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DESIGN OF SMART VERTICAL HYDROPONIC SYSTEM

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KEYWORDS

hydroponic system, IoT, sensors, raspberry pi controller, wireless connectivity.

ABSTRACT

All horticultural regions of the world have fundamentally developed in the programmatic era through farmer impact and imaginative development practices. The methods described are used to monitor satisfaction and crop yields. Because of the quality of the soil and the nourishment of the land, their cultivation has improved and created more money. The disadvantage is that it took them a long speculation to acquire the crops, and the level of nutrition was not usually put at its obvious level. In addition, many areas were devoted to production, which required a lot of work to treat the whole area. In order to control the time and methods well, the majority of the regions switched to careful development principles with IoT structures. Growing on water is the most progressive strategy to grow natural plants, vegetables and fruits without using land. The use of Rockwool in agricultural strategies where water contamination is possible for a certain period will result in huge yields and the requirement of longer growing times will be waived. Most of the countries that have practiced smart and economic development with little external intervention. IoT sensors are used in the water cultivation development system to test the situation and quality of yields continuously. They will effectively provide information to the whole system when the water or nutrient level has dropped. In the beginning, the development of hydroponics was done horizontally in small spaces in order to maintain the water flow. Today, it is applied on a vertical structure to save space and water flows when needed. With this method, yields are likely to be achieved even more space-efficiently and with little external intervention. Vertical hydroponics performs better than previous conventional approaches; perhaps the farmers in the extension unit have considered the cost of the total layout. This evaluation paper describes the use of procedures and development of automated methods using IoT platforms. Many reference materials can be used big data.

INTRODUCTION

Tunisia is a region with a predominantly agriculture-based economy, 70% of provincial family farmers are largely dependent on agriculture and 82% of farmers are poor. Tunisia is therefore facing severe incentives and is losing its importance to urbanization (Pu et al., 2022). This study aims to boost the farmer's life by overcoming the above-mentioned problems through a vertical IoT based device. The vertical hydroponic horticulture remembers the trends, regeneration history and appropriate information regarding the farmers so that they have better access and more useful use of prolific crops while not being on the ground (Dowlatshah et al., 2020). The water growing structure should help farmers in confined range conditions to successfully bring in production yields. A quality method with less soil (Kumar et al., 2022). Hydroponics was focused on the horizontal plane in this new world, which excusable more space and tomorrow of opens to control a complete structure (Trisnani & Utami, 2020). Figure 1 below shows a model of current hydroponics.

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FIGURE 1. Plants created in hydroponics: structures.

RELATED WORKS

Tunisia could be an agricultural nation, but it is weakened by concrete problems such as poor quality of seeds, fertilizers, excreta, biocides, water and insufficient execution procedures (Hemanth et al., 2020). To increase the degree of evolution of agricultural occasions, new units of creating innovative super advanced structures are needed to overcome this possible drawback with the presence of water, control of the level of feeding, maintenance, and soil water framework system, another brilliant technique is applied, which is highlighted immediately "Hydroponics" (Reddy et al., 2022). Hydroponic development is the strategy of soil-less development, currently anchored in a way is not vertical, which takes a satisfactory area for plant production, and which has not been fully automated, it is the fundamental idea of the technique inside the limited scale of the individuals of the earth have not used to apply hydroponics. A yield impact rate is stuck by the external intervention. Besides, it is worked on a vertical hydroponic device, which can decrease the need of space with a completely modernized application based on IoT, big data analysis (Sabri et al., 2017). The pipes are consistent for the determined floating of water to the cultivated plants to promote the always full well and solve the water problems. This is a reasonable configuration of challenges and disadvantages in hydroponics, despite the truth that conventional groups of people will grow plants in their homes with a less expensive plan. The total device is realized in an automatic way using very small and adapted microcontrollers to monitor the nutrient level. The hydroponic system allows reducing the use of fertilizers and water in the respect of the environment, while increasing the production and improving the quality of the harvest (Belkadi et al., 2020); in the same way, it is a relevant management of the environment and of the climatic disturbance factors, which offers extreme attention and financial compensations to the concerned people. This vertical hydroponics method has been used to reduce water usage up to 70% of the repairable strength and can be used to minimize the area. These devices needs differ from the current water culture by the use of sensors, rock wool, and important lighting system for plant growth, underwater engines, service materials and mineral composts (Belkadi et al., 2019). The P.V.C. pipes are associated with a vertical structure for growing plants. The seeds of the plants are placed in rock wool, which helps to retain them and immerse them in water.

The underwater engine components the feeding plan of the nutrient-rich water to each plant according to their appropriate demands in the device. The latter was followed in an automatic way thanks to Arduino and raspberry pi 3 boards. The correspondence between the evaluation systems is thanks to 4G LTE (module) (Sharma et al., 2018). The control system is equipped with a component for temperature detection, a component for pH and E. C. detection and various sensors.

The control system is equipped with a temperature detection component, a pH and E. C. detection component and various sensors that allow determining the decision and defining the fundamental element that has an impact on the crop yield (Mzid, 2022; Kumar, 2021a).

Vertical hydroponic systems are a new improvement in the field of agriculture and are used to allow farmers to benefit from a favorable environment. This skillful cultivation system similarly helps farmers to try to perform all the work with less maintenance or automating their prerequisites. Through this economic methodology (Moghimi et al., 2019; Indira et al., 2020; Oktarina et al., 2020), they will be expanded and actually created with clever ideas in order to reduce the water consumption. The plant absorbs these needs from the nutrient solution provided. The researchers work in collaboration to save the data recorded between the different units especially in the area of protection and communication (Belkadi et al., 2021; Balashova et al., 2017; Kumar et al., 2021b).

The nutrient and salts melted in the water. Evaluations have been carried out on several occasions, such as the level of pH parameters, temperature and electrical conduction (EC) of the nutrient, using a modern device and an innovative evaluation technology that provides the plants with the nutrient at any time. In this way, it is not only a reaction for difficult lands, but also a way to improve the quality of the crops (Soni et al., 2022; Dhonde et al., 2022). Many researchers have implemented different techniques (Belkadi et al., 2020; Zevenhoven, 2015; Qadeer, 2020) to photograph disease identifications and supervise IoT devices to remove the information.

ENVISAGED DESIGN OF THE SYSTEM

The implementation of an intelligent robotic device for the development of the vertical hydroponic system started with a prepared model. Since energy is expected to be the most important concept in plant production, sources such as water, soil, food and land must be considered as a fundamental parameter in off-grid cultivation. The main goal of the vertical device is to obtain additional yields and vegetation with less water resources. In this study, water and different sources are used exclusively when the plants need it (Madushanki et al. 2019; Soni et al., 2022; Belkadi et al., 2019).

In the underlying step, we will usually use a couple of PVC lines to form a vertical support, where several lines support each other while remaining vertical; for each vertical line, we will often drill a 5 cm hole at a 30 degree angle. On top of each pipe, a loop valve has been mounted. These valves work to control the water flow, and Rockwool is used to soak the water drops that enter the pipe from the nutrient solution tank. we have presented a pH sensor, a temperature sensor, an EC electrical peculiarity indicator and a water flow detector on the storage device whose main purpose is to examine this system in real time. In addition, the pH sensor determines the pH level of the water. The water has a normal pH of seven, but if there are supplements, the pH level can go down to five or six. Plants need a limited amount of water, which we tend to use as manure; we observe the water flow using loop valves to control it. By evaluating the degree, the ultrasonic sensor is used to effectively monitor the plants. The adaptable application of the brought robot can obtain indications of all relevant data, which can then be collected productively from sophisticated peripherals.

If there is less water than the reference level, then the water filling system can turn on, fill the accessibility level to the sufficient level of water, and build an orientation on the manager. In addition, since the water temperature is important for small plants, we tend to use a sensor to set the temperature value. The water combination pond supply is used to store piles of water that can be used later in the reuse. The water reuse unit collects wasted or excess water from the complete structure and reuses it for the accompanying framework to counteract any delay. The general water flow of the system is available in the pipes stabilizing the subsistence levels in the basin. Our system has been schematized in figure 2 below.

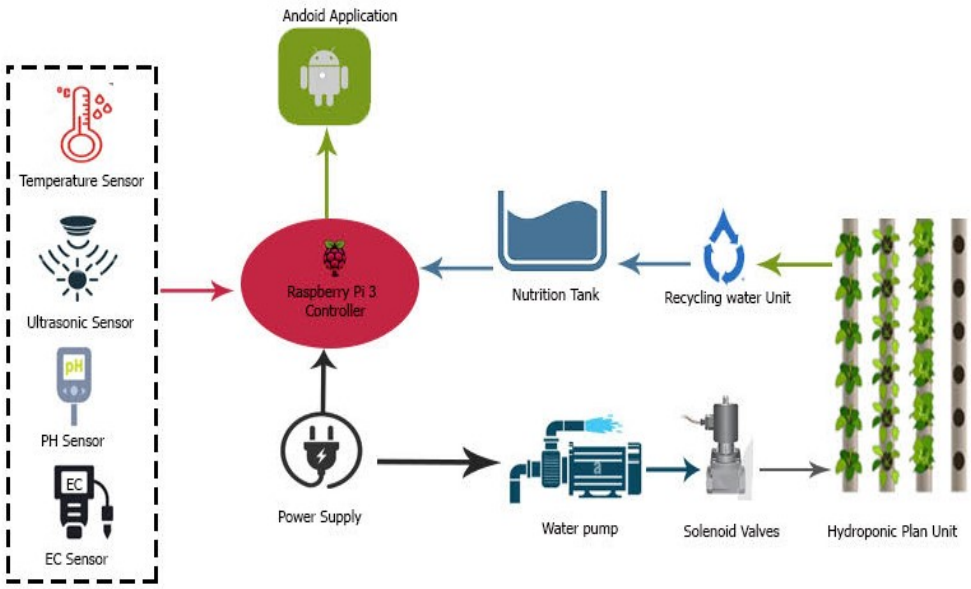

FIGURE 2. The model envisaged for the vertical structure of hydroponic production.

DESIGN AND OPERATING STRUCTURE

The use of the vertical water growing system is made possible by the ability of the plant to grow outside the soil and with less water. Their realization is aware of how the water cycle is renewed automatically, and determined with the placement of pipes in the hydroponic system. In addition, he examines the pH and plant enhancements to determine if they are appropriate. He chooses the lighting and wind, as well as the temperature.

Construction

For plants to develop, the influence of light is important. We tend to regionalize the means by which plants create under lights that allow their chloroplasts to capture energy. While bound plants need more sunlight to develop, all plants need solar light to maintain the ecological flow of the nursery. The light for these plants is mounted on the vertical device declining by thirty degrees. The model of the hydroponic vertical growing system and the unit of the development area are shown in Figure 3 below.

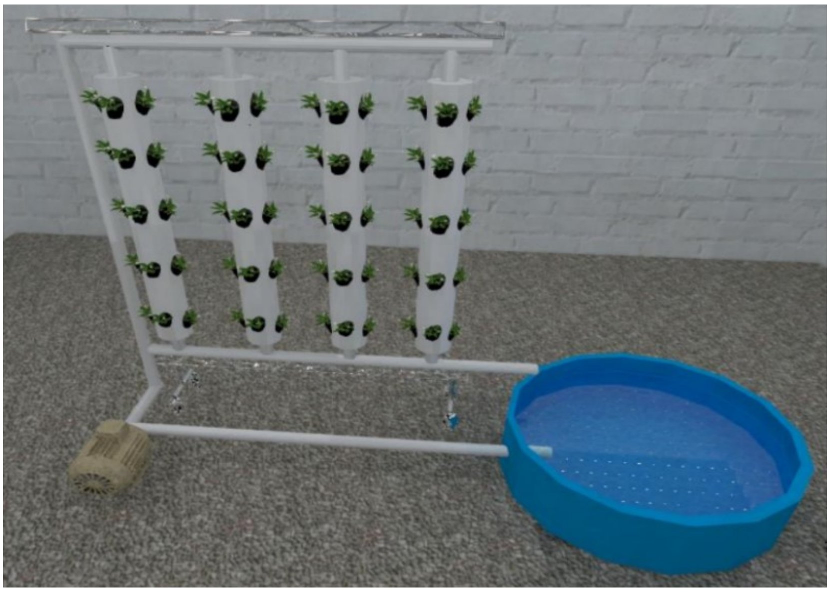

FIGURE 3. Layout of the structure and working model.

The construction of the vertical hydroponic device

For the work surface, a position produced using four typical PVC pipes with outside diameters of two inches, likewise, 3 inches is developed vertically. Then, at that time, around this material was decided to make action all the lines in e very similar essential device. In addition, due to their size and improvement materials, metal, plastic and wood do not seem to be suitable for hydroponic structures. Water flow can significantly affect plant development if the lines are similar in size. Four 2-inch lines will be attached at the same time with 4.5 inches between them. This length is often modified depending on the amount of plants that can be grown. The level at which the plants grow may very well concede the quantity of lines between them. The basic style was characterized by verifiable comparable means, utilizing pipes 4 feet high and two chips long. The water growing cycle incorporates food tank, and different units presented. Using the lines and food, the submerged motor is used to run the water from the base to the top of the pipes. When sunlight is not available throughout the seasons, artificial light sources are also used on the upper part of the system to introduce light effects to the plants' evening hours. The plants receive sufficient heat or temperature from these light sources to allow them to function continuously.

Re-use the water.

The unit of pipelines is cut according to the farmers' subtleties. The Rockwool has been placed at a specific level on this inclined system and is prepared for production. Due to the vertical construction of the system, the rock wool probably saw only a limited amount of water once it entered, and the rest absorbed by the nearby structure.

This procedure is used for all lines in the same way in order to reduce water consumption and speed up the production process. The elevation of the structure is high enough that the total water flow is minimal. Then the hydroponic structure uses the underwater engine to siphon the water at the base and reuse it according to the demand. The vertical hydroponic system has split accidental stains to help farmers gather more crops and improve yields. The water reuse cycle of the system is illustrated in the associated figures 4 and 5.

FIGURE 4. Use of water.

FIGURE 5. Water re-use management.

Working flow chart

The most important thing is to have an overview of the level of the pond and the rainwater storage tank using the higher level (UL) and lower level (LL) classes. To siphon the water into the plants through the lines, an electronic valve should be connected with the RPI 3 microcontroller and the motor in an arranged way. Close limits must be respected for all sensors, such as humidity, pH, electrical conductivity (EC), and ultrasound. In addition, all these sensors must be connected and available for installation. The microcontroller receives the readings from the gadget and chooses a decision according to the situation of the agriculture. In case the water level is sufficient, it can flow to the plants for a well-defined period and the engine then automatically deactivates. The food is supplied by the equivalent tank. Finally, for the reasons that motivate further examination, all the values are sent to a flexible application and server. The operating diagram and its different characteristics of the vertical hydroponic structure is presented in the illustrative figure (Fig. 5).

The flow of water heights and its states

When condition LL ≤ UL, reveals No Action

Then F ≤ LL, Solenoid valve opened for certain time

If F ≤ UL, then Valve Close

Where:

LL = Low level,

UL = High level, and

F = Water flow in a vertical hydroponic structure, the above mentioned conditions are used to water the plants properly.

The microcontroller unit has completed the ability to open the valve and the duration of its opening according to the programming, that has been done on the unit. As soon as one of these three conditions is met, the valve remains inactive; however, if the water flow is below the low level, the valve opens quickly for a predefined time. The third situation is that the valve can then close when the water level is higher than the desired level.

RESULT AND DISCUSSION

The preliminary plan of action for the aforementioned vertical hydroponic system has been implemented in very restricted environments such as the home, and the findings have been considered for study. A total of four pipes, a pump in the basin, a food tank and Rockwool were considered to be used in the production. This course of action was done in regular temperature mode for thirty days. After evaluating all the information, totally different results were obtained and placed in the android mobile app. When the engine is running, all the sensors in the station are connected to a microcontroller unit to determine the levels on board the equipment. When the loop valve is open, water can normally flow through the pipes. Accurate assessments are made based on the amount of water in the pipes and the constant function of the motor. The expected time for water levels to flow through the pipes from the capacity tank is shown in Figure 6 below.

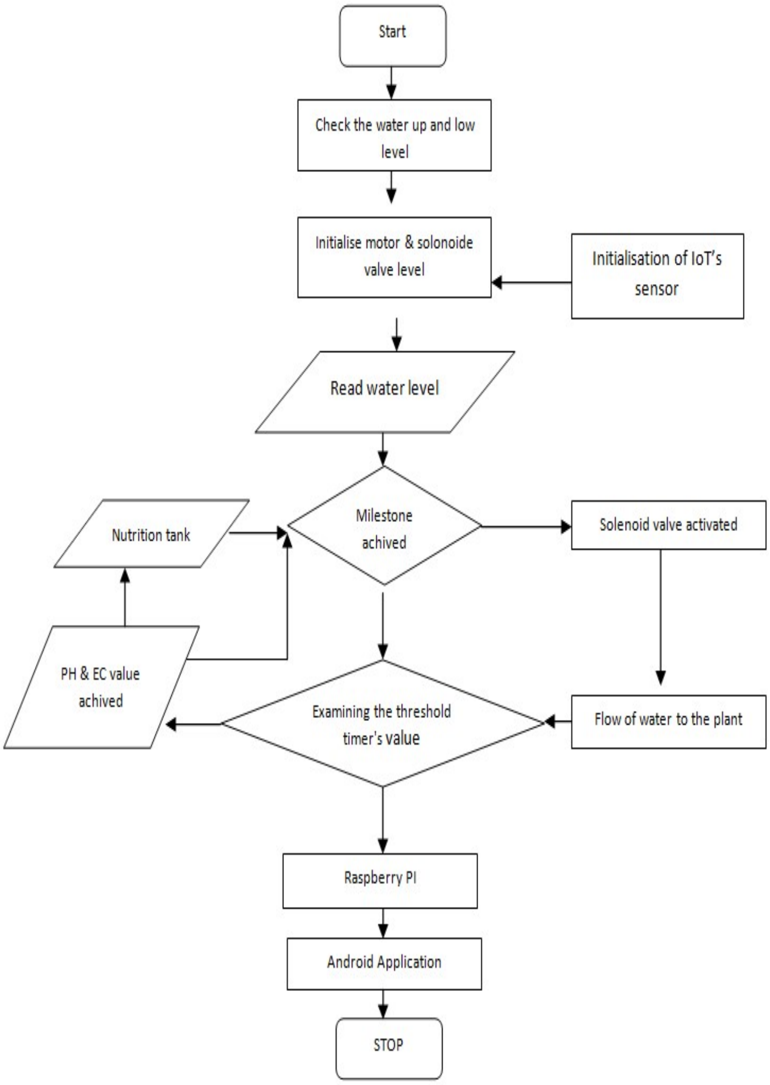

FIGURE 6. Flow chart of the hydroponic vertical growing system.

The water is drained from the engine at the appropriate time, when it will carry the plants before it appears on the pipes. At this time, the plants are mounted outside and covered with rock wool. The plants use the vital water, and the rest is passed on to the corresponding unit. The leftovers are used to be reused and can be sent to the reservoir. The use of water can therefore be maintained through this technique. The level of water in the pipes with totally different techniques is displayed inside Figure 7.

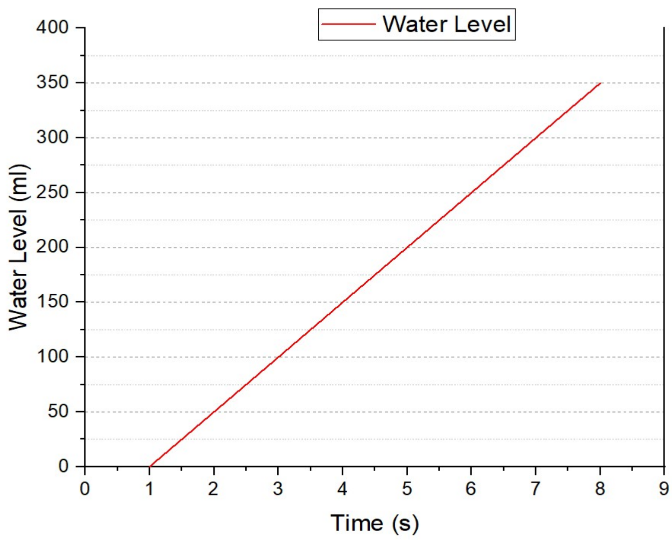

FIGURE 7. The level of water flowing into the system as a function of time.

The quantity of water that the engine releases on each path is similar, but the quantity that reaches the plant is different. This depends on how much food and water the plants need.

IoT sensors allow the control and visualization of the entire system in the smallest endpoints. In addition, the performance of the devices is determined according to the response time the output produced by the structure. The output result to the user from the different paths on the tubes is described in detail in the following Figure 8.

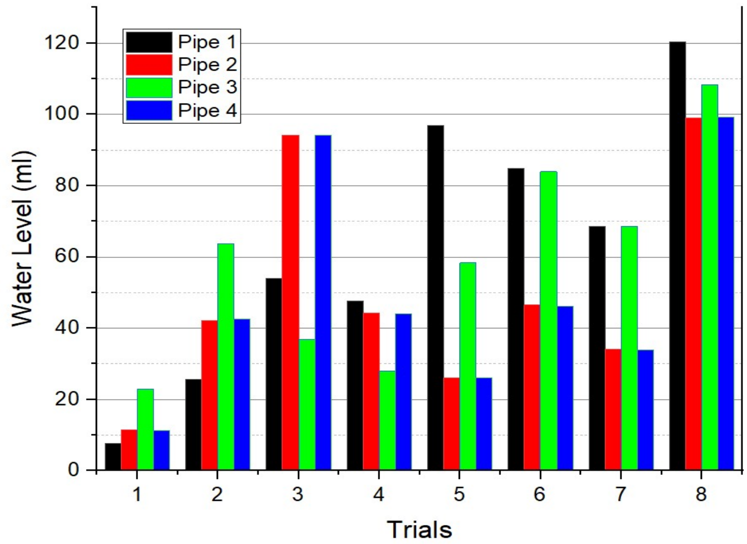

FIGURE 8. Water levels at various times in various lines.

The vertical and horizontal hydroponic structure are not the same whose water consumption and furthermore the strategy it takes to water the plant. Due to the vertical development of the pipes, water levels emitted by the pump are totally arrived on them in a different way.

Due to the installed Rockwool and furthermore the size of the sustenance tank, the water flow is very different on the lines. Fig. 9 shows the variations of water flow in the pipes at different starting units.

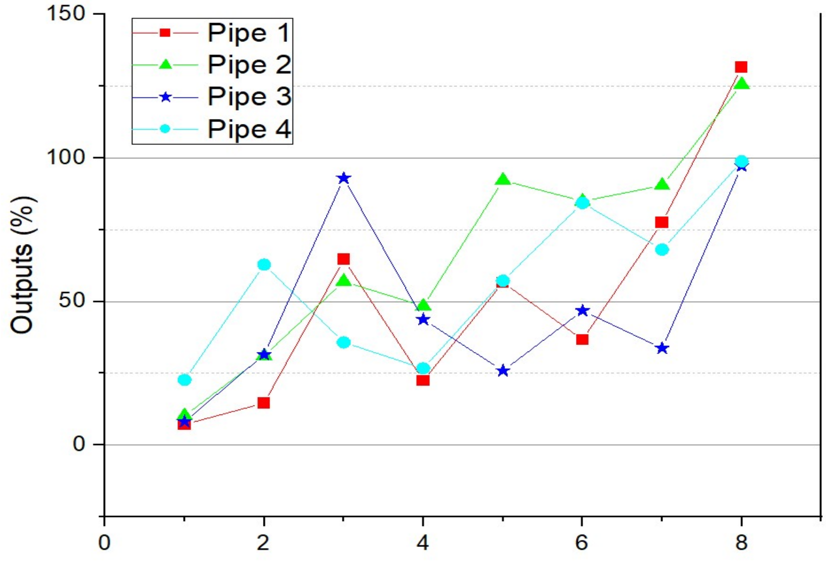

FIGURE 9. Realization of a vertical hydroponic device.

TABLE 1. Smart vertical hydroponic system.

Plant delails	Pipe 1	Pipe 2	Pipe3	Pipe 4
H(cm)	12.1	11.9	12.2	12.1
W(cm)	5.5	5.6	5.4	5.5
Leafs producted	10	10	10	10

TABLE 2. Normal vertical hydroponic system.

Plant delails	Pipe 1	Pipe 2	Pipe3	Pipe 4
H(cm)	10.9	9.8	11.0	10.6
W(cm)	4.7	4.2	3.9	2.8
Leafs producted	9	9	9	9

In a system of structure is installed with four lines, the time required for the flow of water to differ is not constant. This is in many cases a result of the plant's production and their ability to absorb the nutrient solution. Depending on the needs of the plants at different times, fully variable water flow units are available in each line. Plant cultivation will not be overwhelmed by fluctuating water levels in the lines due to the undeniable reality that the ultrasonic sensing component can use the IoT construct to track the improvement. The time required to vary the water flow in the lines at different distances is shown in Figure 10 below Fig 11.

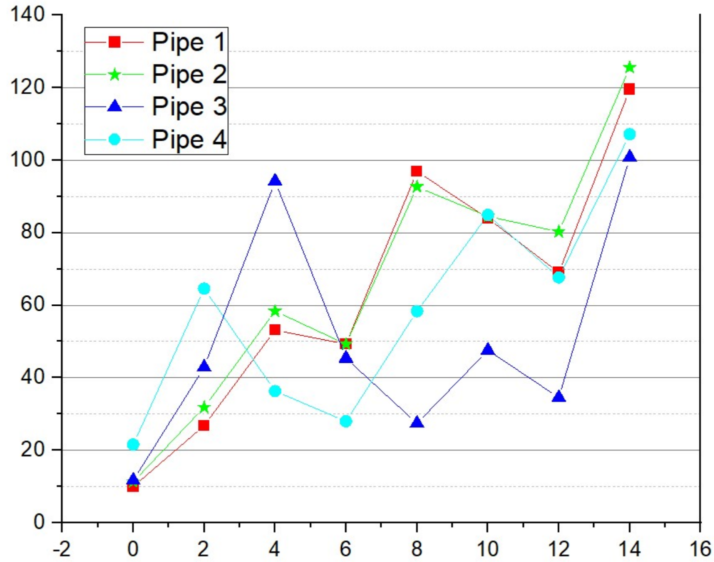

FIGURE 10. The different water flows in the pipes at different times.

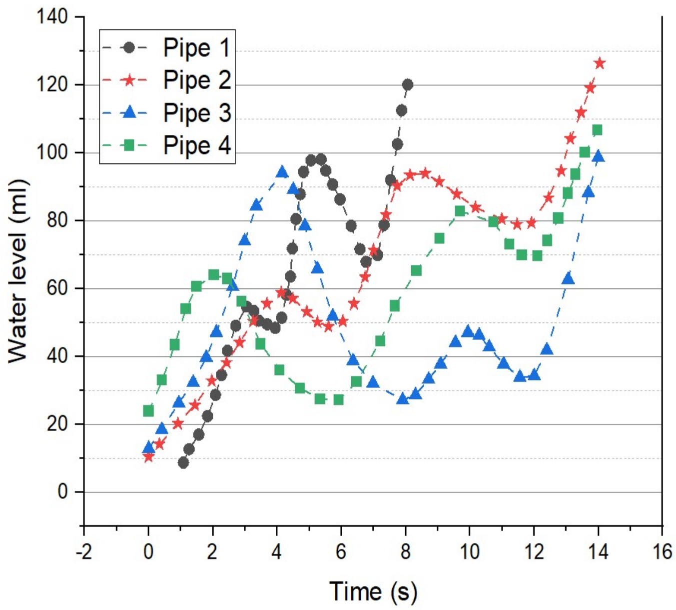

FIGURE 11. Time required for water flow variations in system conduits.

A robotic mobile android application on a smart comfort system is used to filter and display the vertical hydroponic structure, and the data is then placed in databases for evaluation. Finally, information was collected from the results and disseminated to users. This could be exceptionally educational and straightforward to get effective results. Plant height, leaf extent, and the amount of leaves carried by the structure are the fundamental variables considered. Although the results are unique, a smart hydroponic system performs better than a standard structure. An excellent system uses the level of the leaves, their width and number. Since the water flow and feed rate are determined continuously, perception is not done in an extremely normal structure. In a quite reasonable automated structure, water is probably given once the plant has explicitly requested it. Table 1 and Table 2 below presents the results obtained for the device during one month on a limited area.

- IoT framework-based automated system
- Monitoring water flow and level is step two
- Measuring water nutrients is step three.
- Monitoring of temperature and moisture.
- Plant growth & water recycling.

CONCLUSIONS

The huge development strategy with gigantic Big Data analysis is to reuse water, which could also reduce the cost of development and land to create a large farm.

Through the adaptable Android app, IoT steps work with farmers to constantly check and perceive water levels and very unexpected contamination. The farm owner is immediately informed of low water levels or evaporation. Several sensors are used to evaluate the water flow and quality to improve the plants. Each time the plants change, their level is recorded and the results are communicated. Farmers use big data evaluation to understand the plants, vegetables and natural fruits are created in light of the seasons, such as winter and summer. This system is both modest and suitable for data collection by small-scale farmers. With the help of this system, women explicitly fill in the technical and financial.

FUTURE WORK

The use of water level would be reused to hold the vertical characterization of the crop and to extend the cycle of plant progression. Once appeared differently compared to the structure to proceed with the components associated with exceptional development. It may very well be the least difficult yield structure return after a short time for plant development with less work as well as reduce the production area. The IoT would be used to store all the evaluation in the form of monster data, and it could then be presented to various logical methods. Essentially limited-scale farmers use this structure, which has been found on smaller plots of land. Data will be collected from gigantic land locations during a creative strategy, and entirely unexpected yields, vegetables and fruits will be shot. Water reuse can have an additional effect from now and in the foreseeable future and can likewise be extended to local structures. Knowledge evaluation will be used in relation to the structure set up and can inform farmers about the level of subsistence in the future to help them encourage their properties in a useful way .Totally different guiding shows and estimates are used to convey plan information to the world, including the progress being made to enable IoT construction to machine-driven automated structures (Huo et al., 2020; Balashova et al.,, 2017; Dlamini et al., 2022). In addition, it is about giving the IoT framework a long life. Given the gigantic volume of information that has been under constant evaluation, the life expectancy of the IoT design is not entirely determined by its careful guidance methods.

REFERENCES

Balashova IT, Sirota SM, Kozar EG, Pinchuk EV (2017) Technologies of the future in greenhouse vegetable production: multicircle hydroponics on narrow banches. Vestnik OrelGAU 3(66): 71–74. https://doi.org/10.15217/issn1990-3618.2017.3.71

Belkadi A, Mezghani D, Mami A (2019) Energy design and optimization of a greenhouse: a heating, cooling and lighting study. Engineering, Technology & Applied Science Research 9 (3):4235–4242. https://doi.org/10.48084/etasr.2787

Belkadi A, Mezghani D, Mami A (2020) design and implementation of flc applied to a smart greenhouse. Engenharia Agrícola 40(6): 777–790. https://doi.org/10.1590/1809-4430-eng.agric.v40n6p777-790/2020

Belkadi A, Mezghani D, Mami A (2021) Energy study of a greenhouse and optimisation of the choice of its shape and covering material: based on an improved static model. Engenharia Agricola 41(3):297-310. https://doi.org/10.1590/1809-4430-Eng.Agric.v41n3p297-310/2021

Dhonde M, Sahu K, Murty VVS (2022) The application of solar-driven technologies for the sustainable development of agriculture farming: a comprehensive review. Reviews in Environmental Science and Bio/Technology 21(1): 139–167. https://doi.org/10.1007/s11157-022-09611-6

Dlamini DD, Zuwarimwe J, Francis J, Mchau GRA (2022) Risk factor assessment of the smallholder baby vegetable production in Eswatini. Agriculture 12(5):643-652. https://doi.org/10.3390/agriculture12050643

Dowlatshah K, Alizadeh M, Raji MA, Alkhanak E N (2020) A secure and robust smart card-based remote user authentication scheme. International Journal of Internet Technology and Secured Transactions 10(3):255. https://doi.org/10.1504/ijitst.2020.107074

Hemanth DJ, Shakya S, Baig Z (2020) Intelligent data communication technologies and internet of things. Lecture Notes on Data Engineering and Communications Technologies. https://doi.org/10.1007/978-3-030-34080-3

Huo S, Liu J, Addy M, Chen P, Necas D, Cheng P, Li K, Chai H, Liu Y, Ruan R (2020) The influence of microalgae on vegetable production and nutrient removal in greenhouse hydroponics. Journal of Cleaner Production 243:118563. https://doi.org/10.1016/j.jclepro.2019.118563

Indira D, Aruna P, Swetha Kanthi S, Kumar K (2020) Hydroponics as an alternative fodder for sustainable livestock production. World Journal of Advanced Research and Reviews 5(2):087–092. https://doi.org/10.30574/wjarr.2020.5.2.0030

Kumar KA, Navaneetha M, Aravind B, Rajesh T M, Pravallika M, Rao PVKJ (2021a) Effect of drip irrigation combined organic mulching on water productivity and yield of tomato (Lycopersicon esculentum L.). Indian Journal of Agricultural Research 4(2):47-53. https://doi.org/10.18805/ijare.a-5751

Kumar N, Acharya D, Lohani, D (2021b) An IoT-based vehicle accident detection and classification system using sensor fusion. IEEE Internet of Things Journal 8(2):869–880. https://doi.org/10.1109/jiot.2020.3008896

Kumar V, Tripathi S, Mandal MR, Singh B (2022) Hydroponics: a versatile system for soilless vegetable production. Annals of Horticulture 15(2):245–250. https://doi.org/10.5958/0976-4623.2022.00037.8

Madushanki AAR, Halgamuge NM, Surangi WAH, Syed A (2019) Adoption of the Internet of Things (IoT) in Agriculture and Smart Farming towards Urban Greening: a Review. International Journal of Advanced Computer Science and Applications 10(4):56-66. https://doi.org/10.14569/ijacsa.2019.0100402

Moghimi F, Ghoddusi H, Asiabanpour B, Behroozikhah,M (2019) Atmospheric Water Generation (AWG): Performance Model and Economic Analysis. Advances in Production Management Systems. Towards Smart Production Management Systems 5(3):151–158. https://doi.org/10.1007/978-3-030-29996-5_18

Mzid N (2022) The reform of domestic travail in Tunisie. Review of Comparative Labor and Social Security Law 6(1):158–159. https://doi.org/10.4000/rdctss.3295

Oktarina E, Wardhani K, Marwanti E (2020) Implementasi environmental literacy di sd negeri bakalan bantul. Taman Cendekia: Jurnal Pendidikan Ke-SD-An 4(2): 492–500. https://doi.org/10.30738/tc.v4i2.8648

Pu C, Zerkle H, Wall A, Lim S, Choo KKR, Imtiaz A (2022) A lightweight and anonymous authentication and key agreement protocol for wireless body area networks. IEEE Internet of Things Journal 9(21): 21136–21146. https://doi.org/10.1109/jiot.2022.3175756

Qadeer A (2020) Hydroponics as an innovative technique for lettuce production in greenhouse environment. Pure and Applied Biology 9(1): 40-48. https://doi.org/10.19045/bspab.2020.90130

Reddy RVSK, Omprasad J, Janakiram T (2022) Technological innovations in commercial high tech horticulture, vertical farming and landscaping. International Journal of Innovative Horticulture 11(1):78–91. https://doi.org/10.5958/2582-2527.2022.00008.2

Sabri SQ, Ahmad AM, Abdulrazaq MB (2017) Design and implementation of student and alumni web portal. Science Journal of University of Zakho 5(3): 272–277. https://doi.org/10.25271/2017.5.3.39

Sharma N, Acharya S, Kumar K, Singh N, Chaurasia OP (2018) Hydroponics as an advanced technique for vegetable production: an overview. Journal of Soil and Water Conservation 17(4):364. https://doi.org/10.5958/2455-7145.2018.00056.5

Soni S K, Mishra M K, Mishra M, Kumari S, Saxena S, Shukla V, Tiwari S, Shirke P (2022) Papaya leaf curl virus (PaLCuV) infection on papaya (Carica papaya L.) plants alters anatomical and physiological properties and reduces bioactive components. Plants 11(5): 579. https://doi.org/10.3390/plants11050579

Trisnani N, Utami WTP (2020) Peningkatan pemahaman konsep matematika melalui media visual pada siswa kelas iv sd negeri widoro. Taman Cendekia: Jurnal Pendidikan Ke-SD-An 4(1): 422–428. https://doi.org/10.30738/tc.v4i1.6398

Zevenhoven R (2015) Understanding greenhouse gases: mission being accomplished. Greenhouse Gases: Science and Technology 5(6):695–696. https://doi.org/10.1002/ghg.1580