MASTER

The nomadic farm
soilless agriculture

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THE NOMADIC FARM

Soilless agriculture
GRADUATION STUDIO

The Farm

The Nomadic Farm
This book is the final result of an individual research towards agriculture, and the role of architecture in the future of agriculture. This research is executed as part of the Graduation project 'The farm-Mutant Typology.' The studio aim is to research and design agricultural typologies from the viewpoint of a changing society and a corresponding architectural culture within the agricultural industry.

By 2050 the world's population will reach 9.5 billion, 36 percent higher than today. In order to feed this exponential growth, annual food production must increase by 70 percent.

In order to understand the complex production process of agricultural products, the component within agriculture are analyzed and charted into rational guidelines that can help address food shortages in places where food is the most needed.

A hectic road in a new world with my great love; coffee, sleepless nights with pleasing and illustrative results. I consider this book as a revelation to anyone who is not familiar with non-traditional agricultural systems. Furthermore, the book contains basic design ratios and strategies to design a generic agricultural production machine. I hope you enjoy reading this book as much as I have enjoyed the process of creating it.

I want to use this preface to thank a number of people who helped me throughout the process. First of all, I would like to thank my graduate counselors P. Diederen and B. Kaathoven and R. Roorda for the dedication, criticism, and enthusiasm they have shown during this graduation studio. This worked as a motivation to progress every week, and to create this product. I would also like to thank my mother S. Saleh and sister L. Saleh for the unconditional support during this graduation workshop.

Isn't hard to understand that if the world produces food for 12 billion people, then why millions of people go to bed with an empty stomach?
Soil-based agriculture is facing major threats with the world rising population, decrease land per capita, industrialization as well as threats from climate change and its related effect.

Today, global food production is being undermined by land degradation and shortages of cultivatable land and water resources. Feeding the rising world population will be a challenging objective. In order to understand the field that is initiated to work in, the research attempts to give inside in the agricultural systems to aid as guidance through land scarcity.

Soil-less farming, or hydroponics, is a plant growth system that replaces soil with nutrient-rich water. The system allows crops to access the required minerals and nutrients for growth directly, eliminating some of the plants requirements, as the roots no longer need to seek for nutrients in the soil. Supplying the plants with an artificial natural soil environment with irrigated nutrients intravenously instead of plain water, the systems allows the use of solid materials such as gravel, peatmoss, perlite and vermiculite in some cases as supporting mediators. The benefits of soil less culture includes the reservation of cultivated lands for other purposes, it saves 90 % of irrigated water, it uses recycled water with minimized nutrient waste, It allows crops to be grown faster and in larger sizes. As it yields considerable higher productivity than traditional agriculture.

Such farming systems can help address food shortages, especially when communities lack viable arable land to carry out conventional farming methods.

The final result sketches a architectural design and or solution for the future of agricultural direction, mobile farming.
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Can global food production keep pace with the soaring human population? The United Nations Food and Agriculture Organization has forecasted that the amount of food we produce will need to jump by 70% by 2050 (FAO, 2017). The global population has just hit 7.5 billion, and another billion people likely to be living on earth by 2025. By 2050, this is expected to reach 9.6 billion (UN, 2016). According to the UN’s Food and Agriculture Organization, the increase in food production will be most needed in developing countries.

So far, however, the world has managed to keep up with food demand and human ingenuity should be capable of meeting the rising challenge in future. Agricultural productivity has rocketed over the past few decades. Thanks to the advent of new technologies, ranging from smarter harvesting systems to advances in fertilizers, yields should continue to advance. With demand for food, fuel, rising land prices, and the market for smarter farming technologies is growing.

However, soil-based agriculture is facing some major challenges with the advent of civilization all over the world, such as decrease per capita land availability. The world has lost a third of its arable land due to erosion or pollution in the past 40 years (Dockril, 2015) with potentially disastrous consequences as global demand for food soars. New research has calculated that nearly 33% of the world’s adequate or high-quality food producing land has been lost at a rate far outstrips the pace of natural processes to replace diminished soil (Milman, 2015). The continual ploughing of cultivated land, heavy use of fertilizers has degraded soils across the globe, causing erosion at a pace of up to 100 times greater than the rate of soil formation. It takes around 500 years for just 2,5 cm of top soil to be reated into its natural compound (Arsenault, 2017).

Agriculture is strongly influenced by weather and climate. While farmers are often flexible in dealing with weather and year-to-year variability, there is nevertheless a high degree of adaptation to the local climate in the form of established infrastructure, local farming practice and individual experience. Climate change can therefore be expected to impact on agriculture (e.g. rising sea level, temperature shifts, extreme weather, shortage sweet water), potentially threatening traditional farming systems but also providing opportunities for improvements and new ways of thinking. More exactly, as the human population growth, soil based agriculture cannot cope with food demand due to land scarcity.

Urbanization will continue at an accelerated pace, and about 70% percent of the world’s population will be urban compared to 49 percent today (UN, 2016). There are currently 23 cities with population exceeding 10 million, mostly located on the delta. Moreover, world cities are expanding to meet the demands for housing, makes the distance between consumers and agriculture greater than ever. The knowledge about healthy food and food production will continues to decline within a constantly expanding logistics of the production process. The constantly growing production process has influence on the quality and taste of food, fruits and vegetables are often picked unripe to be delivered on time.

The nomadic farm produces fresh fish and leafy vegetables with better taste on daily bases close to the consumer. Furthermore, the transparent farm provides civilians with education, an acquaintance with all the processes that take place during the cultivation of agricultural products. Agriculture will have to adapt to climate change, but it can also help mitigate the effects of climate change, and useful synergies exist between adaptation and mitigation. The mobile agricultural production machine is provided with climate control, solar and rainwater farming systems to adapt and mitigate to our ever changing environment.
**Research Question**

This research began with the following hypothesis: As the human population growth, soil based agriculture cannot cope with food demand. This hypothesis led to the following research question:

"IS THE SOIL AN INDISPENSABLE ELEMENT FOR AGRICULTURAL PRODUCTION AND ARE THERE ALTERNATIVES?"

The phenomenon 'soil less agriculture', 'climate change' and 'the agricultural production process' are the most noticeable from literature studies and the preliminary research on agricultural production process conducted during the preliminary research. The connection between climate change and the future of the agricultural product are extensive and are in need of further research to guarantee the future of agriculture.

**Methodology and objectives**

In order to get the most out of the research question and the design, objectives will be set, and the sub research questions will be further examined through literature reviews and a survey, to set a specific design assignment. This research begins with comprehensive literature analyses and reviews on soil-less alternatives for agriculture, plants that go well in soil less culture, a survey, followed with a research driven design. The purpose of this research is to investigate the current barriers and benefits of soil-less systems in agriculture. In what doctrines should be set to design the system of the agricultural production unit.

The preliminary research on the agricultural product and the research questions should lead into qualitative and quantitative principles for the design of the agricultural production machine.

The research question will lead into the following objectives and principles that can be applied into the architectural design;

"WHAT ARE THE BARRIERS AND BENEFITS OF THE ALTERNATIVES FOR SOIL LESS AGRICULTURE?" By analyzing and reviewing on the barriers and benefits of soil-less systems, possibilities should be set.

Moreover, specific doctrines will be set that can be integrated into the design of an agricultural production unit.

"WHAT ARE THE IMPACTS OF THE YIELDS PRODUCED ON THE AGRICULTURAL PRODUCTION UNIT ON THE FUTURE OF AGRICULTURE?" By analyzing and reviewing on literature, a mathematical equation should be set. In order to the provide knowledge about the annual production of the agricultural production unit. Furthermore the results should lead into a bundle of cartographic charts.

"WHAT IS THE MOTIVATION FOR CONSUMING LOCAL, REGIONAL AND DUTCH PRODUCTS?"

The questionnaire, a systematic way to ask a group of peoples the same equations that can be measured. The purpose of this questionnaire is to survey the motivation of the consumer to buy local, regional and Dutch products. There are three main goals to this survey:

- **Goal 1:** The motivation of purchasing local or regional agricultural products
- **Goal 2:** The motivation of purchasing Dutch produced agricultural products
- **Goal 3:** The validity of the main research question.
The human population keeps growing at an outstanding speed (Loudenback, 2014) and is expected to reach 9.3 billion people by 2050.
OVER 80% OF THE WORLD’S SUITABLE LAND FOR RAISING CROPS IS IN USE
CHANGES IN THE INTENSITY, FREQUENCY AND SEASONALITY OF PRECIPITATION
TEMPERATURE INCREASE OF MORE THAN 4°C WILL ENDANGER THE ABILITY OF FARMS AND ECOSYSTEMS TO ADAPT
WE WILL NEED TO PRODUCE AT LEAST 70% MORE FOOD BY 2050.
Figure 5: Mega-cities, not nations, are the world’s dominant, enduring social structures. 25 out of 35 mega-cities have sea access.
GRADUATION STUDIO

The Farm

Nomadic Farming
LETS BRING FOOD PRODUCTION CLOSER TO WHERE ITS NEEDED
INTRODUCTION

Soil-based agriculture is facing major threats with the world rising population, decrease land per capita, industrialization as well as threats from climate change and its related effect. Almost all of the vegetables found on the shelves of our supermarkets are yields either directly or indirectly of open-fields soil. However, soil itself is not necessary for plant growth, only some of its constituents.

Soil is usually the most available growing medium for plants. It provides anchorage, nutrients, air, water, etc. for the growth of plants [Ellis, 1974]. Figure 1 gives an overview of the available techniques for soilless culture. Field soils serve to basic purposes: it acts as a basin to retain nutrients and water, and it provides support for the plant through the root system. These two basic purposes are important for the growth of the plant. However, soil doesn’t always occur with a package of well-drained, pathogenic free soils with a uniform texture.

Some soils come with poor texture and do not provide the necessary root environment and at times come with serious limitations for plant growth. Some of them are presence of disease causing unsuitable soil reaction, poor drainage, degradation due to erosion etc. Moreover, open field agriculture is difficult as it involves large space, lot of labour and large volume of water [Beibel, 1960]. Furthermore, in most urban and industrial areas, soil is less available for crop growing, or in some areas, there is scarcity of fertile cultivable arable lands due to their unfavourable geographical or topographical conditions [Beibel, 1960].

"Man started agricultural pursuits by growing plants in soil but as the knowledge of plant nutrition increased, he learned to grow plants in artificial media, such as quartz, sand, gravel, etc." [Hayami, 1971]. Artificial means can also provide these requirements for plant growth with equal, and frequently better growth and yield result compared with traditional soil bases agriculture. Soilless culture is the fastest growing sector of agriculture, and it could be impetus to food production in the future [Hussain, 2006]. Soiless industries are growing exponentially, as conditions of soil growing become difficult and as greenhouses in ha are increasing, while systems become more efficient [Marcelis, 2017]. Any plant can be grown without soil. Tomatoes, cucumbers, lettuce, beans, potatoes, corn, oats, fruits, flowers, and many others have all been grown without soil. Tomatoes are the one of the major crop produced commercially, without soil, in the Netherlands [Snoei, 2016].

DEFINING SOIL-LESS CULTURE

Soiless culture is an artificial means of providing plants with physical support and a reservoir for nutrients and water. Soilless culture is the technique of growing plants in soil-less condition with their roots immersed in nutrient solution [Maharana & Koul, 2004]. To understand the principal of growing plant, the knowledge of physiology and agronomy in agricultural production is essential. The supplementation of nutrients and water to plant provides only two of the physiological process of plant growth. The knowledge of other related process has to be understood, especially photosynthesis, respiration, reproduction and transpiration.

The oldest practise for soilless culture is a vessel of water in which nutrition’s are included to supply plans with substance [Davis]. Often named; water culture, this approach is primitively named as hydroponics. Hydroponics has been in use for thousands of years, the famous Hanging Gardens of Babylon 600 B.C. [Turner, 2015] are believed to have functioned according to hydroponic culture.

Over the years, water culture has been used sporadically throughout the world for commercial means. Today, it is widely used in research centres as a procedure for studying plant nutrition [J.N. Egilla, 2016]. Adjustments in pure mono solution cultures, moreover, gravel or sand are occasionally implemented in soilless systems to provide plant support in addition to nutrients and water. "Since the major constituent of the media in artificial growing systems may be solid or liquid, it is appropriate to use the term soilless culture in reference to this general type of growing system and reserve the term hydroponics for those in which water is the principal constituent” [H. Johnson 1971]. Soilless culture practice could thus be classified as solid or liquid systems.
Hydroponics

WATER CULTURE IN LIQUID MEDIUM AND SOLID MEDIUM

Liquid system (hydroponics) are generally of a closed circuit regarding nutrient solution supply, the solution is recalculated into a reservoir, and based on two methods; Nutrient-flow technique (NFT) and gravel-bed cultures.

NFT, Figure 2 is a hydroponics system where the plant roots are directly exposed to nutrient solution. This media is composed out of a series of narrow channels through which nutrient solution are recirculates from a reservoir. The plumbing system consists out of plastic tubing, a mechanical pump and a tank. In hydroponic, plants are grown with their roots partially submerging in to a solution-obtaining nutrient for plant growth. The liquid solution does not provide physical support to the roots of the plant, the plant holder, frequently of a plastic compound, have to retain the plant without blocking the roots into the solution.

One of the benefits of this system is the shallow depth of the channels, by means of nutrient periodic solution circulation. Furthermore, periodic flow management able aeration of the root system, with possibilities of different flows in water, nutrient, aeration and temperature based on the stages in development of the plant. The application of soilless culture systems using artificial substrates are effective and efficient in water use, fertilizers and minimizes the alterations of pesticides [Beibel, 1960].

“Plants grown in soil less culture has consistently superior quality, high yield, rapid harvest, and high nutrient, content compared with traditional crop growth” [Hussain, 2006].

Moreover NFT systems are very vulnerable to power interruption and pump failures, subsequently roots dry out very rapidly when the flow of the solution is interrupted (Cooper 1979).

“Soilless culture can be implemented for the growth of popular local crops with the appliance of food safety standards and at a reasonable price” [Paul, 2000]. This system will also corporate with the challenge that comes with climate change and it also helps in production system management for efficient utilization of natural resources (Butler & Debker, 2006).

SOLID MEDIUM

Gravel-bed culture, Figure 3 is composed out of a vessel filled with pea gravel, or any inherent material with same size, which is plumbed and connected to a nutrient solution reservoir. The pumping system is based on two principals; fed with solution from tubes to the surface or drained through a slopped drain line.

Feeding from the surface comes with the benefits of uniform distribution of nutrient solution as in water culture, the major difference is that plants are grown in silica sand or any other inherent material. The silica sand allows drainage, in this way the plant is provided with nutrients, aeration and the roots of the plant are supported. Gravel-beds are generally 60 to 90 cm in width and 20 cm deep. When managed properly, gravel-bed systems are adequate of growing crops and recirculation of the solution [Maharana & Koul, 2004]. Furthermore, systems in solid mediums employ diverse type of media with the same characteristics (e.g. rockwool, sand, loam, cork etc.).

However, the system comes also with disadvantages. The nutrient concentration in the solution is in continues stage of change due to diverse uptake of the plant in the various growth stages. Moreover, different material usage comes with contrasting capability (e.g. weight, water permeability, intake, aeration etc.), making the size of the partials of huge importance. Therefore, monitoring systems are essential to replenish the desired nutrient compound, making it a power dependent system, in the means of electrical energy.

“Full-floor sand culture has been successful for vegetable culture in greenhouses and is considered a good means of providing plants with a uniform, well-drained rooting medium” [Johnson, 1990]. The less medium a system requires the easier and less expensive it is to operate (Husain, 2006).

BAG CULTURE

“Soilless culture in bags, pots with a lightweight medium is the simplest, most economical, and easiest to manage of all soilless systems” (H.Johnson, 1990). Peat-
Aquaponics

The most implemented media in containerized systems of soilless culture, followed with mixture of bark and wooden chips (Boodley and Sheldrake 1977). These media are generally filled into polyethylene bags or rigid plastic pots containing multiple plants. "The media combined portable bags come with great flexibility, by the means of lightweight as they are readily moved in or out of greenhouses when desirable, as they are easily handled" [S.Witmer 1979]. One of the most significant advantages of these systems is that the solution is not recirculating. In recirculating systems the solution is continuously changing in concentration, thus the nutrient balance is shifting due to plant intake. However, in bags or pot system, the solution is not recirculated. The solution is usually supplied to the surface, any excess is drained away form the system through drainage holes. Making the concentration of nutrients in the solution the same at each irrigation cycles. Compared to circulated, container growing eliminates the need of samples or monitoring in periodic bases [Bauerie1984]. This system can be established in a open space or in protected greenhouses.

AEROPONICS

Aeroponics is a method of growing plants where the plants are anchored in holes in Styrofoam panels and their roots are suspended in air beneath the panel. The panels compose a sealed box to prevent light penetration to the roots, to encourage root growth and the prevention of algae growth. In figure 5, nutrient solution is sprayed in fine mist to the roots. Misting is done for a few seconds every 2 – 3 minutes. This is sufficient to keep roots moist and nutrient solution aerated. The plants obtain nutrients and water from the solution that adheres to the roots [Nickleson, 2015]. The aeroponic culture is usually practiced in protected structures and is suitable for low leafy vegetables like lettuce, spinach, et (Vaughan, 2011). The principal advantage of this technique is the maximum utilization of space. In this technique twice as many plants may be accommodated per unit floor area as in other systems. [powerhousehydroponics, 2017]

The aeroponic system is probably the most high-tech type of hydroponic gardening. Like the N.F.T. system, the growing medium is primarily air. The roots hang in the air and are misted with nutrient solution. Because the roots are exposed to the air like the N.F.T. system, the roots will dry out rapidly if the misting cycles are interrupted. In other words consistent monitoring and a great amount of energy is needed to keep the system running.

AQUAPONICS

Hydroponics comes from the Greek words ‘hydro’ (water) and ‘ponos’ (work). The growing of plants within a liquid or solid media uses a wide range of dissolved macro and micro-nutrients, which are supplied in aqua solution. Aquaponics is a food production system that combines intensive
Aquaponics and hydroponics systems usually come in a wide variety of forms, ranging from a simple fish tank set below a gravel filled vegetable bed, with water from the fish tank pumped up and through the grow bed; to highly sophisticated systems with multiple tanks, solid waste removal systems, intensive aeration systems for both plants and fish, and water quality monitoring systems.

Aquaponic systems are dominated by vegetable production in terms of area and quantity of product (Austin, 2017). This is biologically determined by the quantity of plant production required to absorb the waste nutrients generated by fish. Independence from soil, this system can be established in urban or harsh rural environments where land is limited or with a poor soil quality. Furthermore, aquaponic systems use 10% or less of the water (Nelson and Pade 2010) used in conventional soil based agriculture systems.

Labour inputs in conventional agriculture are hugely varied dependent on the degree of mechanization and chemical additions. Aquaponics and hydroponics systems usually use raised beds and do not need weeding.

However, characteristics of aquaculture also introduce significant disadvantages from both product and marketing perspectives (Hambrey 2013). Intensive aquaculture production may be subject to losses or reduced productivity related to the water chemistry, temperature, lack of oxygen, and diseases. Intensive horticulture (hydroponics) may also be subject to losses from system failure (water supply), pests and diseases (Lennard, 2014). Integration of intensive horticulture with intensive aquaculture increases these risks since problems or failure of any component are likely to reduce performance of the other.

Furthermore, the range of management responses for each component is constrained by the sensitivities of the other, and it may take some time to restore the whole system to optimal performance.

These production risks are further compounded by high capital and fixed operating costs. Any break in production will have substantial cost implications (Hassall, 2011). Optimal water chemistry and temperature are slightly different for fish and plants in most cases. Most aquaponic systems will require more energy than conventional horticulture or hydroponics systems, primarily related to the oxygen demand of both fish and bacteria, and the need for intensive aeration as well as pumping (Grabber, 2009). It is important to recognize that aquaponic systems are primarily vegetable production systems, simply because of the biological nature of the relationship between fish nutrient production and plant nutrient uptake.

**BIOPONICS**

Bioponics is a new technique of soilless farming. It is similar yet distinct from hydroponics and aquaponics. Bioponics utilizes one or more of the following techniques; flood and drain or ebb and flow with media beds, nutrient film technique, deep water culture on floating rafts and the air layer technique on stationary rafts with ebbing and flowing water levels.

Bioponics is 100% organic (Yarrow, 1997), without the implementation of any petrochemical fertilizers, pesticides or herbicides. The benefit of this technique is that by growing with organic nutrients, beneficial microbes colonize on and around the plant roots (bioponica, 2015). This aids in biofiltration and improves fertilizing nutrient uptake. Bioponics does not allow for the use of chemical fertilizers. Because of that it is distinct from hydroponics, a soilless technique that primarily uses inorganic fertilizers.

As with the best soil care, bioponics is about nourishing the diverse of living organisms that support the plant roots. "The more common, and important microbes in the organic garden include nitrifiers and decarboxylators along with rhizobacteria, microrhizomes, protozoans, nematodes and earthworms" (bioponica 2015). Bioponics is similar to both hydroponics and aquaponics in that it is soilless. As described with aquaponics, it is possible to grow plants organically without soil. And yet, bioponics is able to provide more nutrients than aquaponics because there are more options for nutrient inputs than simply fish feed and the fish waste. There is also more tolerance in a bioponic system for concentrating nutrients, such as ammonia and nitrates, without harming the fish which require a minimum of oxygen (Texier, 2016).

The various soilless environments known for raising plants in hydroponics and aquaponics are also possible with bioponics. This includes deep water culture, flood and drain or ebb and flow media beds and NFT nutrient film technique.

However, characteristics of bioponics also introduce significant disadvantages from both product and marketing. The same as with hydroponics Intensive aquaculture production may be subject to losses or reduced productivity related to the water chemistry, temperature, lack of oxygen, and diseases. Bioponics may also be subject to...
losses from system failure (water supply), pests and diseases.

These production risks are further compounded by high capital, energy usage and fixed operating costs. Any break in production will have substantial cost implications.

AGRICULTURAL PRODUCT THAT CAN BE GROWN IN SOIL-LESS CULTURE CONDITIONS

Type of crops, figure 7, “Everything starting from flower to fruit crops to medicinal plants can be grown using soil-less culture.” [Mamta D. Sardare 2013], as for “aquaponic systems leafy vegetables are the most popular, especially lettuce and basil. These systems are generally less suitable for fruit vegetables because of the longer production cycle and preference for different nutrient ratios” [Consulting 2013]. Moreover, each crop comes with its own characteristics (e.g. tomatoes require moist substrate, while lettuce requires a highly ventilated rooting) making the choice for substrates of a great importance.

<table>
<thead>
<tr>
<th>TYPE OF CROPS</th>
<th>NAME OF CROPS</th>
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<tr>
<td>Cereals</td>
<td>Rice, Maize</td>
</tr>
<tr>
<td>Fruit</td>
<td>Strawberry</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Tomato, Chili, Eggplant, Green bean, Beet, Winged beam, Pepper, Cabbage, Cauliflower, Cucumber, melons, Radish, Onion</td>
</tr>
<tr>
<td>Leafy vegetables</td>
<td>Lettuce, Paksoy, Kang Kong, Spinach, Mustard Green, Collard Green, Arugula</td>
</tr>
<tr>
<td>Condiments</td>
<td>Parsley, Mint, Basil, Drogano</td>
</tr>
<tr>
<td>Flower</td>
<td>Marigold, Roses, Camations</td>
</tr>
<tr>
<td>Medicinal crops</td>
<td>Indian Aloe, Coleus</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>Sorghum, Alfalfa, Barley, Bermuda-Grass, Carpet grass</td>
</tr>
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</table>

A wide variety of fish can be grown in aquaponic systems, Tilapia is by far the most preferred species to breed. [Brook, 2003]. As they survive a wide ranges in pH, temperature and ammonia than many other fish species, and they quickly adapt to varying conditions. Moreover, Tilapia may be cause problem in some systems, by the means of rapid fry spread throughout the whole system. Trout are also favoured as they growth well in cold climates, but vegetable growth is likely to be poor at the temperatures preferred by this species [11-17°C]. [Brook, 2003]
Aquaponics

SUPPLY OF NUTRIENTS TO THE PLANTS
From the limited nutrient-buffering characteristics of substrates implemented in hydroponics and the capacity to make fast adjustments, monitoring in these systems are necessary based on the nutrient delivery of the systems and the plant nutrient response. As the frequency and amount of the nutrient solution supplied depends on the type of substrate, the plant and the size of the container. The plant nutrients responses for the most common plant are determined (Jones, 1991). The controlled supply and monitoring of nutrient supply creates greater yields.

FISH AND PLANT RATIO
Aquaponics is an approach where the waste produced by fish in the system is utilized by the plant in the system as a nutrient source. This means that the fish are fed, the fish produce waste and the plants use that waste as a feed [nutrient] source. The balance between the amount of fish waste produced and the amount of that waste that the plants will uptake as their nutrient source is the basic principal to create a zero waste system. Logically the amount of fish waste produced is directly linked to the amount of fish feed the fish eat. Furthermore, the number of plants that can be grown is based on the amount of nutrient available (produced waste). It is indisputable that the number of plants that can be grown is directly related to the amount of fish feed that enters the system.

DESIGN RATIO
From the number of plants grown can the space requirement be derived, or area, that is needed to grow the plants. For example, lettuce grow nicely at approximately 30 lettuces plants per square meter (Rakocy, 1989). Therefore, if the number and species of plants is known, the preferred or maximal density, output of plants that can be cultivated in an area can be expressed.

The weight of fish in the system and the amount of food the fish need is can be calculated. Therefore, if the number of fish is known, fish feed can be calculated that should enter the system. The calculation can also relate to the weight of fish, e.g. older fish eat amount 1% (Rakocy 1994) of their weight in feed per day. Thus, if we need 100 gram of fish food to enter the system to match the number of the fish, then 100 kg of fish is needed. The latter can also be related to the amount of food needed to create the required nutrition for the plant uptake.

The University of Virgin Island feeding rate ratios are expressed in a range; from 60–100 gram of fish feed per square meter of plant growing area per day (60–100g/m2/day) for tilapia (Rakocy 2004).

This feeding rate ratio is expressed across a wide range because plants that feed lightly (e.g. lettuce, basil etc.) can be grown at the lower end of the range (i.e. 60 gram/2l/day) and plants that are heavy feeders (e.g. tomatoes, peppers etc.) may be grown at the upper end of the range (i.e.; 100 g/m2/day) (Lennard 2006)

Lennard, came up with a scientific proven ratio in which he states that for fish species like Tilapia, 1 kg of fish feed, fed daily, will support approximately 1500 lettuce plants and 100 kg of grown Tilapia in a rational planting/harvesting scheme. If we assume that the lettuces are planted at a density of 30 plants per square meter, in what it can be calculated to commercial crop-production.

The described approach is very specific and so this ratio will not hold true for any other fish or plant species than the Tilapia or lettuce. Fish can be produced in relatively large quantities, but this will require additional investment in settling and water treatment to take care of the increased waste generated over and above that which can be absorbed by the plants. A solution can be found in the production of heavy consuming plant (e.g. tomatoes, peppers etc.) and the additions of several filtration layers.

HOW TO DESIGN AQUAPONIC SYSTEM
1. Determine how many plant, and of what species, are wished to grow.
2. Determine the area those plants need to grow.
3. Determine how much fish feed the fish need to eat to meet the nutrient requirement of the plants.
4. Determine what weight of fish is required to eat the amount of fish feed.
5. Determine what volume of water that fish needs to grow in.

SUPPLY OF NUTRIENTS TO THE PLANTS
From the limited nutrient-buffering characteristics of substrates implemented in hydroponics and the capacity to make fast adjustments, monitoring in these systems are necessary based on the nutrient delivery of the systems and the plant nutrient response. As the frequency and amount of the nutrient solution supplied depends on the type of substrate, the plant and the size of the container. The plant nutrients responses for the most common plant are determined (Jones, 1991). The controlled supply and monitoring of nutrient supply creates greater yields.

FISH AND PLANT RATIO
Aquaponics is an approach where the waste produced by fish in the system is utilized by the plant in the system as a nutrient source. This means that the fish are fed, the fish produce waste and the plants use that waste as a feed [nutrient] source. The balance between the amount of fish waste produced and the amount of that waste that the plants will uptake as their nutrient source is the basic principal to create a zero waste system. Logically the amount of fish waste produced is directly linked to the amount of fish feed the fish eat. Furthermore, the number of plants that can be grown is based on the amount of nutrient available (produced waste). It is indisputable that the number of plants that can be grown is directly related to the amount of fish feed that enters the system.

DESIGN RATIO
From the number of plants grown can the space requirement be derived, or area, that is needed to grow the plants. For example, lettuce grow nicely at approximately 30 lettuces plants per square meter (Rakocy, 1989). Therefore, if the number and species of plants is known, the preferred or maximal density, output of plants that can be cultivated in an area can be expressed.

The weight of fish in the system and the amount of food the fish need is can be calculated. Therefore, if the number of fish is known, fish feed can be calculated that should enter the system. The calculation can also relate to the weight of fish, e.g. older fish eat amount 1% (Rakocy 1994) of their weight in feed per day. Thus, if we need 100 gram of fish food to enter the system to match the number of the fish, then 100 kg of fish is needed. The latter can also be related to the amount of food needed to create the required nutrition for the plant uptake.

The University of Virgin Island feeding rate ratios are expressed in a range; from 60–100 gram of fish feed per square meter of plant growing area per day (60–100g/m2/day) for tilapia (Rakocy 2004).

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5. Determine what volume of water that fish needs to grow in.
Soil

Inorganic

Sand, clay, silt, gravel

Decomposed Minerals

Dissolved in soil water

Humus

Decomposed Minerals

Soil solution

Contact plant roots

Nutrient Solution

Dissolved in water

Inorganic Salts

Mineral and water uptake by plants

Soil

Organic

Bacterial decomposition

Hydroponics

Figure 13: Flow chart of nutrient supplementation soilless culture
In preposition of the validity of the main research question, the citizens of Rotterdam are surveyed to chart the motivation and or the trend of consumers to buy local and regional products.

**SURVEY ABOUT BEHAVIOUR OF CONSUMPTION OF THE CITIZENS OF ROTTERDAM ON LOCAL, REGIONAL AND NATIONAL DUTCH PRODUCTS.**

The survey took place between 10 and 20 June at various locations in Rotterdam. 317 respondents participated in the survey.

The survey is not a reliable reflection of the citizens, as the percentage of the highly educated is over represented, figure 9. At the level of the education, 1% of the respondents did not graduate with a diploma, the percentage of vocational education is 6%, 16% have a graduate-school diploma, and the majority have followed university education (77%).

The same goes, for the age structure, figure 10, about 31% of respondents are in an age range between 50 and 64 years. Slightly more than a quarter (28%) is between 35 and 49 years, followed by 12% between 65 and 79 years. 14% is between 28 and 34, 6% between 23 and 27 years, 5% between 18 and 22 years, 3% are 80 years or older and 1% did not fill in the age. The male / female ratio is representative: 53% of respondents is female, 46% is male and 1% has not completed the gender question.

Furthermore, the responded were asked about barriers (maximum of three answers) for purchasing local an regional products. Surprisingly, the most nominated barriers was the lack of local produces (48%) (Table 1).

**RESULTS**

Due to globalization, the shelves of supermarkets are packed with food products from all over the world. Yet, by this phenomenon, consumers increasingly value their local and / or national identity. Throughout this development, there has been a trend in recent years showing the increase in the range of regional products (Rijksoverheid, 2015) and also consumers focusing more on the origin of the products. By traceability and origin, but also authenticity become more important for the consumer. Buying local products has an impact on the local economy, and food transports are shorter, which has an impact on our environment.

Are you or someone in your household buying any regional products or local products? With the possibility to chose a maximum of three options.

Around 61% citizens of Rotterdam buys local or regional products, 26% never buy any regional products and 13% answered that they did not know.

Furthermore, the respondents were asked about barriers (maximum of three answers) for purchasing local an regional products. Surprisingly, the most nominated barriers was the lack of local produces (48%) (Table 1).

**FREQUENCY OF PURCHASING LOCAL OR REGIONAL PRODUCTS**

Around the respondents around 24% buys one a week or more, 42% give up once a month to weekly purchase, the percentage of local products purchased one to four times a year is 27%, 2% % buys it once a year or less and 5% indicates not knowing how often they buy local products (Table 2).

**FREQUENCY OF DUTCH PURCHASING PRODUCTS**

The respondents who buy Dutch products, 49% buy them once a week or more, 36% states that once or more in a month to a week, 9 purchases one to four times a year, and 6% indicate not to know how often they buy Dutch products (Table 2).
MOTIVATIONS FOR BUYING LOCAL OR REGIONAL PRODUCTS

In the survey it was asked what are the reason for purchasing regional products. Almost half or the responds argue that it is better for the environment, nature and landscape (42%). Followed by that the transportation distances are shorter (40%), local products are more tasty (39%), I know were the products come from (28%) and that farmers get a fair price (27%).

The respondents who already indicate that they buy local products, another 70% would like to purchase these products more often, 14% does not want to buy more often and 16% do not know.

The biggest obstacle to buy local and regional products is the availability. Nearly two-thirds (60%) indicate that there are not enough local products nearby, 40% find the higher price of local products a barrier and 38% indicates that

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local products are more expensive</td>
<td>25</td>
</tr>
<tr>
<td>There are few local products for sale</td>
<td>30</td>
</tr>
<tr>
<td>There are little local products that can be prepared quickly</td>
<td>6</td>
</tr>
<tr>
<td>Local products have a lower quality</td>
<td>23</td>
</tr>
<tr>
<td>I do not know many local products</td>
<td>68</td>
</tr>
<tr>
<td>Local products are not good for our environment, nature and landscape</td>
<td>1</td>
</tr>
<tr>
<td>I do not need it</td>
<td>32</td>
</tr>
<tr>
<td>Otherwise</td>
<td>6</td>
</tr>
<tr>
<td>I do not know</td>
<td>9</td>
</tr>
</tbody>
</table>

they do not know enough local products. The people who indicate that they do not want to buy local and regional products more often, the main reason is that its not needed (45%).

The respondents were also asked about their purchasing behaviour on Dutch products. The question that was asked was whether people sometimes bought products because they were produced in the Netherlands. Nearly two thirds (62%) of respondents indicate that indeed buy Dutch products. More than a quarter (28%) replies with a no and about 10% do not know if it happens in the household.

MOTIVATIONS TO NOT PURCHASE DUTCH PRODUCTS

The respondents who indicate never buy products because they are produced in the Netherlands, more than half (54%) find it not important that products are produced in the Netherlands. 28% indicate that their known with few products that come from the Netherlands [Table 3].

Motivations to purchase Dutch products

Just like for the local and regional products the respondents were asked for motives to buy Dutch products. The reason for more than half was that transport distances were shorter (52%), followed by the consideration that it is better for environment, nature and landscape (45%) and for the Dutch economy (38%).

Of the respondents who already indicate that they buy Dutch, 70% would like to purchase these products more often. 11% does not want to buy this more often and 19% do not know. These are exactly the same as the local products.

Table 1 barriers to buy local or local products in proportion of the population Who does not buy local or regional products.

Table 2 Consumption of local or regional products or production of products from the Netherlands in proportion of the population purchasing local or regional products or products from the Netherlands.

Table 3 Barriers to buy Dutch products in proportion to respondents who do not buy Dutch products.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Local or regional products</th>
<th>Dutch products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Once a week or more</td>
<td>24</td>
<td>49</td>
</tr>
<tr>
<td>Once a month to once a week</td>
<td>42</td>
<td>36</td>
</tr>
<tr>
<td>Once to 4 times a year</td>
<td>27</td>
<td>9</td>
</tr>
<tr>
<td>Once a year or less</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I do not know</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Citizens of Rotterdam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch products are more expensive than foreign products</td>
<td>8</td>
</tr>
<tr>
<td>There are few products that I know which come from the Netherlands</td>
<td>14</td>
</tr>
<tr>
<td>There are few Dutch products to be prepared quickly</td>
<td>1</td>
</tr>
<tr>
<td>Products from the Netherlands have (sometimes) a lower quality than foreign</td>
<td>3</td>
</tr>
<tr>
<td>I do not know many products from the Netherlands</td>
<td>28</td>
</tr>
<tr>
<td>I do not think it is important that products come from the Netherlands</td>
<td>54</td>
</tr>
<tr>
<td>Otherwise</td>
<td>11</td>
</tr>
<tr>
<td>I do not know</td>
<td>8</td>
</tr>
</tbody>
</table>
Local or regional products | Dutch products
---|---
It is better for environment, nature, landscape | 45 | 45
The transport distances are shorter | 38 | 52
It’s better for my health | 11 | 11
It has more taste to it | 36 | 23
It is more animal friendly | 8 | 6
It is cheaper | 4 | 5
I know where the products come from | 30 | 33
It gives farmers a fair price | 29 | 19
It is better for the Dutch economy | 13 | 38
Otherwise | 7 | 9

The respondents who indicated they did not want to buy Dutch products more often, they feel that they already bought many Dutch products, or did not need it.

ADVANTAGE OF SOIL-LESS CULTURE

There are many advantages of growing plants under soilless culture over soil-based culture. An extensive amount of research work is published in recent years asserting the advantages of soilless-culture. The advantages in this paper does not necessarily apply to all the soilless systems and all substrates employed, by the means of variation between the systems and the extend of sophistication applied.

Moreover, due to the absence of cultivation techniques (e.g. soil cultivation, soil sterilization etc.), the number of crops per year can be maximizes as the interval between crops can be almost fully excluded.

Nutrient culture has possibilities in the growing of highly priced crops, particularly out of season greenhouse, in localities where good soil is not available, or when maintained of highly favourable soil condition is found to expensive.

INCREASE IN PRODUCTIVITY

Soilless culture can provide optimal conditions for plant growth and therefore, higher yields can be obtained compared to open field agriculture, figure 11. Soiless culture can provide higher averages in yields compared with ordinary soil yield, by the means of control over soil-borne diseases and pests. This advantages could be traced to the fast increase of fields in soilless-culture in Spain and other European countries (European Commission 2016), that have occurred due to commercial growers confident in the yields increase to help the gab in additional cost of soilless culture. The system is also effective for the regions of the World having scarcity of arable or fertile land for agriculture (Sonneveld, 2000). It is obvious that soils with problems (i.e. poor soil, saline soil, toxicities in soil etc.) will produce lesser yields compared to monitored soil-less culture. It reduces the cost and time taken for various tasks, which are avoided, in soilless culture of cultivation.

Production rates of vegetables in hydroponic and aquaponic systems are typically around double those achieved in more conventional horticulture. Production amount usually depends on the production cycle, planting density, and the growth rate of the plant. Commercial planting densities for such as lettuce are regularly in the range of 20-40 kg/m² although rates as high as 50-60 kg/m² are possible (Barbosa 2015).

The production rate of herbs and leafy vegetables in aquaponics and hydroponics systems are between the range 2-6kg/m² per 3-5 week crop (Resh 2004). Based on substantial experience Resh suggests typical production rates of lettuce at 2.3kg/m² per crop, which might translate to 23kg/m²/year for locations where year round production is possible.

Yields of cucumber may be 7kg/m²/crop. In an efficiently run tropical or sub-tropical system we might therefore anticipate 20-40kg of leafy vegetable production per m² per year. McCurry (McMurty 1997) projected annual yields of 30-60 kg/m² of tomato, and 60-80kg for cucumber/m²/yr. Higher rates have been recorded for semi-aquatic species such as water spinach.

Production rate in the University of the Virgin Islands systems have been recorded as high as 338g/m²/2/day corresponding to over 100kg/m²/yr (Rocky 1997). Annual production will depend on stocking and harvest density, growth rate and harvesting management. Recommended stocking densities for Tilapia are typically in the range of 20-40kg/m³. It should be possible to grow a 500g Tilapia in one 1 year, and if the fish are harvested and restocked on a quarterly basis, it should be possible to achieve an annual production of roughly double the standing stock (Lennard 2006). This studies create bases to setup a system with the potential of a zero nutrient waste. Furthermore it provides the spacial requirements and stocking density for both fish and crop production for an closed aqua and hydroponic systems.
CONTROL NUTRITION
The systematic control of plant nutrition compared to soil cultures, are one of the most significant advantages of soilless culture. By the means of solution control that can be applied to the various crops, varied environments, PH control and stages in plant growth.

Furthermore, the uniformity in which nutrition can be supplied to plants comes with major advantages, in what waste of nutrition’s can be excluded. This is not the case with soil cultures, an excessive amount of nutrient level in the soil can produce salinity in soil, leading to lesser yields.

WATER CONTROL
Hydroponics, recirculated aquaculture all require less water than conventional production systems and no soil. They can therefore be cultivated in urban areas closer to the consumer. Water is the most important element for crop production, advantages in soilless-culture come with the ease and efficiently and control of the irrigation systems (e.g. NFT, mist aeration). The latter can come with disadvantages (e.g. more system implementation, costs, monitoring).

in sub-irrigated substrate cultures implementing organic substrates should be provided with irrigation based on the water holding capacity of the substrates. Furthermore, most of the soilless-cultures are placed inside green houses, leading to exclusion of rainfall. Nevertheless, most of the soilless systems are based on a closed water recirculation, with minimization in water evaporation by the operational arrangement of these systems. Moreover, accurate control in water supply can be practiced. Research over many years has estimated the required replacement rate of water for aquaponics is between 0.5 to 4.6% of the total system volume per day (c.a.Nagel 1977). Water consumption in recirculated aquaculture has been estimated at 0.5-1.4 m 3/kg fish production compared with 3 to 30 m 3/kg fish production in traditional pond or more intensive raceway aquaculture (verdegem. 2006).

LIMITATION OF SOILLESS CULTURE
Despite of many advantages, soilless culture has some limitations. Application on large scale requires technical knowledge and high capital expenses. Introducing of soilless systems involves an increase of inputs for the construction and maintenance, compared to the cultivation in soil culture.

This will be higher if the soilless culture is combined with controlled environment agriculture (Sonneveld, 2000). High degree of management skills is necessary for solution preparation, maintenance of PH levels, nutrient content judgment and correction, ensuring aeration, maintenance of favourable condition inside protected structures.

Furthermore, soil culture has the capacity to correct to some limit any mistakes in nutrient supply. However, small errors in composition of nutrient solution can disastrous effects on the plant in soilless-culture. Great care is required with respect to plant health control. Finally energy inputs are necessary to wheel this system (Van Os et al., 2002).

Soil beds in greenhouses often become infected with disease-producing organisms, or toxic substances may accumulate. Installation of adequate equipment for sterilizing soils and operation of the equipment may require considerable expense (Lennard, 2014). Also, maintenance of fertility in the soil beds is often laborious and expensive. On the other hand, a synthetic nutrient medium, expertly supervised, can serve as a continuously favourable source of nutrients and water and, especially if combined with automatic devices, can bring about economies in labors.

The choice of both fish and plant species is more limited in aquaponic systems compared with hydroponic or recirculated aquaculture. This is because some plants do less well in some aquaponic systems, especially those with high nutrient requirements. Equally some fish species have more demanding water quality and will not flow well in nutrient concentrations suited to plants.

CONCLUSION
Soilless culture is gaining fields and it is one of the fastest growing sectors in agriculture. Soilless-culture could dominate food production in the future. As population increases and arable land declines due to climate change, poor land management,

<table>
<thead>
<tr>
<th>Crop</th>
<th>Agricultural average per acre</th>
<th>Hydroponic equivalent per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>272 kg</td>
<td>2268 kg</td>
</tr>
<tr>
<td>Oats</td>
<td>286 kg</td>
<td>1360 kg</td>
</tr>
<tr>
<td>Rice</td>
<td>386 kg</td>
<td>5443 kg</td>
</tr>
<tr>
<td>Maize</td>
<td>680 kg</td>
<td>3629 kg</td>
</tr>
<tr>
<td>Soy-bean</td>
<td>272 kg</td>
<td>680 kg</td>
</tr>
<tr>
<td>Potato</td>
<td>8 ton</td>
<td>70 ton</td>
</tr>
<tr>
<td>Beet root</td>
<td>4082 kg</td>
<td>9072 kg</td>
</tr>
<tr>
<td>Cabbage</td>
<td>5896 kg</td>
<td>8165 kg</td>
</tr>
<tr>
<td>Peas</td>
<td>907 kg</td>
<td>6350 kg</td>
</tr>
<tr>
<td>Tomato</td>
<td>5 - 10 ton</td>
<td>180 ton</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>5670 kg</td>
<td>1361 kg</td>
</tr>
<tr>
<td>Lettuce</td>
<td>4082 kg</td>
<td>9525 kg</td>
</tr>
<tr>
<td>Lady’s finger</td>
<td>3175 kg</td>
<td>8618 kg</td>
</tr>
<tr>
<td>Cucumber</td>
<td>12700 kg</td>
<td>12799 kg</td>
</tr>
</tbody>
</table>

Table 5: Hydroponics averages compared with oil yields (Ajc26 2008)
Conclusion

land scarcity, sweet water scarcity, people will turn to new technologies like soilless-culture for agricultural production. Soil is the natural habitat for plants; it supplies support, nutrients, and water.

However, where good soil is not accessible, where maintenance of acceptable soil conditions is too expensive, or where growth out-of-season crops is recommended, growing plants without soil may be necessary. With sufficient water supply, but where soil is not accessible, climate control is needed to grow the crop without soil.

Plants grown in soil-less culture have normally greater quality, higher yields, vast harvest, and high nutrient content compared with traditional crop growth. Aquaponics is based on the principal of both fish and vegetable production, using a single nutrient source; fish feed. Furthermore, it ensures that most of the wastes that would normally be deposited from the fish culture are instead used to grow vegetables. Intensively grown fish produce a lot of nutrients, the consumption of which could foster large quantity of plant production. A further possible advantage lies in the complex organic nature of the aquaponic nutrient solution compared with the relatively simple chemical based solutions used in hydroponics. The systems allows organisms to be added to the system for higher quality nutrient creation for the plants.

Against these advantages there a some significant disadvantages. Integrating aquaponics with hydroponic plant production increases complexity, multiple risk, system optimisation for either product, management responds. Specifically in relation to pest, disease and water quality. Energy use is relatively high because of the need for both aeration and pumping in most systems. System failure can result in a long restart and readjust cycle. Given that most aquaponic systems are dominated by plant production this is a heavy price to pay. Furthermore, the released nutrition are purely based on fish feed, by the means of one sided nutrient supply. Nevertheless soil-less culture, can cultivate fresh vegetables in countries with limited cultivable land as well as in countries with land scarcity and large population. It can provide the fresh food for near markets, where the crop may be marketed soon after harvesting. Allowing the product to ripen on the plant, providing products with higher quality and notable taste than those harvested before maturity and held for long period in distribution journey before its available to the consumer.

On the basis of the results of the survey, we can conclude that a great deal of the citizens of Rotterdam buy local and regional products and many of them even want to buy these products more often. There are opportunities, because many citizens of Rotterdam find that there are few local products available in their supermarkets and that the local products are not highlighted. If supermarkets and local shops provide the residents with more local products and if the supply of such products increases, the consumption of local products can increase significantly. The same goes for the purchase of Dutch products, many people buys these product because of their origin. Supermarkets or other shippers could respond to consumers wishes by putting a clear indication of origin on the products and informing consumers better.

There is global concern about how future generations will produce more food sustainably. Agriculture has considerable environmental impact on natural resources, the discussion of natural land to agriculture, nutrient inefficiency and the use of chemicals are all genuine concerns. Reducing land use can increase sustainability, and it could provide solution to land scarcity. Moreover, nutrient concentration in the solution is in continues stage of change due to diverse uptake of the plant in the various growth stages. Different material implementation comes with contrasting capability (e.g. weight, water permeability, intake, aeration etc.), making the size and characteristics of the partials of huge importance. Aquaponics, by combining fish and vegetable production and maximizing land use, minimizing water and nutrient use, offers a way forward, and has particular allure in locations where water is scarce and/or soil is poor, and where there is strong demand for both fish and vegetables. In consideration of agricultural systems are often rejuvenated and a large amount of conduct is required, partially due to backup systems, the flexibility of space becomes essential.

Despite its high demand for energy, hydroponics remains a promising technology. Several factors could influence the feasibility of hydroponic production of crops, specifically lettuce, in the future. As more sophisticated control devices become available, the cost of maintaining the controlled environment of hydroponic greenhouses could decrease. The future availability of water, land, and food will also influence feasibility through increased demand. Increasing land and water scarcity will make the more land- and water-efficient hydroponic systems more appealing.

Each plant comes with its own characteristics, thus each specie has its own ideal substrate assembly. For instance, the implementation of hydroton (clay pellets) as solid media for tomato grow are optimal in a ebb and flow system, as the pellets allow storage in microscopic holes that could be utilize roots after the flooding if the nutrient. At this point in time, hydroponic farming of lettuce cannot be deemed a more sustainable alternative to conventional lettuce farming techniques, but it provides promising concepts that could lead to more sustainable food production. In summary, hydroponic gardening of lettuce uses land and water more efficiently than conventional farming and could become a strategy for sustainably feeding the world’s growing population, if the high energy consumption can be overcome through improved efficiency and/or cost-effective renewables. The consolidation of Tilapia fish and leafy crops are an ideal combination as the nutrient composition are one sided.
Furthermore, both species grow ideally in a temperature around 20 °C. Moreover, the selection of NFT goes with the light weight of this systems and a excellent nutrient circulation for leafy species.
With the advent of civilization, soil based agriculture is facing major challenges to cope with the future's demand for agricultural products. According to FAQ, cities on the world delta's will and are experiencing immense urbanisation. The design of a mobile farm with the implementation of aquaponic and hydroponic system could aid with the coming world food demand, on locations where it is the most needed. Within a concept that produces more food on a much smaller footprint with better taste and quality, simply by minimizing or excluding the distribution process of the agricultural product, vertical farming and by bringing the product closer to the consumer. Moreover, the mobile characteristics of the Nomadic farm provides the possibility to relocate the building to a suitable climate. In this manner the production unit can produce the same product all year round, without major changes in energy requirement for the same agricultural production.

Furthermore, the nomadic farm is accommodated with solar panels to produce the energies needed in the process of the productions of the agricultural product. Besides, According to World Food program, the quantity of sweet water is declining, on that account the production unit is provided with systems that consumes 90% less water in addition to rainwater collection.
Isometric view
North and South elevation
East and West elevation
Legend

1  Reception
2  Sanitation and vertical transport
3  Slaughterhouse
4  Cold storage fish 4°C
5  Hatchery
6  Technical space
7  Selling point (optional)
8  Dinning strip
9  Open system smart farming
10  Closed system aquaponics
11  Herb production Carousel
12  Deck

Ground floor
Legend

1. Leafy vegetable production
2. Sanitation and vertical transport
3. Restaurant (optional)
4. Cold storage fish 7°C
5. Conveyor
Legend

1  Solar farming
2  Glass roofing
According to the World Health Organisation, the distance between the consumer and the agricultural product becomes greater with each generation, described as ‘the generation that has not heard a ‘cow moo’. To minimize this distaste, it is important to design a building with transparent fixtures that provides an educational experience to our future generations.

The plug-in plug-out concept provides the ability to become a catalyst in places where poverty prevails and or temporary food is needed due to [natural] disasters.

Due to constant changes and innovations in this sector and the flexibility in production (e.g. seasonal crops, alteration for food) spatial flexibility within the building is very valuable to extent the production life of the nomadic farm. To maximize the flexibility and logistic output of the production unit, all servant and fixed spaces are brought together in one strip that also contributes in the balance of the floating body. In this manner the volume is provided with maximum flexibility and clear programmatic arrangement.

Adjacent to the fixed and servant spaces the strip provides space for additional functions (e.g. restaurant, shop), that could be of importance if the building is not clustered and used as a showcase.

The nomadic farm provides a flexible production volume that produces herbs, leafy vegetables (e.g. lettuce, paksoi, spinach, tilapia, trout, etc.)
The Nomadic farm, forms a rectangular mass with two layers surrounded by a transparent curtain wall. The openness of the building should attract visors and more importantly educate our future generations. The light and open character of the building is reinforced by the designed roof lights, that are also providing the crops with natural light.

The building is symmetrical on the longitudinal elevations, and is asymmetrical on the width elevations that highlights the visitors entrances. The grit that dominates the facades of the building continues to each individual pattern that repeats itself on each floor and sections. In the facade the emphasis is on the vertical aluminum curtain wall frames, ended by a elegant horizontal aluminum strip that cornices the outer contours of the mushrooms.

As the results of a generic designed floating body, demoted on wave heights of 4 meters (average wave height of the North Sea), the mooring heights will differ with each location. Since there is no specific or international measures for the height of quays on the delta.

Mooring the floating body is possible in differed ways (e.g. stairs, bridge risers, etc.) . Based on the location and the in what the distance of the floating urban extension to the ‘main land’ is established.

Besides, the floating farm can also be provided with additional wave breakers while transported and or while the floating structures are on open water, where high altitude waves are possible. The concept of wave breakers are not new, South Korea uses the floating structures to farm wave energies.

Urban section and typologies

The Nomadic farm plugged-in as an urban extension

The Nomadic farm plugged-in as an urban extension
Urban section and typologies

Clusterings of the Nomadic farm

Possibilities to moor the floating farm
Based on literature, the following calculations are charted to depict the annual production of the autonomous farm and its impact, based on annual production, projected on a urban environment.

The footprint of the agricultural unit grand a total of 14,100 m² (6 layers) of solid and liquid media (hydroponics) production beds. The dimensions are based on industrial standardized vertical farming grow-beds.

The density for Tilapia fish farming is around 0.5 kg/20-25L. Moreover, 1.5 kg of fish is needed to feed one sq m of lettuce production (Rakocky, Lennard). That is to say that a total of 211.68 kg of Tilapia is needed to feed the available grow beds. On this bases the capacity of the fish culture can be calculated, making a volume with 465,700 L aqua culture (22 L/kg) is required to design a circular nutrient cycle. It takes six to eight months to farm 600 gr of tilapia meat (University of Virgin Island, 1994), bringing the annual production of tilapia meat to 22,22 ton. A volume with of total of 6048 m³ open system aqua culture is also added to the structure to maximize the output of the farm. In this manner local fish culture can be farmed in its natural environment. The Rijnhaven is taken as an example to show the impact of the farm as a food supplier. Furthermore, the water temperature of the Rijn provides a perfect environment to farm rainbow trout, as the water temperature corresponds to the natural environments of that species. The total volume of the open system 45L / kg (Wymanovich, 2011) provides an annual production of 80 ton of rainbow trout.

Additionally, 100 crops of lettuce can be farmed in one sq. m annually, around half of the hydroponic system have been made available for lettuce production, bringing the annual production up to 123 ton of lettuce. Furthermore, the production unit produces, 22 kg/sq.m (Gifactueel), 112 tons of herbs each year.

The density of the urban population is decisive to make further statements and to chart the impact of the production unit on the urban environment. Furthermore, the demand or the average consumption of vegetables and fish meat per person is needed to project its impact on its urban environment. According to Bos.G founder of HorecaNederland, the average Dutchman eats around 4.5 kg of fish per year. Moreover, the average Dutchman consumes 35 kg of fresh vegetables yearly (de Rooi, 2008).

The population density of Rotterdam is estimated around 7,948 (oozo, 2017) per sq. km. In this manner the impact of the agricultural production could be charted on a urban environment, as the buildings provides fish for 22,666 heads and vegetables for 6,000 persons. By this mean, the agricultural unit can provide daily fresh food to more than 14,000 heads, covering an area of 2 km².
Clusterings, transportation, plug-in and plug-out concept of the Nomadic farm.
LOGISTICS

The main entrance for public is located on both cross elevations of the Nomadic farm. These entrances are directed towards the reception and servant spaces at process corridor of the building [red arrow]. Once inside the building visitors are free to walk around within the rational scheme. Moreover, the programmatic strip is provided with two vertical transportation units which contributes to a rapid transport of the agricultural production. Furthermore, the flexibility and technical development of the structure allows transportation ducts outside of the main volume [rendering]. In what the transportation of living sea animals is easily sucked out of the production pools into transportation vessels.

The grid of the building and or the rational floating body provides the interior of the building with functional inner streets, designed with the industries dimensions, that maximizes the in and output of the production machine.
Construction

The Nomadic farm, forms a rectangular shape of two layers, 64.800 m x 100 m. The floating body is based on a system with a core of polystyrene foam (EPS), steel reinforcement and a shell of fibreglass concrete.

The composition consists of the repetition of a series of mushroom structures, six bays long and y bays deep, each with a span of 28 m made up of conical steel columns with eight ribbed and rejuvenated steel yokes, between which glazing and or sandwich elements are span to cover the hall. The choice for steel comes with the lightness of this structure, as the weight and the type of the mechanical forces have major effects on the balance and the height of the floating body. The balance of the floating body is based on the principle of Archimedes [the buoyant forces are equal to the weight of the displaced water].

The mezzanine is supported by columns and HEA beams. The floor is composed out of castellated beams topped by corrugated steel finished in concrete. The castellated beams provide the production with maximal flexibility for piping and drainages and lighting fixtures.
Extruded view rejuvenated umbrella structure and connection (top)

Isometric view umbrella structure (bottom)

Butterfly cross connection
Production in agriculture within aqua and hydroponic-systems requires extensive installation techniques. Moreover, if the production unit is required to produce the same product all year round, climate control (e.g. air flow, heating and natural lighting) are of a significant importance. The hydroponic system is provided with ultraviolet led lighting fixtures, as it provides the best light tone for leafy vegetables. Moreover, the roof is designed to collect rainwater, the farm is also provided with solar panels, in what the building has the potential to become an autonomous mobile farm.

The Nomadic farm implements a circular aquaponic and hydroponic system. The waste in the fish tanks are accumulated to the plant, as it serves as nutrients to feed the agricultural product. Moreover, fish breath in oxygen and breath out carbon-diode, that is absorbed by plants, which leaves oxygen-rich water for the fish.
Aquaponics

Fish breath in oxygen and break out carbon dioxide. Plants absorb the carbon, which leaves oxygen-rich water for fish tank.

Once fed, fish produce ammonia-rich waste.

Bacteria convert ammonia into nitrates and nitrites.

Plants absorb the nitrates as nutrients.

After water is filtered by the plants, it returns to the fish tank.
Rainbow trout is native to the cold water rivers and lakes of the Pacific coasts of North America and Asia. It has been introduced to practically everywhere the conditions are favorable, rainbow trout tolerates a wide range of environmental conditions.

There are four vital habitat factors that influence the growth of rainbow trout. Including basic water qualities and the availability of food. Rainbow trout is a typical cold water fish ideal for production in an open system.

Water temperature is a decisive factor for the various stages of fish production. The body temperature of embryos, fry and developing fish adjust their temperature to that of the water. Logically, body temperature has major influences on the intensity of the metabolism.

The developing embryos and fry feed from the yolk sac and receive oxygen through the entire body surface. When the water temperature is higher, the embryos and fry develop more rapidly, while at lower water temperatures the speed of development reduces (Woynarovich 2011). Fish develops and or growth within a certain range of water temperature. Moreover, the open system can come with disadvantages, as favorable trout growth requires water free of harmful solids and other possible waste dumped in to rivers by the industries.

Eyesight is crucial for the efficient feeding of trout, natural daylight from the transparent elevations cannot penetrate the whole depth of the basin (4m). The placement of skylights should alter the amount of direct natural light filtration.

The Nomadic farm implements a rational farming principle, the fish are grown in various ponds based on the age categories and the weight of the fish. In this manner farming, feeding and or aeration of fish can be monitored. Furthermore, the development of the trout (life cycle 1 until 5) are separated and kept in the hatchery for superior monitoring and control.
Life cycle and development stages for controlled trout farming

Legend

1. Fertilized eggs
2. Eyed eggs
3. Hatched sac fry
4. Swim-up fry
5. Fry
6. One summer fish
7. Sexual matures male
8. Sexual matures female
The building knows six main materials that occur throughout the interior and exterior of the floating production machine, destined into a building with a light industrial appearance.

The floating body is based on a system with a core of polystyrene foam (EPS), steel reinforcement and a shell of fibreglass concrete. The sides of the floating body are provided with a U sheet pile profiling, a very common appearance on the quays of industrialized cities.

The prime structure is designed in steel rejuvenated trusses topped with corrugated steel. Shed and insulation. The columns are polished and buffed in a highly reflective ultra-smooth mirror finishing, to great a surface with a clear distinct reflection. The longitudinal facades are wrapped in transparent curtain walls, corniced with a thin aluminum roof trim.

The roof have a bluish reflection due to the placement of the solar panels, which will be visible from high-rise buildings in the surrounded area of the mobile farm. The composition and the calm colors create a clinical display that goes well together with the industrial appearance of the building.

The fixed programs [strip] is finished in warm light colored wooden planks that speak the same architectural language of the building, while referring to the ‘romantic image of farms. The wooden finishing emits the building with a more welcoming appearance.

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Detail
The prognosis for the future: extreme population growth, urbanization, decrease land per capita, climate change, rising sea levels and desertification. As a consequence, the demand for food will grow exorbitantly.

Today, global food production is being undermined by land degradation and shortages of cultivable land and water resources. The world has lost a third of its arable land due to erosion or pollution in the past 40 years. Feeding the rising world population will be a challenging task.

More people now live in cities than in rural areas around the world, and that number is climbing. Today 54% of the world's population lives in urban areas, but by 2050 the urban population is expected to rise to 62% in Africa, to 65% in Asia, and to 90% in Latin America etc.

25 out of 35 mega-cities have seawater access. For example, Singapore imports 99% of its food. Resulting into products with less taste, as they are picked unripe. For the reasons of expiring date, distance between product and consumer and transportation.

The possible solution for the already on-going world food system crisis: smart farming. The Nomadic farm, a floating agricultural production machine for coastal mega-cities based on aqua and hydroponic farming. The waste in the fish tanks are accumulated to the plant, as it serves as nutrients to feeder the agricultural product.

The concept provides the opportunity to grow food in places were its the most needed, with better taste and quality. The farm is designed to collect rainwater, and is also provided with solar panels, in what the building has the potential to become a autonomous mobile farm. Moreover, the mobile characteristics provides the possibility to relocate the building to a suitable climate. In this manner the production unit can produce the same product all year round, without major changes in energy requirement for the same production.

By the reason of continual changes and innovations in the agricultural sector, market demand and flexibility in production e.g. seasonal crops, the Nomadic farm is designed with a flexible interior. To maximize the flexibility and logistic output of the production unit, all servant and fixed spaces are all organized together in one strip which also contributes in the balance of the pontoon. The floating body of the agricultural unit grinds a total of 14100 m$^2$ (vertical farming) of solid and liquid media (hydroponics) production beds, based on the crops produced, as crops comes with peculiar growing conditions.

According to World Health Organisation, the distance between the consumer and the agricultural product becomes greater as urbanisation growth. To minimize this distaste, it is chosen create a transparent building that provides a educational experience to our future generations.

An urban extension, a place to come closer to our food. Knowing where the products that we eat come from, or even having the opportunity to shake the hand of the person who grows our fruits and vegetables.

Designed in a building with an industrial timeless architectural appearance, a generic model that has the ability to adapt and become a catalyst in places where poverty prevails and or (temporary) food is needed. As the buildings provides fish for 22,666 heads and vegetables for 6,000 persons, based on Dutch consuming figures. By this mean, the agricultural unit can provide daily fresh food to more then 14,000 heads on annual basses.
Agricultural practice has experienced an explosive development over the past 200 years as a result of industrialization. It has become an industrialized process where people have lost connection to food production. A world of functional and rationality that has been transformed into a system and mega-farms that is hidden in the countryside and away from people living in cities.

The preliminary M3 research was a good way to understand the process of the production, to get an idea of the various aspects and stages that the agricultural products pass through.

This process line is displayed by building types that are passed during the complete process from production to consumer. A comparison of the production lines conclude that the time of origin between these products differ greatly, but are all continuous processes. All products share a striking amount of transportations between locations that is combined with a diversity of type of buildings. Furthermore, the research explained exorbitant demand for food in the future.

The design of a generic floating production machine came with some difficult issues. It was a new world for me, a design task in which agriculture and the product are the most important. For a better understanding, many theoretical frameworks were examined, with emphasis on the systems and the properties of the products being taken as the starting point.

My first design where the wheelchair users had little influence on the logistics of the building, it was the mechanic machines and their dimensions that were decisive for the rational scheme. The choice for a mobile production unit has, however, led to a timeless image, an answer to the phenomenon of 'land scarcity' and the growing world population. I think that the Nomadic farm can have major contribution to places where food is most needed.

Moreover, the floating farm will contribute to the ambition of these world cities, an answer to the trend that has been living in our society in recent years; where does my food come from?

An question that one needs to ask, the M3 research has shown that it is a world full of secrets. An image that is often unknown to the consumer, a world of production, it is not about the quality and the well-being the production, but rather about quantity of yields.

Although some design decisions have been part of the design from the very beginning, I have struggled for a long time to come to the final design. I abandoned several ideas and thoughts, because in the end it was the simplicity that brought the desired appearance.

Although I had a good idea of what the building and spatial experience should look like, I found it hard to convey this image due to the functionality of many case studies. At end of the finishing line, the impressions give a good atmospheric display. The final model and presentation will reinforce this image.

I experienced the graduation workshop as very pleasant. Partially due to the critical attitude of the tutors during coaching sessions, it brought me to field beyond my own vision. Resulting into a production machine, designed with simplicity creating a product with satisfying results.

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GRADUATION STUDIO
The Farm
Nomadic Farming
LIST OF REFERENCES
GRADUATION STUDIO
The Farm
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APPENDIX
Enquête over motivatie consumptiegedrag
Rotterdammers

In dit onderzoek word uw op de onderwerp
consumeren bevraagd. Concreet zijn de vragen
gesteld over de volgende onderwerpen;

Het kopen van lokale of streekproducten.
Het kopen van Nederlandse producten.

1. Wat is uw geslacht?
   o ❑  Man
   o ❑  Vrouw

2. Tot welke leeftijdscategorie behoort
   u?
   o 17 jaar of jonger
   o 18-22 jaar
   o 24-34 jaar
   o 35-49 jaar
   o 50-64 jaar
   o 65-79 jaar
   o 80 jaar of ouder

1. Wat is uw hoogst voltooide opleiding?
   o ❑  Geenopleiding
   o ❑  Lagere school/basisonderwijs
   o ❑  LBO, VBO, LTS, LHNO, VMBO
   o ❑  MAVO, VMBO-MBO
   o ❑  MBO, MTS, MEAO
   o ❑  HAVO, VWO, Gymnasium
   o ❑  HBO, HEAO, PABO, HTS
   o ❑  Universiteit
   o ❑  anders, namelijk ............................

2. Koopt u of iemand in uw huishouden
   weleens streekproducten of lokale
   producten?
   o  ja
   o Nee

1. Wat zijn de belemmeringen voor het
   kopen van lokale en streekproducten?
   O, mag meerdere antwoorden aankruisen.
   o Ik heb er geen behoefte aan
   o Lokale producten zijn duurder
   o Er zijn weinig lokale producten bij
     mij in de buurt te koop
   o Ik ken weinig lokale producten
   o Er zijn weinig snel te bereiden
     lokale producten
   o Lokale producten hebben
     mindere kwaliteit
   o anders, namelijk .........................

6. Wilt u in de toekomst vaker lokale of
   streekproducten kopen?
   o  Ja
   o Nee

2. Koopt u weleens producten omdat ze
   in Nederland zijn geproduceerd?
   o ja
   o Nee
   o anders, namelijk .........................

3. wat zijn de belemmeringen voor het
   kopen van Nederlandse producten?
   O, mag meerdere antwoorden aankruisen.
   o Nederlandse producten zijn
     duurder dan buitenlandse producten
   o Er zijn weinig producten waarvan
     ik weet dat ze uit Nederland komen
     in mijn winkel
   o Er zijn weinig snel te bereiden
     Nederlands producten
   o Producten uit Nederland hebben
     mindere kwaliteit dan buitenlandse
     producten
   o Ik ken te weinig producten
     waarvan ik weet dat ze uit Nederland
     komen
   o Ik vind het niet belangrijk dat
     producten uit Nederland komen
   o Weet ik niet
   o Anders, namelijk .........................
9. Hoe vaak koopt u producten die in Nederland geproduceerd worden?
   o Een keer per week of vaker
   o Een keer per maand tot een keer per week
   o Een tot vijf keer per jaar
   o Eens per jaar of minder
   o Nooit
   o anders, namelijk ..............................

10. Wat zijn de motieven voor het kopen van in Nederland geproduceerde producten? Uw, mag meerdere antwoorden aankruisen.
   o Nederlandse producten smaken beter
   o Nederlandse producten zijn goed voor milieu, natuur en landschap
   o Nederlandse producten zijn gezonder
   o Lokale en streekproducten zijn diervriendelijker
   o Transportafstanden van Nederlandse producten zijn korter
   o Ik weet waar het vandaan komt
   o Het levert boeren een eerlijke prijs op
   o Het is beter voor de Nederlandse economie
   o anders, namelijk ..............................

11. Wilt u in de toekomst vaker in Nederland geproduceerde producten kopen?
   o Ja
   o Weet ik niet
   o Nee
   o Geen behoefte aan