Group ID : 31

A Project Report on

To Design and Develop Controlled Environmental Agriculture Vertical Farming with water management and automation using NFT for Producing Exotic Leafy Greens for food chain businesses.

By

Ms. Pranita Pachkawade (B150330941)

Ms. Sneha Patil (B150330953)

Mr. Digvijay Thakare (B150331012)

Ms. Dhanashree Bhoge (B150330827)

Guide
Mr. Avinash Borgaonkar

Department of Mechanical Engineering
PIMPRI CHINCHWAD COLLEGE OF ENGINEERING

[2021-22]

A Project Report on

To Design and Develop Controlled Environmental Agriculture Vertical Farming with water management and automation using NFT for Producing Exotic Leafy Greens for food chain businesses.

Ms. Pranita Pachkawade (B150330941)
Ms. Sneha Patil (B150330953)
Mr. Digvijay Thakare (B150331012)
Ms. Dhanashree Bhoge (B150330827).

Guide: *Avinash Borgaonkar*

Department of Mechanical Engineering

Pimpri Chinchwad College of Engineering

[2021-22]

Pimpri Chinchwad College of Engineering

C E R T I F I C A T E

This is to certify that,

Pranita Pachkawade (B150330941)

Sneha Patil (B150330953)

Digvijay Thakare (B150331012)

Dhanashree Bhoge (B150330827)

have successfully completed the Project entitled "To Design and Develop CEA Vertical Farming with water management and automation using NFT for Producing Exotic Leafy Greens for food chain businesses." under my supervision, in the partial fulfilment of **Bachelor of Engineering - Mechanical Engineering** of Savitribai Phule Pune University.

Date :

Place: Nigdi, Pune

Avinash Borgaonkar
Guide

Internal Examiner

Dr. P.A.Deshmukh
Head of the Department

Dr. Govind N. Kulkarni
Director

External Examiner

Seal

1. ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude and honor towards our respected guide Prof. Avinash Borgaonkar for his inspiring guidance and constant encouragement. His committed devotion, dedication and encouragement with full faith on us were like a lamp in our path which keeps us constant throughout project work.

Special thanks to Prof Avinash Borgaonkar for his guidance and support at various stages during the course of our project completion.

We also express our honor and gratitude to Professor and Head of Mechanical Department Dr. P.A. Deshmukh for consistent encouragement for completing our project work successfully.

We are also thankful to our respected Director Dr. Govind N. Kulkarni and the P.C.E.T's (Pimpri Chinchwad Education Trust) for supporting our project financially which helped us in successfully completing our project.

We are thankful to all Teaching and Non-Teaching staff member of the institute and our classmate who had directly or indirectly made me enthusiastic for the project work.

As we conclude, we would like to state that just as a positive attitude pays off our hard efforts to bring this project to successful end, would also pay off. We hope that this project would be one of the most significant steeping stones for our career and would fulfill our aspiration in every aspect.

Pranita Pachkawade

Sneha Patil

Digvijay Thakare

Dhanashree Bhoge

Table of Contents

List of Tables

List of Figures

List of Photographs / Plates

Abstract

Vertical farming is the practice of growing crops in vertically stacked layers which need a controlled environment to optimize plant growth. It uses soilless farming techniques such as hydroponics, aquaponics, and aeroponics. Vertical farming is therefore a form of urban agriculture. The main advantage of using Vertical farming technologies is the increased crop yield that requires a smaller unit area of land. And also a Vertical farm can use 95% or less water than traditional farming because it is recycled. Vertical farming also allows for the production of a larger variety of harvestable crops because of its usage of isolated crop sectors. As opposed to a traditional farm where one type of crop is harvested per season, vertical farms allow for a multitude of different crops to be grown and harvested at once due to their individual land plots. By using foggers, sprinklers, NFT, etc. according to the requirements, we can manage the water usage and consumption and can vary according to the planting stages.

Keywords: Vertical Farming, Controlled Environment, Automation, Water Management, Data Extraction.

1. Introduction

1.1. Problem Statement

- To design and develop Controlled Environment Agriculture Vertical Farming with water management and using Arduino for Data Acquisition and Automation.
- Hydroponics to achieve Controlled Environment thereby producing exhaustive leafy green for food chain business with multifold production and good quality crop by using minimum water and minimum land.

1.2. Objectives

- Minimize the use of water as compared to traditional farming method.
- Maximize the quantity of production in minimum area.
- Reusability of nutrients present in water with proper management system.
- Environment friendly use of nutrients, model.
- Improve quality of plants and protection against pest's attack and other diseases.
- Automation to achieve controlled environmental conditions

1.3. Scope

Extensive use due to less effort.
High efficiency due to less water usage and wastage.
Offers quality produce due to controlled and pest free environment.
Growing exotic plants can generate high income.

1.4. Methodology

Hydroponics to achieve Controlled Environment thereby producing exhaustive leafy green for food chain business with multifold production and good quality crop by using minimum water and minimum land.

METHODOLOGY:

The Methodology followed in the project is as follows:

- Literature Survey:

Literature survey is done to examine the current agricultural practices were exhausting our natural resources and whether it was sensible to explore other farming options. Literature Survey was done to study about various water management methods, their advantages, limitations, etc. The knowledge about the nutrients and essential parameters required was also obtained through various books, research papers and datasheets available.

- Designing:

Selection of proper components like sprinklers or foggers was done according to the requirement of system and the pump was selected according to the flow rates and other requirements. The modelling and drafting of water management was done on CAD software Siemens NX.

- Manufacturing:

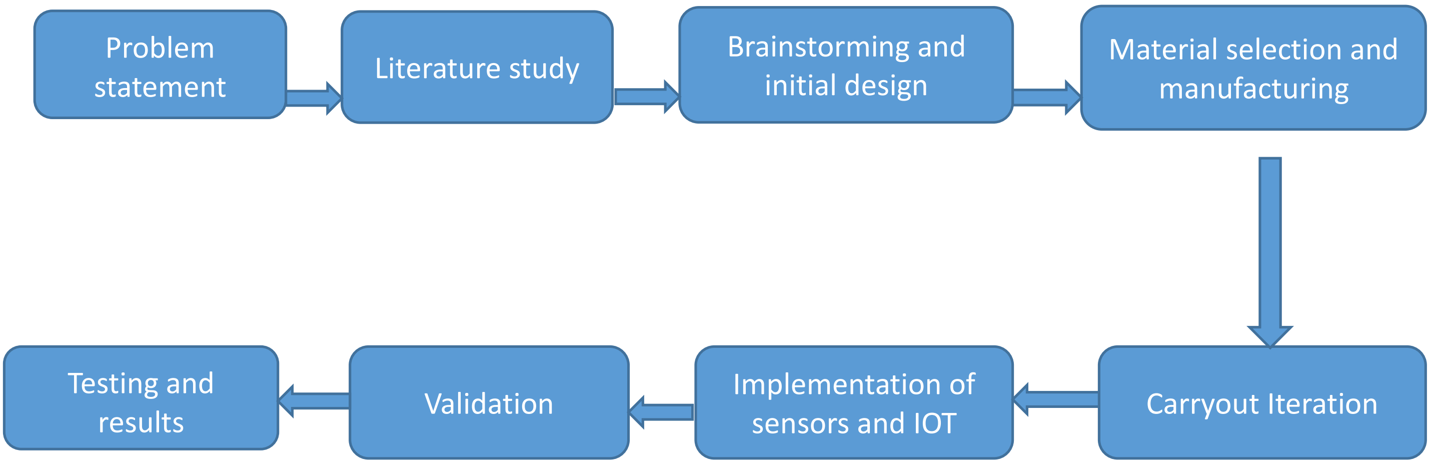
The model is to be manufactured according to the CAD model. The circuit diagram, sensors are calibrated and tested and implemented to acquire required data.

- Testing:

Once the model is manufactured and sensors are implemented, the water management and HVAC system is operated and seeds are planted in coco peat.

- Data Validation:

The Data obtained from sensors is then passed to the AI system. The water flow is managed and maintained according to the planting stage and the nutrient usage is properly managed.



Methodology flowchart

2. Literature Survey

2.1. Hydroponics:

Soil-less culture mainly refers to the techniques of Hydroponics. The term Hydroponics was derived from the Greek words hydro' means water and ponos' means labour. It is a method of growing plants using mineral nutrient solutions, without soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium such as perlite, expanded clay pellets, coco coir, gravel and mineral wool. Hydroponics is the technique of growing plants in soil-less condition with their roots immersed in nutrient solution. This system helps to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition. Soil-less culture mainly refers to the techniques of Hydroponics. The term Hydroponics was derived from the Greek words hydro' means water and ponos' means labour. It is a method of growing plants using mineral nutrient solutions, without soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium such as perlite, expanded clay pellets, coco coir, gravel and mineral wool. Hydroponics is the technique of growing plants in soil-less condition with their roots immersed in nutrient solution. This system helps to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition. In India, Hydroponics was introduced in year 1946 by an English scientist, W. J. Shalto Duglas and established a laboratory in Kalimpong area, West Bengal. Mr. Shalto Duglas has also written a book on Hydroponics, named as “Hydroponics the Bengal System”. Later on during 1960s and 70s, commercial hydroponic farms were developed in Abu Dhabi, Arizona, Belgium, California, Denmark, German, Holland, Iran, Italy, Japan, Russian Federation and other countries. During 1980s, many automated and computerized hydroponics farms were established around the world. Home hydroponics kits became popular during 1990s.

2.2. Types of Hydroponics

2.2.1. Passive Hydroponics

In a passive system, the plants roots are in touch with the nutrient solution and the plants are supported using a suspension method. The main disadvantage of this system is that it is difficult to support plants as they grow and get heavier. However, a passive system is a very basic system and is therefore easy for a beginner to set up. A passive system tends to be very portable and quite inexpensive. One example of a passive system is the Wick System.

2.2.2. Active Hydroponics

Active systems are more efficient and productive because they use pumps to supply nutrient solutions to the plants and a gravity system to drain off any excess solution which is then recycled and reused. Various types of materials used to quick drain system are perlite, rockwool, expanded clay pebbles or

Coconut Coir. The main difference between an active and passive system is that an active system uses pumps to supply nutrient solution whereas a passive system uses a wick to draw in the nutrient solution.

2.2.3. Nutrient Film Technique NFT

The Nutrient Film technique uses an automated pump and reservoir system to supply and recycle nutrients. NFT system has constant flow of nutrient solution so no timer required for the submersible pump. The nutrient solution is pumped into the growing tray and flows over the roots of the plants and then drain back into the reservoir. The main drawback of this system is that the plants can suffocate and die because of a lack of oxygen using this system.

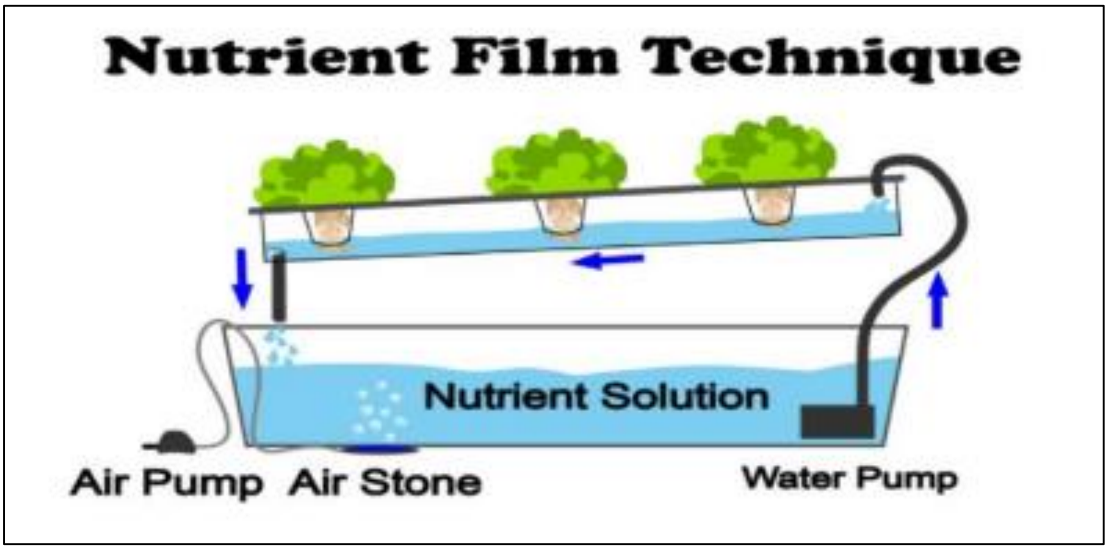


Figure 1: NFT

2.2.4. Aeroponics

A recent development in which plants are suspended in midair and then supplied with nutrients has resulted in a system known as Aeroponics. Nutrients are sprayed to the roots and their exposure to air provides them with maximum oxygen. In this system, the supply of nutrients and oxygen is maximized. However, care needs to be taken in order to maintain 100% relative humidity. The main drawback of this system is the functioning of the pump and reservoir in the event of power failure. As it is a reasonably new system, it is currently quite expensive to set up and is more often used in laboratory studies.

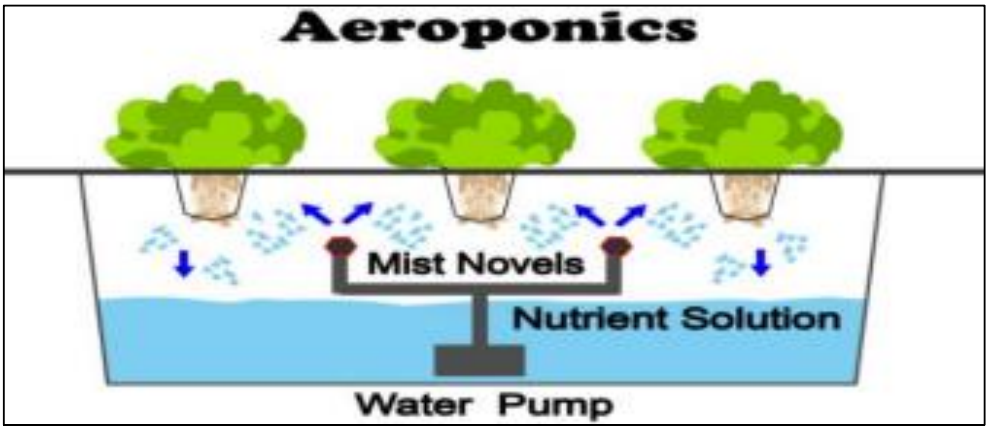


Figure 2: Aeroponics

2.2.5. Vertical Hydroponics

Hydroponics is a method of growing plants without soil in vertical fashion, where mineral nutrients are provided through water. Vertical hydroponics works by using conventional hydroponics technique in a vertical, gravity fed system. The nutrient-rich water is fed from the top and collected at the bottom. Vertical hydroponics has various advantages over traditional crop production methods including:

- Allows for high density yield per unit area.
- Good for small sunny places like balconies, patios and rooftops.
- It allows year around production inside.
- It often can provide more than 90 percent efficiency in water use.
- No soil-borne diseases.

Advantages of Vertical farming:

1. **Low water usage:**

Being a totally closed growing system with controlled transpiration losses, vertical farm system use only around only 20% of the water required for traditional open field farming. Water from transpiration is harvested and reused and spent nutrients water is also processed for re-use.

2. **Low labour cost:**

Vertical farming system are fully automated growing system. Manual labour is only required for planting, harvesting and packaging of crops and required skill level are very low.

3. **Weather resistant:**

Traditional farming is subjected to unpredictable weather patterns and natural disasters such floods, droughts, wildfires, etc. In a controlled environment of vertical farming such factors are negated and thus less susceptible to disruption in the supply chain process.

4. **Environmental Conservation:**

Vertical farming helps in environmental conservation as deforestation that accompanies traditional farming can be negated, thus saving resources in the long run.

5. **Doesn't Involve Chemicals or Pesticides:**

When you grow food in a vertical farm, you have the chance of completely cutting down on the need to invest in pesticides. That is because your farming is practiced in a controlled environment that prohibits the entry of pests. This prevents crop damage and reduces the chance of a range of fungal ailments as the humidity levels are now duly managed. At the end of the day, you are left with a product which is not just better, but also healthier and safer to consume.

Disadvantages of vertical farming:

1. **High upfront costs:**

For the initial construction and installation costs can be quite high.
Since vertical farming systems are often quite complex and require plenty of planning, the initial costs can be huge. Thus, companies have to take great care when it comes to

the decision of whether vertical farming will be suitable for them or not since wrong decisions can lead to serious financial downsides in this field.

2. **High energy consumption:**

Another downside of vertical gardening is that it requires significant amounts of energy. Since many layers of plants have to be covered by proper lighting, the electricity bill will grow rapidly over time.

Thus, compared to outdoor farming, the costs for energy will usually be much higher with vertical farming.

The huge energy consumption can also be regarded as an environmental issue since most of our energy is still produced out of fossil fuels, which in turn implies serious greenhouse gas emissions.

3. **High maintenance costs:**

Since vertical farming systems are usually quite complex, there will be the need for highly qualified workers who have to monitor these farming processes on a constant basis.

These high efforts also imply significant labor costs related to vertical gardening.

Thus, in many cases, vertical farming will not be senseful from an economic perspective.

4. **Pollination problems:**

Since there are no insects inside the vertical farming systems, there might be issues regarding the pollination of crops.

Outdoor, the plants are usually pollinated in a natural manner through bees and other insects.

However, since those insects are missing in vertical farming systems, the staff may have to pollinate the plants manually in order to assure a satisfying crop yield.

Conclusion:

From the above Review, we considered that in a closed type hydroponic method, the amount of nutrient solution per plant largely affects the changes in concentration and composition during the cultivation period. In general, smaller the quantity of the nutrient

	Drip irrigation	**NFT hydroponics**	**Aeroponics**
Water usage	Medium	High	Low
Energy usage	Medium	Medium	High
Complexity	High	Low	High
Maintenance	Low	Low	Medium
Water wastage	Medium	High	Low

Table 1: Decision Matrix

solution more variable in the quality of the nutrient solution. Thus, the management system for nutrient solution is very important. It is therefore necessary to measure the nutrient and water uptake rate of the plant for better management of nutrient solution. In most of the studies they used pots or containers, showed that there is a change in the concentration and the amount 22 of water uptake for a certain period. However, under low mineral concentration in hydroponic solution it is difficult to get exact values because solution concentration changes within a short period of time. In the vertical hydroponics system, the root system of the plant can contact nutrient solution frequently, less space is required and this method was thought to be better to measure the minimum absorption concentration compared with other growing systems. Hence, vertical hydroponics system was adopted in this study.

After briefly studying about the different water management techniques, we made a decision matrix which consists of important parameters, which helped us to select vertical hydroponics with sprinklers as our main system for project.

2.3. NUTRIENTS:

When considering the nutrients required to grow different types of plants, it is important to realize that each plant variety is unique. As such, each may require a different combination of nutrients, different concentrations of nutrients, or supplied in different stages in the plant's life cycle. However, there are some nutrients that are fundamental to plant growth, meaning that they are found in the requirements of most plants across many varieties.

List of Nutrients needed for plant growth:

1. Nitrogen
2. Phosphorus
3. Potassium
4. Calcium nitrate
5. Micro nutrients

2.3.1. **Nitrogen:**

Nitrogen is central to plant growth. It is a major component of amino acids which are the building blocks of all proteins including enzymes, which control metabolic processes. Nitrogen is present in chlorophyll, the green pigment required for photosynthesis. It is also responsible for the plant‟s overall growth, increasing seed and fruit production and leaf quality. Calcium nitrate and potassium nitrate are major fertilizers used in most hydroponics mixes. Ammonium nitrate and Ammonium sulphate are also used in small amounts to supply the ammonium form of nitrogen.

2.3.2. **Phosphorus:**

Phosphorus is used in photosynthesis and in the production of flowers and seeds. It also encourages root growth. Plants deficient in phosphorus can develop sparse dark green leaves with brown or purple discoloration of the lower leaf surface. The most common fertilizers used to supply phosphorus in hydroponics mixes are mono-ammonium phosphate and potassium dihydrogen phosphate.

2.3.3. **Potassium:**

Potassium is necessary during all stages of plant development, particularly during fruit development. It is absorbed by plants in larger amounts than any other nutrient with the exception of nitrogen and in some cases calcium. It is involved in the production of chlorophyll, sugars and starches and regulates stomatal opening in the leaves. The main fertilizers used to supply potassium in hydroponics mixes are potassium nitrate and potassium dihydrogen phosphate. Potassium sulphate and potassium chloride can be used to supply small amounts.

2.3.4. **Epsom salt:**

Epsom salt is also known as magnesium sulphate. It's a chemical compound made up of magnesium, sulphur, and oxygen.

2.4. INTRODUCTION TO AUTOMATION IN VERTICAL FARMING:

Automation is the process of making human tasks and jobs easier and faster. Vertical farming can be a perfect example of automation as it is the system that represents a new way of producing food in a sustainable way.

Vertical farming is an agricultural solution to some of the most pressing problems facing agriculture today, such as climate change, global population growth, and increasing food shortages.

Vertical farming uses hydroponic or aeroponic systems to grow crops indoors under artificial light without soil or sunlight. It can be used to grow all kinds of plants including fruits, vegetables, herbs, mushrooms, flowers and more.

2.5. BENEFITS OF AUTOMATION IN VERTICAL FARMING

The future of vertical farms includes automation in the form of artificial intelligence (AI) and robots because they will be able to manage this system more efficiently than humans can.

With the rise of automation and new technologies, people are starting to rethink how we produce our food. Vertical farming uses less space and resources than traditional agriculture. It also has a smaller ecological footprint because it doesn’t need pesticides or herbicides. And due to the complete control of the process, it is more efficient and produces higher yields of crops such as tomatoes and peppers.

2.6. DIFFERENT TYPES OF AUTOMATIONS FOR GREENHOUSES

There are many types of automation that is being used in the field of agriculture. They have different uses and can provide different benefits to the users.

There are many uses for automated systems in greenhouses. They help in controlling temperature, humidity, and CO2 levels which can be difficult to monitor manually. Automated systems also make it easier for farmers to keep track on the amount of water they need to irrigate their crops by measuring soil moisture levels automatically.

Automation is a key factor in achieving sustainable agricultural production.

The increased level of automation in vertical farms is making the production process more efficient. The use of a centralized computer system to control a series of self-contained computer-controlled environmental and climate systems is leading to a significant decrease in the cost of production while simultaneously increasing the quality of output.

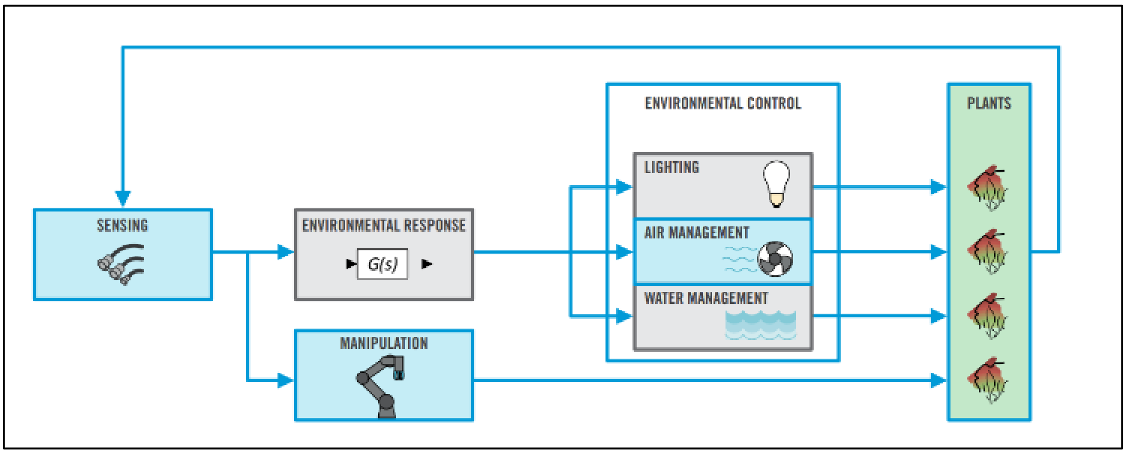


Figure 3: Automation

The ideal automated farm environment includes control of the complete environment, together with feedback from the plants on their requirements. We have just begun to realize the potential of this feedback and the limitations of the control systems.

TECHNOLOGY LEVEL	ENVIRONMENTAL RESPONSE	AUTOMATION
Level 1	Maintain fixed conditions	Manual labor
Level 2	Conditions manually selected	Assisted manual labor
Level 3	Respond to phase of life	Automation with manual intervention
Level 4	Control of crop quality though real-time response	Fully automated environment

Table 2: Levels of Automation

TECHNOLOGY LEVEL	LIGHTING	AIR MANAGEMENT	WATER MANAGEMENT
Level 1: Lifted directly from other applications	▪ Industrial lighting	▪ Use of standard HVAC system	▪ Automated irrigation system ▪ Nutrient dosing into the water
Level 2: Some adaptation of existing technology for application	▪ Efficient spectrum use, high PAR ▪ Focus only on the plant	▪ Higher power density ▪ Increased CO_2 levels	▪ Nutrient monitoring and control
Level 3: Specialized technology requiring custom development	▪ Adjustable spectrum, trigger growth phases when required	▪ Higher humidity ▪ Fully homogeneous conditions	
Level 4: Sub-system integrated with overall environment for an optimized system	▪ Closed-loop crop control through lighting	▪ Localized control of conditions	▪ Per plant nutrient dosing

Table 3: Levels of Lighting, Air management and Water Management

The following list contains ways automation can be used within vertical farming:

2.6.1. **Planting seeds**

Vertical farming starts with seeds that are planted into starter mediums and then cultivated under the lights until they're ready for transplanting.

Transferring seedlings into vertical farming beds

In vertical farming, seedlings are placed in vertical beds rather than in rows on horizontal plots of land. Once the seedlings get too large for their container, they will need to be transferred to a growing bed.

2.6.2. **Automated watering, lighting, and fertilizing**

One of the key advantages of vertical farms is their ability to carefully monitor and adjust growing conditions for plants year-round. In a controlled environment, you can adjust the ambient temperature, spectrum and intensity of light, and irrigation/fertilization for each plant depending on what is best for that plant.

2.6.3. **Vision systems to monitor crop growth and health**

With high-tech visioning technology, you can employ cameras to monitor the growth & health of your plants. If any irregularities are detected, alerts can notify key personnel of the issue so they can take action.

2.6.4. **Automated harvesting**

Harvesting crops traditionally takes a lot of time and effort. Fortunately, early farmers invented new farm equipment that made crop harvesting easier. Automated technology can be used in greenhouses and vertical farms.

Robots are often more precise than humans and can pick vegetables more efficiently. Robots can also be used for planting vegetables. A crop handling palletizer moves the crops through a conveyor system, where the spoils are cut before they are transferred safely on to the next component. A range of innovative solutions help you get more out of your machine.

2.6.5. **Cleaning and reloading farming beds for re-use**

Vertical farming allows for new plants to be grown as soon as the old crop is harvested. This means that multiple crops are ready to harvest each day which saves time and effort. This can be done with high powered cleaning equipment, like pressure washers. They can make cleaned pallets and pots in minutes.

Combining detection of individual structures, using optics and other sensors, enables those managing vertical farming to control the system in real time, responding to the health of the crop so that each fruit can be optimized. Within a single plant there might be some leaves or fruit in inferior condition, which would also compromise the quality of the rest of that plant. By isolating these plants, it is possible to ensure the maximum yield from every plant. Harvest can also be carried out at the optimum time per fruit or leaf, to maximize uniformity. Predictability of crop is one of the most valuable elements of vertical farming.

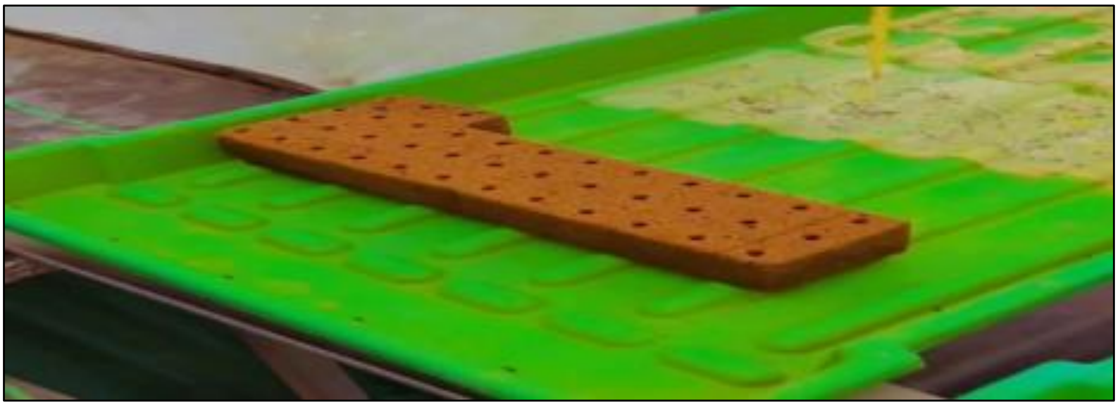
Detection methods are likely to include optical techniques, such as multispectral imaging and pattern detection through machine learning, but manipulation is also likely to provide some input. Human assessment of plants often includes touching and squeezing, a task that is extremely difficult for robots, that tend to have only a few tactile sensors, while humans have many thousands per finger. Context appropriate application of a small number of sensors, as well as the creation of new sensor types, will bring robots closer to mimicking the abilities of a human.

2.7. **Growth Stages of Plants**:

2.7.1. **Stage 1**:

Dry weight of 10gms coco pit was taken and mixed thoroughly by adding some amount of water. Germination tray was filled with mixed coco pit and small holes were made in each pot for placing of seeds. Seeds were placed in each pot and completely filled with mixed coco pit then seeds were irrigated twice a day up to 7 days. After the process of germination, the appearance of seedlings with two leaves was been transferred from tray to growing net pots filled with clay pebbles were placed in structure.

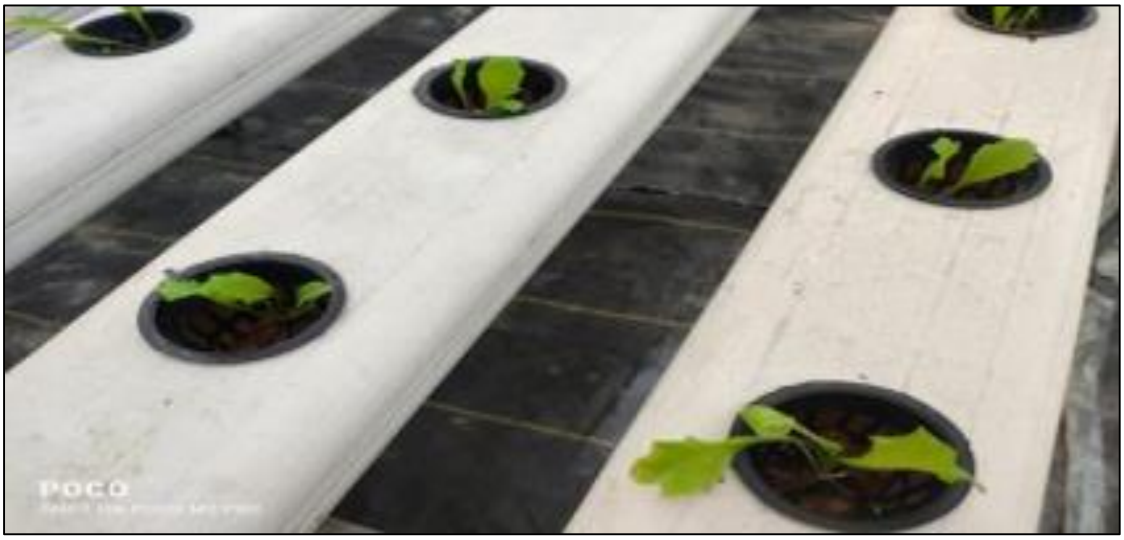
Picture 1: Germination Stage



Picture 2- Cocopeat Blocks

2.7.2. **Stage 2**:

This is the stage of plant for 25 to 30 days after germination. In this stage plant growth will be more desirable and fast, where we will put our plant in system. TDS Range 0-100ppm before addition of nutrients. Max 500ppm after addition of nutrients.



Picture 3: Stage 2

2.7.3. **Stage 3**:

Stage 3 start after 35 days. In this stage plant become bulkier. In this stage required ratio of nutrients i.e NPK is 30:10:10.We need more amount of nutrients in stage 3 as compared to stage 2.

For stage 3 the TDS Range is 500-1000ppm.

Picture 4: Stage 3

	Basil	Lettuce	Coriander
pH	6.0- 7.5	5.8- 7.2	5.8- 7.3
Electro Conductivity EC Ms	1.0-1.6	0.8-1.2	1.2-1.8

Table 4: Water Parameters

2.8. Electronics Components:

2.8.1. **Arduino**

The ATmega/2561 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega 2561 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The AVR® core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega640/1280/1281/2560/2561 provides the following features: 64K/128K/256K bytes of In-System Programmable Flash with Read-While-Write capabilities, 4Kbytes EEPROM, 8Kbytes SRAM, 54/86 general-purpose I/O lines, 32 general purpose working registers, Real-Time Counter (RTC), six flexible Timer/Counters with compare modes and PWM, four USARTs, a byte-oriented 2-wire Serial Interface, a 16-channel, 10-bit ADC with optional differential input stage with programmable gain, programmable Watchdog Timer with Internal Oscillator an SPI serial port, IEEE® std. 1149.1 compliant JTAG test interface, also used for accessing the On-chip Debug system and programming and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning.

I/O and Packages

– 54/86 Programmable I/O Lines:- ATmega2561

– 64-pad QFN/MLF, 64-lead TQFP (ATmega2561)

– 100-lead TQFP, 100-ball CBGA

– RoHS/Fully Green

• Temperature Range:

– -40C to 85C Industrial

• Ultra-Low Power Consumption

– Active Mode: 1MHz, 1.8V: 500µA

– Power-down Mode: 0.1µA at 1.8V

• Speed Grade:

– ATmega640V/ATmega1280V/ATmega1281V:

• 0 - 4MHz @ 1.8V - 5.5V, 0 - 8MHz @ 2.7V - 5.5V

– ATmega2560V/ATmega2561V:

• 0 - 2MHz @ 1.8V - 5.5V, 0 - 8MHz @ 2.7V - 5.5V

– ATmega640/ATmega1280/ATmega1281:

• 0 - 8MHz @ 2.7V - 5.5V, 0 - 16MHz @ 4.5V - 5.5V

– ATmega2560/ATmega2561:

• 0 - 16MHz @ 4.5V - 5.5V

2.8.2. **DHT 11- Temperature and Humidity Sensor:**

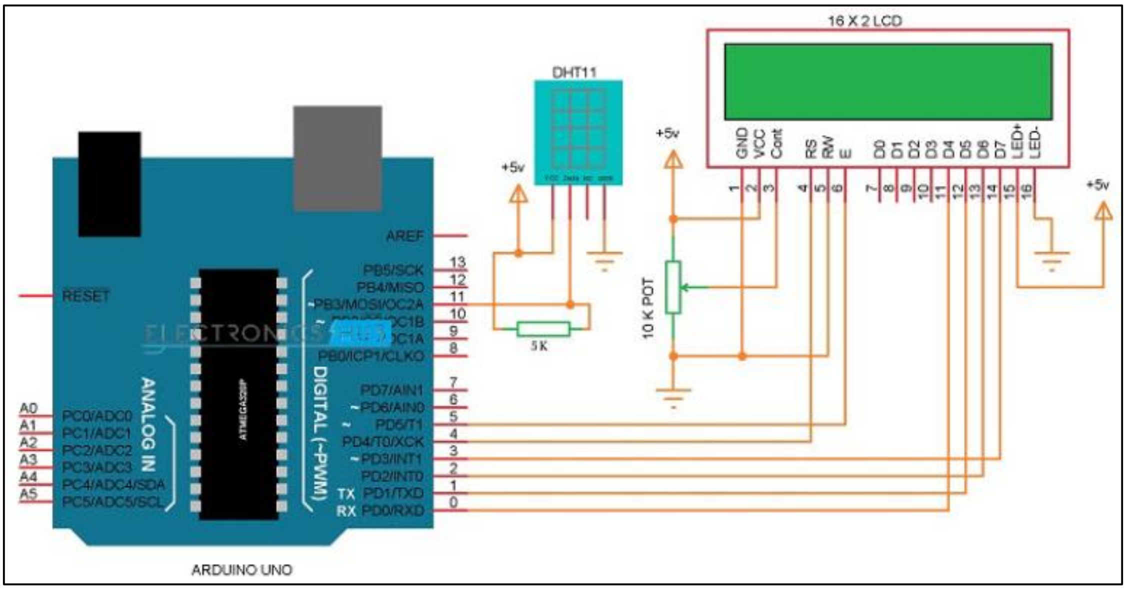


Figure 4: DHT 11 Sensor

2.8.3. **Light Intensity Sensor:**

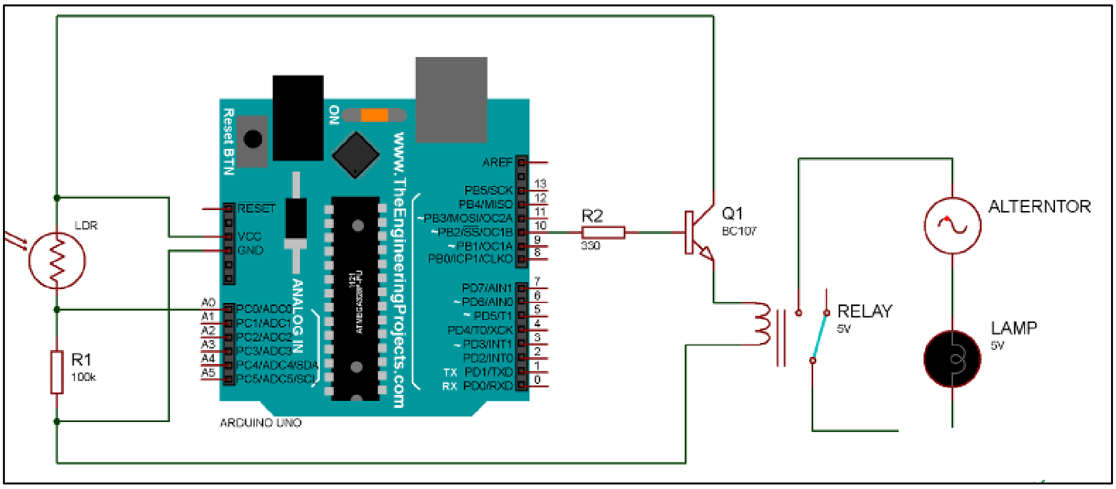


Figure 5: Light Intensity Sensor

2.8.4. **pH Sensor:**

Picture 5: pH Sensor

2.8.5. **TDS Sensor**:

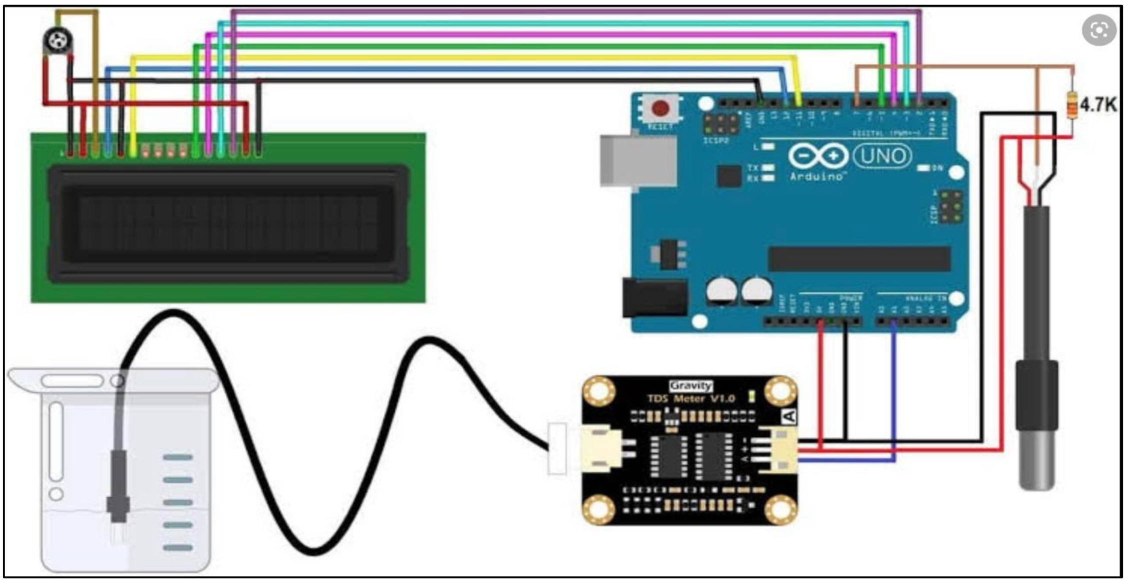


Figure 6: TDS Sensor

3. Design

3.1.MATERIAL REQUIRED:

1. One Frame- PVC Pipes ∅25mm, 5 Feet x 6 Feet x 7 Feet.
2. Polythene sheet for enclosing structure.
3. Six Tower- PVC Pipes ∅110mm, height 5 feet.
4. One Tank- 175 Litre.
5. Drainage System- PVC Pipes ∅75 mm, Seven Elbow ∅75mm, Six Reducer ∅110mm to ∅75mm, One Tee joint ∅75mm, Two Cross ∅75mm, Flexible Pipe.
6. One Pump- 0.5 HP
7. One Platform- Wooden Ply 4.5 Feet x 4 Feet, thickness 8mm, MS Angle 25mm, Fasteners.
8. Net pots- 96
9. One Filter
10. Irrigation Pipe ∅25mm.
11. Six Sprinkler- 1.5 LPH

3.2.ELECTRONICS COMPONENTS:

1. Arduino
2. Power Supply SMPS 12V 5A PG
3. Display 20/4 Green
4. PH Sensor
5. Electrical Conductivity
6. DHT11
7. Light Intensity Module
8. Water Turbidity Sensor
9. Printed Circuit Board/ Universal board
10. Relay DC 5V
11. Mini Submersible Pump
12. Hook Wires

3.3. Tools Required:

1. Heat Gun
2. Drilling machine
3. Grinder
4. Radial Drill machine
5. Heck saw blade
6. Tape measure, ruler
7. Spanner and screw driver
8. Soldering Gun

3.4. Parts and Assemblies:

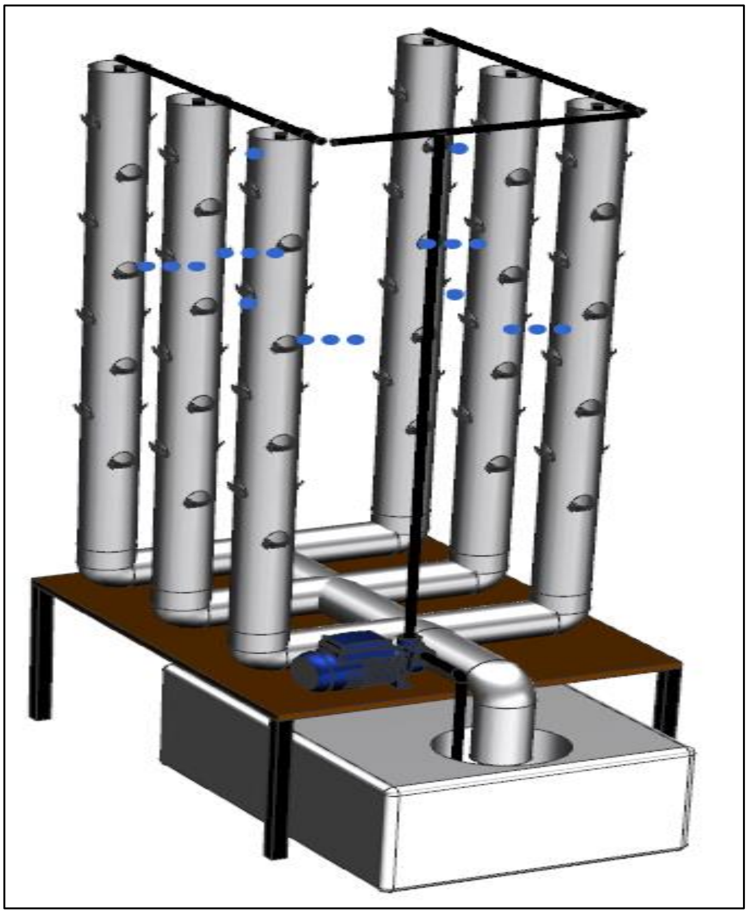


Figure 7: CAD Model

3.4.1. **Tower Garden**:

Picture 6: Vertical Tower

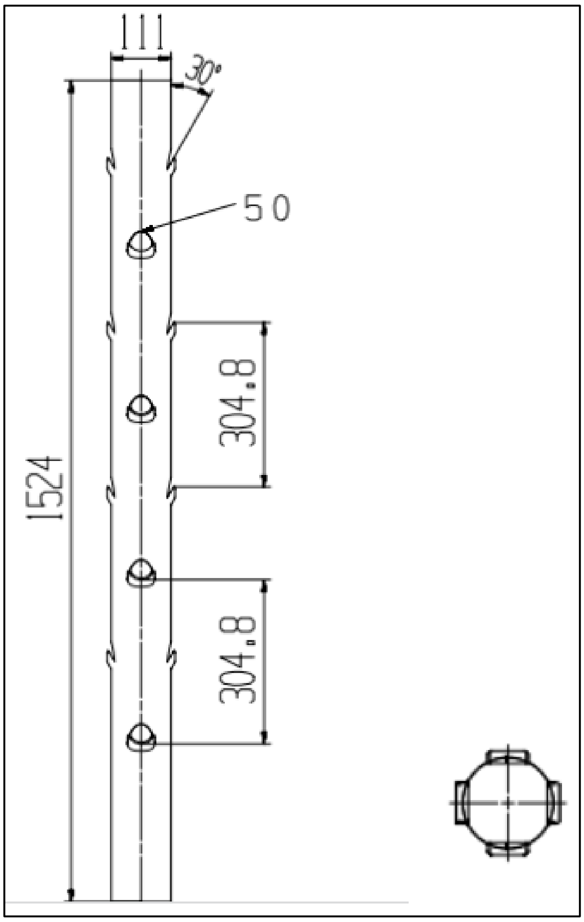


Figure 8: Vertical Tower CAD

A tower garden, also called a window farm is a system of vertical hydroponics, which includes a frame hydroponics system, hydroponic wall and is enclosed using polythene sheet. PVC pipes of 4” diameter are used as a tower which has 16 slots such that 16 plants can be grown, according to our design 6 vertical towers which can hold 96 plants in total. 6 towers can be placed in 4.5 feet x 4 feet space. The design can be modified according to preference. It can be used for growing various crops like lettuce, coriander, spinach, basil and broccoli. It can also be used for growing plants indoors if lights are provided around the tower of required spectrum, which is popular in urban areas with only a small space for gardening.

3.4.2. **Drainage System**:

The structure is kept on a platform at a height above the tank which is mounted on the drainage system made of PVC pipes. Platform will allow the water to directly drain the water into the tank and will restrict the backflow of water. A polyethylene tank of 175 litres is used as per our requirements to the store nutrients filled water. Water will be circulated throughout the system for recycling purpose by filtration.

Picture 7: Drainage System

3.4.3. **Water Management**:

A tank of 175 litres will store nutrients filled water which will be circulated in the system using pump of 0.5 HP according to requirement and calculations. Pump will lift the water upto 5 feet height. Irrigation pipes are used to connect pump and sprinklers. Sprinklers will sprinkle water inside the water tower which will reach to the roots of plants and this water will be again collected in the tank via drainage system. In this way recycling of water will be achieved.

Picture 8: Sprinklers

3.4.4. Platform:

Platform was made to raise the entire assembly of tower, water management and drainage. The main reason to make the platform and raise the assembly us to let the water flow back to the tank through the drainage system. If drainage system and tank were at the same level, then the water could flow back in the drainage system and may imbalance the whole assembly. The platform frame was made by mild steel and a wooden ply was kept on top. Fasteners were used to assemble the angles as welding may hamper the transportability.

Picture 9: Platform

3.5.Previous Design Error:

According to previous design consideration, bamboo was selected. According to previous design consideration, bamboo was to be used as support member for net pots. During processing of bamboo, we came across various issues related to machining and post processing.

The time required for machining was high and required high precision. Radial drill machine was used to drill holes of ∅25 mm. The nodes were chopped using chisel and hammer. The undercut nodes could cause issue for free water flow. Machining process was more time consuming than machining on PVC Pipes. Radial drill machine with special tool was also required.

Picture 10: Bamboo Manufacturing

Picture 11: Bamboo Drilling

Picture 12: Bamboo

3.6. Arduino Code:

```
#include <BH1750.h>

#include <Wire.h> // Library for I2C communication

#include <LiquidCrystal_I2C.h> // Library for LCD

#include "DHT.h"

#define DHTPIN 2

#define PH_6_above_control_pin 3

#define PH_5_below_control_pin 4

#define EC_control_pin 5

#define TDS_control_pin 6

#define AC_control_pin 7


#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);

#define PhSensorPin A0          //pH meter Analog output to Arduino Analog Input 0

#define Offset 39.456875     //deviation compensate

#define samplingInterval 20

#define printInterval 800

#define ArrayLenth  40    //times of collection

#define uart  Serial

int pHArray[ArrayLenth];   //Store the average value of the sensor feedback

int pHArrayIndex = 0;
```

```
BH1750 lightMeter;

LiquidCrystal_I2C lcd = LiquidCrystal_I2C(0x27, 20, 4);

#include "DFRobot_EC.h"

#include <EEPROM.h>

#define EC_PIN A1

float voltage,ecValue,temperature = 25;

DFRobot_EC ec;

#define Ec_offset 0.01 //deviation compensate

int turb_sensorPin = A2;

float volt_turb;

float ppm;

#define turb_offset 0.1  //deviation compensate

void setup() {

pinMode(PH_6_above_control_pin, OUTPUT);

pinMode(PH_5_below_control_pin, OUTPUT);

pinMode(EC_control_pin, OUTPUT);

pinMode(TDS_control_pin, OUTPUT);

pinMode(AC_control_pin, OUTPUT);

digitalWrite(PH_6_above_control_pin, HIGH);

digitalWrite(PH_5_below_control_pin, HIGH);

digitalWrite(EC_control_pin, HIGH);

digitalWrite(TDS_control_pin, HIGH);
```

```
Serial.begin(9600);

  dht.begin(); // initialize the sensor

  Wire.begin();

  lightMeter.begin();

  lcd.begin();

  ec.begin();

  lcd.backlight();

  lcd.setCursor(0,0);

  lcd.print("WATER QUALITY TESTER");

  lcd.setCursor(0,1);

  lcd.print("Please wait...");

  delay(3000);

  lcd.clear();

  Serial.println("CLEARDATA");

  Serial.println("LABEL,Light(lux),Temp(C),Humidity(%),PH,EC(ms/cm),Turb(NTU)"); }

void loop() {

   lcd.clear();

   int lux = lightMeter.readLightLevel();    // read humidity

  float humi  = dht.readHumidity();           // read temperature as Celsius

  float tempC = dht.readTemperature();

  if (isnan(humi) || isnan(tempC)) {         //Serial.println("Failed to read from DHT sensor!");
```

```
Serial.begin(9600);
  dht.begin(); // initialize the sensor
  Wire.begin();
  lightMeter.begin();
  lcd.begin();
  ec.begin();
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("WATER QUALITY TESTER");
  lcd.setCursor(0,1);
  lcd.print("Please wait...");
  delay(3000);
  lcd.clear();
  Serial.println("CLEARDATA");
  Serial.println("LABEL,Light(lux),Temp(C),Humidity(%),PH,EC(ms/cm),Turb(NTU)"); }
void loop() {
   lcd.clear();
   int lux = lightMeter.readLightLevel();    // read humidity
  float humi  = dht.readHumidity();           // read temperature as Celsius
  float tempC = dht.readTemperature();
  if (isnan(humi) || isnan(tempC)) {         //Serial.println("Failed to read from DHT sensor!");
```

```
} else {
   //Serial.print("Humidity: ");
   //Serial.print(humi);
   //Serial.print("%");
   //Serial.print("  |  ");
   //Serial.print("Temperature: ");
   //Serial.print(tempC);
   //Serial.println("°C");}
static unsigned long samplingTime = millis();
  static unsigned long printTime = millis();
  static float pHValue, voltage;
  if (millis() - samplingTime > samplingInterval)
   {pHArray[pHArrayIndex++] = analogRead(PhSensorPin);
   if (pHArrayIndex == ArrayLenth)pHArrayIndex = 0;
   voltage = avergearray(pHArray, ArrayLenth) * 5.0 / 1024;
   pHValue = -19.18518519 * voltage + Offset;
   samplingTime = millis(); }
  if (millis() - printTime > printInterval)  //Every 800 milliseconds, print a numerical, convert the state
of the LED indicator
  { //uart.print("Voltage:");
   //uart.print(voltage, 2);
   //uart.print("    pH value: ");
   //uart.println(pHValue, 2);
```

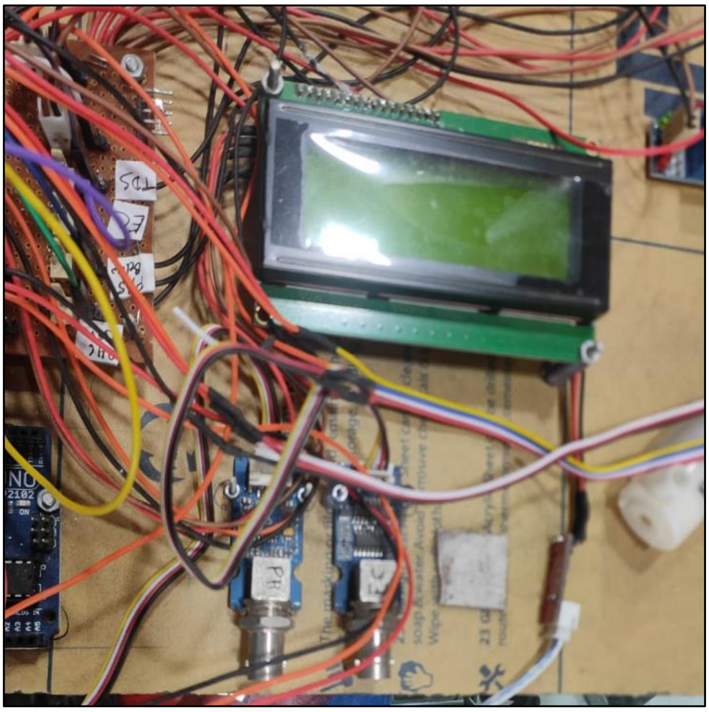
```
printTime = millis() }
static float voltage_EC;
 static unsigned long timepoint = millis();
    if(millis()-timepoint>1000U)  //time interval: 1s
    { timepoint = millis();
      voltage_EC = ((analogRead(EC_PIN)/1024.0*5000)+Ec_offset);   // read the voltage
      //temperature = readTemperature();         // read your temperature sensor to execute temperature compensation
      ecValue =  ec.readEC(voltage_EC,temperature);  // convert voltage to EC with temperature compensation
      //Serial.print("EC:");
      //Serial.print(ecValue,2);
      //Serial.println("ms/cm");}
    ec.calibration(voltage,temperature);         // calibration process by Serail CMD
volt_turb = 0;
    for(int i=0; i<800; i++)
    {volt_turb += ((((float)analogRead(turb_sensorPin)/1023)*5)+turb_offset); }
    volt_turb = volt_turb/800;
    volt_turb = round_to_dp(volt_turb,2);
  {        ppm = (-1120.4*square(volt_turb)+5742.3*volt_turb-4353.8)/3; //reading in PPM
 }
    //Serial.print("Turbidity:");
    //Serial.print(ntu);
    //Serial.println(" V");
```

```
lcd.setCursor(0, 0);
  lcd.print("LightINTSTY: ");
  lcd.setCursor(12, 0);
  lcd.print(lux);
  lcd.print(" Lux");
  lcd.setCursor(0,1);
  lcd.print("Temp:");
  lcd.setCursor(5,1);
  lcd.print(tempC);
  lcd.print(" C");
  lcd.setCursor(0,2);
  lcd.print("Humidity:");          lcd.setCursor(9,2);
  lcd.print(humi);                lcd.print(" %");
  delay(2000);
  lcd.clear();                    lcd.setCursor(0,0);
  lcd.print("PH value:");         lcd.print(pHValue);
lcd.setCursor(0,1);               lcd.print("EC:");
  lcd.setCursor(3,1);             lcd.print(ecValue);
  lcd.print("ms/cm");             lcd.setCursor(0,2);
  lcd.print("Turb:");             lcd.setCursor(6,2);
  lcd.print(ppm);
  lcd.print("PPM");
  delay(2000);
```

```
//below code is for excel entry

Serial.print("DATA,");

Serial.print(tempC);

Serial.print(",");

Serial.print(pHValue);

Serial.print(ecValue);

Serial.print(ppm);

Serial.print(lux);

Serial.print(",");

Serial.print(humi);

Serial.print(",");

Serial.print(",");

Serial.println(",");

if (pHValue > 6)

digitalWrite(PH_6_above_control_pin, LOW);

 if (pHValue < 5.5)

digitalWrite(PH_5_below_control_pin, LOW);

if (6 < pHValue > 5.5)

{           digitalWrite(PH_6_above_control_pin, HIGH);

  digitalWrite(PH_5_below_control_pin, HIGH);}

if (ecValue > 1.2)

digitalWrite(EC_control_pin, LOW);

else digitalWrite(EC_control_pin, HIGH);

if (ppm > 50)

digitalWrite(TDS_control_pin, LOW);

else digitalWrite(TDS_control_pin, HIGH);

if ( tempC > 32)

digitalWrite(AC_control_pin, LOW);

else digitalWrite(AC_control_pin, HIGH);
```

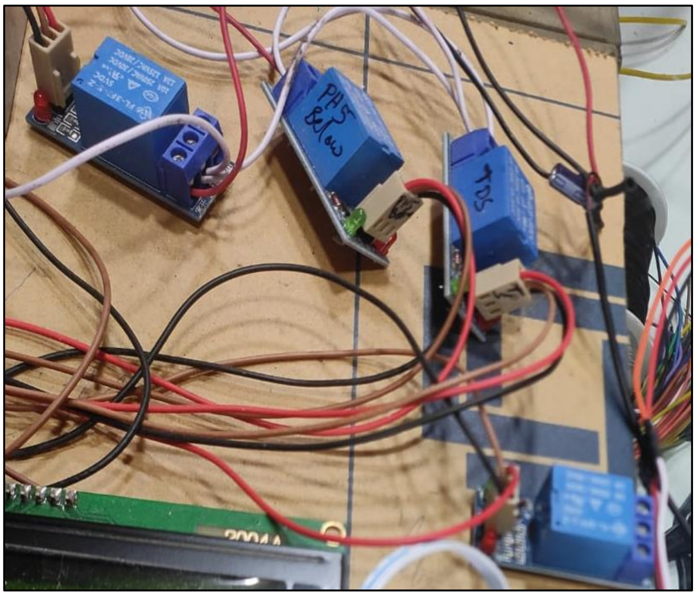
```
double avergearray(int* arr, int number) {

  int i;

  int max, min;

  double avg;

  long amount = 0;

  if (number <= 0) {

    uart.println("Error number for the array to avraging!/n");

    return 0;}

  if (number < 5) { //less than 5, calculated directly statistics

    for (i = 0; i < number; i++) {

      amount += arr[i];  }

    avg = amount / number;

    return avg; } else {

    if (arr[0] < arr[1]) {

      min = arr[0]; max = arr[1]  }

    else {

      min = arr[1]; max = arr[0]; }

    for (i = 2; i < number; i++) {

      if (arr[i] < min) {

        amount += min;     //arr<min

        min = arr[i];

} else {

        if (arr[i] > max) {

          amount += max;  //arr>max
```

```
max = arr[i];
        } else {
          amount += arr[i]; //min<=arr<=max
        }
      }//if
    }//for
    avg = (double)amount / (number - 2);
  }//if
  return avg;
}
float round_to_dp( float in_value, int decimal_place )
{
  float multiplier = powf( 10.0f, decimal_place );
  in_value = roundf( in_value * multiplier ) / multiplier;
  return in_value;
}
```



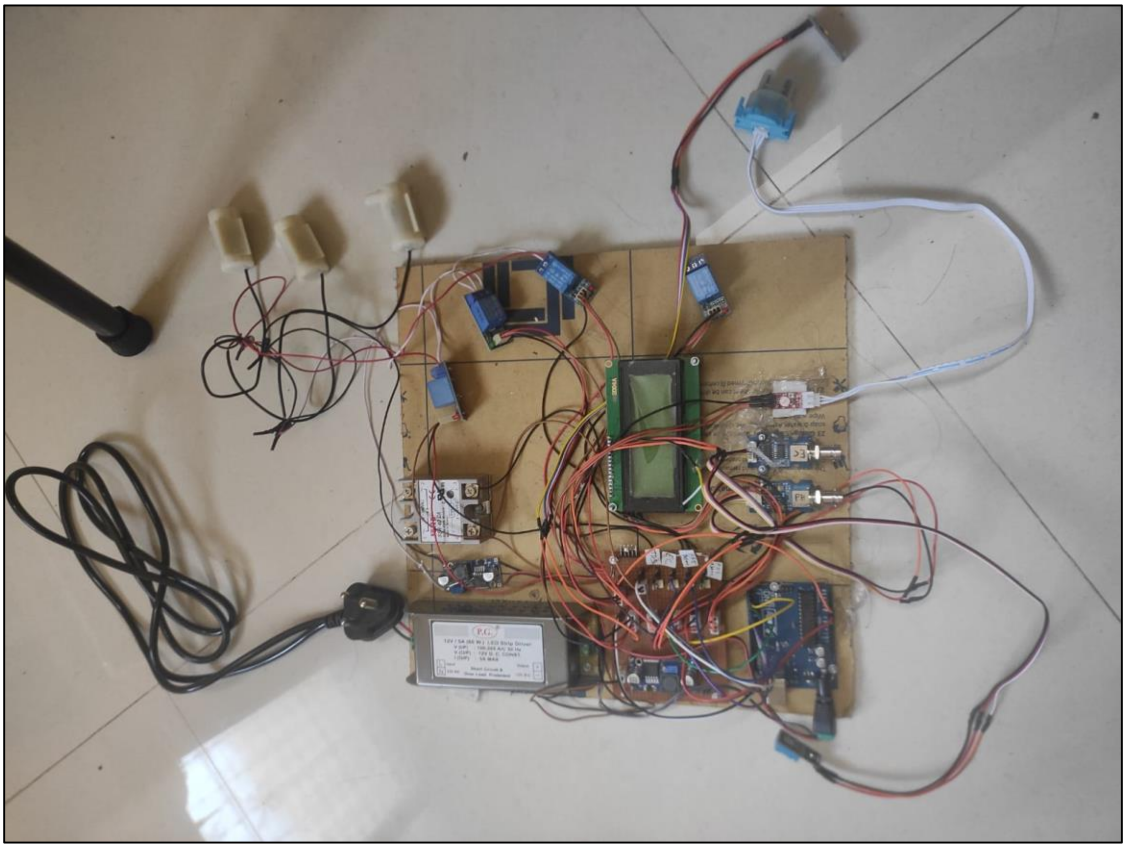
Picture 13: Display

Picture 14: Pumps



Picture 15: Relays

Picture 16: Power Supply



Picture 17: Automation Circuit

3.7. **Pump Calculations:**

Diameter of Nozzle: Dn= 1.9mm, Nozzle Pressure: Pn= 50Kpa, Number of Nozzle:

Nn=6

Nozzle Flow Rate: Qn= 0.0666*$\boldsymbol{Dn2}$*√$\boldsymbol{Pn}$= 2.94 LPM

Pump Flow Rate: Qp= Qn* Nn= 17.64 LPM

∴ Pump Flow Rate: Qp= 1059 LPH

With height about: 1.5-2 mtr

According to calculations, the pump should have flowrate of about 1100 LPH.

4. Manufacturing and Testing Details

4.1. Steps for building frame:

1. Take PVC pipe of 10 feet according to the requirements and cut according to the height wanted for the tower.
2. Take tee and cross to connect pipes for the frame which is 5feet x 6 feet x 7 feet.

4.2. Steps for building tower:

1. Take PVC pipe of ∅110 mm of length 5 feet.
2. Using hex saw blade, cut slot of 72 mm on circumference of pipe as per requirement and having vertical distance of 150 mm between 2 slots.
3. Using heat gun, heat the area around slots made previously. Heat it till the pipe can be easily bent.
4. Take an another piece of pipe of ∅ 40 mm and insert in slot and fold and make a pocket for net pot.

Picture 18: Processing 1

Picture 19: Processing 2

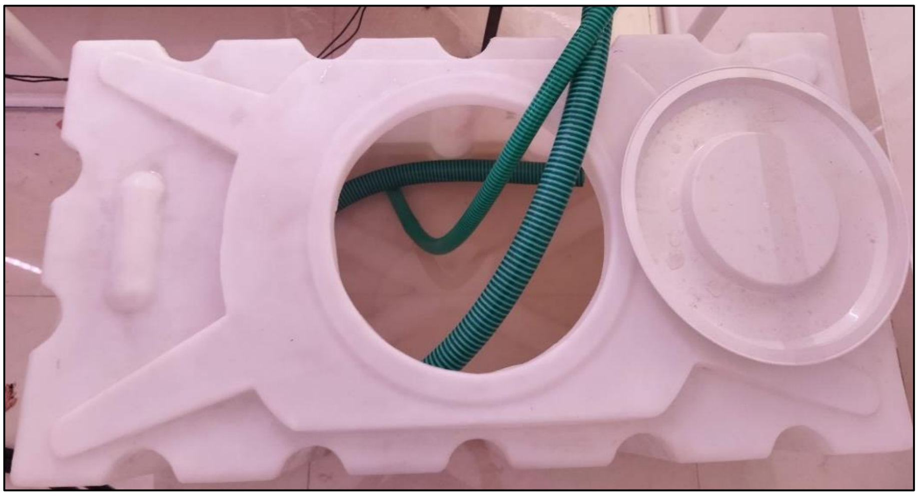
Picture 20: Processing 3

4.3. Piping:

1. Take irrigation pipe and cut according to the required length.
2. Connect the elbow and tee connectors wherever required.
3. Connect the input end to the pump and close the other open end with an end clip.
4. Take scissors and make a small hole so that the irrigation tube of lesser diameter can be attached with a connector.
5. Connect the connector and sprinkler to the small diameter irrigation tube by heating the tube for better connection.
6. Insert the connector in the main irrigation tube.
7. Ensure that the sprinkler is pointing at the center.

4.4. Drainage system:

1. Cut the pipes according to the length required to keep between two towers, consider the elbow length.
2. Attach the pipes and connect using elbow and tee's.
3. Extend the open end so that we can drain the water in the tank.
4. Attach a filter to remove any residues at the end of pipe.
5. Fix all joints with solution and look for any leakage.


Picture 21: Tank


Picture 22: Structure

COSTING:

1.AUTOMATION COSTING:

SR. NO	Description of goods	HSN/SAC	QTY	Rate	Per	Amount
1	SEEDSTUDIO GROVE PH SENSOR KIT	85429000	1 NOS	3,500.00	NOS	3,500.00
2	GY-30 BH1750 Light intensity module	85381010	1 NOS	500.00	NOS	500.00
3	SEEDSTUDIO GROVE EC SENSOR KIT	85429000	1 NOS	6,000.00	NOS	6,000.00
4	WATER TURBIDITY SENSOR + MODULE ANALOG OUTPUT	9027	1 NOS	1,000.00	NOS	1,000.00
5	DHT 11 HUMIDITY SENSOR	85381010	1 NOS	190.00	NOS	190.00
6	Display 20/4 (GREEN)	85312000	1 NOS	350.00	NOS	350.00
7	SK90-S-DC5V-1C T RELAY (30A/250VAC)	85364900	1 NOS	80.00	NOS	80.00
8	ARDUINO MEGA 2560 CH340 COMPATIBLE	84733020	1 NOS	1,400.00	NOS	1,400.00
9	POWER SUPPLY SMPS 12V 5A PG	8504	1 NOS	700.00	NOS	700.00
10	HOOK UP WIRE 1/23	8544	20.00 Mtr	5.00	Mtr	100.00
11	PCB-80X63 MM SS	85340000	1 NOS	150.00	NOS	150.00
						13,970.00
	OUTPUT CGST 9%			9	%	1,257.30
	OUTPUT SGST 9%			9	%	1,257.30

Table 5: Costing of Automation

2.COMPONENT COSTING:

SR.NO	Material used	No. of quantity/	Rates	Total amount
1.	PVC Pipe(110mm)	6	750	4,560
2.	PVC Pipe (75mm)	2	254	508
3.	Sprinkler	6	5/ piece	30
4.	Irrigation pipe	10m	200	200
5.	Tank	1	960	960
6.	Pump	1	2480	2480
8.	Platform	1	1000	1000
9.	Elbow	1	75	525
10.	Cross	3	100	300
11.	Tee Joint	2	100	200
				Total amount= 10,763

Table 6: Costing of Components

5. Results and Discussion

Date	Days	pH	EC	TDS
10-04-2022	1	5.6	1.2	120
11-04-2022	2	5.8	1.2	128
12-04-2022	3	5.75	1.2	137
13-04-2022	4	5.8	1.3	154
14-04-2022	5	5.9	1.3	169
15-04-2022	6	6.1	1.4	183
16-04-2022	7	6.3	1.4	192
17-04-2022	8	6.5	1.4	237
18-04-2022	9	6.2	1.4	278
19-04-2022	10	6	1.5	341
20-04-2022	11	5.8	1.5	396
21-04-2022	12	5.9	1.6	417
22-04-2022	13	6.25	1.8	472
23-04-2022	14	6.4	1.7	522
24-04-2022	15	6.75	1.8	569
25-04-2022	16	6.9	1.8	648
26-04-2022	17	7.1	1.8	690
27-04-2022	18	7.4	1.9	779
28-04-2022	19	7.5	1.8	854
29-04-2022	20	6.8	1.5	927
30-04-2022	21	6.8	1.4	981

6. Conclusion

Based on literature review, experimental study on performance of CEA vertical farming and results obtained, the following conclusions are draw:

- The pH value range observed for 21 Days was ranging 5.5- 7.5 and ideal value range expected for the plants is 5.5- 7.0, so when the pH value was increased above 7, the automation system automatically added required amount of acidic solution and the pH value came back to normal required range.
- The observed Electrical Conductivity value for 21 Days was ranging within 1.2-1.8. As observed the value was changing randomly but it was within required range for the controlled environment agriculture system.
- As results were taken after the germination stage, the range of TDS Value observed was from 100- 200 ppm for first 7 days. The value was increased upto 500 ppm. In next 7 days the value was increased upto 1000 ppm in the last stage. The TDS value was also within required range for our CEA System. The nutrients solution was added with the help of Automation system as per requirement.
- Vertical farming system uses only around 20% of water required for traditional open field farming as the water can be filtered and reused.
- Vertical farming requires almost half of the area of traditional farming area for producing same amount of crops.
- Vertical farming proves to be far better than traditional farming in terms of space and water requirements.

7. Future Scope

7.1. Use of renewable resources:

There are some energy requirements for our project as we are using pump and LED lights which is definitely increasing cost of our project. And in case of large plants energy consumption will be more which will create economic problems so we can use solar panels and other renewable resources.

7.2. Variety of crops:

In our project we have grown exotic leafy vegetables but there is big challenge to grow flowering and other plants giving fruits.

7.3.Scope of Automation

A new generation of farmers are rising to the sustainability challenge. This agricultural revolution presents the transition from traditional farming to futuristic high-tech artificial intelligence (AI) and robotics.

Vertical farming is by no means a new idea. However, recent supply chain disruptions coupled with the falling price of produce, is opening new doors for a farming method previously deemed unviable by many. Here, John Young, APAC country manager at automation parts supplier EU Automation, highlights the renewed interest in vertical farming among a new generation of farmers, and explores the advantages it offers in tackling some of the biggest challenges facing the sector.

Turn the clock back approximately 1000 years, and less than four per cent of the world's habitable land was used for farming — that is the equivalent of four million square kilometres. Today, farmland takes up more than half of the world's habitable land, which equates to a landmass larger than South America.

Our World in Data reports the alarming facts associated with industrialized livestock farming, involving climate change, extinction of species, widespread destruction of habitat, and 80 per cent of cropland grown to feed livestock. With the population of the

Asia Pacific region expected to reach 5 billion by 2050, the responsibility to supply food to an ever-growing population is becoming difficult.

A new generation of farmers are rising to the sustainability challenge. This agricultural revolution presents the transition from traditional farming to futuristic high-tech artificial intelligence (AI) and robotics. Whether it's weed-killing robots, harvesting and picking robots, or autonomous tractors, the farming landscape is evolving. In this age of robotic farming, producers believe incorporating automation and data will enable farmers to produce more, while damaging the environment less.

One major process change that is currently on the rise is the shift to vertical farming. Currently, 16.55 million square feet (sq ft) of indoor farms operate across the globe. However, the State of Indoor Farming report suggests this figure will increase to 22 million sq ft by 2022. The demand is high, and the AI journey is only getting started.

Why are farmers suddenly interested in vertical farming?

Vertical farming is the practice of producing food in vertically stacked layers. The climate-controlled indoor farms contain rows of plants situated next to each other, growing vertically, and hanging from the ceiling. Robotics help manoeuvre the products around, and AI can monitor the different parameters that are required for the crops to grow, such as the levels of water, temperature, and light.

Indoor agriculture is at an exciting point in its development. Key technologies used in farming systems today range from perception technologies which use cameras and sensors to detect and monitor various factors of the lifecycle. AI processes the data from sensors and provides solutions, while automated and autonomous mechatronics that use robotics and automated machines collect products when ready to dispatch to the market and recover the crops from ailments during the growing cycle.

Right now, the focus is to take vertical farming to the next level by developing smart robots which can increase precision and productivity, while minimizing environmental impact and risk. Agriculture, one of humankind’s oldest inventions, is merging with the latest technology, and farmers will soon be looking to pair with a reliable automation parts supplier to make the step up to vertical farming.

Vertical farming offers a unique set of advantages. Farmers understand there are many urgent and practical reasons to grow upwards rather than outwards. This farming method has huge potential for sustainability and food security, while protecting the environment, economy, and ecosystems.

In addition, the inclusion of AI and robotics ensures high-quality growth of products all year round, while preserving water, nutrients, and land consumption by 95 per cent. The controlled process of indoor farming with the help of AI and robotics also protects crops against pest invasions, and ensures they are well insulated — this is an aspect field farming cannot guarantee since it requires amenable weather conditions and labour.
Vertical farms can operate anywhere with no geographical constraints and are not subject to the limitations presented in outdoor farming, such as extreme conditions. This not only protects the crops, but also provides a safer working environment for labourers. What's more, labour costs can be significantly reduced due to the automated indoor growing systems; thus, there is no longer a need for manual labour all year long.

In addition, energy consumption can be drastically reduced in vertical farming by implementing LED lighting to mimic the sun as a light source. A minor change like this can limit heat waste while increasing energy efficiency and cutting energy costs. Not only can LED lighting be used as an alternative, but renewable energy generated from wind turbines can be paired with vertical farming to ensure 100 per cent of its energy is produced from renewable sources. It is a win-win situation.

How will it boost the economy?
This sector is expecting a huge boom in investment and interest and manufacturers, suppliers and retailers are therefore preparing for this shift through early adoption. In the past, vertical farming was viewed as theoretical, but now the vertical farming market in the APAC region is expected to grow at a compound annual growth rate (CAGR) of 29 percent, rising from its current value of $0.78 billion to $2.77 billion by 2026. This is largely due to the advancement in technology such as sensors and smart energy systems that have improved the efficiency of growing products.

Although vertical farms will not replace traditional ways of farming, they hold great potential to revamp the future of agriculture in the APAC region by pushing towards a sustainable, environmentally conscious, tech savvy, economically rational, and health-sensitive world.

References

1. G W Michael1 , F S Tay1 * and Y L Then1 1 Faculty of Engineering, Computing and Science, Swinburne University of Technology, Sarawak Campus. Jalan Simpang Tiga, 93350 Kuching, Sarawak, Malaysia Email: fstay@swinburne.edu.my*

2. Ahsan Ullah, Sadia Aktar, Nipa Sutar, Rafsan Kabir, Afzal Hossain Department of Computer Science and Engineering, World University of Bangladesh, Dhaka, Bangladesh Ullah, A., Aktar, S., Sutar, N., Kabir, R. and Hossain, A. (2019) Cost Effective Smart Hydroponic Monitoring and Controlling System Using IoT. Intelligent

3. Fatemeh Kalantari1,a* , Osman Mohd Tahir2,b , Ahmad Mahmoudi Lahijani3,c and Shahaboddin Kalantari4,d 1,2Department of Landscape Architecture, Faculty of Design and Architecture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia 3 Department of Mechanical Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia 4 Department of Civil Engineering, Islamic Azad University of Chalous, Chalous, Iran a Fatimah.Kalantari@gmail.com.

4. Madhuvarshini M1 , Kaviyan J2 , Maharaja M3 , Muraliprasanth R P4 , Sangavi K B5 Electronics and Communication Engineering Sri Shakthi Institute of Engineering and Technology L and T bypass Road, Coimbatore, India 1 madhuvarshinim2019@srishakthi.ac.in , 2 kaviyanj2019@srishakthi.ac.in

5. Guilherme Lages Barbosa 1 , Francisca Daiane Almeida Gadelha 1 , Natalya Kublik 1 , Alan Proctor 1 , Lucas Reichelm 1 , Emily Weissinger 1 , Gregory M. Wohlleb 1 and Rolf U. Halden 1,2,* 1 School of Sustainable Engineering and the Built Environment, Arizona State University, Tempe, AZ 85287-5904, USA; E-Mails: glagesba@asu.edu (G.L.B.); falmeida@asu.edu (F.D.A.G.); Natalyaemmanuely.Mohrkublik@asu.edu (N.K.); ajprocto@asu.edu (A.P.); lreichel@asu.edu (L.R.); eweissin@asu.edu (E.W.); gwohlleb@asu.edu (G.W.)

6. Nilton N Cometti1 ; Diene M Bremenkamp2 ; Karla Galon2 ; Leonardo R Hell3 ; Marinaldo F Zanotelli3 1 Instituto Federal de Educação, Ciência e Tecnologia de Brasília (IFB), SGAN 610, Módulos D, E, F e G, 70860-100 Brasília-DF; www. niltoncometti.com.br; nilton.cometti@gmail.com; 2 Universidade Federal do Espírito Santo (UFES–CCA), Alto Universitário s/n, 29500- 000 Alegre-ES; dienemkamp@yahoo.com.br; karla_galon@hotmail.com; 3 Instituto Federal do Espírito Santo (IFES), Campus Itapina, BR 259 km 70, 29709-910 Colatina-ES; leonardoraashhell@hotmail.com; mazanotelli@bol.com.br
7. FATEMEH KALANTARI*, OSMAN MOHD TAHIR, RAHELEH AKBARI JONI AND EZAZ FATEMI Faculty of Design and Architecture, University Putra Malaysia, Kuala Lumpur, Malaysia, *Corresponded author - e -mail: Fatimah.Kalantari@gmail.com

8. Sagar J. Dholwani, 2 Sagar G. Marwadi, 3 Vandan P. Patel, 4 Vijeta P. Desai 1,2,3Students, 4Assistant Professor 1Civil Engineering Department 1 Sardar Patel College of Engineering, Bakol-Anand, India.

9. Imran Ali Lakhiar ,[1] **Gao Jianmin** ,[1] Tabinda Naz Syed,[1] Farman Ali Chandio ,[1] Noman Ali Buttar ,[1] and Waqar Ahmed Qureshi [2]

   2. [1]Key Laboratory of Modern Agricultural Equipment and Technology, Ministry of Education, Institute of Agricultural Engineering, Jiangsu University, Zhenjiang, 212013 Jiangsu, China

3. [2]Research Centre of Fluid Machinery Engineering and Technology, Jiangsu University, Zhenjiang, 212013 Jiangsu, China

10. B Frasetya*, K Harisman and N A H Ramdaniah Department of Agrotechnology, Faculty of Science and Technology UIN Sunan Gunung Djati Bandung, Bandung, Indonesia *budyfrasetya@uinsgd.ac.id
11. C. Aswath, G.Selvakumar, C. Zimmerman, M.Bajikar. “Utilization of vertical spaces for horticultural crop production in urban and peri-urban areas.” Current Science. Vertical Farming Association. 6.10.2016. Accessed 1.15.2018.