URBAN AGRICULTURE -FARMING VERTICALLY WITHIN A MULTISTOREY COMPLEX

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ABSTRACT

As agriculture is one of the largest sector in the Indian economy of food production, there is a need to look into the issue that have affected the agricultural industry due to urbanization in major cities. This paper talks about the effects of urban boom on agriculture in the city of Bengaluru, Karnataka. There is a need to bring in a balance where architecture is used in combination with agriculture for finding a potential solution to create a sustainable environment as well as solve the issues regarding agriculture food production. Over the years new technologies and inventions have been adopted in different parts of the world, as population growth, environmental changes as well as depletion of natural resources across the world is a never ending issue, methods have been employed to help counter against this issues. Therefore, the main aim of this thesis is to study the problems faced in terms of food production, water quality and help solve it by the introduction of a Vertical Farming complex that can help elevate the issue of clean food production.

ACKNOWLEDGEMENT

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CONTENTS

1. INTRODUCTION

The aim of this research is to introduce an alternative method of farming where the crops are grown vertically. To grow farms vertically within a multistoried complex using various new-age techniques and technology. These methods of farming will help to improve the upcoming crisis in food production in metropolitan cities like Bengaluru, India. A study on urban states that it is estimated about 50% of the population in the world lives in urban areas and the overall proportion of urban population will reach 69.9% by 2050[1]. And for a country like India, it is a well known fact that has the fastest growth in population and it has been growing steadily from 27.81% in 2001 to 31.16% in 2011. In the state of Karnataka, the capital city Bengaluru district houses a large population of 9.6 M from the last census undertaken in 2011 (A, 2015). Due to the expansion of the urban landscape, food production has been effected which has resulted in loss of farm lands. What with Bengaluru being the 6th largest city in India, the city attracts people due to the Information Technology and Bio-technology industries.

People migrate in the name of seeking better opportunities, hence the result in the urban boom. This in turn adds pressure to the farms to produce enough food to feed the ever growing city. Another issue in the picture is the quality of water and supplies used for crop production which in turn leads to us questioning the quality of the yields produced. As it is a well-known fact that agriculture is a large economic part of India's production in food and on par with China and few other nations. In the state of Karnataka, agriculture is one of the main occupation of the rural zones where it forms 56% of the workforce.

Therefore, this paper talks in detail about a possible solution of using Hydroponics, Aeroponics and Aquaponics as an answer to grow healthy crops. These new techniques of farming would help combating the food production crisis that will occur due to the rapidly growing population and the need to be able to feed the populace. With the idea of farming vertically, we will be able to help the environment to recharge itself, as stated by Dickson Despommier[2], we would allow the soil to recharge itself and let it regain the nutrients that it lost, the green cover that was destroyed would grow back and the ground water table would recharge itself.

[1] Study on Urban expansion in Bengaluru city (A, 2015)
[2] The Rise in vertical farms (Dickson, 2009/11/01)

2. WHAT IS URBAN AGRICULTURE?

Urban Agriculture to me is defined as an integration of farming within an urban context. Alternative definitions by various researchers portray Urban agriculture as the creation of a diverse ecosystem within an Urban setting where it is possible to include rearing of animals and farming in cities. According to researcher Pranati Awasthi[3], she believes that Urban Agriculture can help give a new form of livelihood to the urban poor within the growing cities. And this is true, as cities grow beyond there limits it in turn creates a pressure on the rural sector. Where the farmers whose livelihood depends on farming must one day choose to either relocate to a new place to continue their traditional methods of farming or give it up and take up employment within cities.

Figure 1Verticrop System (Photo taken by Mike Nasseri,2013 (Naseeri, 2017))

Urban agriculture has been in discussions for a long time, the advantages and disadvantages of the new age technology for producing healthier and clean crops. In the current time, researchers and various non-profit organizations are coming up with projects where they can grow vertically. This will definitely have a positive impact upon the environment. According to Despommier, if we adopt the methods of growing vertically and creating an ecosystem within an urban environment then there is no need to further extend the limits of the city, we in turn are allowing the earth to recharge itself[4]. Basically, without any more interferences from humans and further development on land, we can help reduce the damage that has already been caused and over time the water table, eroded soil, damaged land and forests would return to its original state. Therefore, the use of technologies such as Hydroponic, Aquaponic and Aeroponics systems and future upcoming inventions will help in redoing the damage that has been done to the environment and also help future generations to have access to healthy food produce and they are educated by the advantages of these resourcefulness of these technologies.

[3] (Awasthi, 2013)
[4] (Dickson, 2009/11/01) The Rise of the Vertical Farms

Figure 2 Graph that shows the future change in food production using machines, Concept by Michael Moll (Graphics by Yuriy Kyrov, 2017)

Hence, according to various studies we shall learn more about these systems. As this can be a possible solution to help combat the food quality as well as other issues in Bangalore. Therefore, this paper introduces the idea to implement Vertical farming within a mutli-storied building in the city of Bangalore. Where the ever growing city is in need of an intervention to combat the loss of agricultural land due to city expansion beyond its limits.

3. Hydropnics System

As per many studies on Hydroponics, this system is a well-designed method where cultivation of plants or crops in done through a soil-less growth medium and an optimized nutrient is used to feed and produce the calculated resources necessary by a crop. As a result, plants can absorb the maximum amount of nutrients most efficiently to achieve their best possible healthy end products which are pesticide free.

Agriculturists or individuals who have this system already set up can have complete control over managing the working of the system. They are able to oversee the pH scale and supplements to make sure the crops are receiving the necessary nutrients needed. The entire set-up is an enclosed network where the nutrient filled water is reused when it is not utilized by the plants. As the crops are cultivated indoors, the temperatures and lighting are manually controlled according to the growth conditions of the crops. This helps in the production of the best yield possible. Since hydroponics does not require soil as a medium to grow crops, this system can be used anywhere as long as the conditions are favorable for plant growth[5].

Advantages of Hydroponics:

Crop	Soil	Soilless
Soya	600 lb	1,550 lb
Beans	5 tons	21 tons
Peas	1 ton	9 tons
Wheat	600 lb	4,100 lb
Rice	1,000 lb	5,000 lb
Oats	1,000 lb	2,500 lb
Beets	4 tons	12 tons
Potatoes	8 tons	70 tons
Cabbage	13,000 lb	18,000 lb
Lettuce	9,000 lb	21,000 lb
Tomatoes	5-10 tons	60-300 tons
Cucumbers	7,000 lb	28,000 lb

Figure 3Types of crops grown hydroponically and amount of harvest comparison between soil vs soilless type of farming. (White, 2010)

Through various research, different methods of hydroponic systems have been adopted to grow different types of crops. These methods are used for crops that are favorable towards a particular method, which leads to better and healthier yields. The following methods are as follows[6]:

- Nutrient Film Technique (NFT) – In this method, the nutrient supplement is introduced into channels that hold the crops. The channel is inclined so that the nutrient water can flow freely and runs over the roots of the crops. The excess solution is collected and reused again hence completing the loop. Due to the design of the set-up, the NFT method is suitable for plants that have small root systems.

[5] Green Our Planet is an online blog that talks about the benefits of hydroponic system. According to the website, this group is a non-profit conservation organization whose aim is to spread environmental awareness through project based programs in schools in the United States.

[6] NoSoilSolutions is an online blog that takes about Hydroponics and the different types of growth methods in this system.

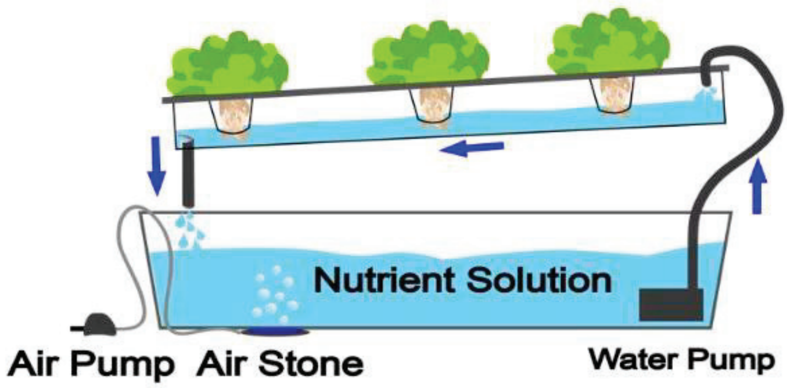


Figure 4. Nutrient Film Technique set-up (Online blog NoSoilSolutions)

As per an experiment, the flow rate for this method must be at-least 1L per minute and 2L per minute maximum. Since there may be an emergence of nutritional problems when the flow rate exceeds its limit. There have been cases where the growth rate of the crops have reduced when the length of the channels exceeds 12m and the nitrogen content in the supplement is reduced faster in fast crowing crops. A solution to combat this error was to introduce nutrient supplement in the middle of the channel to ensure the continuity of even growth.

- Wick system- A wick system is a very basic when compared to the other hydroponic systems. The method consists of a container that has a layer of the growth material that holds the plant, then there are wick attached to the material which is dipped into the nutrient solution that is placed below. The wicks absorb the solution and transfers the solution into the growing medium and the roots absorb the necessary nutrients. In this method, there is no need for a pump to transfer the nutrient water for the plants. Therefore this is a low maintenance method that is easy to setup[7].

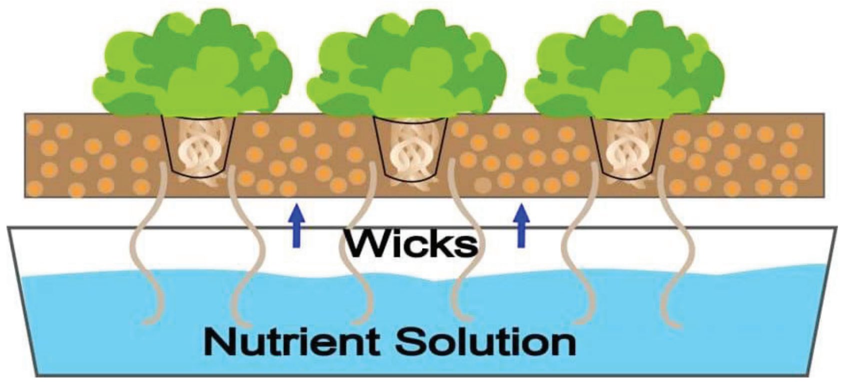


Figure 5 Wick System(Online blog Smart Garden Guide)

For experiments that can be practiced at home, the NoSoilSolutions online blog suggests use of simple materials that is used as growth medium for a hydroponic mini-crop. This is interesting since there are individuals who would like to try installing a small crop in their back yards or

[7] Smartgardenguide online blog (What Is Wick System Hydroponics?, 2019)

balconies, and this is an interesting project to take up at their leisure. Materials such as Rockwool and Oasis cubes are said to be good for seed germination, while rockwool needs to be pre-soaked in a solution, Oasis cubes has neutral pH level and has good water retention and it can also be transplanted to different hydroponic systems. Expanded clay pebbles are used to hold the plant/crops in placed in net pots and it is said to have a good pH level. Coco fiber/ chips is a common element that is a popular material used for plant growth material, especially know for growing cacti plants and terrariums. It is a well known fact that it is a fiber that is a product of coconut husks. Since it provides good moisture retention and can trap air in the pores, it is a great option as a growth medium for plant. Perlite is also commonly used for the growth of cacti plants, this material allows the water to drain evenly and as per the blog, it is good for drip irrigation systems.

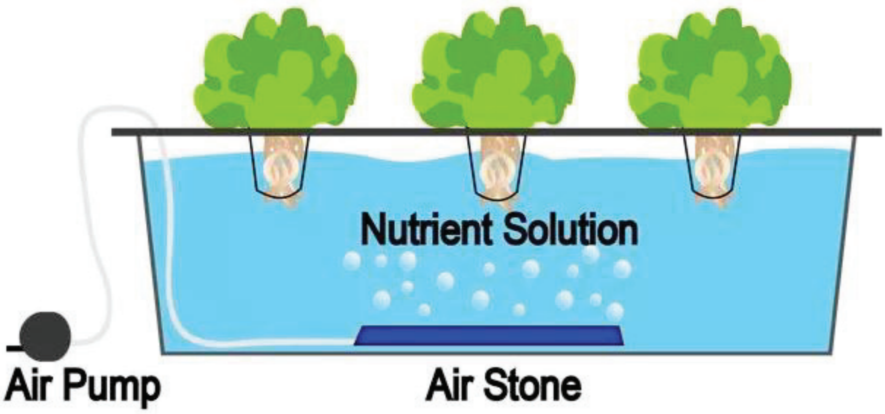


Figure 6 Deep Water Culture (Online blog NoSoilSolutions)

- Deep Water Culture(DWC)- In this type of system, the roots of the crops are submerged within the nutrient solution and a diffuser is used to provide air to the root ends. The crops grow fast and are very lush since crop roots are supplied nutrients continuously through this type of method. This type of system is suitable for plants that have big root structures or crops that bear an abundance of fruits.

  As seen in the Figure 3, the main container is filled with the necessary fluid and an air pump is connected to it. And the air stone present inside is a porous material that is used to make the small bubbles and smaller the air bubbles then the water is better aerated. Since the main element in this system is the use of oxygen, the oxygen pumped affects the growth of the plant. As per a study larger the root mass, larger is the amount of oxygen required to cover it for beneficial growth. Some of the disadvantages in this method talks about stagnation of the nutrient water, this could lead to damaging the roots of the plants. Or overconcentration of the solution. Therefore, the water must be replaced and treated so that it can be reused again[8].

[8] NoSoilSolutions online blog (6 different types of Hydroponic systems, 2019)

- Ebb and flow method- This method of hydroponics consists of a reservoir filled with Nutrient solution and this is connected to the grow trays or a growing chamber where the solution will be flooded into the trays. The solution is left for a particular amount of time allowing the plants to absorb the required nutrients and the solution is drained out.

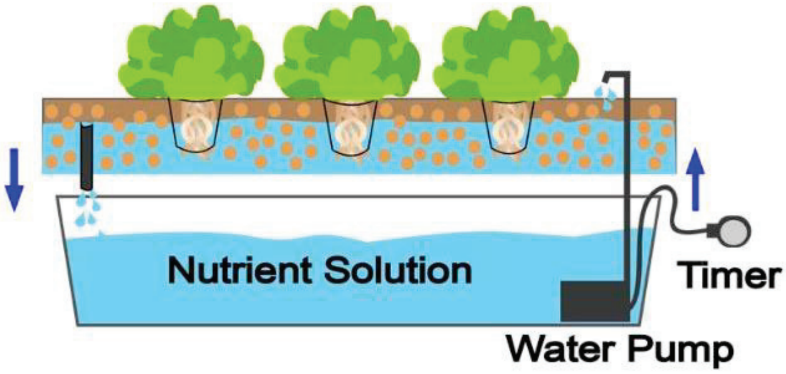


Figure 7 Deep Water Culture (Online blog NoSoilSolutions)

In this set-up, this system can be adaptable to different types of spaces from small to big. The reservoir can be placed below the grow trays saving space or have a large scale unit and grow different types of crops adapting to the set conditions. This method is resource efficient since the fluid running through can be automated and have a set timer to let it run for days. This method as per an article, it is suitable for plants like cucumbers, beans, tomatoes etc.

- Drip System- This type of system in quite commonly known since it is usually used to water plants or irrigated crops with a set timer. When used in the hydroponics context, the nutrient solution is pumped directly to the crops by dripping the solution through tubes. In the Figure 5, we can see that the supplement is directed towards the plants and the excess water goes back into the container. The whole loop is repeated.

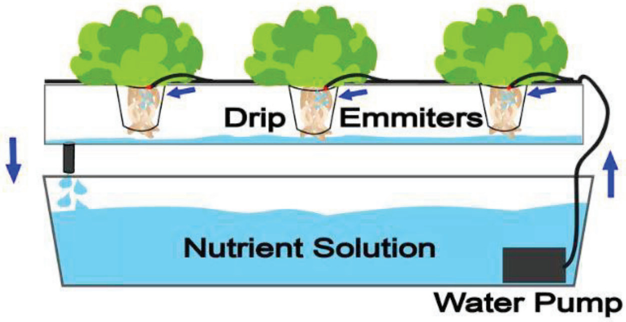


Figure 8 (a) Drip System (Online blog NoSoilSolutions)(b) Drip system hydroponic crops(Published on Green and Vibrant blog, 06/06019)

There are variations in the drip system that is available and this is used based on the treatment of excess water derived from the irrigation process.

Recirculating or Recovery System- It is explained that when excess nutrient solution is returned to the main reservoir. The pH scale of the existing solution may be affected by the waste water that is returned to the tank as the necessary nutrients were not absorbed leading to a type of stagnation. Therefore, continuous maintenance of the solution is done to maintain pH levels for good plant growth.

Non-Recovery or Non-Circulating system- In this type, the excess waste water is expelled. Since there is not a lot of wastage in the drip system, the excess solution is negligible. In large commercial setup, due to efficient equipment and timers, there is less water run-off[9].

The types of plants used to grow using the drip system are *"lettuce, leeks, onions, melons, peas, tomatoes, radishes, cucumbers, strawberries, Zucchini and pumpkins".* (Max, 2019)

Nutrient Solutions for Hydroponic systems

The Nutrient supplement is the main factor that is responsible for the growth of the plants, it is important to understand the type of nutrients that are applicable for positive end results. An expert in agriculture field[10] talks about the importance of the types and usage of fertilizers, first the nutrients are divided into macro and micro elements.

It is stated that macro elements are consumed in large quantity when compared to micro elements although it is equally important. Therefore, it is easily neglected by growers leading to plants that have lower immunity towards probable diseases and failed produce.

> *"The macro elements are: Nitrogen(N), Phosphorus(P),Potassium(K), Calcium(Ca), Magnesium(Mg), Sulphur(S), Oxygen(O), Carbon© and Hydrogen(H).*
> *The micro elements are: Iron(Fe), Boron(B), Manganese(Mn),, Zinc(Zn), Copper(Cu) and Molybdenum(Mo)."* (Antonius, 2013)

Antonius explains that the fertilizers are applied according to the nutrient type absorbed by plants. It is said that nitrite(NO2-) must not be used since it is dangerous to plants, iron(Fe) can be absorbed in the form of Fe2+ with the help of a water-soluble agent. The table below is a list of nutrients that have macro and micro elements that can be absorbed by the crop roots.

[9] Online website on hydroponic system (Max, 2019)

[10] A list of 43 important hydroponic fertilizers (Antonius, A list of 43 important hydroponic fertilizers, 2013). Antonius is the editor of the online blog post on Hydroponic fertilizers and an expert in the field of Agriculture. He studied agriculture at the University of Stellenbosch in South Africa in1984 and M.Sc Agric. in 1998.

Nutrient	Form absorbed	Method of uptake
N	NO_3^-, NH_4^+, N_2	Active, electro-chemical gradient
P	$H_2PO_4^-$, HPO_4^{2-}	Active
K	K^+	Active, electro-chemical gradient
Ca	Ca^{2+}	Active & diffusion
Mg	Mg^{2+}	Active, NH_4^+, H^+ dependant
S	SO_4^{2-}, SO_2	Active, electro-chemical gradient
Na	Na^+	Active, electro-chemical gradient
Cl	Cl^-	Active, metabolically controlled
Fe	Fe^{2+}, Fe Chelates	Active, metabolically controlled
Mn	Mn^{2+}, Mn Chelates	Active, metabolically controlled
Zn	Zn^{2+}, Chelates	Active, metabolically controlled
Cu	Cu^{2+}, Cu Chelates	Active, metabolically controlled
Mo	Molybdate	Active
B	Boric acid	Passive non-metabolic process

Figure 9 List of Macro and Micro nutrients for hydroponic plants (Antonius, A list of 43 important hydroponic fertilizers, 2013)

1. Potassium nitrate (KNO_3) 62.90% K
2. Calcium nitrate ($CaNO_3.4H_2O$) 24.39% Ca
3. Sodium nitrate ($NaNO_3$) 72.94% N
4. Ammonium sulphate ($(NH_4)2SO_4$) 21.33% N
5. Ammonium nitrate (stabilized) (NH_4NO_3) 35% N
6. Urea ($CO(NH_2)_2$) 46.67% N
7. Am. dihydrogen phosphate (MAP) ($NH_4H_2PO_4$) 12.17% N
8. Di-Am. Dihydrogen phosphate (DAP) ($(NH_4)2HPO_4$) 24.24% N
9. Potassium dihydrogen phosphate (KH_2PO_4) 22.79% P
10. Monocalcium phosphate ($CaH_4(PO_4)2.H_2O$) 24.6% P
11. Phosphoric acid (H_3PO_4) 31.63% P
12. Potassium sulphate (K_2SO_4) 44.83% K
13. Potassium chloride (KCl) 50% K
14. Calcium sulphate ($CaSO_4.2H_2O$) 23.26% Ca
15. Magnesium sulphate ($MgSO_4.7H_2O$) 9.75% Mg
16. Magnesium nitrate ($Mg(NO_3)_2.6H_2O$) 9.38% Mg
17. Na-Fe EDTA (Chelate) 4.1043% Fe
18. Na-Fe HEDTA (Chelate) 4.1038% Fe
19. Na-Fe EDDHA (Chelate) 6% Fe
20. Na-Fe DTPA (Chelate) 10% Fe
21. Ferrous sulphate (green vitriol) ($FeSO_4.7H_2O$) 19% Fe
22. Ferric sulphate ($Fe_2(SO_4)_3.4H_2O$) 23% Fe
23. Ferrous oxide (FeO) 77% Fe
24. Ferric oxide (Fe_2O_3) 69% Fe
25. Ferrous ammonium phosphate ($Fe(NH_4)PO_4.H_2O$) 29% Fe
26. Ferrous ammonium sulphate ($(NH_4)_2SO_4.FeSO_4.6H_2O$) 14% Fe
27. Iron ammonium polyphosphate ($Fe(NH_4)HP_2O_7$) 22% Fe
28. Boric acid (H_3BO_3) 17.74% B
29. Solubor ($Na_2B_4O_7.5H_2O$ + $Na_2B_{10}O_{16}.10H_2O$) 20.5% B
30. Sodium tetra borate ($Na_2B_4O_7.10H_2O$) 2.83% B
31. Copper sulphate ($CuSO_4.5H_2O$) 25.6% Cu
32. Copper sulphate monohydrate ($CuSO_4.H_2O$) 35% Cu
33. Cu Chelate ($Na_2CuEDTA$) 13% Cu
34. Cu Chelate (NaCuHEDTA) 9% Cu
35. Ammonium molybdate ($(NH4)_6.Mo7O_{24}.4H_2O$) 54.37% Mo
36. Sodium molybdate ($Na_2MoO_4.2H2O$) 39% Mo
37. Zinc sulphate ($ZnSO_4.7H_2O$) 22.65% Zn
38. Zinc sulphate monohydrate ($ZnSO_4.H_2O$) 35% Zn
39. Zn Chelate (Na2ZnEDTA) 14% Zn
40. Zn Chelate (NaZnNTA) 13% Zn
41. Zn Chelate (NaZnHEDTA) 9% Zn
42. Manganese sulphate ($MnSO_4.4H_2O$) 24.63% Mn
43. Mn Chelate (MnEDTA) 12% Mn

Figure 10. List of fertilizers using the necessary elements. (Antonius, A list of 43 important hydroponic fertilizers, 2013)

Hydroponic Experiments

Cucumber crop and the effects of Nitrogen during growth (Antonius, 2017)

This experiment talks about the effects of nitrogen level for the growth of the cucumber plants. It is commonly know that nitrogen component is essential for healthy plants. The quality of the growth depends upon the amount of nitrogen it receives and the effects can be seen on structure of the leaves, amount of flowers its produces etc. Hence, the experiment talks about the ideal conditions needed and the amount of nitrogen concentration for good growth.

Cucumber Seedling conditions

Root temperature- It is said that cucumbers cannot grow well when the temperature is low since the cucumber plant is tropical type with soft tissues. For good growth, the temperature for its roots must be around 20-30 degree Celsius. Antonius mentions another researcher Qiuyan Yan, where in his own experiments with the cucumber seedlings, he used the components of Nitrogen, Potassium and Phosphorous as the fertilizers. And it was found that the dry weight of the seedlings were low when the temperature was low.

When the nitrogen supplement was increased over a certain period, the dry weight also increased accordingly. Whereas, Phosphorous and potassium had a different effect upon the seedlings as the dry weight did not increase at lower temperature. After few trial and errors it was found that there was an accumulation of nutrients when the temperatures were at ±10º C than ±20ºC.
Hence it was concluded that nitrogen supplied should exceed a certain amount when there is drop in temperature so that accumulation of nutrients is avoided.

NH4 sensitivity- It is said that ammonia is not a good fertilizer for the cucumber seedlings as well as other commercial crops. Since ammonia has a tendency to decrease essential enzymes during the nitrite conversion, this effects the general growth of the plants. Antonius mentions that the ammonia intake by plant roots can be reduced with the addition of Cu^{2+}.As quoted from a research paper this addition may lead to an *"inhibitory effect of Cu^{2+} on important enzymes such as glutamine synthetase and NADH-glutamate dehydrogenase"* (Antonius, 2017) and the roots are also effected since the ammonia starts to accumulate around it.

Maturation of the crop- In order to understand the importance of the nitrogen content in the solution, Antonius talks about the distribution and absorption rate of the plant during the first harvest. It is said that average rate of absorption by the plants was between 181-196 mg. per plant per day[11]. As per a study by researcher Tanemura, he found that after the production of the first fruit harvest, the nitrogen component within the fruit was the only element whose concentration level increased where as there was a decrease in the nitrogen concentration level within the plants. Hence, in conclusion it shows that the fruits produced by the plants is dependent upon the Nitrogen element.

[11] 1 gram/liter=1000 milligram/liter. Therefore, 196mg makes 0.196g per liter over a certain period.

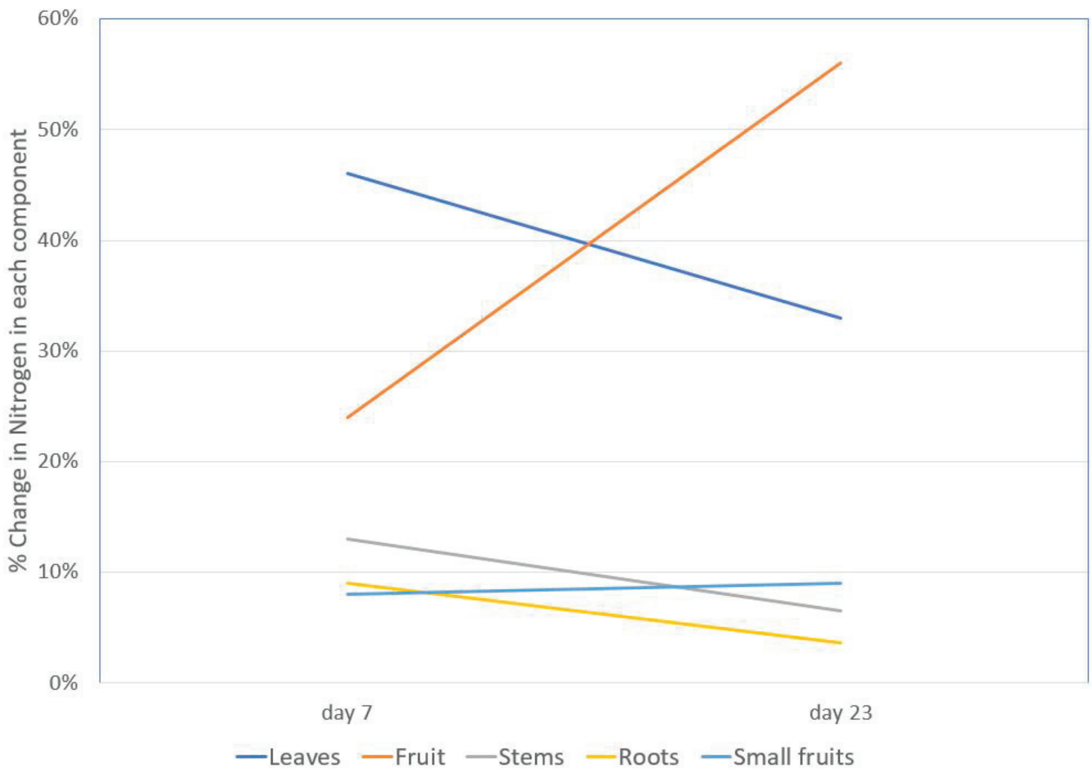


Figure 11 Graph depicting Nitrogen percentage in Cucumber fruit during the first fruit harvest after a duration of 23 days. (Antonius, 2017)

Element	Before fruiting	Mature fruit	Late stage
	ppm	ppm	ppm
N	190-200	175-190	165-170
P	50-60	40-50	
K		220-235	235-250
Ca		165-180	
Mg		30-40	
S		38-48	
Fe		1.0-1.5	
Mn		0.2-0.5	
B		0.5	
Zn		0.1-0.2	
Cu		0.05	
Mo		0.05	

Figure 12 The table indicates the Concentration of elements for the Cucumber fruit and different stages of the crop growth. (Antonius, 2017)

Spinach Crop growth Hydroponically (Antonius, 2015)

In general, it is commonly known that spinach can be grown easily and it is always available in the market. This is one of the few crops that can grow in different climates.

Temperature- As spinach is said to be aa sturdy plant, it is capable of growing in high temperatures. A type of spinach that is known as Swiss chard can grow between temperatures from 13-32º C. But the quality of the produce varies accordingly, at high temperature conditions the quality is low and may lead to the produce getting rotten, while slow growth during low temperatures.

Fertilizer- Nitrogen component fertilizer works well for spinach. Which is why some growers tend to over use the fertilizer and add too much to the plants. It is stated that the tomato nutrient method is beneficial for spinach plants since there is no wastage of produce.

Disease control-

Nutrient	Concentration in nutrient solution (ppm)
Nitrogen (N)	145 - 165
Phosphorus (P)	23 - 35
Potassium (K)	230 - 250
Calcium (Ca)	95 - 110
Magnesium (Mg)	20 - 30
Sulphur (S)	30 - 45
Iron (Fe)	1.5 - 2.5
Manganese (Mn)	0.2 - 0.5
Boron (B)	0.5 - 0.8
Zinc (Zn)	0.1 - 0.2
Copper (Cu)	0.05
Molybdenum (Mo)	0.05

Figure 13.Fertilizer concentrations for Hydroponically grown Spinach (Antonius, 2015)

Life cycle of crops

Tomatoes: Based upon the variety type, the life cycle of tomato crop runs accordingly. In general, it is said that various greenhouses grow their tomato crops for a duration of 8-11 months. An online blog mentions a farm located in Colorado as an example, The farm known as Bayberry Fresh start the germination of seeds in the month of March and the crop growth runs until November.

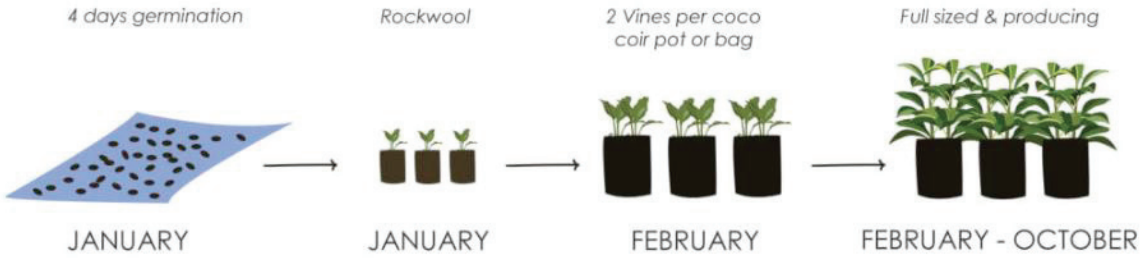


Figure 14. Life cycle of the tomato crop (Storey, 2017)

It is said that the general life cycle of the crop may take up 5-10 days to germinate, transplanting of the saplings is done after 4-6 weeks and it starts bearing fruits from 1-2 months[12].

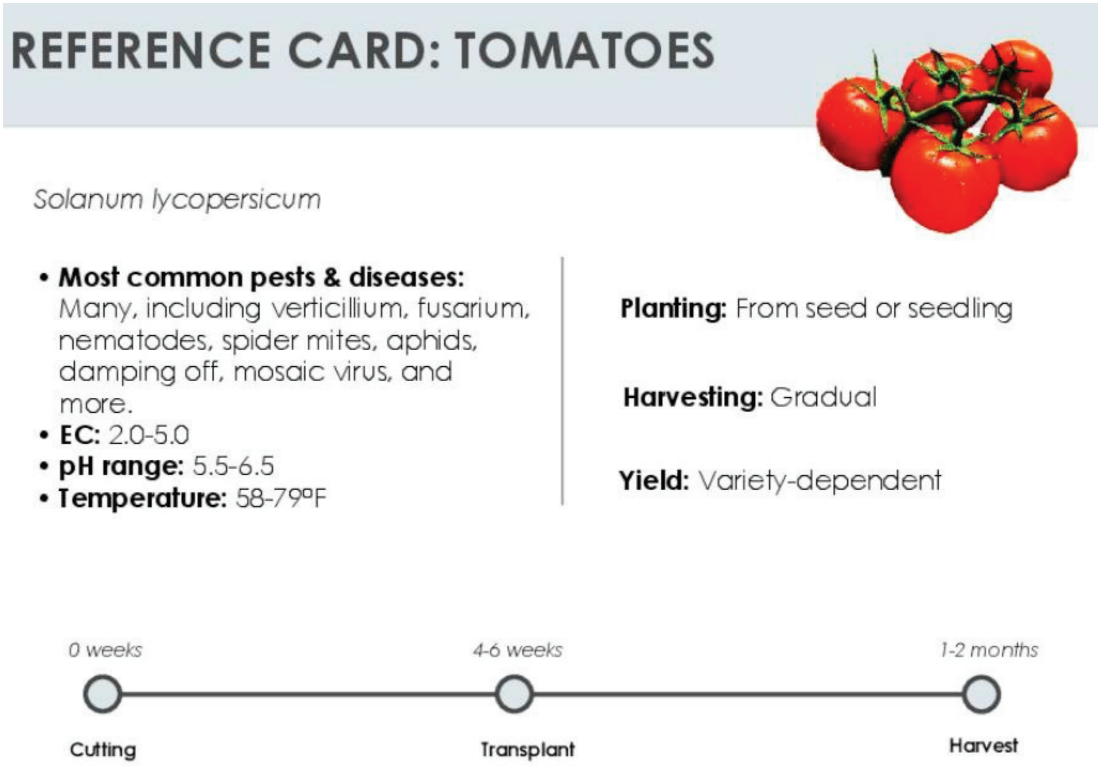


Figure 15. Ideal conditions for the Tomato crop Solanum lycopersicum (Storey, 2017)

[12] Online blog on Hydroponic Tomatoes (Storey, 2017)

4. Aeroponic System

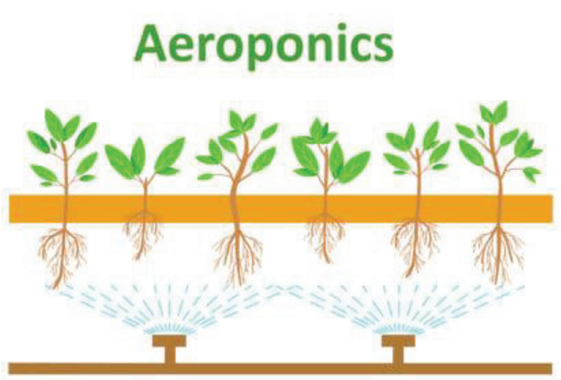


Figure 16 (16a) Aeroponics System(Posted on ModernFarmer blog post) (16b) Aeroponics farm (Posted on ModernFarmer blog post)

Among studies, aeroponics is said to be a method of growing plants by exposure to air or mist without any soil. The main idea in this method is to rear crops by spraying nutrient induced water over the roots of the crops.

In comparison with the hydroponic systems where the growing mediums are continuously induced with nutrient water, in the aeroponic system the misters are activated in a timely manner to spray the nutrients. According to an article that explains this system, the seeds of the crops are *"planted in pieces of foam stuffed into tiny pots, which are exposed to light on one end and nutrient mist on the other."* And it is later stated that the form is used as a steady grip to hold the plant in place as the growth continues. This system is used to grow crops similar to the hydroponic system such as various greens like lettuce, spinach, herbs, strawberries tomatoes and cucumbers[13].

5. Aquaponics System

Aquaponics is a generally known to use the combination of hydroponics and aquaculture to grow crops. This system uses the nutrient waste from the aquaculture water i.e., the fish waste and use it as a nutrient supplement for the crop and it is introduced hydroponically. According to studies and experiments undertaken, water derived from recycling of wastewater can also be used for the crops.

As per a research by Andreas Graber and Ranka Junge[14] (Andreas Graber, 2008), they observed the RAS system also known as recirculating aquaculture system that was established in an aquaponic farm located in Waedenswil, Zurich. During the study, three types of crops were observed and assess the nutrients absorbed from fish water waste.

[13] Modern Farmer online article on Aeroponics (Barth, 2018)
[14] An aquaponic research study on nutrient recycling undertaken in Zurich (Andreas Graber, 2008)

The setup consisted of trickling filters that is used for nitrification process of fish wastewater, which is basically a light-expanded clay mixture known as LECA that formed a 30 cm layer in vegetable boxes, supplying each surface for biofilm growth and crop production.

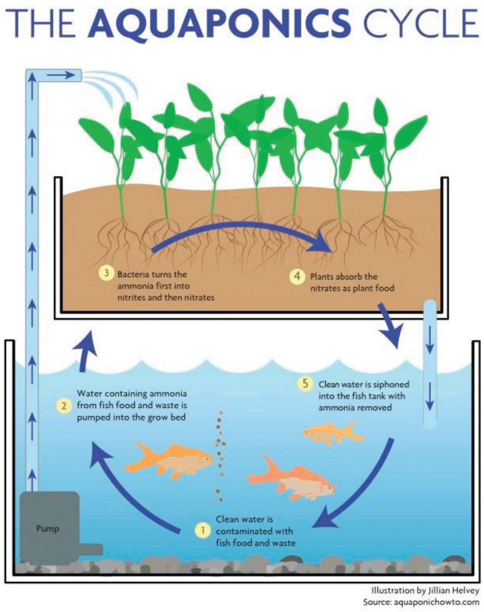


Figure 17. Aquaponics system concept(Picture taken from online site (Postma, 2017))

As seen in Figure 18. The setup is a closed RAS loop where fish feces was also used. It is said that the effluent from the fish tank was distributed in the LECA filter, and a standard sewage piping was levelled over the LECA rows where each of the boxes were irrigated through a drilling hole. They set the water rate to zero and the water that was evaporated was substituted with tap water. Hence, completing the closed loop system. The type of fishes used in this system were Tilapia and Eurasian perch[15]. And these were used in the tomato and cucumber cultures.

The crops used for the experiment were brinjal, tomato and cucumber which were fixed with the LECA filter and for a period between 45-105 days the nutrient removal was calculated from fish wastewater. It was found that tomato culture showed the highest rate of nutrient removal. After the experiment, it was found that 69% of the nitrogen content removal both hydroponically and aquaponic ally can be converted into fruit harvest. Therefore the yields in both hydroponics and aquaponics were similar.

[15] The fish species were Oreochromis niloticus and Perca fluviatilis

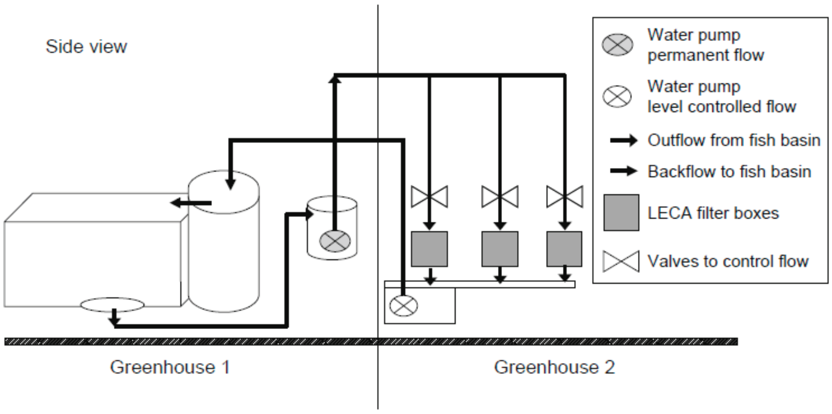


Figure 18. Aquaponic research unit in Zurich(Picture taken from (Andreas Graber, 2008))

6. LITERATURE STUDY

Over the years various organizations and companies have taken the initiative spread awareness on Urban agriculture technology as well as produce organic produce that is pesticide free and healthy.

Letcetra Hydroponic Farm, India

This is a hydroponic farming company known as Letcetra Agritech that was founded in the year 2016 (Naik, 2019). The company provides hydroponically grown harvests and also equipment for individuals who want to set-up their own at home hydroponic farm. Their main agenda is to promote pesticide free healthy produce.

Letcetra is one of the first hydroponic farming companies in India. They incorporate educational sessions for school groups as well as the general public regarding the advantages of the hydroponic system. As people are not aware of this type of farming, especially the farmers this leads to them being hesitant over using the technology. Therefore, Letcetra has taken an initiative to spread the knowledge as well as improve the current products.

(19a)

(19b)

Figure 19. (19a & 19b) Stack of grow tables growing crops (Pictures taken from Letcetra Website (Naik, 2019))

(a)

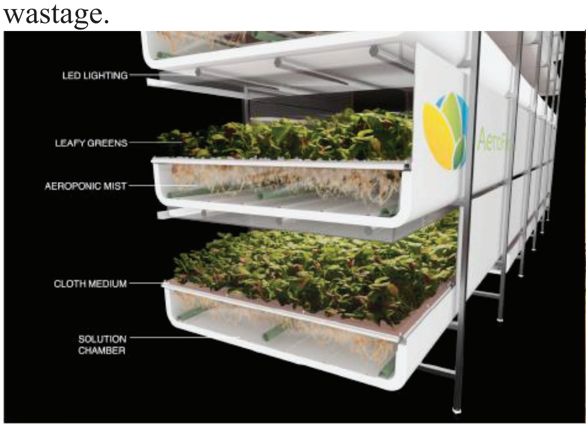
(b)

Figure 20. (20a & 20b) Letcetra Agritech hydroponic farm set up(Pictures taken from Letcetra website (Naik, 2019))

Aero Farms

Aero Farms is a company that specializes in indoor aeroponic farming. They grow crops that have been adapted to grow in controlled environment without sun or soil. They have mastered the growing system for crop harvests that are fast in growth cycles and produce successful harvests.

As mentioned earlier, the company uses the aeroponic system. They use a closed loop system where the water used is less that 95% of water that would generally be used in traditional farming fields and 40% less water than hydroponics. Since the crops are dependent upon misters, there is no wastage of water. LED lighting of specific frequency is provided for the crops to grow healthy harvest (David Rosenberg, 2019). As for the nutrient fertilizer, they have incorporated micro and macro nutrient formulae for the plants and after each harvest the data is collected and growth conditions are monitored. The growth medium used is a reusable cloth that is used for germinating, growing crop and harvesting. Therefore, the method of farming is sustainable since there is no wastage.



(21a)

(21b)

Figure 21.(21 a & b) Aero Farms aeroponic system set-up tray(Picture taken from AeroFarms website (David Rosenberg, 2019))

Agricultural robotics, Israel

Israel in known for using advanced technology in agriculture as well as taking initiatives to reduce the carbon footprint in the environment. Researchers have taken to using robotics to help monitor the conditions of the crops and also equip crop with automated timers to feed the crops with necessary supplements. Avital Bechar is a researcher whose aim is to derive possible solutions for agricultural problems in Israel. One of the issues stated is the large variation in growth pattern among products such as fruits, legumes, cereal etc. Therefore, technology is used to correct such errors. The proposed solution by the researcher and the team is a smart algorithm that can adapt to the environment regardless of the changes. They developed a smart robot known as iROBOT, this robot was placed in the pepper crop greenhouse to monitor the conditions and spray the required nutrients in a timely manner. And the data that is collected is reviewed, and researchers are able to get accurate readings on the plant conditions.

And the best thing about this invention is that, it is equipped with SONAR sensors, therefore there is no physical contact with the plant. It is an automated independent device.

(22a)

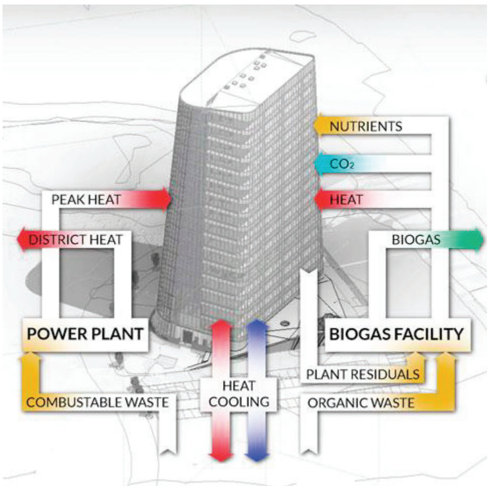
(22b)

(22c)

Figure 22.(22 a, b & c) iROBOTs placed in grow areas to assess crop conditions (Picture taken from IsraelAgri website (Bechar, 2018))

Plantagon

Plantagon is a Swedish company that was founded by Hans Hassle and the Native American indigenous people of Onondaga Nation in the year 2008. The company is known for building vertical farm projects, the project was taken place in Linköping. The concepts followed by Plantagon is to reduce use of artificial lighting through architectural design and an automated system of growing crops over conveyors that move continuously from top to bottom. Their main aim is based upon a vision of production large amount of produce that is able to feed a large population (Plantagon, 2019). The company offers Retro-fitting for office buildings/spaces, residential complexes, factories etc, Vertical façade installation, and they also offer concepts for new buildings that incorporated Vertical food production concepts. One of their concepts talks about a symbiotic system, a concept where an infrastructure combines cooling, heating, biogas, waste, water and energy with food production (PLANTAGON INTERNATIONAL, 2017).



(23a)

(23b)

Figure 23. (23 a & b)Symbiotic system and new building concept by Plantagon (PLANTAGON INTERNATIONAL, 2017)

Another concept proposed by the company is the introduction of CoolFarms, it is an enclosed vertical system with a clean and climatized environment where within the ideal conditions is used to grow seedlings, microgreens, leafy greens, herbs and flowers. Apparently the amount of water used is reduced by 90% when compared to traditional agriculture and there is no use of pesticides or herbicides.

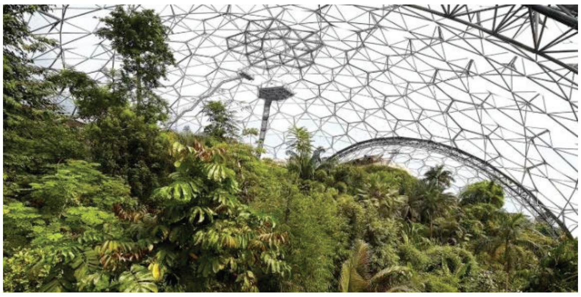
Figure 24. CoolFarm concept by Plantagon (PLANTAGON INTERNATIONAL, 2017)

Eden Project

The Eden Project is a famous attraction that is located in Cornwall, England, UK. It is a series of large domical structures that houses a controlled rainforest environment and a Mediterranean environment. It is said that the tropical Biome occupies an area of 3.9 acres and it is used to grow tropical fruit plants like bananas, coffee, rubber and bamboo. Whereas, the Mediterranean Biome occupies an area of 1.6 acres, since the climate is controlled at higher temperatures to mimic the actual conditions, it is used to grow plants such as olives, grape vines and other plants.

The dome structures are double-skinned structures consisting of steel tubular claddings. The shape is hexagonal and the external cladding material used is the ETFE thermoplastic material and it is very durable and light. Glass was avoided due to it's weight and future hazards. The cladded panels consists of several layers of the ETFE film. The Vector Foiltec company in known for supplying and installing the ETFE panels (Eden Project, 2019).

(25 a)



(25b)

(25c)

Figure 25. (25 a, b & c) Eden project in Cornwall (Pictures taken from (Eden Project, 2019))

Pasona Headquarters, Tokyo

The Pasona headquarters office which is located in Tokyo, it is said to be a 9 story high building that underwent a huge renovation (Andrews, 2013). The corporate office after its renovation consists of façade that incorporates a double skin with greenery, office spaces, auditorium, garden on the rooftop as well as urban farming technology integrated into the complex. The Urban farming technology is the most prominent features that the office boasts about. The farms harvests various species of fruits and vegetables as well as rice. The hydroponics system and soil based techniques are utilized for growing the crops, and the most notable feature in this complex is that the growing crops are a part of the interior spaces. Spaces such as the conference rooms, partitions between meeting spaces etc., all these spaces have tomato vines, fruit trees and creepers growing in the spaces.

(26 a)

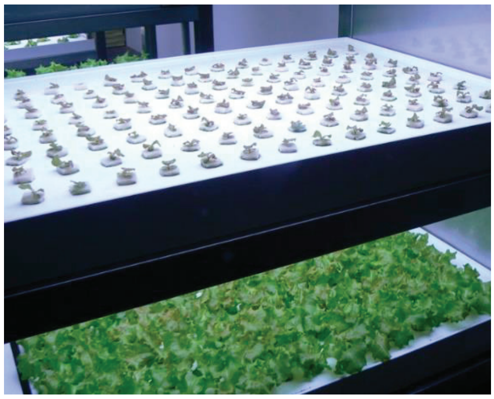
(26b) (26c)

Figure 26. (26 a-c) Pasona office interior spaces(Pictures taken from Dezeen Website (Andrews, 2013))

All of these crops have LED, HEFL, fluorescent and metal halide lamps attached to them. The interior temperatures are monitored regularly throughout the day. The main concept for incorporating urban agriculture was to bring in a healthy working environment for the employees. The blog talks about studies that show that the general population of 80% tends to spend time indoors. As it is commonly known that plants are able to clean the air by absorbing the carbon content, having greenery integrated within an interior space improves the quality of air. Hence this leads to a healthy environment visually, mentally and physically.

As seen in the images, the crops blend perfectly with the interior spaces of the office. The lighting lamps used also complement the spaces without looking gaudy and it also serves its purpose, providing light for the plant growth (Pasona H.Q. Tokyo, 2019).


(27a) (27b)


(27 c) (27 d & e)

Figure 27. (27 a-e) Grow room and interior spaces incorporating crops (Picturestaken from Dezeen website (Andrews, 2013))

Japan Grandpa Dome- Hydroponics farm

This hydroponic farm is located in Rikuzentakata, Japan. The farming is carried out within a dome structure. It consists of a conveyor belt in the center, exhaust fans are fixed inside so that the air is well ventilated. In case the interior is overheated, there are sprinkler that are fixed on the ceiling and sprays mists at gradual intervals.

The concept behind this system is based on the use of a conveyor belt onto which the crops are placed. In this set up, the young saplings are placed at the center of the conveyor and along the growth period of the plant, the crop gets pushed towards the end and it is collected at the end of its harvest. On one end the nutrient solution is continuously injected in to tube to supply nutrition for the crops (Hydroponic farm Japan Gandpa Dome, n.d.).

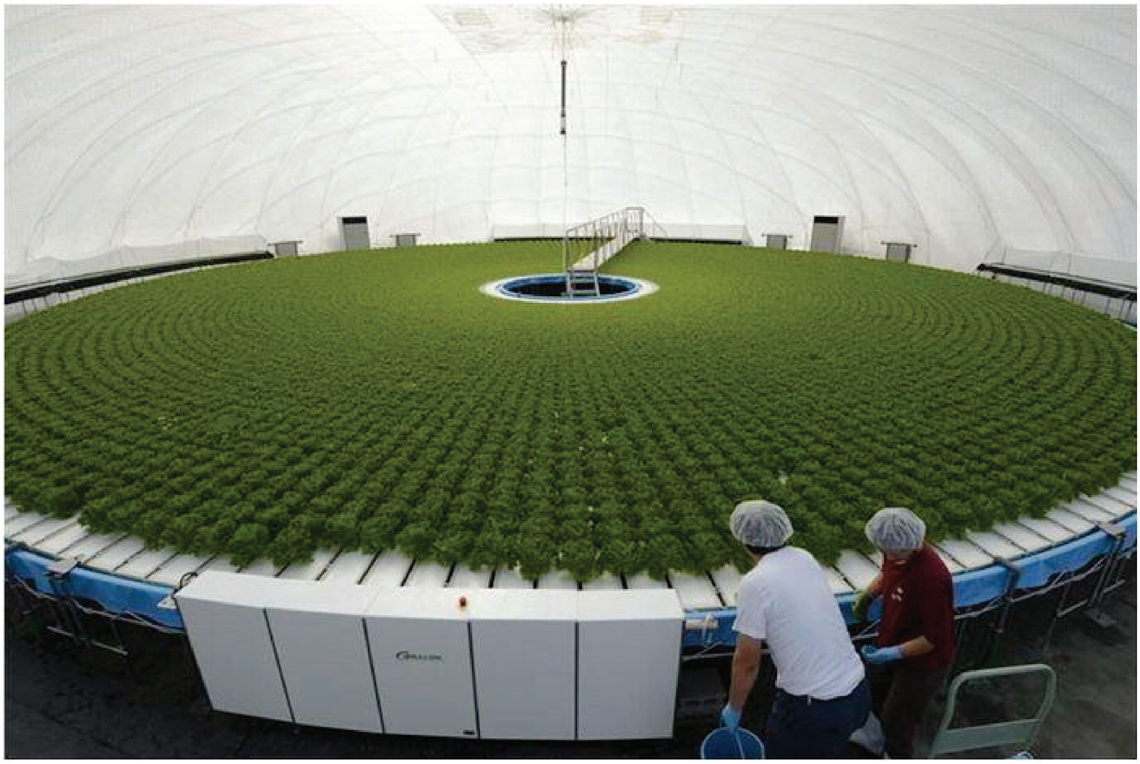


Figure 28. Grandpa Hydroponic Dome(Picture taken from (Hydroponic farm Japan Gandpa Dome, n.d.))

Hence the conclusion of the literature study on organizations that have incorporated urban technology to create a sustainable environment and also different methods of food production. Now we shall focus on the metropolitan city Bengaluru, capital of Karnataka. With reference of the earlier studies, my proposed design shall incorporate the necessary elements in the design.

7. BENGALURU STUDY

The city of Bengaluru (also known as Bangalore) is situated in the Southern part of India in the Indian state of Karnataka. A common known fact is that the city is a land-locked city that is situated upon the Deccan Plateau. The city is divided into two sectors, Bangalore Urban And Bangalore Rural. As mentioned earlier, the city is land locked, therefore it is dependent on rivers and lakes for water supply. The Kaveri river is the main source of water for the city which falls under 80% and the remaining 20% belongs to other river tributaries.

According to an article, the topography of the city is flat mostly, with the exception of slightly hill region in the western part of the city. It is said that the plateau of Bangalore used to be an area filled with grassland and thorn forest. The city originally had a low percentage of trees, at a much later time the initiative was taken to plant trees and build water reserve tanks to supply water to the city. And thanks to these efforts, the city was rich in greenery and is blessed with moderate climate throughout the year. Until recently, due to the urbanization boom in the city, in order to contain the growing population, the limits of the city is stretching into the rural area (Bangalore geography and environment, 2019).

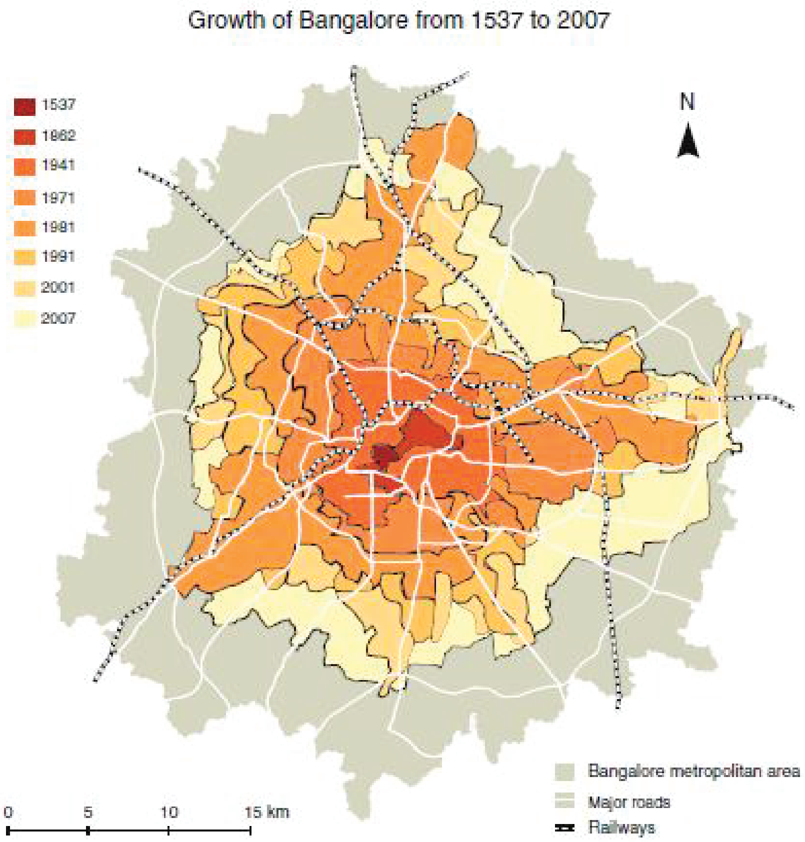


Figure 29. Spatial growth of the City(Picture taken from (Sudhira, 2013))

As per city urbanization study, the population of Bangalore as of 2011 was 8.4 million. The population has grown upto 47% over a duration of 10 years. Hence, the city is known to be one of the fastest growing cities *(S, 2016)*. Current studies show that the current population of the city is 12 million.

Bangalore Population Data (Urban Area)

Year	Population	Growth Rate (%)	Growth
2035	18,065,541	2.17%	1,838,715
2030	16,226,826	2.42%	1,831,383
2025	14,395,443	3.15%	2,068,911
2020	12,326,532	3.74%	443,866
2019	11,882,666	4.04%	1,741,586
2015	10,141,080	4.10%	1,845,516
2010	8,295,564	4.10%	1,509,663
2005	6,785,901	3.99%	1,204,638
2000	5,581,263	3.26%	827,035
1995	4,754,228	3.30%	711,630
1990	4,042,598	3.54%	645,384
1985	3,397,214	3.85%	584,786
1980	2,812,428	5.91%	701,829
1975	2,110,599	5.50%	495,843
1970	1,614,756	3.23%	237,442
1965	1,377,314	3.39%	211,336
1960	1,165,978	4.42%	226,582
1955	939,396	4.72%	193,397
1950	745,999	0.00%	

Figure 30. Population rise in Bangalore over the years (Picture taken from (S, 2016))

Climate

The general climate of Bengaluru is tropical climate and it was known as the Garden city of India due to its green cover and pleasant climate. And due to the elevation of the city(2,953 ft), the city enjoys a moderate climate all year long with few heat waves during summer. The minimum temperature during the month of January is 15º and the temperature in April is at an average level of 35º as it is known to be the hottest month.

Bengaluru receives plenty of rainfall during the monsoon season from both northeast and the southwest monsoon periods.

Climate data for Bangalore													[hide]
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	32.8 (91.0)	35.9 (96.6)	37.3 (99.1)	39.2 (102.6)	38.9 (102.0)	38.1 (100.6)	33.3 (91.9)	33.3 (91.9)	33.3 (91.9)	32.4 (90.3)	31.7 (89.1)	31.1 (88.0)	39.2 (102.6)
Average high °C (°F)	27.9 (82.2)	30.7 (87.3)	33.1 (91.6)	34.0 (93.2)	33.3 (91.9)	29.6 (85.3)	28.3 (82.9)	27.8 (82.0)	28.6 (83.5)	28.2 (82.8)	27.2 (81.0)	26.5 (79.7)	29.6 (85.3)
Average low °C (°F)	15.8 (60.4)	17.5 (63.5)	20.0 (68.0)	22.0 (71.6)	21.7 (71.1)	20.4 (68.7)	19.9 (67.8)	19.8 (67.6)	19.8 (67.6)	19.6 (67.3)	18.0 (64.4)	16.2 (61.2)	19.2 (66.6)
Record low °C (°F)	7.8 (46.0)	9.4 (48.9)	11.1 (52.0)	14.4 (57.9)	16.7 (62.1)	16.7 (62.1)	16.1 (61.0)	14.4 (57.9)	15.0 (59.0)	13.2 (55.8)	9.6 (49.3)	8.9 (48.0)	7.8 (46.0)
Average rainfall mm (inches)	1.9 (0.07)	5.4 (0.21)	18.5 (0.73)	41.5 (1.63)	107.4 (4.23)	106.5 (4.19)	112.9 (4.44)	147.0 (5.79)	212.8 (8.38)	168.3 (6.63)	48.9 (1.93)	15.7 (0.62)	986.8 (38.85)
Average rainy days	0.2	0.4	1.1	3.1	6.7	6.2	7.2	9.9	9.8	8.3	3.8	1.4	58.1
Average relative humidity (%)	60	52	30	43	60	72	76	79	76	73	70	68	63
Mean monthly sunshine hours	262.3	247.6	271.4	257.0	241.1	136.8	111.8	114.3	143.6	173.1	190.2	211.7	2,360.9

Figure 31. Record of climatic conditions in Bengaluru(Picture taken from Wikipedia (Bangalore geography and environment, 2019))

Issues in the city

According to a recent study on the land-use planning of Bangalore, the revised Master Plan-2031 by BDA states that the city will have 20.3 million residents residing in the city. And BDA had allowed 277 sq.km of agricultural land to be used for Urban expansion (Bharadwaj, 2017). Due to this urban sprawl, the forest zones are decreasing.

In recent studies various issues have come into the picture, such as loss of green cover due to urbanization, depletion of the ground water table, contamination of lakes etc. A paper on Land Use policy talks about vulnerable zones in the city that has started to experience increased number of hot days *(Bureau, 2016)*. Due to the ever growing population in the city, the urban zone limits of the city has extended into the rural zone in order to meet with the housing and other aspects of the population. This has caused loss in farm land and farmers are either selling their land to builders of migrating to different zones.

A news article talks about a farmer in Bangalore who uses the contaminated water from a lake to grow his spinach crops since he has no other method of getting a cleaner source for his crops *(The urban farmers battling Bangalore's concrete jungle, 2017)*.

T.V.Ramachandra a professor talks about the issues of pollution in the city[16]. He states that in his study on vegetable, it was found that there were high level of metal elements found in the products. This is due to untreated water used for growing the produce.

[16] T.V. Ramachandra is a professor at the Indian Institute of Science (The urban farmers battling Bangalore's concrete jungle, 2017)

As per the Department of Agriculture in Bangalore, due to the IT boom there has been a distinct decrease in farmland from 0.1 millionn hectares in 2000 to 0.04 million hectares by the year 2015. Which shows that the production of vegetables has gown down by a large percentage.

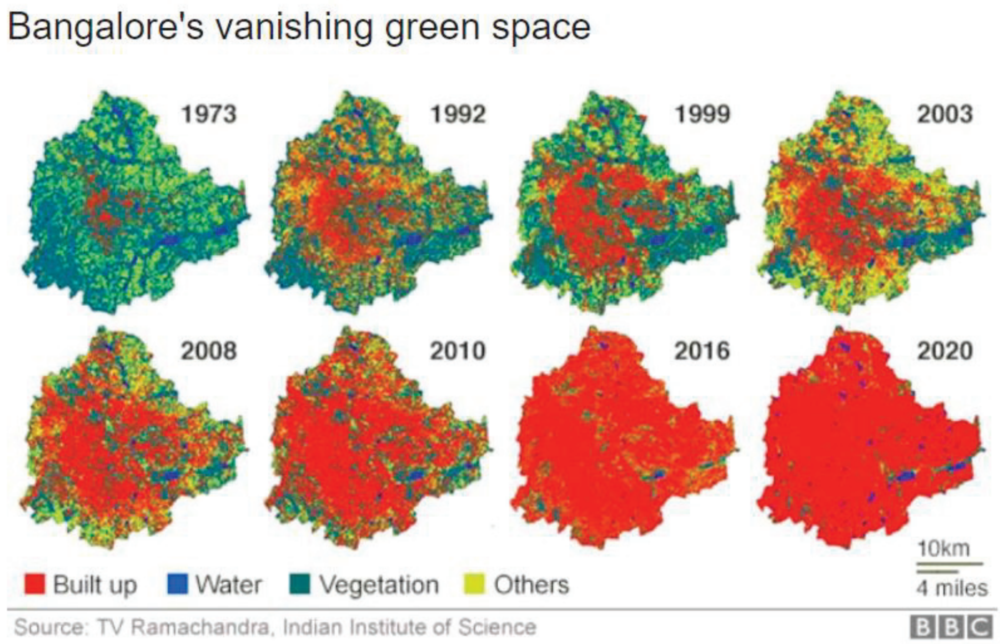


Figure 32. Bangalore's disappearing green spaces as per T.V. Ramachandra (The urban farmers battling Bangalore's concrete jungle, 2017)

Figure 32 shows a clear picture of the impact urbanization has had on the once green city. Therefore, a possible solution must be introduce to help combat one of the main issues that is affecting the city. And based upon the new technologies for alternative farming techniques and literature studies on projects undertaken for successful crop production.

People want to have access to healthy and fresh produce, we want to live in a clean environment free from any kind of pollution, hence many small time organizations have taken to create an awareness about the potential dangers in the future.

Which is why the proposal of a high rise Vertical farm may be the key for future solutions. The proposed design is situated in the Bangalore urban sector, it is placed in a location that has easy access and can generate a wide awareness among the general population. This is also a potential source of employment for the farmers who are unable to continue performing their traditional methods of farming. They can learn this new technology and implement the techniques on their own.Recently, people have taken to installing their own little vegetable gardens in their homes. Through awareness, people can have their own set up of hydroponic farm in their back yards or balconies.

The following study will talk about the location of the proposed design and the advantages of proposing in the specified area.

8. SITE LOCATION AND STUDY

The proposed site is located in Bangalore East. It is a public zone, where the land belongs to the Karnataka Trade Promotion Organization(KTPO) . It is a trade expo that is funded by the Government of Karnataka. And the total plot area is 50 acres. Based upon the requirements of the proposal, I have considered an area of 10000 sqm which is approximately 3 acres.

The plot is surrounded by various zones such as the industrial, commercial and residential zones. Within the site, there is an existing structure which is the main Expo center (KTPO). The place is very active as there are regular events taking place at the Expo. Therefore, I propose a vertical farming complex within the plot. The idea is that it can be funded and run by the government of Karnataka. Since farming is one of the main occupation of the state due to the large rural percentage. The vertical farming complex can be the solution to help counter loss of farm land. As there is already an existing Expo within the site, the new inventions developed in the proposed complex can be put on display in the Expo which in turn helps in generating a lot of attention towards this solution of urban farming.

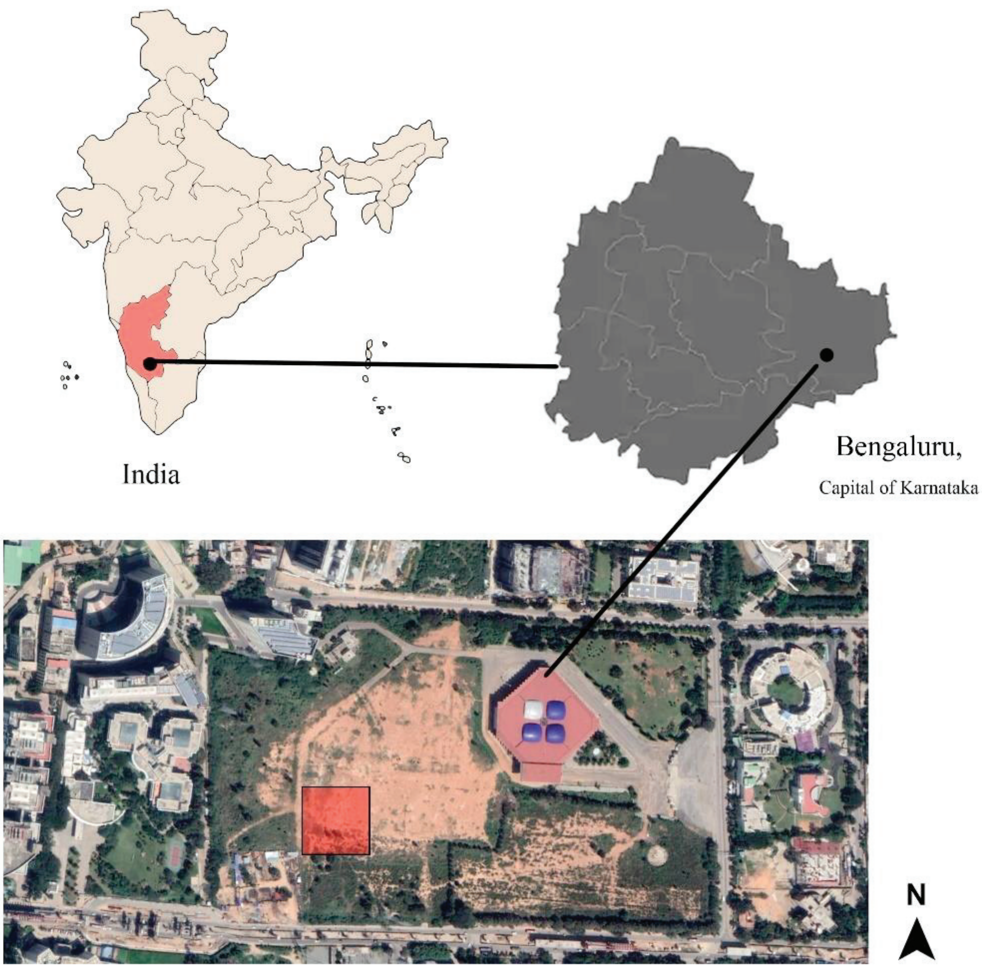


Figure 33. Location of site (Image taken from GoogleEarth)

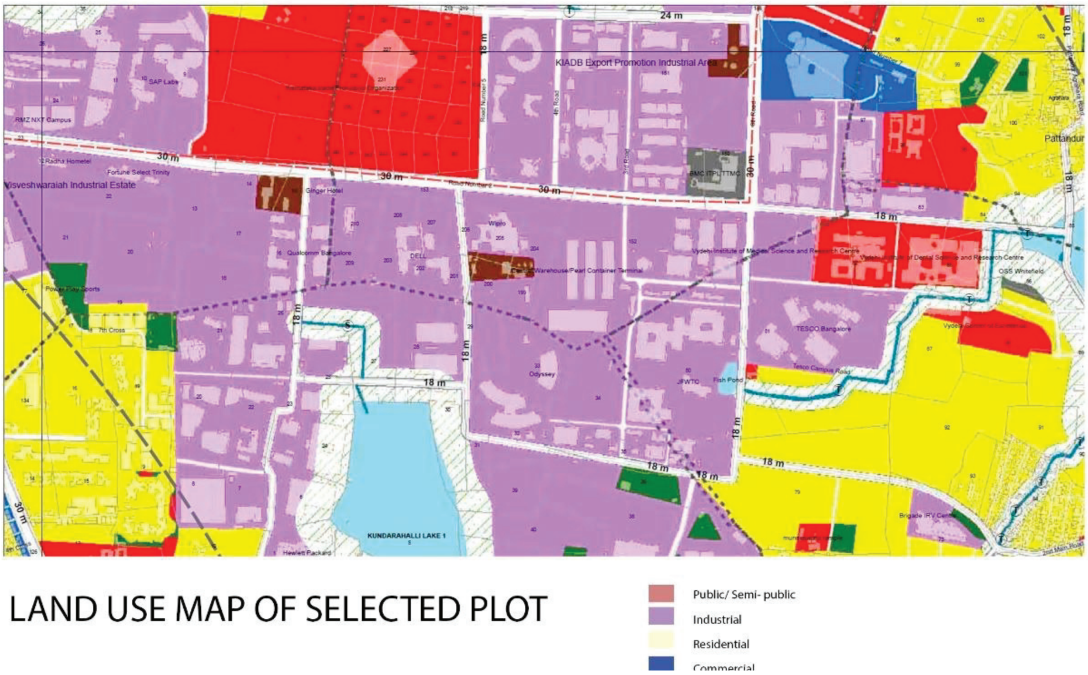


Figure 34. Screenshot of selected area showing the zones surrounding it, Main map scale is in 1:5000 scale (Picture from main Land Use BDA Map (BDA Revised Master Plan 2031, 2017))

The total site measures about 50 Acres and the plot selected within the complex measures upto 3 Acres. Within the selected area, I am proposing vertical tower that serves various purposes both for the public as well as the private sectors. After creating a rough grid of 100 x 100 m, I selected the plot for the proposed design.

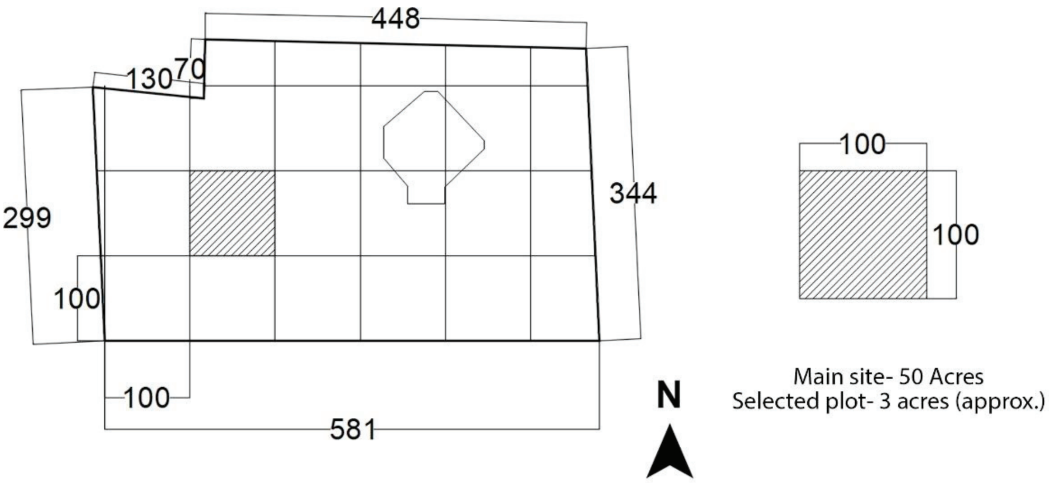


Figure 35. Site dimensions

9. PROPOSED DESIGN AND ANALYSIS

The general concept was to create a complex that would serve multiple functions. It is divided into various sectors, the public zone and private zone. The public zone consists of The general supermarket, restaurant, workshops and seminars. While the private sector consists of the main experiments zone, grow rooms, offices etc. Based upon various studies and experiments on crops that have been successful, the following list consists of the types of crops to grow within the complex. As there are many varieties in the tomato, lettuce and spinach crops, the idea is that during the end of every cycle, a different variety will be produced accordingly. Also the fish pool proposed in front of the building, the main purpose is to use the nutrient waste produce and have it circulated throughout the building.

The main concept was to create a self-sustaining building that is able to reuse water by treating it, meaning that there is a unit that treats grey water, wastewater from fish water and plant nutrient waste, rainwater and the excess solution that is left by the plants. Inclusion of compost pits and biogas plus methane digesters where the organic waste is converted to produce biogas and the gas is later converted into electrical energy to help run the complex.

List of Plants considered

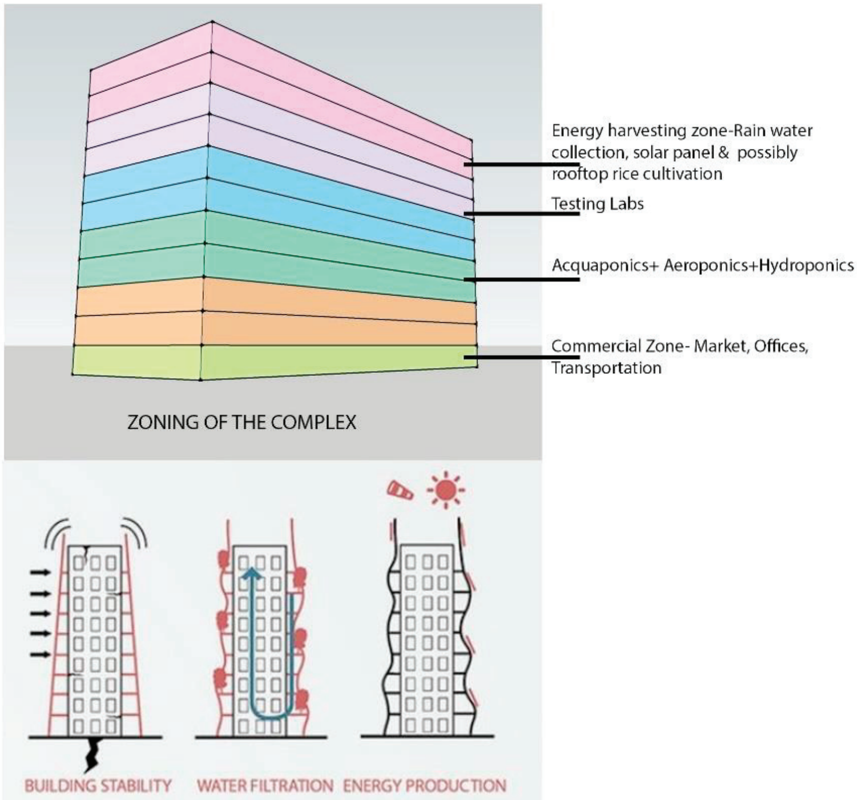
CROP	SCIENTIFIC NAME
Tomato	Solanum lycopersicum
Lettuce	Lactuca sativa
Spinach	Spinacia oleracea
Beans	Phaseolus vulgaris
Onions	Allium cepa
Potatoes	Solanum tuberosum
Carrots	Daucus carota subsp. sativus
Capsicum	Capsicum annuum
Radish	Raphanus raphanistrum subsp. sativus
Squash	Cucurbita maxima
Pumpkin	Cucurbita moschata
Herbs- cilantro, mint, parsley, basil etc.	Coriandrum sativum, mentha piperita etc.
Strawberries	Fragaria x ananassa
Cucumber	Cucumis sativas
Blueberries	Rubus fruiticosus, Vaccinium cyanococcus stc

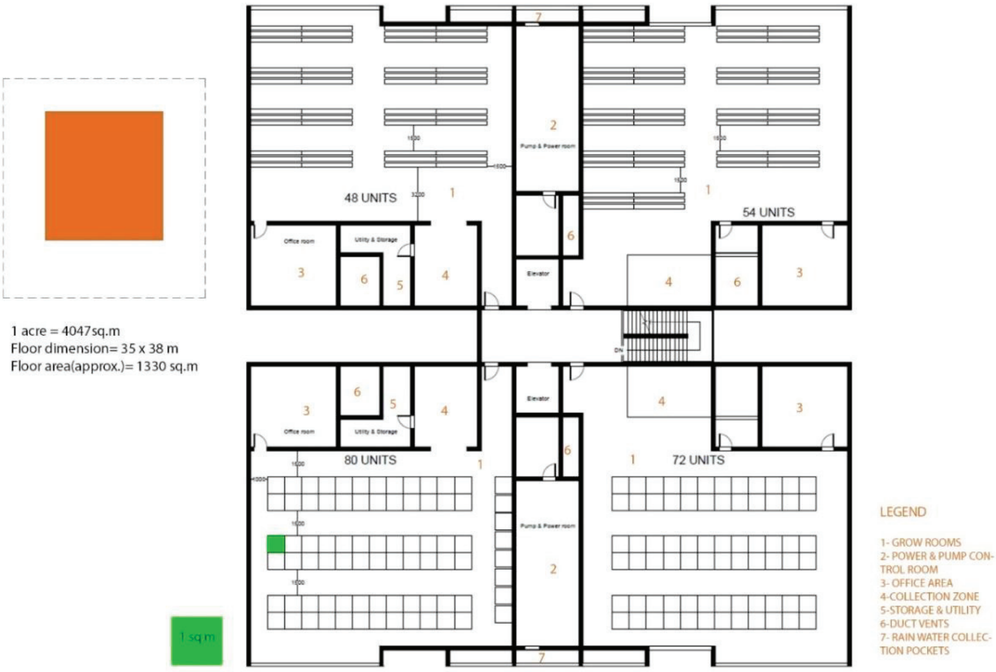
Artificial lighting for Vertical farming
Artificial lighting is very important for the growth of healthy crops. There are a variation of lights that are used according to the conditions of the plant (Leblanc, 2019).

- Fluorescent grow lights- These age said to good for growing herbs and are available in two type, fluorescent tubes and Compact Fluorescent Lights (CFLs). CFLs consume only 30% of energy and have a long lifespan.
- HPS Grow lights- High Pressure Sodium lights are said to be more common in use for commercial production of urban farming. Although it produces a lot of heat, it works well for sturdy planters.
- LED grow lights- These are the most efficient type of lighting used for the planters. When compared to CFLs, they are said to be more efficient.

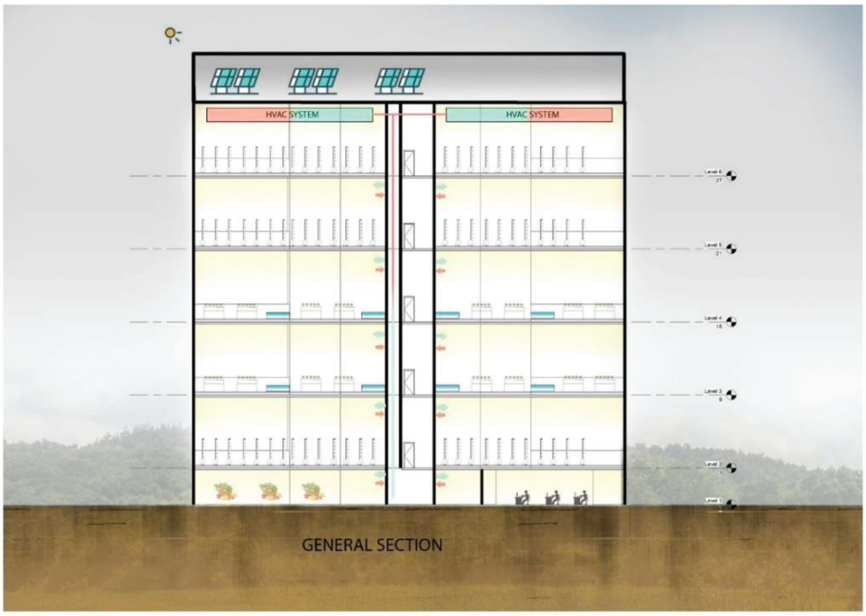
Scematic concepts, zoning and Design detail

The following building zoning shows the initial idea on space division and purpose on every floor. And also the idea was to create a modular design that can be placed anywhere and easy to execute. This is a single unit that is meant to feed a large community. Hence this modular unit can be placed in cities with different climatic conditions since the environment within the complex is artificially controlled. And the design of the building is a tall tower with grow rooms on every floor producing “n” times more harvests when compared to traditional farming techniques.



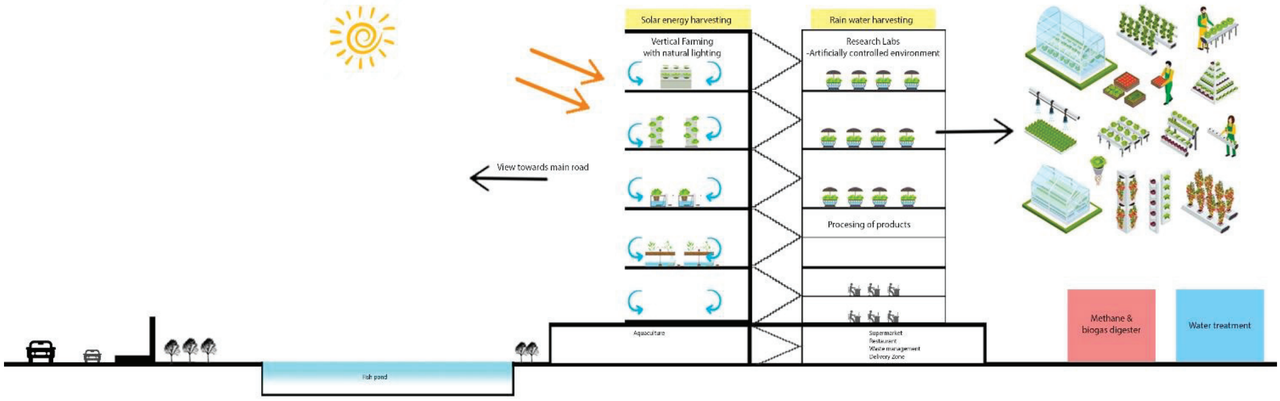


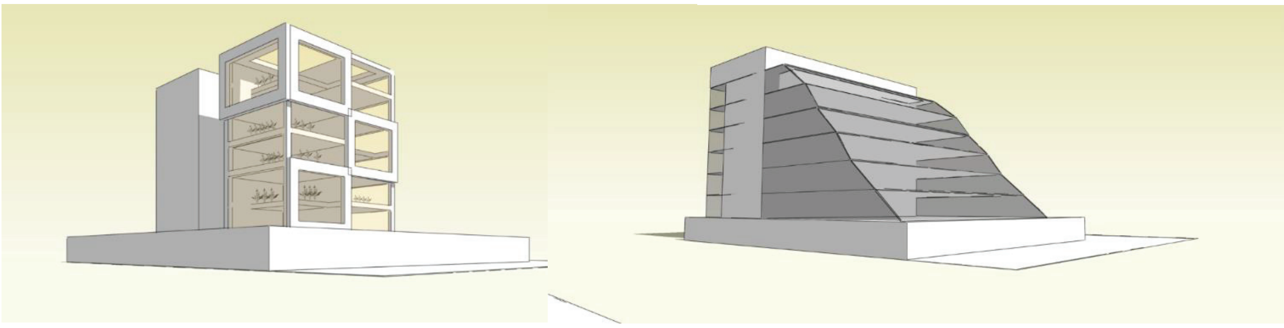
TYPICAL FLOOR PLAN LAYOUT



In the above mock plan and section, the first idea that I had in mind was to create 4 divisions of grow spaces, each zone would consist of different type of grow system, for example the four different hydroponic system would be installed and different crops would be grown in each zone like tomato, cucumber, brinjal and lettuce. And each zone has common control room where the temperature and supplement provision for crops would be controlled according to crop condition. And these would be grown in multiple layers. As seen in the section, except for the ground floor where the proposed supermarket is situated, the floors above is used for cultivation purposes.

Urban Agriculture- Farming Vertically within a multi-storeyed Complex





The pictures depicted show the later progress in design ideas. The next idea was to create a 2-zoned complex where we can mass produce harvests are sell commercially and also have a testing zone of potential future crops.

The proposed method is meant to be a cost-effective method since there is no need for transportation of the products as there is a proposed supermarket within the complex where the products are sold. As seen in the side section, there is a zone for cultivating fish, the fish waste water is used as nutrient for the aquaponic crops.

There is also the proposed Anaerobic digester where all of the biowaste would be collected and transferred to the unit and the waste would be converted into energy. This would in turn help in running the facility.

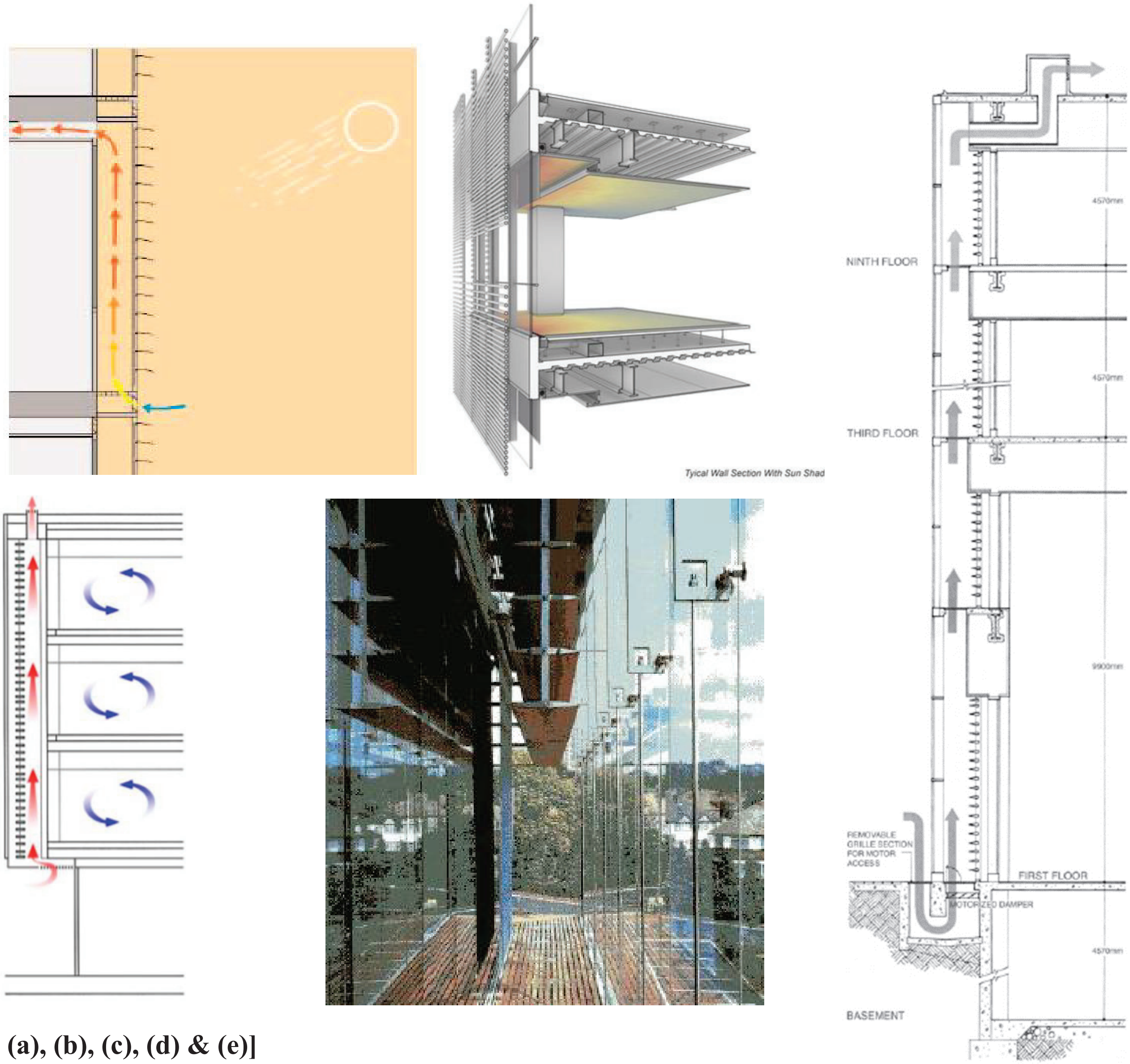
Hence, creating a closed loop system similar to the Symbiotic System concept adopted by the Plantagon company. And this will be a general module that can be built in any space within a city and help produce large amount of food that can feed a huge community. It can also be a place of employment for farmers and other.

The above designs show the initial concept of grow rooms and exterior façade treatment. The grow tables were initially in a single layer consisting of multiple rows of grow trays to grow crops in an area. And another area would consist of vertical modules that would support multiple number of crops.

The concept of the façade design in the picture was supposed to incorporate cladded shading devices that works on an automated system. The cladding is lightweight steel structures that would shade the building and change directions according to the sun movement and intensity of the solar radiation.

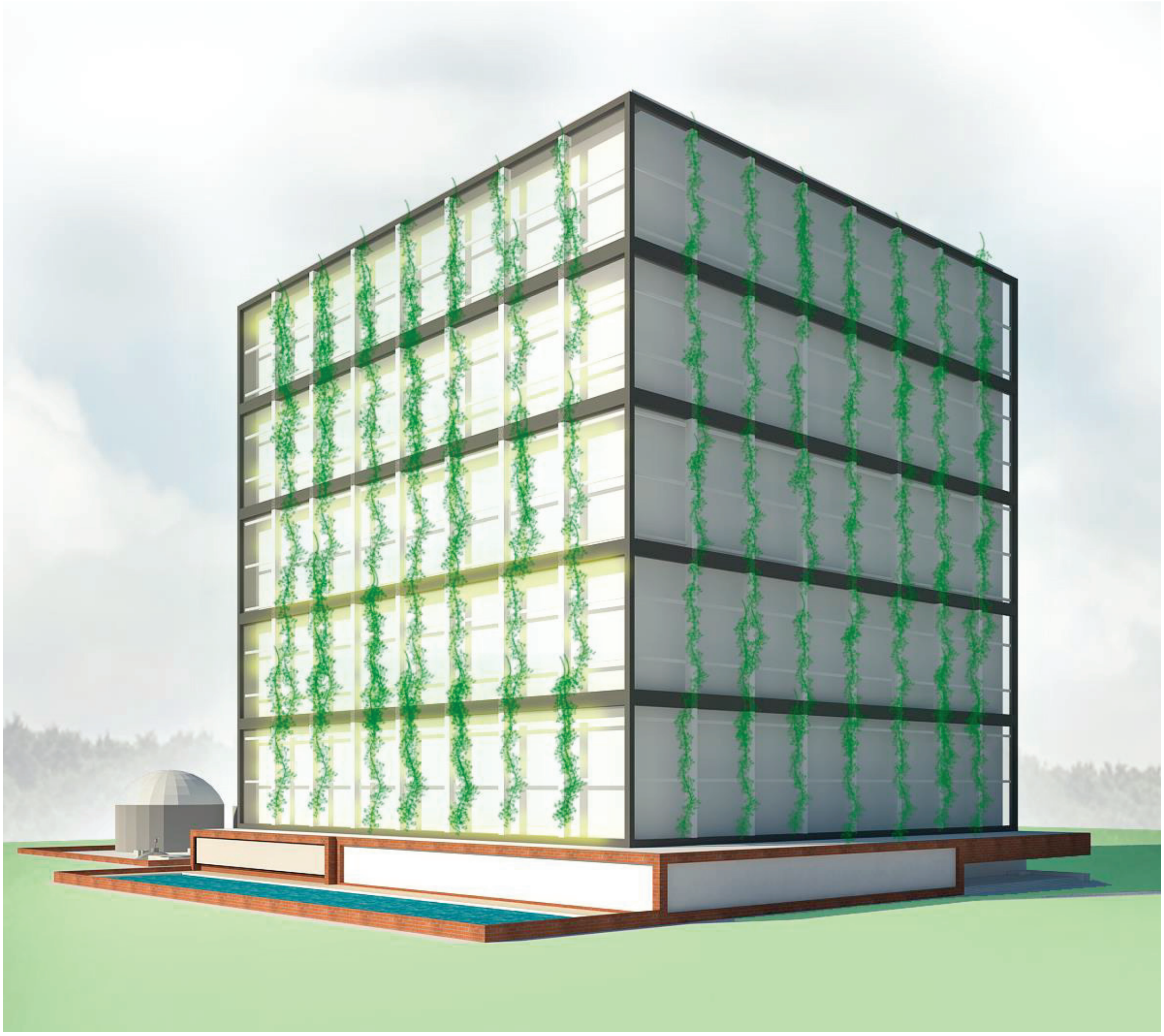
Double-skin façade- Façade treatment option 1

For the façade treatment of the proposed building, the double skin treatment works best. This façade consists an external surface with double glazing of glass. The space between the glass is offset at a particular distance for ventilation purpose. The advantages of this type of treatment is that it provides good ventilation system, energy saving, sound proof, wind barrier, protection from pollution and also blocks out/ reduces the intensity of solar radiation (Asdrubali, 2014).
The ventilation space is driven by the buoyancy effect.



[36 (a), (b), (c), (d) & (e)]

Figure 36.(36 a-e) Double Skin facade with glass, (Asdrubali, 2014)



The above picture shows the initial idea of using the double glaze façade. The exterior would be treated with two layers of glass with a gap of 1m in between. The gap is meant for the circulation of air, which helps in cooling down the amount of heat absorbed and reducing the intensity of the solar radiation. For further cooling, The idea I had in mind was to install vertical poles with horizontal planter box to grow vines, this was intended to reduce the radiation even further. Hence keeping the building cool and protecting it from sun, air pollution and noise. The East and South facing sides are treated with this type of treatment as these sides are mainly affected by the solar radiation. The west side of the building consists of the main services zone and ducts concealing service lines, therefore it does not need any additional treatment. The general structural build of the building consists of the local concrete slab and column construction and all raw materials are available locally.

The HVAC system and artificial lighting is incorporated within the structure is used for artificially controlling the environment inside the building according to the crop conditions. The fish pool is situated in front of the building and provides a scenic view from the gallery.

Double-skin Green façade- Façade treatment option 2

Due to concerns regarding the environment, the idea to grow a green cover over the building façade helps with the topo-climate of the environment. Many studies talk about the advantages of having vegetation on the building façade, such as thermal impact and temperature reduction, shading and insulating, evaporative cooling and effect of wind on the building. It is said that the vegetative cover can reduce the building temperature by shading the exterior from sun radiation by 50 %. Through the process of evapotranspiration, the huge amount of sun's radiation would be converted into latent heat therefore rendering the rise in temperature. In regards to shading treatment, an experiment that is known as "Bioshader" was conducted at the University of Brighton, here an office space was used. The window was covered with vegetation and the change in temperature was noted. The reduction of temperature was between 3.5ºC to 5.6ºC, and solar radiation was reduced by 37% for a single layer of vegetative cover and upto 86% with five layers of vegetative cover (Dr. Samar Mohamed Sheweka, 2012).

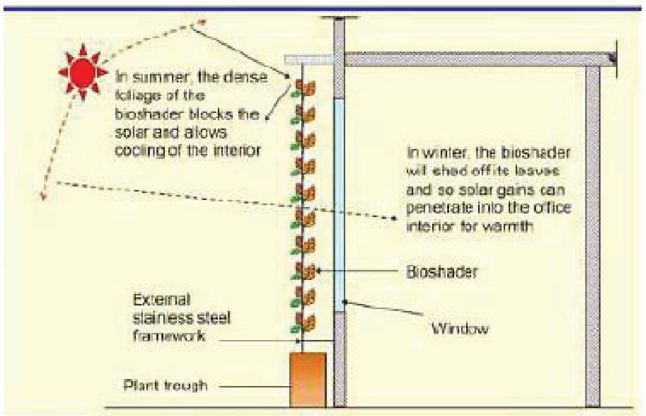
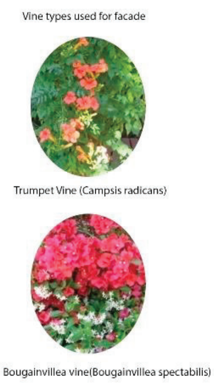
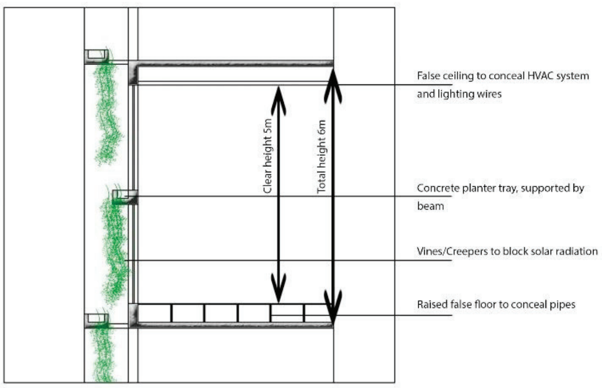
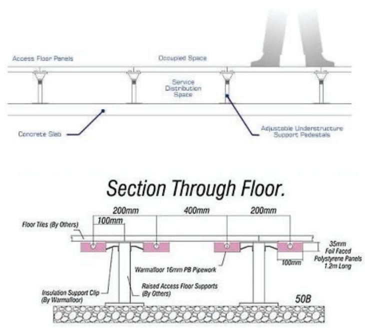


Figure 37. Greening of exterior facade (Dr. Samar Mohamed Sheweka, 2012)

Therefore, after considering the pros and cons of the type of façade that will benefit the environment, I have decided to use this method of façade treatment for the designed tower.







Also taking inspiration from the façade treatment of the Pasona office and Eden project, the façade is treated with horizontal rows of planter boxes which will support the creeper plants that will grow vertically downwards according to gravitational pull. This method reduces the strain of making the plant grow upwards. This layer of foliage is the first layer. And the second layer is on the interior side and it consists of the glazing. The common glazing used is glass as it is commonly available and easily installed. Another option for the glazing treatment is using ETFE which is also known as Ethylene tetrafluoroethylene. It is a fluorine based plastic and was designed to have high corrosion resistance and durable under high temperatures. The ETFE panels were incorporated in the Eden project. Depending upon the availability, it is known to be a better alternative to glass.

Space Requirement Specifications

Area Considered: 3 acres

Space divisions:

No.	Space	Area (sqm)
1	Museum	4000
2	Supermarket	1270
3	Storage (Supermarket)	350
4	Equipment Store	250
5	Classrooms	460
6	Workshops	890
7	Seminar room	240
8	Office	1060
9	Conference/ Meeting rooms	1000
10	Restaurant	1240
11	Grow Rooms	33000
12	Rooftop farm	1200
13	Laboratory	15150
14	Collection & Preparation	4875
15	Control room & tank room	2500
16	Germination room	10500
17	Rainwater collection	1000
18	Solar energy harvesting	2000
19	Water treatment	315
20	Loading/Unloading dock	150
21	Biogas Digester	1400
22	Fish Pool	1500

Design of floor levels

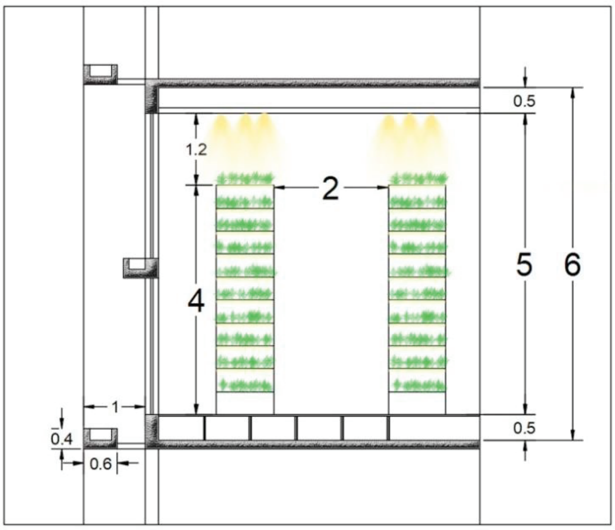
There are 15 floors in total in the proposed tower. The base of the tower is wider and consists of 3 levels. The floors starting from third floor level upto roof level is more slender and consists of the remaining levels and it is the main private sector that houses the lab zone as well as grow zone.

- Basement floor- Service zone consisting of Electric control, waste management, production area and loading/unloading.
- First & Second Floor- Main Public sector consisting of Supermarket, Museum, Aquaponic center connected to the fish pool, administration zone and workshop zone for the public.
- Typical Floor- This zone is divided into the main testing area and the grow zone. The potential crops are tested in the labs and based upon the success rate of the tested crops, the seeds are cultivated in a germination room and the saplings are transferred for main production.
- Roof level- Proposed rooftop restaurant with rooftop farm, solar harvesting zone and rainwater collection zone.
- Anaerobic Digester- Proposing the Biogas + Methane digester and water treatment zone.

Crop Yield Calculation

Method of estimating crop yield

As per a rough calculation stated in a study (Dickson, 2009/11/01), it is said that a 30-storey building would provide 150 acres of land vertically. And by stacking layers of crops the amount of yeild would be multiplied "n" times.



Therefore, by combining these facts, a multiplying factor pf 16 is considered, hypothetically each floor considers 4 growing seasons, double the plant density and 2 layers per floor equates to 16 (4*2*2=16)[17].

Hence a 30 level building in one city block would produce 30 floors* 5 acres* 16=2,400 acres of food produced.

Therefore, the number of levels considered for this design is 15 levels, with a little more than1000sqm of spaces for multilayer grow space. About 10 layers of grow layers is considered for mass production of the crops, hence 10 times the density of crops. As per India meteorological department, it is stated that India has 4 season, whereas the astronomical and other traditional charts state that there are 6 season.

For the purpose of calculation, four growing seasons is considered. Therefore, the multiplying factor used is 400 (4 * 10*10=400).

Number of levels in building= 15

Total area of grow space= 18.5 acres

Multiplying factor= 400

Hence, Amount of food produced= 15* 18.5* 400= 1,11,000 acres of food.

In conclusion, the amount of food generated in the tower is capable of feeding a large community. If one structure is able to produce this big amount, then multiple centers of vertical food production complexes in different zones in metropolitan cities can help reduce the pressure on land.

[17] Rough calculation for food procuction (Dickson, 2009/11/01)

Figure 38.Master plan, sclae in 1:100 (Illustrated in Adobe photoshop)

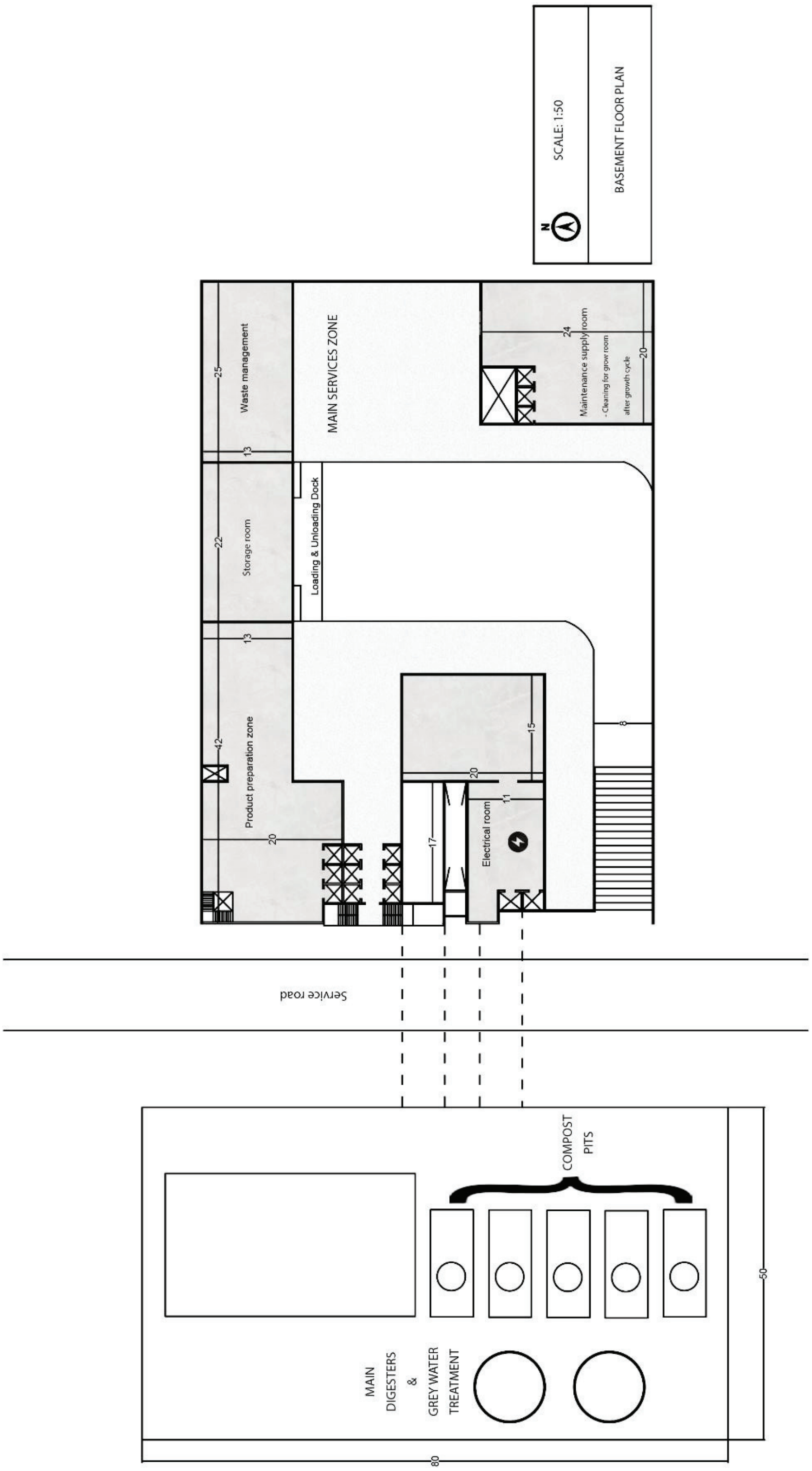


Figure 39. Basement Floor plan (Illustrated in Adobe photoshop)

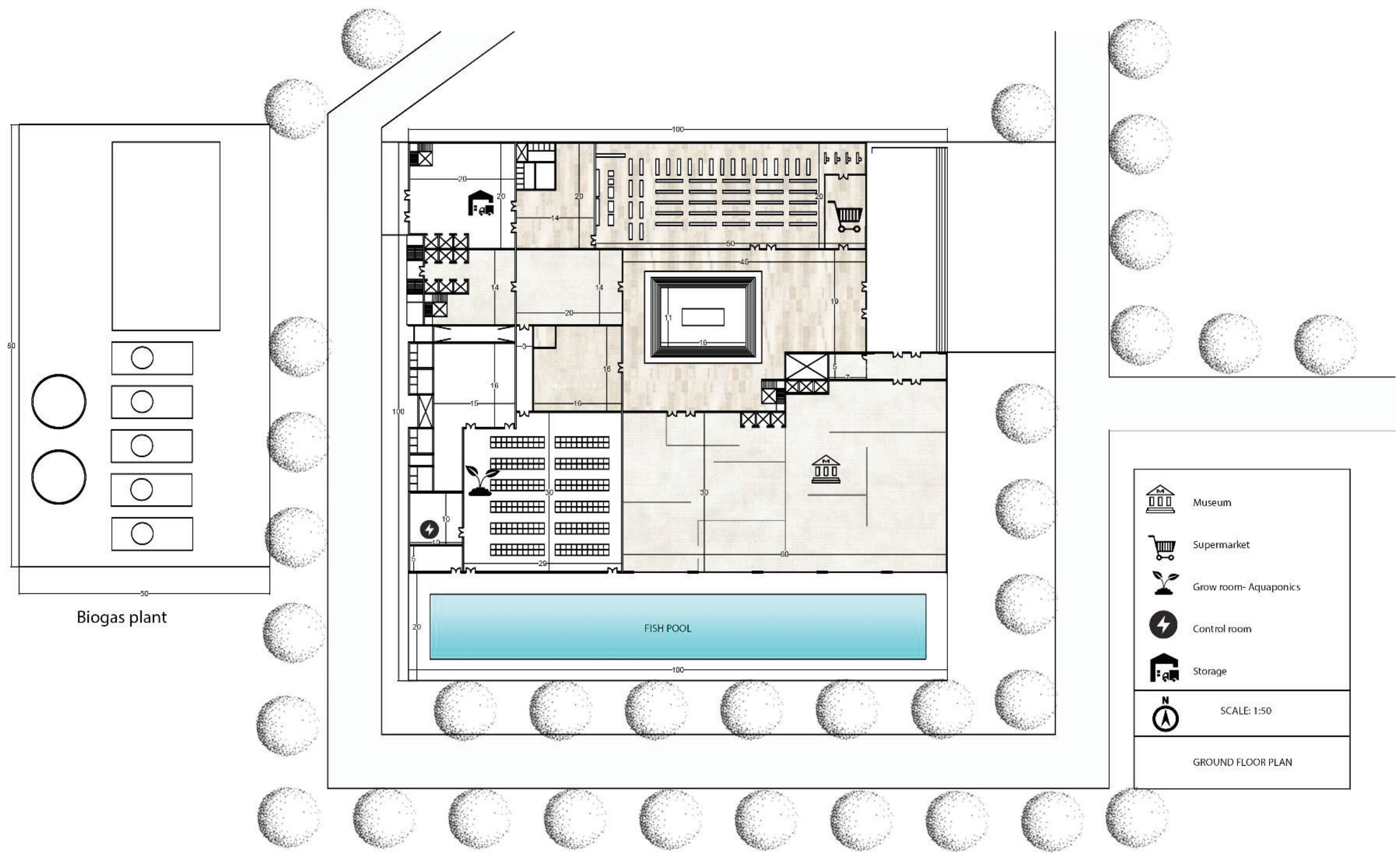


Figure 40. Ground Floor Plan (Illustrated in Adobe Photoshop)

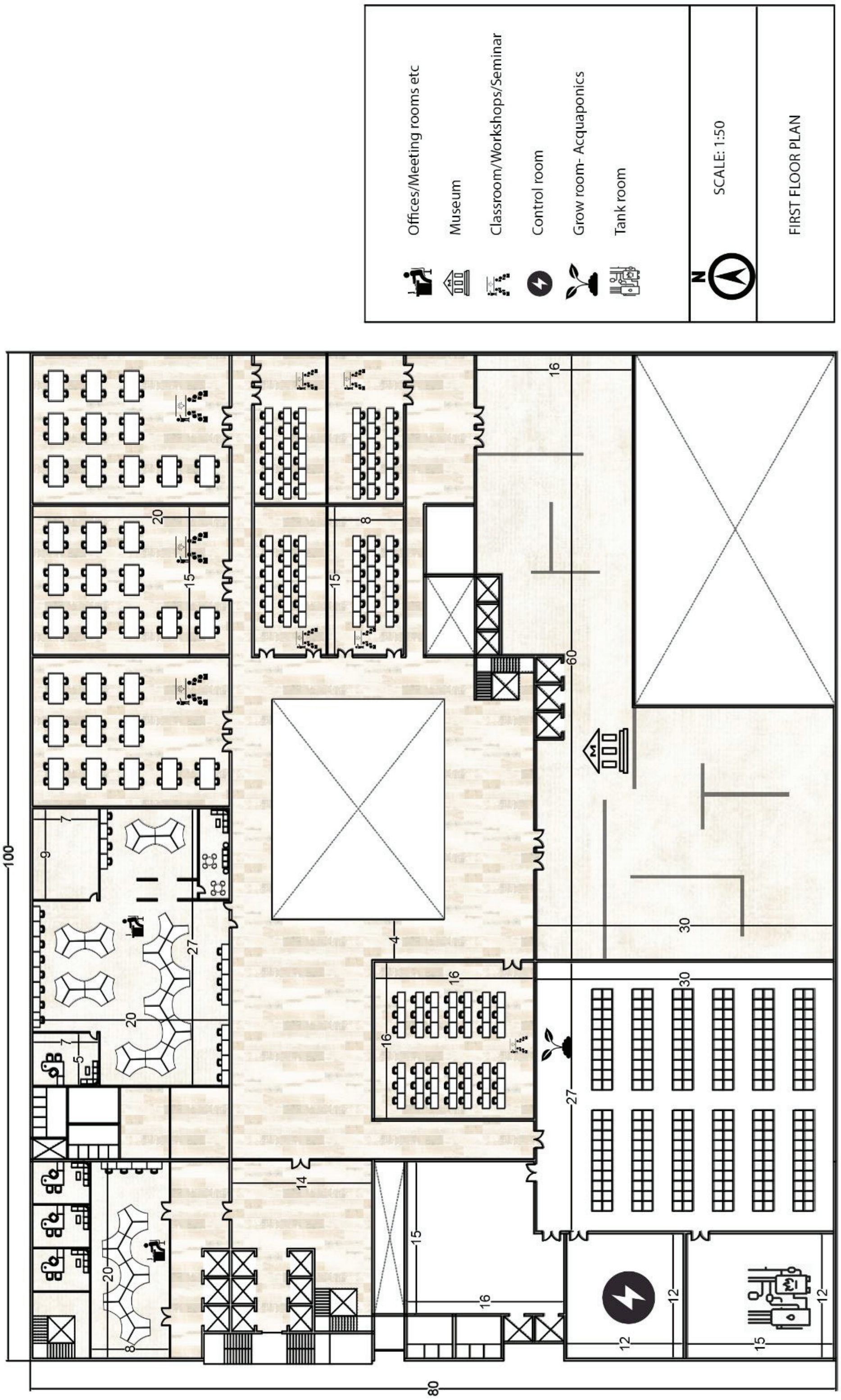


Figure 41. First Floor Plan (Illustrated in Adobe photoshop)

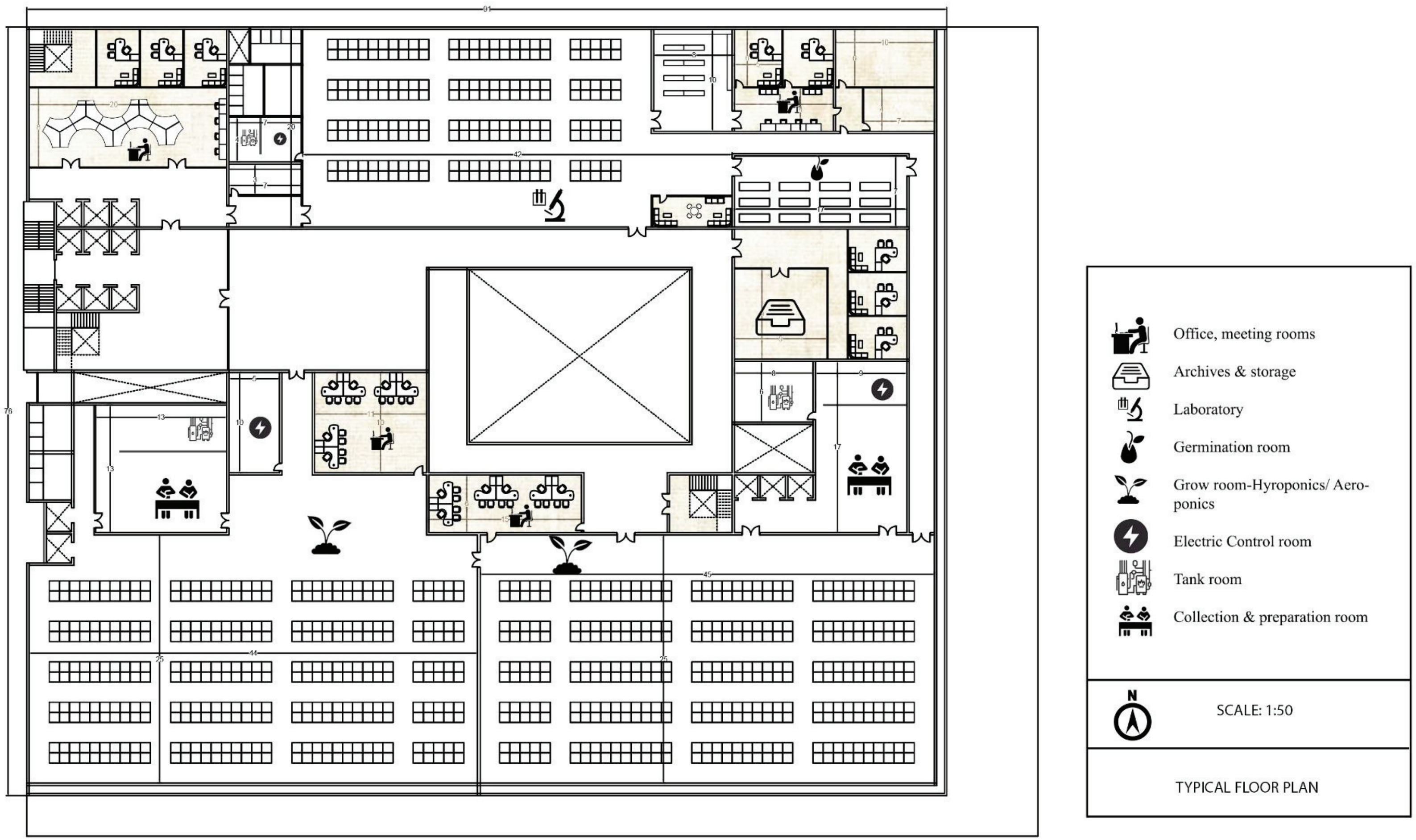


Figure 42. Typical Floor Plan, from 2nd floor upto 14th floor (Illustrated in Adobe photoshop)

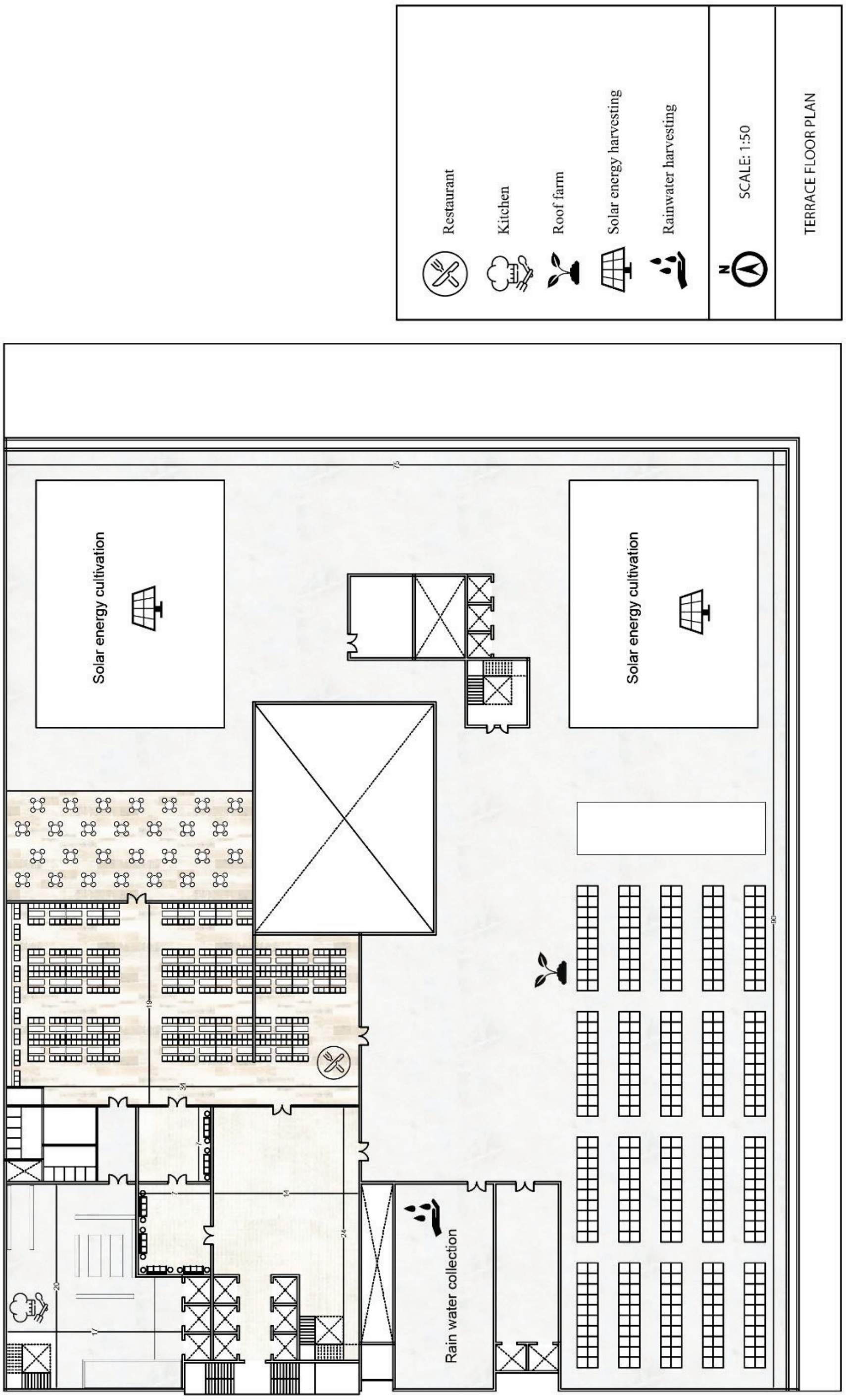


Figure 43. Terrace floor plan (Illustrated in Adobe Photoshop)

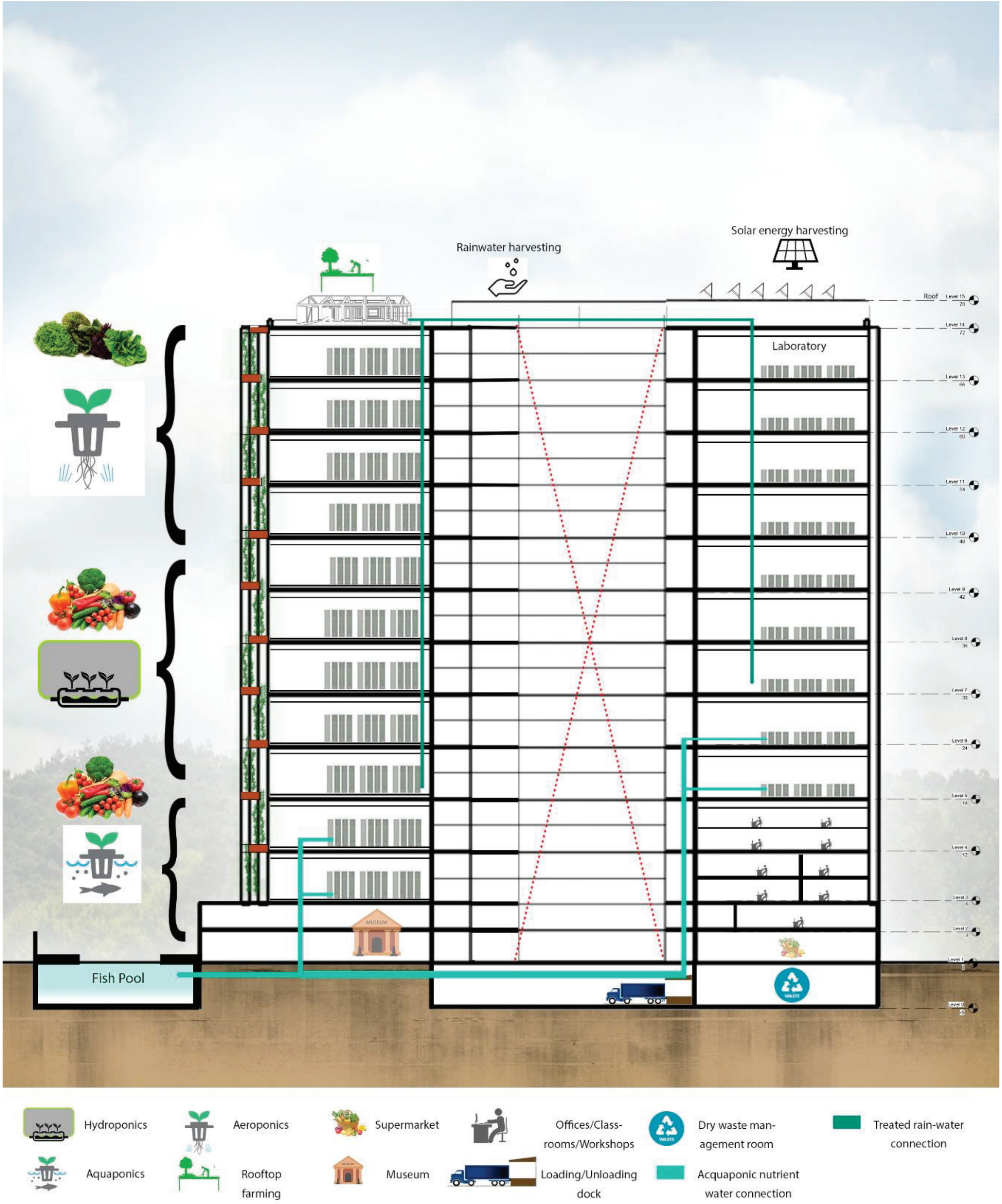


Figure 44. Section A-A'

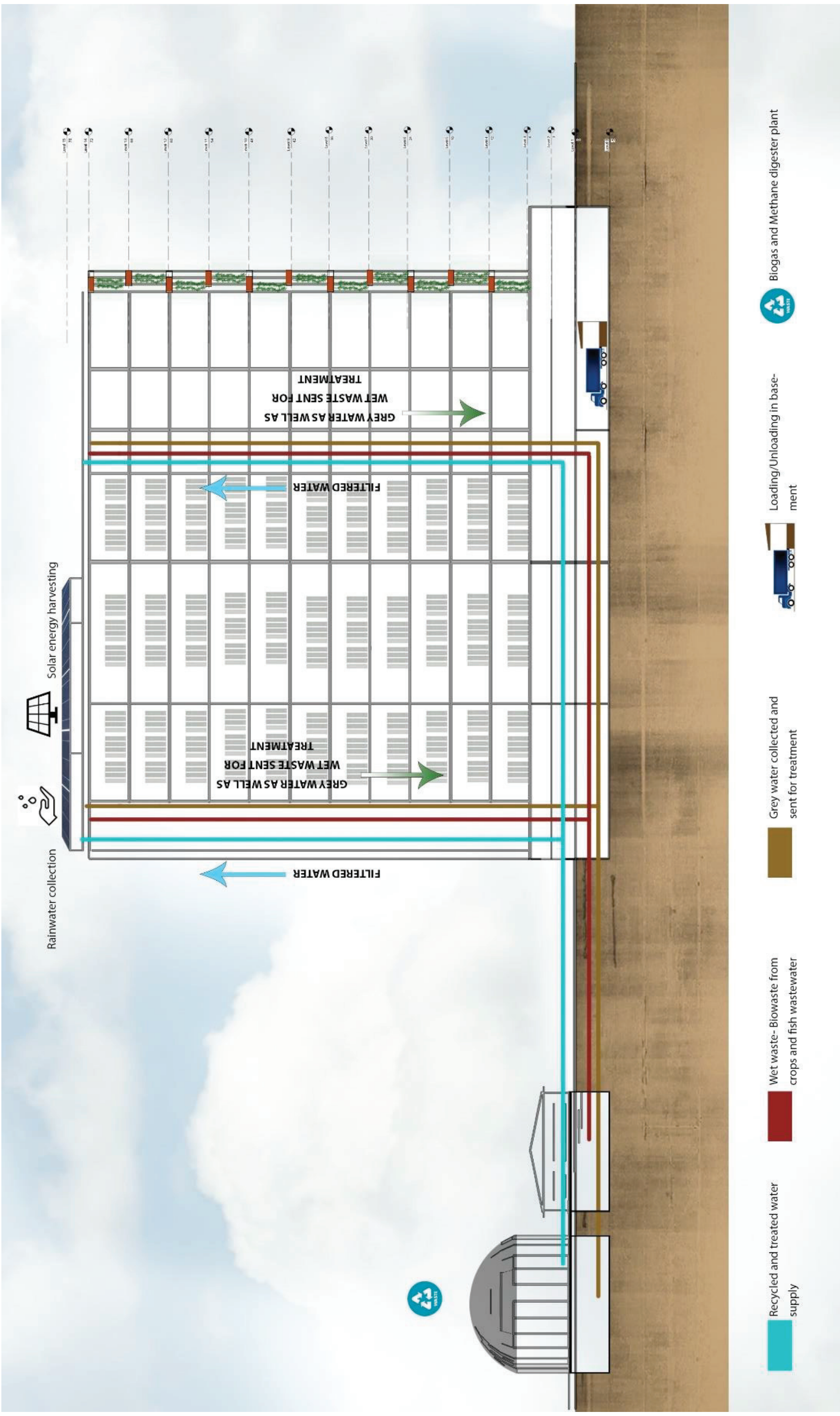

Rainwater collection
Solar energy harvesting
FILTERED WATER
GREY WATER AS WELL AS WET WASTE SENT FOR TREATMENT
FILTERED WATER
GREY WATER AS WELL AS WET WASTE SENT FOR TREATMENT
Recycled and treated water supply
Wet waste- Biowaste from crops and fish wastewater
Grey water collected and sent for treatment
Loading/Unloading in basement
Biogas and Methane digester plant

Figure 45. Proposed grow rooms

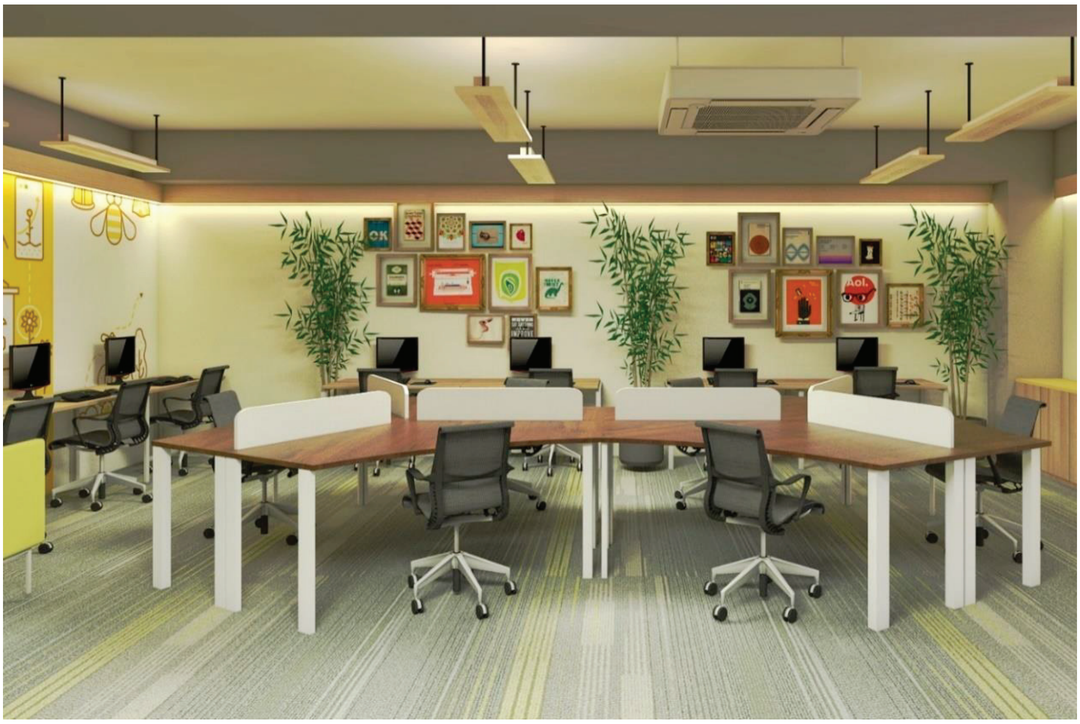


Figure 46. Proposed office space and restaurant

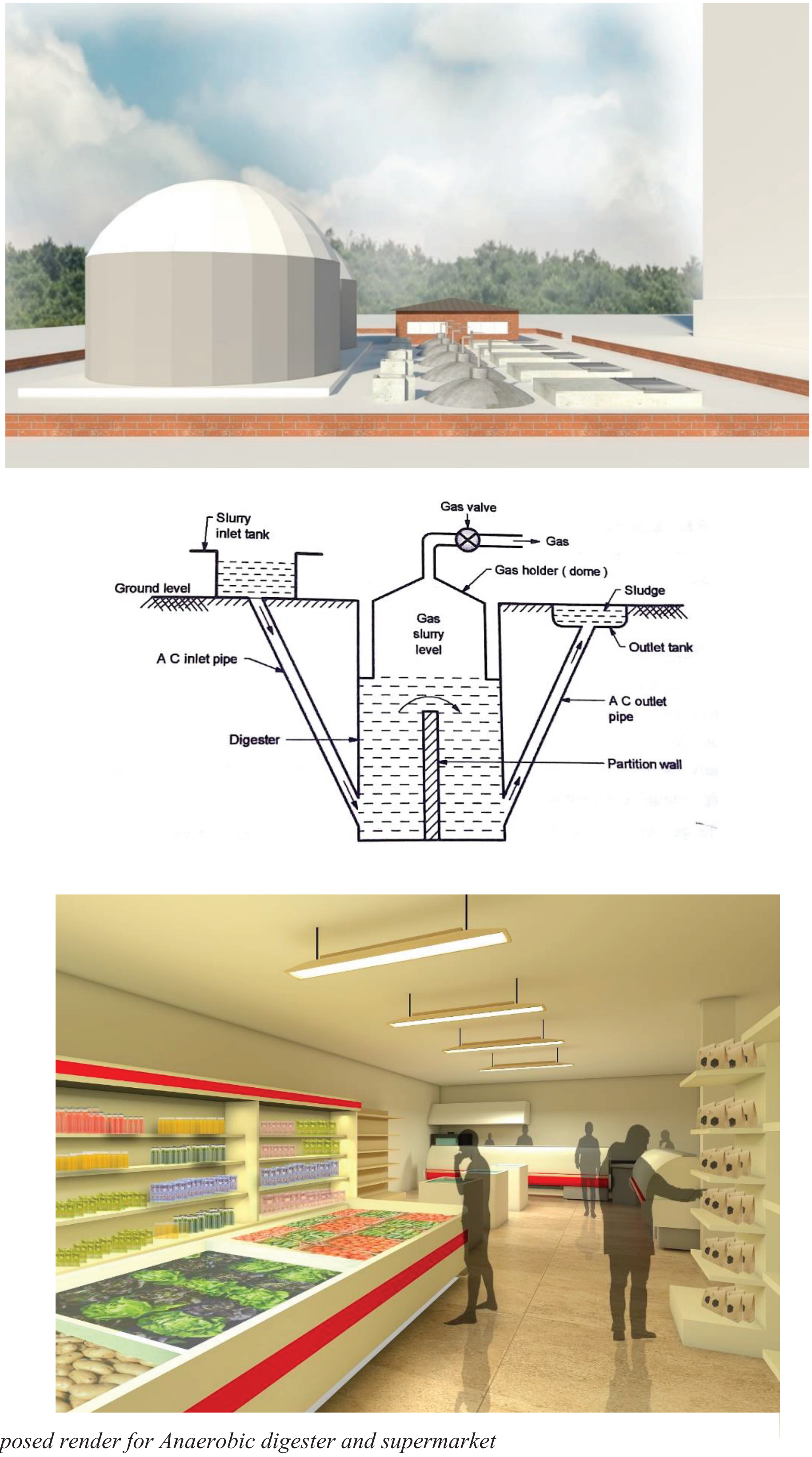


Figure 47. Proposed render for Anaerobic digester and supermarket

10. CONCLUSION

In final conclusion, I feel that there are many advantages that a Vertical farming complex offers to a city like Bangalore. This paper attempts to find a solution in response to the urban growth in the Bangalore city. Cities like Bangalore face many issues due to the Urbanization. There is increase in people shifting to cities, there is an increase in traffic which affects transportation of goods and more fuel is consumed on a daily basis to make ends meet. Traditional agricultural practices will not be able to sustain the large demands set out by the ever growing population. And this would lead farmers to give up their livelihood and sell their land to potential buyers. And this is another issue in cities, the agricultural land is converted for commercial expansion. At the rate at which high rise commercial and residential complexes are built, then where is the land to grow crop production? And we have to also consider the contamination of lakes and rivers. Due to excessive overuse of pesticides, the runoff water is contaminates the water sources.

In the current scenario where we are looking for possible solutions to reduce the carbon footprint, pollution, saving the natural resources and also have access to fresh and healthy vegetables and fruits. And the means to achieve this was to find an economical, sustainable and an ever-lasting method that tries not abuse the natural resources. After studying the various methods that have been invented for the betterment of the environment. There is hope for cities to incorporate these methods.

Various studies, researches and experiments have been carried out using hydroponics, aeroponics and aquaponics to test the crop production. And these experiments are still taking place as researchers continue to refine the current methods. Companies, organization and offices like Plantagon, Eden Project, Israel AgriTech and various other organizations in the world used different concepts of creating green wall to reduce carbon footprint, new technological solutions used in agriculture like robotics that would collect accurate data and help in improving the quality of crop yields, creation of artificial environment to grow vegetation etc. Currently in India, there are many minor startups that have started to spread awareness regarding the alternative techniques of farming. Currently they focus on small scale at home production except for the Goa based Hydroponic farm Letcetra.

Therefore, the proposed Vertical farm complex is a possible answer to one of the problems that the city faces. As it will be a center that focuses on large scale production of healthy pesticide free crop harvests, integration of advanced technology that is based on soil-less farming (hydroponics, aeroponics and aquaponics) and providing activities that will spread knowledge to people talking about the benefits of these indigenous methods. For a developing country like India that faces many issues with regards to water problems, land, pollution, poverty and other aspects, funding for this type of proposal may not be possible just yet. The farmers are hesitant to let go of their roots and most are not aware of the new developments made towards agriculture. But gradually over time as people learn more and are more aware of the situation, we can start off from small scale production and over time it can turn into a full-fledged production of food at a larger scale. Perhaps with time, advanced forms of food production would be achieved and one day it would be possible to convert the city into an environment that employs a symbiotic system where every building is incorporated with energy saving and energy harvesting elements, incorporation of methods to recycle waste, water etc. Hence creating a living city that does not produce or generate any kind of pollution. And the recycled energy it put to use for commercial crop production, which in turn would feed the city. Therefore, the current society must also evolve and adapt to changes and make use of the knowledge to help create a sustainable healthy environment.

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