic system and an aquaculture together, using the fish waste as a fertilizer for the plants. The water from the fish tank goes through a biofilter, in which bacteria convert the fish waste into useful nutrient solution. Those solutions will then go to the roots of the plants and the roots will take the water and nutrients.

Since the only addition is an aquaculture, all types of hydroponics can be used for aquaponics. For the aquaculture, there are two setups, a traditional aquaponics and a decoupled multi-loop aquaponics. In the second setup, a hydroponics system is set apart from an aquaculture so that optimal conditions in both systems can be achieved. This takes up more space than the first one, where the two systems are placed near each other, like in the picture. However, this system will increase yield, since the hydroponics and aquaculture are growing in optimal circumstances.

'Advantages of decoupled aquaponics systems is a higher water and nutrient use efficiency and presumably higher yields compared with the traditional approach and stand-alone hydroponics systems' (Delaide et al. 2016; Dijkgraaf et al. 2019; Goddek and Vermeulen 2018; Nicoletto et al. 2018; Nozzi et al. 2018; Saha et al. 2016, quoted by Simon Goddek and Karel J. Keesman, 2020).

5.4.2 Why we should use it

Just as hydroponics, aquaponics use a lot less water for the crop growth. The fish need a lot of initial water, but after that only about 1/10th of the water used in regular farming is needed. All other benefits of hydroponics (no fertilizer, no soil diseases, uses less space, closed system) also apply to aquaponics. In addition, aquaponics has some more advantages, chemicals can't be used since they would harm the fish, thus the vegetables are healthier. This also has a downside unfortunately. Furthermore, the fish only need to be fed and no other nutrients have to be added, it is a closed system. The big bonus of an aquaponics system over hydroponics is that there is a bigger output, you can grow fish and plants, with more possibilities.

5.4.3 Disadvantages

Just as in hydroponics, in a aquaponic setup a constant pH should be sustained, this is however easier in a hydroponic setup. In an aquaponic system, there are more organisms (the fish and some bacteria) that needs to be taken into account. In order to find the ultimate pH, all organisms should be considered. In a hydroponic setup it is also easier to lessen the waste of nutrients and decide the input of nutrients. Whereas in a hydroponic setup just the plants need to be considered, aquaponics include more organisms and therefore it is harder to determine the optimal amount of nutrients and which combination of fish and plants works good. Fish food is the primary input of nutrients, since it is the origin of all sources of nutrients, the fish poop and uneaten food. The amount of fish food, amount of fish poop, kind of bacteria and kind of plants all need to be taken into account when determining the input.

Furthermore, since there are more organisms involved in aquaponics, the chances of diseases and pests are bigger and require more work to prevent. Most regularly used pesticides are a danger to the fish and therefore cannot be used in a aquaponics setup. This does however ensure healthier vegetables.

6. Conclusion

In this conclusion two plans are proposed about setting up a permaculture for food production in the slums of Mumbai, India. The two plans are based on the research done in this research. One of the plans is a normal farm upgrade, the other one is a hydroponics system.

Upgrade the farms

The first plan is to upgrade existing, regular farms to produce more yield and improve sustainability. With some 'normal' farming methods (nutrient management, cover crops and crop rotation) the yield of farms can already be quite improved. To even better the food production a layer of cardboard can be added on the soil to keep more water there, so less water is needed and worms can also live there. Their excrements will help the plant to grow better. A bigger yield means the prices will go down and more people in the slums will be able to buy basic necessities. The only downside of this is that farms are not in the slums, so the crops would need to be transported to the slums and since transport is a big polluter, it will be less sustainable.

Advantages:

- Increased yield due to improved farming techniques
- No big changes/technologies needed
- Very easy to implement
- No new space needed

Disadvantages:

- Transport needed
- Advise on farming methods might not be followed
- Doesn't directly help the stakeholders

Hydroponic setup

This plan is based on the hydroponics section of this report. Hydroponics is currently quite high-tech so a more simple design should be made, but this is doable. People in the slums are very creative and know how to use their waste in the best way, they can recycle

like no other and this can be beneficial for the design. There is no need to fully design a hydroponics setup, the stakeholders should just be informed about the possibilities and how it works. A suggestion for a design can be made, like how to build a standard hydroponics system. However, it can be implemented differently based on the context. The stakeholders will probably come up with easier to build, cheaper designs, that is their expertise. It might also be easier for the stakeholders to alter the design to their wishes and homes. The plan is that everyone gets a personal supply of food, provided by a personal hydroponics structure. This plan will help the stakeholder directly.

Advantages:

- No soil needed
- Less water used
- Can be made from waste material
- Low maintenance
- No pollution due to transport

Disadvantages:

- Requires certain knowledge and skill set
- Nutrient solution needed

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Conclusion deepening

In this section I will assess whether or not my evidence (the deepening report) is sufficient for me to have completed my intended learning outcomes. To quickly recap, my intended learning outcomes were the following:

1. I want to conduct research about what a permaculture is and how it could be set up
2. I want to conduct research in the field of farming in difficult areas, exploring different methods
3. Lastly, I will combine the topics of my research and make a report about how a permaculture can be set up regarding food and what is the best solution for our context.

I think my deepening is extensive and thorough and therefore ILO's 1 and 2 are met. Although there is a lot more information to be found about farming methods and urban farming, all the necessary information is there. There are more examples of permaculture that could have been listed in this report, but I felt like they couldn't provide new information. The third learning outcome is met as well I feel like, although it is not a final advise, the advises are both relevant and well-constructed I feel like.

Design sketches