DESIGN AND DEVELOPMEENT OF AUTOMATIC ROBOTIC SYSTEM FOR VERTICAL HYDROPONIC FARMING USING IOT AND BIG DATA ANALYSIS

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ABSTRACT

In this digital world, all the developing countries' growth has improved elastically with the impact of farmers and their innovative farming processes. Generally, the farming process can be developed with ancient traditional methodologies for maintaining the quality of the crops and their yields. Their farming was developed and has given more profit only with the quality of the soil and the nutrition's used on land. But the drawback is they were spending much time to get their yields from their land and the nutrition level was not maintained at all times. Moreover, more space was used for farming with huge manpower is required for maintaining the entire land. Most of the countries are moved to smart farming concepts with IoT platforms for optimizing the time and techniques. In that hydroponic the best innovative idea to produce more crops, vegetables, and fruits without soil. Rockwool is used for farming processes with water contaminants at regular intervals will provide huge productions as well as no need to wait for a long time for cultivation. This method was implemented in most of the countries that were doing smart farming with less manpower and low cost. The hydroponic farming methodology is implemented with IoT sensors for monitoring crop's status and health continuously. Once their nutrition level or water level has decreased it will provide all at constant time intervals to the entire system effectively. A few years ago hydroponic farming was horizontally implemented on smaller spaces for the regular water flow. But now a day it is implemented on a vertical surface to reduce the space and water flow is only at the time of need. This technology is used to increase the productivity of the crops with a small space of land and less manpower. Perhaps the cost of the entire system has been taken into the consideration by small-scale unit farmers vertical hydro farming provides better results when compared with previous classical methods. This research paper has given the design and implementation of automated vertical hydro farming techniques with IoT platform and their analytics will be done using big data analytics.

Keywords: Hydroponics, Nutrient Solution, Rockwool, Submarine Motor, Plant growth light

1. INTRODUCTION

India is a majorly Agri based economy with 70% of farmers in rural house depend primarily on agriculture with 82% of farmers being poor due to which India is witnessing stark challenges and losing its importance due to urbanization [1]. This research work is transforming the farmer's life using IoT-based Hydroponic vertical Farm by eradicating the above-said problems. Hydroponic farming proposes suitable weather-based recommendations for farmers to improve their crop yields [2]. Vertical Hydroponic farming remembers preferences, reproductive history, and relevant data about farmers and facilitates better access and efficient use of reproductive crops without soil to achieve optimal soilless crops and plants [3]. Hydroponics System has been developed to facilitate cultivation in small-scale environments, and improve farming quality using soil less methods. [4]. In this novel world, hydroponic farming is formerly entrenched horizontally which takes more space and human power for managing the whole farm [5]. The following figure 1 denotes the existing hydroponic cultivation model.

Figure 1; Hydroponic Farming Systems

2. EXISTING SYSTEM AND RELATED WORKS

India is an agricultural country but it is overwhelmed by practical problems such as low-quality seeds, manures, fertilizers, biocides, irrigation, and lack implementation methods [6]. In order to extend the scope of agriculture development, new innovative Hi Tech production systems are needed. To overcome this problem along with water availability, nutrition level maintenance, manpower, and soil irrigation system, a new innovative approach is used which is highlighted currently is "Hydroponics" [7]. Hydroponic farming is the soilless farming technique, formerly well-established in horizontally which take large space for growing plants and it is not fully automatic that's the main reason for the small scale land people's were not using hydroponics. A crop growth rate is affected by the usage of a large human source. Therefore, it is enhanced vertically which will reduce the space requirement with a fully automated platform using IoT, Big Data Analysis [8]. To solve water issues, pipelines were fixed for continuous water flow to the Hydroponic plants to grow well. It has a lot of challenges and difficulties in farming even though the normal peoples can grow plants in their home with a low-cost setup. The whole system will be managed automatically using microcontrollers which are too compactable and best for analysis of the nutrient level. Hydroponic is helping an efficient use of fertilizers & water, as well as it increases high productivity and better crop quality [9] also it has good control of climate and pest factors, which provides high competitiveness and economic incomes to the former.

An automatic robotic system has been implemented for vertical hydroponic farming with an IoT framework. This vertical hydroponic system is used to reduce the usage of water up to 70% as sustainable energy and will be used to minimize the land without soil crop productions. These system requirements are different from existing hydroponics in using nutrients, sensors, Rockwool, plant growth light, submarine motor, supporting materials, and mineral fertilizers [10]. The P.V.C pipes are vertically connected each to make a platform for growing plants. The seed of the plants is kept in Rockwool which helps to stable the plant and soak to the water for seeds. The submarine motor supplies the nutrient solution water to each plant according to their needs on the entire setup. The whole system is automatically managed using microcontrollers Arduino and Raspberry-pi also it is analyzed using data analysis and android applications. The communication between the analysis systems will be done by 4G LTE (Module) [11]. The automated system provides input of temperature sensor, pH & EC sensor and various sensors which is helping to take the decision and control the major factor which affects the crop yield [12].

Vertical hydroponic systems are the new innovation in agriculture and used to provide sustainability for the small scale farmers with eco-friendly environment. Smart farming also helps the farmers to do all the works with less manpower or automated based on their requirements. Because of these techniques economically they will be improved and technically grown with smart city concepts.

Normally in soil cultivation huge amount water consumption are there but in this hydroponics only 1/10th - 1/5th of the water is utilized by the farmers [13-15]. All necessary nutrients are providing to hydroponic plants through the nutrient solution, which will the presence

of fertilizer and salts dissolved in water. Measurements have taken like pH level, temperature, and electrical conductivity (EC) from nutrient solution using an automated system and analysis system again replacing the solution whenever necessary. The food which is produced by this method is most sustainable model rather than the classical models available for agriculture. Thus, it is not only a solution for problematic soils but it also helps to improve the quality and quantity of agriculture produce [16-17].

3. PROPOSED SYSTEM AND ARCHITECTURE

Implementation of an automatic Robotic system for vertical hydroponic farming has initiated with a proposed model. When sustainable energy concepts are most required in agriculture, the sources like water, soil, nutrition and land has to be taken as a main factor in this hydroponic systems. Vertical farming main goal is to produce more crops and plants with less water resources. In this approach water and other sources are used i=only when it is required by the plants. So minimum amount of natural resources are used to keep maintain the sustainability in the agriculture field. In the initial step we make a vertical stand with couples of PVC pipe, where some pipe stands vertically help of support, every vertical pipe we make the hole of 5cm at a 30-degree angle. Each standpipe has been fixed with a solenoid valve on top. These valves helping to control water drops, and Rockwool is used to soak the drop of water that is coming from the nutrients tank through the pipeline.

For the monitoring automatically these systems we have fixed pH sensor, Temperature sensor, Electrical Conductivity sensor, Water flow sensor on the water tank, this sensor is helping to read all the input value from water in which EC sensor if finding the quality of nutrients and pH sensor maturing the level of pH present in water. The normal pH level of water is 7 if the nutrients present in water then the level of pH are decreasing up to 5-6. Plants need limited water and fertilizer for limitation of water we measuring the flow of the water and control it with solenoid valves. The ultrasonic sensor is used to find the growth of the plants continuously by measuring the heights. Entire details will be sent as notifications to centralized android mobile app and will be compiled from smart devices effectively.

Suppose there will be less than water with the thresh hold level, then automatically the water pump will start and it will fill required level of water in the tank and this message will send to the owner. At the same face temperature of the water is very important for small plants so we are measuring temperature using the sensor. Rainwater harvesting tank used to store huge amount of water while raining and it will be used to do cycling process. The recycling water unit helps to get wastage / extra water from the entire system and recycling to the next round process to avoid delay. Water flow is always in the entire system but the nutrition levels have to be maintained with the help of a nutrition tank. The following figure 2 explains the architecture of proposed vertical hydroponic system.

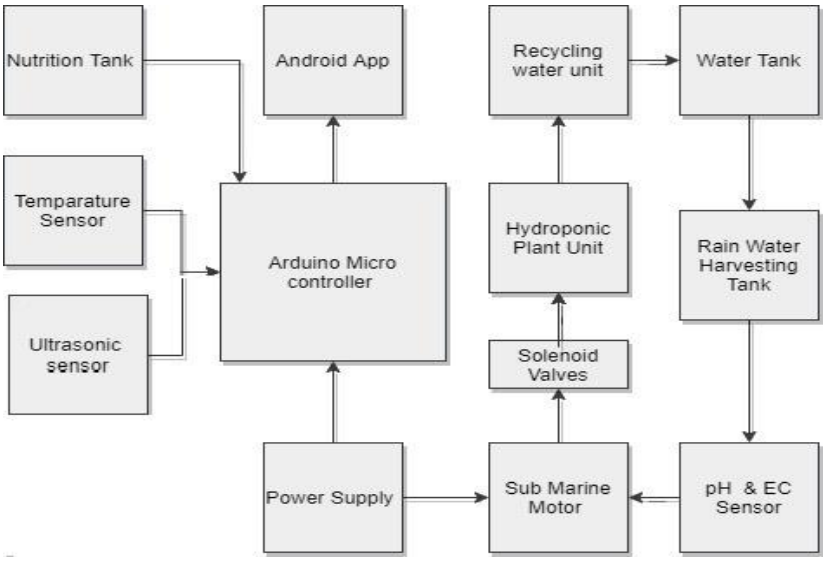

Figure 2: Proposed Architecture of Vertical Hydroponic System

4. DESIGN AND WORKING MODEL

Vertical hydroponic farming is implemented because of the growth of the plant without soil and less water. Their implementation describes the framing of pipe, maintaining, and auto refilling of the water cycle. It also monitors the plant nutrient and pH whether it is correct or not. It determines the air circulation and lighting then controlled with the temperature.

4.1 Structure

The plants need a light effect compulsory for growth. So that we are proving plants grow lights which will provide chloroplasts absorb energy. Some plants need more sunlight to grow but all plants need at least a little and plants to take in carbon dioxide from the atmosphere. These Plants grow light fixed at top of the vertical frame at in angle of 30-degree down. The following figure 3 describes the structure of vertical hydroponic system and its model.

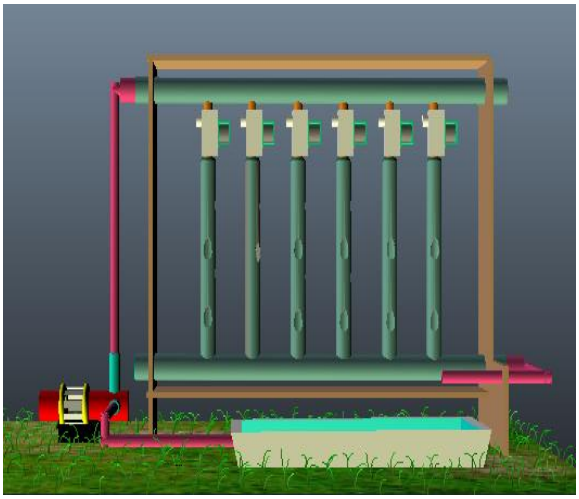

Figure 3: Working Structure and Model Diagram

4.2 STRUTURE OF VERTICAL HYDROPINIC SYSTEM FRAME

A standard 4 PVC pipes with 2 inch and 3 inch outer diameter frame is constructed vertically for the initial set up. Then for easy in sizing of all pipes in the same structure this material have chosen. More over metal/plastic/wood are not suitable for agriculture system, due to its size and manufacturing materials. It is not carrying water effectively when compared with PVC pipes. If the size of the pipes is same in nature then only flow of water will not affect the growth of the plants. The plan is to fix four 2 inch pipes as a tower with 4.5 inch on centre. This length can be varied according the usage of the number of plants to be cultivated. The spaces between the pipes are increased/decreased will decide the growth height of the plants. The bottom structure frame also constructed on the same way with the height of 4 feet and 2 inches pipes in the length. It has two level structures like top and bottom with pipes and the height of the plants are decided by the gap between these structures. There is water tank, nutrition tank and other units also initialized for the hydroponic process. A motor is used to make water flow from bottom to top using pipes along with nutrition. On the top of the frame, light sources are also used to provide lighting effects for the growth of the plants when sun light is not available during night times. These light sources provide enough heat or temperature to the plants for continue their work at every time.

4.3 Recycling

The pipes are cutter with 30-45 degree inclined with the requirement of the users but for the monitoring purposes trails have taken for consideration. On this inclined structure Rockwool is fixed at certain level and now it is ready for farming. When water comes to this system Rockwool observed some amount of water and the remaining will go to the next one due to vertical structure

of the system. This approach will be worked on all the pipes in a same way to reduce the water usage and decreases the time for cultivation. Instead of 6' rises reducing overall water flow, the rise is slightly more efficient to the pump. The submarine motor is used to pump the water from the bottom and recycling it whenever required by the system. The following are the work done by the vertical hydroponic system to increase the productivity of the crops and yields of the small scale farmers.

- Automated system with IoT framework
- Monitoring of water flow & water level
- Measuring nutrient of water
- Temperature and moisture monitoring
- Water recycling & Growth of the plants

The following figure 4 and 5 explains the water consumption model and shows the recycling process of vertical hydroponic structure.

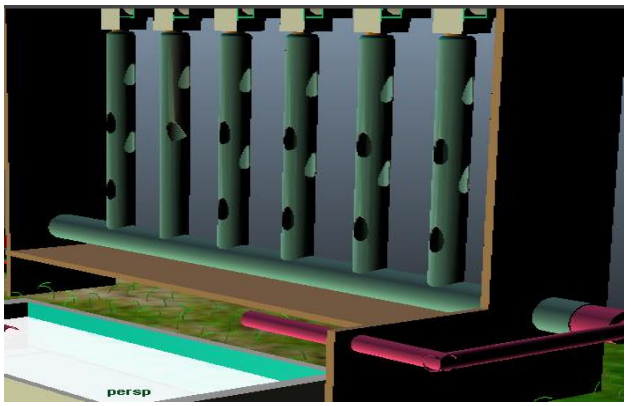

Figure 4: Water Consumption

Figure 5: Cyclic Process of Water Consumption

4.4 Working Flow Chart

Initially the rainwater harvesting tank and water tank level have to be checked with two categories like Upper Level (UL) and Lower Level (LL). Solenoid valve has to be connected with Arduino microcontroller and make a serial connection of motor for pumping water into the plants through the pipes. Similarly all sensors such as temperature, pH, Electrical Connectivity (EC), Ultrasonic, and moisture have to be connected and ready for initialization. The sensor values take reading and send to the microcontroller then it will decide according to the threshold value set by the farmers. If it reached the level then water flows to the plants for a certain time and it will close automatically. Nutrition's are supplied

from the tank parallel. Finally, all the values are sending to a centralized mobile app and server for further analytics process. The following figure 5 denotes the flow chart for vertical hydroponic system and their conditions.

Figure 5: Flow chart of Vertical hydroponic system

Flow of Water levels and its conditions:

I. When condition LL ≤ UL, reveals No Action
II. Then F ≤ LL , Solenoid valve opened for certain time
III. If F ≥ UL, then Valve Close

where F – Flow of Water LL = Lower Level, UL = Upper level

The above conditions are used in a vertical hydroponic system for providing water to the plants at regular intervals. The decision of solenoid valve open function and how much time it will be opened has been decided by the microcontroller unit based on the programming written on that. From that three conditions were used if the water level reached is less than the upper level then no action in the valve section but the water flow is less than the low level immediately valve is opened for a certain time. The third condition is if water flows greater than the upper limit then the valve will be closed automatically.

5. RESULTS AND DISCUSSIONS

The above vertical hydroponic system design was implemented through the experimental setup in smaller areas like home and the results were taken for analytics. There are a total of 4 pipes, submarine motor, nutrition tank and Rockwool for plants have considered for cultivation process and this set up was developed in normal room temperature mode then continuously monitored for 30 days. Different outputs have been taken and stored in the mobile android app then all the data has taken for analytics.

When the motor is ready to start running, all the sensors are connected in a microcontroller unit checking the threshold levels of all types of equipment. Exactly there is no water supply to the plant unit immediately after the solenoid valve is opened and the water supply will go to the pipes automatically. Continuous water supply from the motor through the pipes and their levels, time has taken for analytics. The following figure 6 describes the time taken for releasing the water levels to the pipes from the water tank.

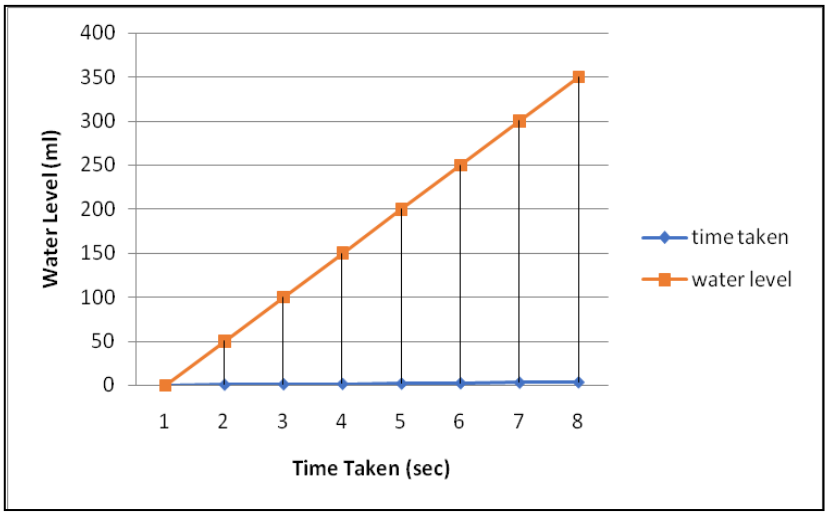

Figure 6: Water released from solenoid valve

After releasing the water from the motor it will reach the pipes at a different time and will be passed through the plants. Already plants are dipped in Rockwool on the pipe vertically. Required water is taken by the plants and the remaining will be going to the next unit. The remaining wastewater will be directly going to the water tank and used for the recycling process. So in this method water usage will be maintained continuously. The following figure 7 denotes the water level in pipes at different trails. On each trail, the level of water released from the motor is the same but reaching the plant is varied. It depends on the nutrition level and water required by the plants.

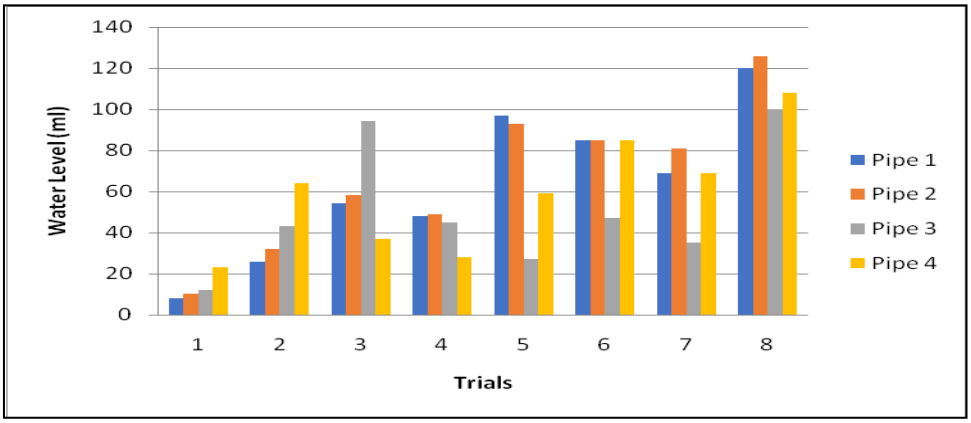

Figure 7: Water levels in different pipes at various trials

The entire system is controlled and monitored by IoT sensors effectively at all endpoints and the performance of the units is measured by important factors like time taken to complete the process and the output given by the system. It depends on the trails taken by the user and the output given by the system. The following figure 8 explains in detail the percentage of output to the user from the different trails on various pipes.

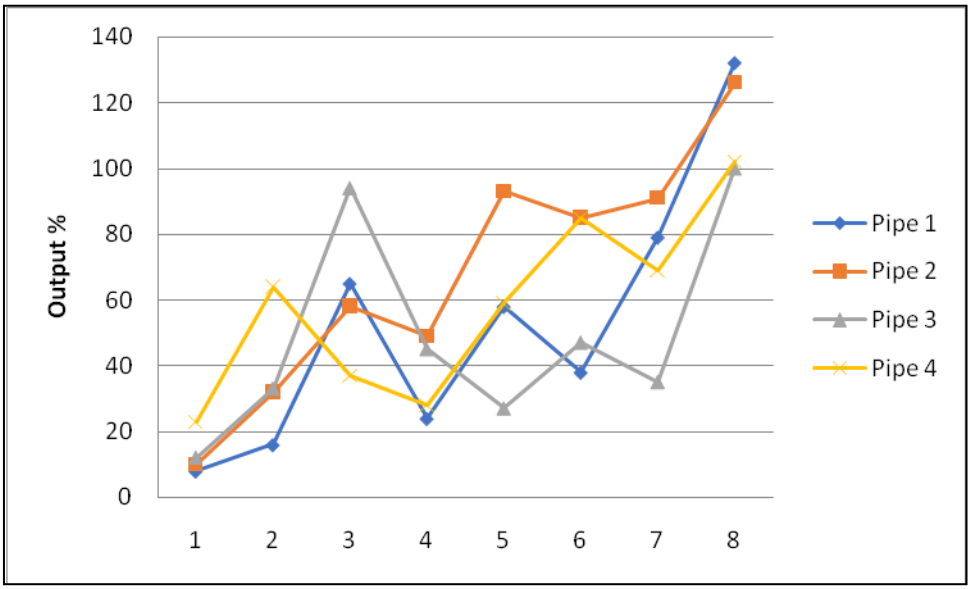

Figure 8: Vertical Hydroponic system performance

The vertical hydroponic system is differing from the horizontal system mainly on usage of water and time taken to reach the plant. As the levels of water released from the motor then will reach pipe in a vertical system, various water level is been running on the pipes due to vertical structure. The water flow is changed frequently on pipes due to the nutrition tank and Rockwool grasping capacity. The following figure 9 describes the changes in water flow through pipes at different trials.

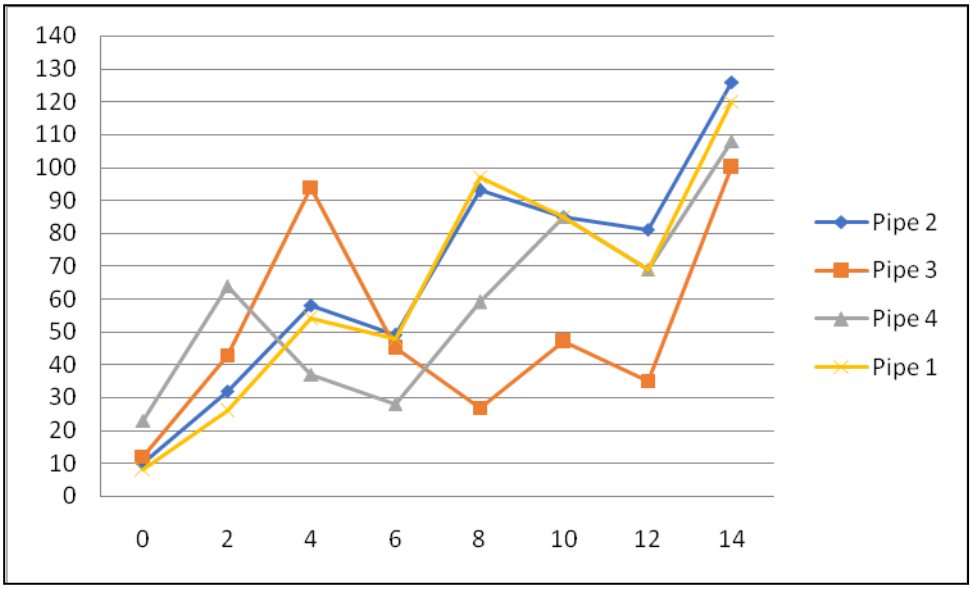

Figure 9: change of water flow in pipes at various trials

There are 4 pipes in a vertical structure system time taken for water flow changes is not the same in all the pipes. This is due to the plant growth and their nutrition grabbed capacity on the pipes. For that various water flow is there in each pipe based on the need of the plants at different

time intervals. Though various water levels on the pipes the plant growth will not affect because growth will be monitored by the ultrasonic sensor through the IoT framework. The following figure 10 denotes the time taken for change of water flow on the pipes at various intervals.

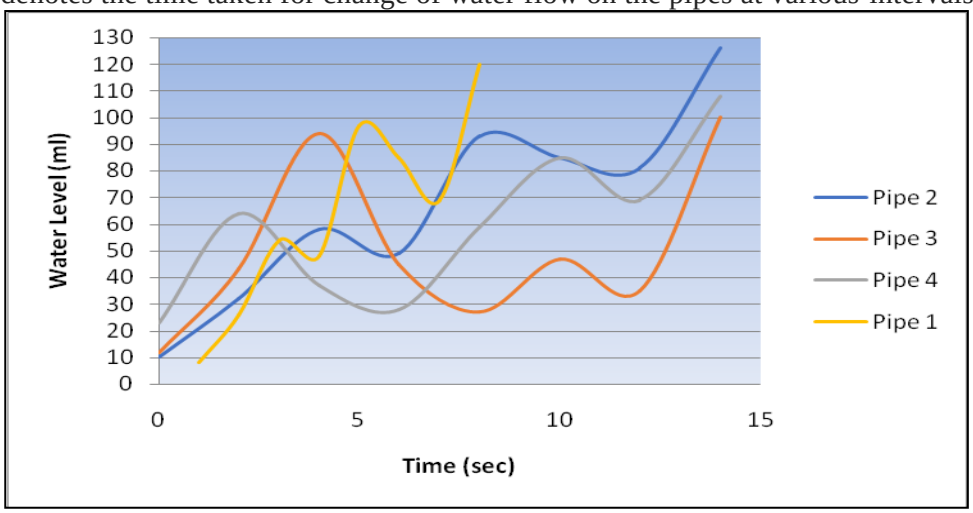

Figure 10: Time taken for changes in water flow at various pipes

The entire vertical hydroponic system is controlled and monitored by an android mobile app with a smart device then the results will be stored in databases for analytics. Finally from the results lot of data has been taken and given to the small-scale farmers. This would be very informative and easy to increase their productivity at all seasons. The main factors taken for consideration are the height of the plant, the width of the leaf, and the number of leaves produced by the system. While checking the results smart hydroponic system gives a better result when compared with a normal system. The height, width, and numbers of leaves are more in a smart system. Because in normal system monitoring are not done but water flow and nutrition percentage was given continuously. In a smart system only when the plant is required water or nutrition then only it was given. The following table 1 provides the details of the plant for the continuous 30 days monitoring on the smaller area home.

Table 1: First month plant growth level

Plant Details	Smart Vertical Hydroponic System				Normal Vertical Hydroponic System			
	1 Pipe	2 Pipe	3 Pipe	4 Pipe	1 Pipe	2 Pipe	3 Pipe	4 Pipe
Height of the Plant(cm)	12.1	11.9	12.2	12.1	10.9	9.8	11.0	10.6
Width of the leaf (cm)	5.5	5.6	5.4	5.5	4.7	4.2	3.9	2.8
Leafs produced	10	10	10	10	9	9	9	9

6. CONCLUSION

This paper would reduce the cost of farming and land for creating a smart farm and also recycling water consumption is the prestigious method of farming with Big Data Analytics. IoT platform helps the small-scale farmers identifying the levels of the water and other contaminants

continuously and monitored with the centralized server through the android mobile app. If the water level decreases or no water in the system will be intimated to the owner of the farm immediately. There are so many sensors that are used to check the flow and quality of the water for the growth of the plants. Their height is monitored at every change that occurred in plants and notified for results. Big data analytics is used for farmers to decide for what crops, vegetables, and fruits will be cultivated based on the seasons such as winter and summer. Most cost-effective system for small-scale farmers and will be used inside the home also. Especially women's are getting developed both technically and economically while using this system.

7. FUTURE ENHANCEMENT

To implement the vertical frame for hydroponic farming the water level consumption would be recycling [18] and it has to enhance the duration of the plant growth. The components used for farming are very cheap when compared with the existing system. In the future, it would be the best crop system for farming with less manpower and planting area also. The detailed analysis would be stored as big data using IoT and it would be analyzed based on various analytic methods. The entire system is used only for small-scale farmers and it was implemented in smaller land areas. The futuristic process will be collected the data from huge land areas and the analytics will be taken for a variety of crops, vegetables, and fruits. Recycling of water will create a new impact in the future and it would be distributed to the neighbouring system also. Predictive analysis also will be taken with the existing system and will tell the nutrition level to the farmers in the future for the development of their farm in a cost-effective manner [19]. To provide IoT framework for automated robotic systems routing protocols and several algorithms are used to carry the plan data to the entire world using any recent technologies. [20-22]. It also used to provide good life time to the IoT Framework. Life time of the IoT framework has to be decided by its energy aware routing techniques because huge volume of data have carried out for analytics on real time applications [23-27].

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