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IOT Based Automated Hydroponics System for Precision Agriculture

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Abstract*: Growing plants hydroponically can be a great option for plants that are traditionally hard togrow in soil due to specific requirements. The aim of this work is to design and construct an indoor automatic vertical hydroponic system that does not depend on the outside climate. The designed system is capable to grow common type of crops that can be used as a food source inside homes without the need of large space. The design of the system was made after studying different types of vertical hydroponic systems in terms of price, power consumption and suitability to be built as an indoor automated system. A microcontroller was working as a brain of the system, which communicates withdifferent types of sensors to control all the system parameters and to minimize the human intervention.An open internet of things (IoT) platform was used to store and display the system parameters and graphical interface for remote access. The designed system is capable of maintaining healthy growingparameters for the plants with minimal input from the user. The functionality of the overall system was confirmed by evaluating the response from individual system components and monitoring them in the IoT platform.*

Keywords: vertical hydroponics; indoor farming; automated system; internet of things (IoT)

I. MATERIALS AND METHODS

The block diagram of the automated vertical hydroponic system consists of five parts: power supply, sensing and control system, vertical hydroponic structure, Wi-Fi module, and online database.The overall block diagram is shown in Figure 1. All the sensors connected to the vertical hydroponic system can be monitored from the IoT platform on any smart device. There is a power meter module for continuous monitoring the power consumption of the system in order to make the system power efficient and possible for large scale expansion. Each part of the block diagram will be discussed in detail in the later sections of the paper. In any hydroponic system, there are several parameters that should be maintained within certain range, such as pH, electric conductivity (EC), temperature of thesurroundings, and water level of the container. An automatic hydroponic system should adjust and maintain these parameters within its suitable value automatically and independently without the requirement of user intervention. Different sensors are connected to the microcontroller to monitor thedifferent parameters of the hydroponic system. A panel electromechanical relay was used to control artificial lights, water pumps and the dosing pumps that were used to add pH and nutrient to the water. Finally, all the acquired data from the central microcontroller circuit was sent wirelessly to Thingspeak, online database through an ESP 8266 Wi-Fi module.

The design of the whole system could be divided into the below subsections:

1. NFT structure and essential components
2. Nutrition and pH controlling system
3. Water flow path system
4. decision making algorithm
5. Internet of Things (IoT) platform

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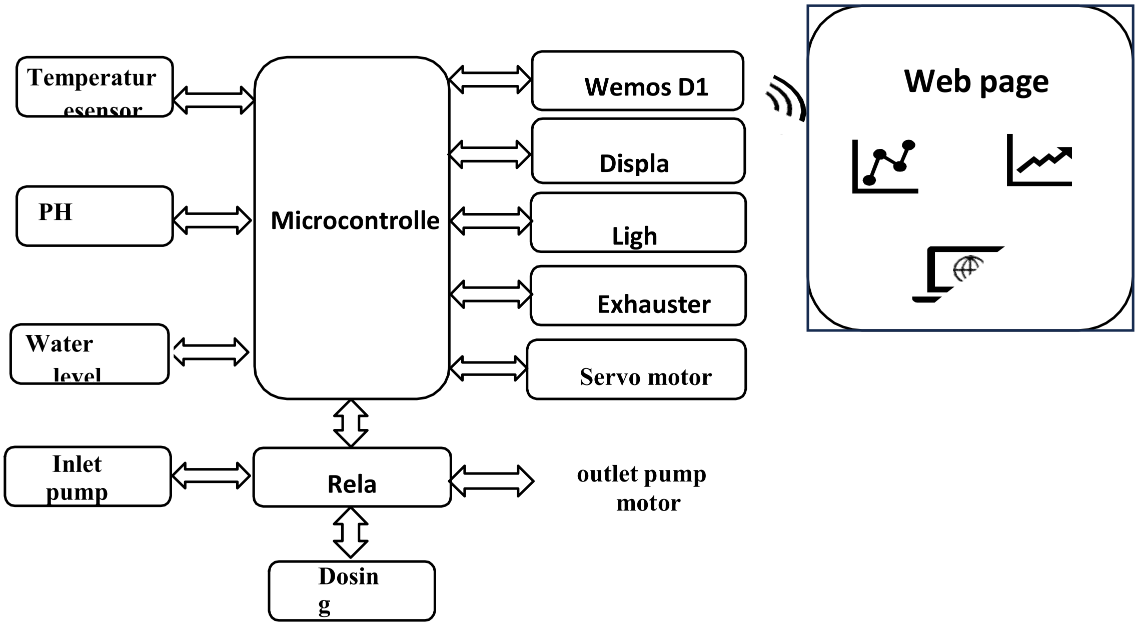
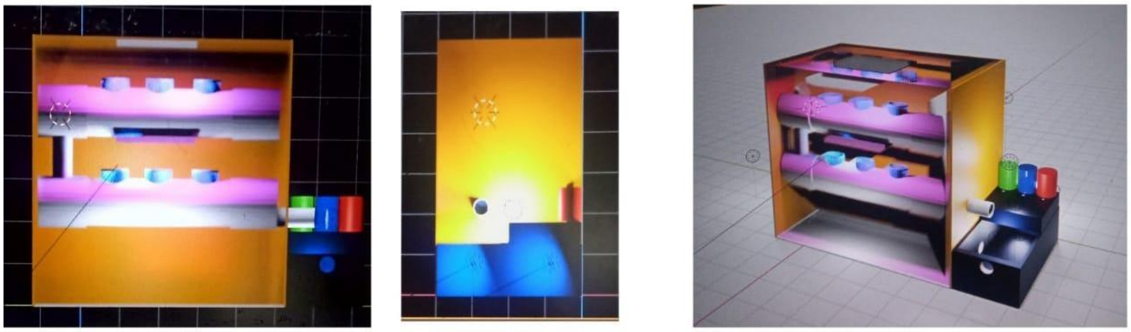


Fig1: block diagram of designed system

II. NFT STRUCTURE AND ESSENTIAL COMPONENTS

The hydroponic system was chosen to be a vertical NFT hydroponic system since it has the greatest benefits compared to the other system. Typical hydroponic system consists of the hydroponic pipes, nutrient container, water pump, artificial lights, nutrient, and pH adjustments' solutions. The nutrient container, water pump, and artificial lights is selected carefully to assure the highest efficiencyof the hydroponic system. This section presents the process of selecting the right size of the nutrient container and the water pumps, the selection of the artificial lights, nutrients, and pH adjustment solutions. The 3d model of the NFT based hydroponic system is shown in Fig2 which is designed uingblender 3d model software.



a) Front view

b) Side view

c) Hydroponics setup in 3D view

Fig 2: structure of NFT system designed using blender 3d software

Essential components:

Nutrient's Container:

A nutrient container is used to reserve the nutrient solution that would be supplied to the verticalNFT system. Since it is a closed system, all the excess solution would return to it. The ideal containershould be made from plastic material, using metal containers is prohibited as they are reactive materials. Moreover, it should block the light to pass through it to prevent the formation of algae. Thesize of the container should be big enough to hold the right amount of the solution, and this amount is decided according to the number of the plants in the system. Number of the plants between 40–50 should use a minimum of 5 gallons (18.9271 L), by adding another 20–25 plants, the amount would be increased by 1 gallon (3.78541 L).

the number of plants in the system can be calculated:
Number of plants = number of pipes × number of shelves × number of plants holes

Water Pump:
Sizing the water pump is very important as selecting the right pump would assure the sufficient amount of water is flowing continuously in the system. For this design, submersible pumps were selected to be used since they suit the small systems that needs 1200 of gallons or less. The sizing of the pump was done in three steps. The first step was to calculate the gallons per hour (GPH) that the pump was required to supply to the system, and the second step was to measure the head height of thehydroponic system and the third step was to use the first two information to verify if the pump was suitable using the water pump datasheet.

The calculation for the GPH of water that the pump needs to supply to the system every hour can be found in the Supplementary Table S2. It is important to consider the loss in efficiency between 15–30% of the pump in the calculations. According to Supplementary Table S2, the NFT system requires 4–6 GPH per trough, by selecting the average value of the flow rate as 5, and the worst-case scenario in the loss in efficiency as 30%, the total GPH was calculated using Equation.

Total GPH = number of pipes × flow rate GPH × loss in efficiency

Artificial Lights:
Lighting is essential for the plants as it plays an important role in the photosynthesis process. Any lack of lights would limit the photosynthesis which affects the growth of the plants. Plants do notrequire the full range of light spectrum for growth. They only absorb their needed amount of light in the spectrum. The lights requirement is between 400 and 700 nm which lies within the visible range and it is also known as photosynthetically active radiation (PAR). Moreover, a high intensity of red and blue lights is needed to grow flowering plants, while for non-flowering plants need a high intensityof red light only.

SI.NO	ModelType	Dominated colour in thespectrum	Peak Wavelength	Electrical Parameter
1	6K3R4	Red	660 nm	V=24V, I=0.7582A, P=18.20W.
2	K6	Red and blue	645 nm	V=231.5V, I=0.08053A, P=17.9W.

Table S1: Specification of Hydroponics Light

Nutrients and pH Controlling System:
There are 17 different type of elements that are important for the complete growth of the plants.In the hydroponic system, these 17 elements were added to the plants as nutrient solution. However, the amount of nutrition must be added within the suitable range for each plant where any incorrect amount added can cause a huge damage to the plants. To confirm the correct range of nutrient amountin the solution, the pH was measured continuously. Furthermore, the amount of pH must be monitoredin the nutrient solution as it is considered essential for plants growth. Atlas Scientific pH Kit 0–14 pH sensor was used for real-time pH measurement. The suitable pH range in the hydroponic system is between 5.0 and 7.5. A higher amount of pH in the nutrient solution from the recommended range forthe plants leads to a higher chance of nutrient deficiencies, which become toxic to the plants.

Plant	Lettuce	Mint	Celery	Cabbage	Spinach	Kale	Beans	Strawberry
pH	6.0–6.5	5.5-6.0	6.0–6.5	6.5–7.0	6.0–7.0	6.0-6.5	5.5–6.5	6.8- 6.0

TableS2: pH and EC range for different plants (Considering that plants have already developed roots.).

Circuit diagram

The Nutrient Film Technique (NFT) vertical hydroponic system uses PVC pipes arranged in layers—ground, first, and second. A pump circulates nutrient-rich water from a reservoir through these layers, feeding plants. Automated control is implemented using stepper motor-operated valves at each layer, allowing precise regulation of water and nutrient delivery. As plants utilize the nutrients, the water returns to the tank, and the ground layer valve opens for recirculation. This system optimizes water and nutrient use, supporting efficient plant growth.

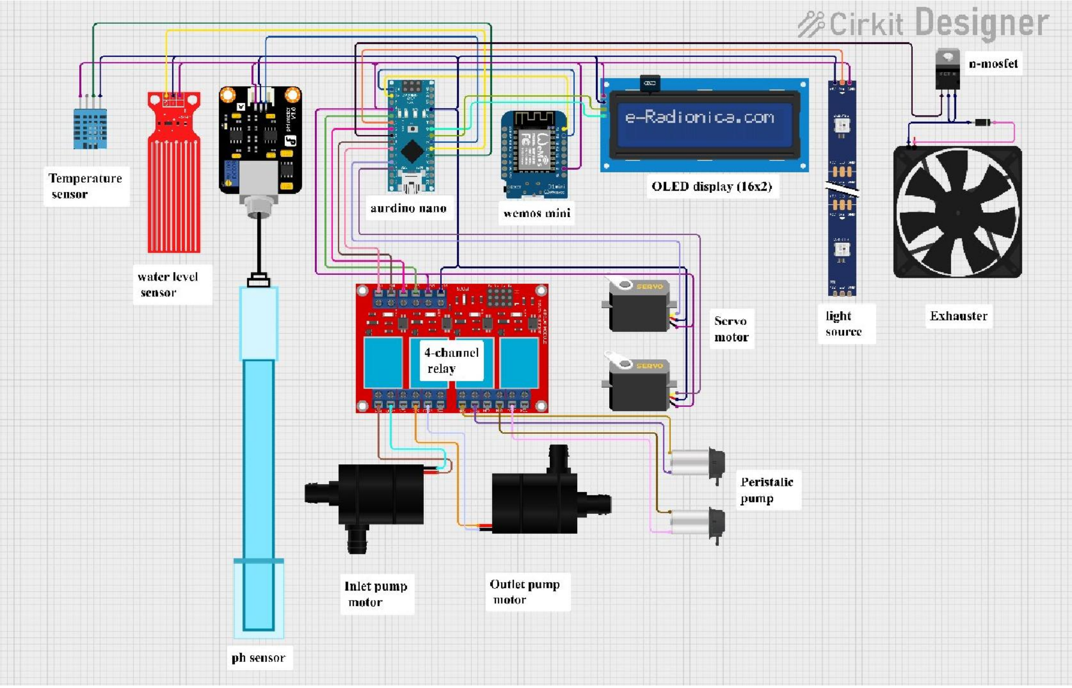


Fig 3: overall circuit diagram of the hydroponics system

III. WATER FLOW PATH SYSTEM:

In the vertical hydroponic system using the Nutrient Film Technique (NFT), the water flow system plays a critical role in ensuring that plants receive an adequate supply of water and nutrients for optimal growth. This system operates as following steps,

Step1: Check the Reservoir, the process begins with a reservoir containing the nutrient-rich water solution. This solution is the source of water and essential nutrients for the plants. The reservoir is equipped with a pump to circulate the water through the system.

Step 2: Pumping Mechanism, the pump directs the water from the reservoir into the vertical NFT system. This water flow is controlled and managed to maintain a consistent delivery rate.

Step 3: Vertical Channels and Layers, the water is pumped into the lower PVC pipe, which serves as the ground layer of the system. The water flows through the PVC pipes, providing nutrients to the plants. As the water moves through the layers, it nourishes the plants' roots.

Step 4: Automated Valves, Automated valves, controlled by stepper motors, are installed at each layer(ground, first, and second) that regulate the flow of water to the different layers. Once the ground layer is filled, the valve for the ground layer is closed, allowing the water to flow to the first layer.

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Step 5: Sequential Water Flow, the water moves sequentially from one layer to another, nourishing the plants in each layer. Once the water reaches the top layer and the plants have absorbed the nutrients,the water is recirculated back to the reservoir.

Step 6: Recirculation and Return to Reservoir, after passing through the layers and feeding the plants,the water returns to the reservoir. This recirculation process is essential for maintaining the nutrient balance in the water and ensuring efficient water use.

Step 7: Water and Nutrient Management, Throughout the system, the water flow and nutrient concentrations must be carefully monitored and adjusted as needed. This ensures that the plants receivean optimal balance of water and nutrients for healthy growth.

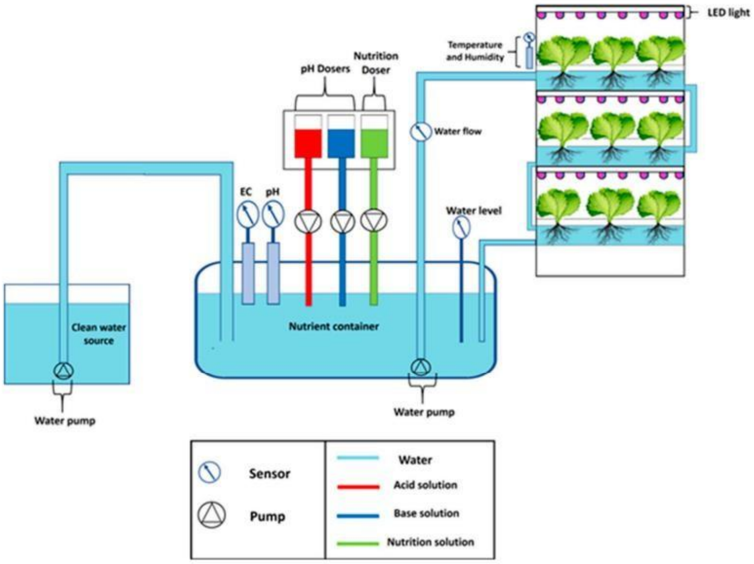

Fig 4: schematic diagram of complex hydroponics system

IV. FUZZY LOGIC CONTROL IN AUTOMATED HYDROPONICS SYSTEMS

In automated hydroponics systems, fuzzy logic offers a flexible and adaptive approach for managing various environmental parameters to optimize plant growth. The fuzzy logic controller effectively integrates different aspects such as pH, nutrient levels, water levels, temperature, humidity, air circulation, and light intensity to maintain ideal growing conditions. By employing fuzzy logic, these hydroponics systems adapt to changes in the environment and plant needs, ensuring consistent and optimal growth conditions. This holistic approach allows for fine-tuning adjustments in real-time,maximizing efficiency and plant productivity.

pH, Nutrient, and Water Level Control:

The system uses fuzzy logic to maintain the optimal pH levels for nutrient uptake. If the pH is low, the controller increases the addition of pH-up solution, while if the pH is high, pH-down solution is added. The system also adjusts nutrient concentrations based on plant growth rate. When nutrient concentration is low, the system increases nutrients, and vice versa. Similarly, water levels are managed to prevent overflow or under-watering.

Temperature, Humidity, and Air Circulation Control:

The fuzzy logic controller adjusts air circulation and ventilation to regulate temperature and humidity levels. For high temperatures and humidity, ventilation is increased significantly. Conversely, when the temperature is low and humidity is low, air circulation is decreased to maintainoptimal growing conditions.

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Light Intensity and Duration Control:

Fuzzy logic helps manage the light intensity and duration for the plants. If light intensity is low and exposure duration is short, both intensity and duration are increased moderately. On the other hand, high light intensity and long duration result in decreased intensity and duration to prevent plantstress.

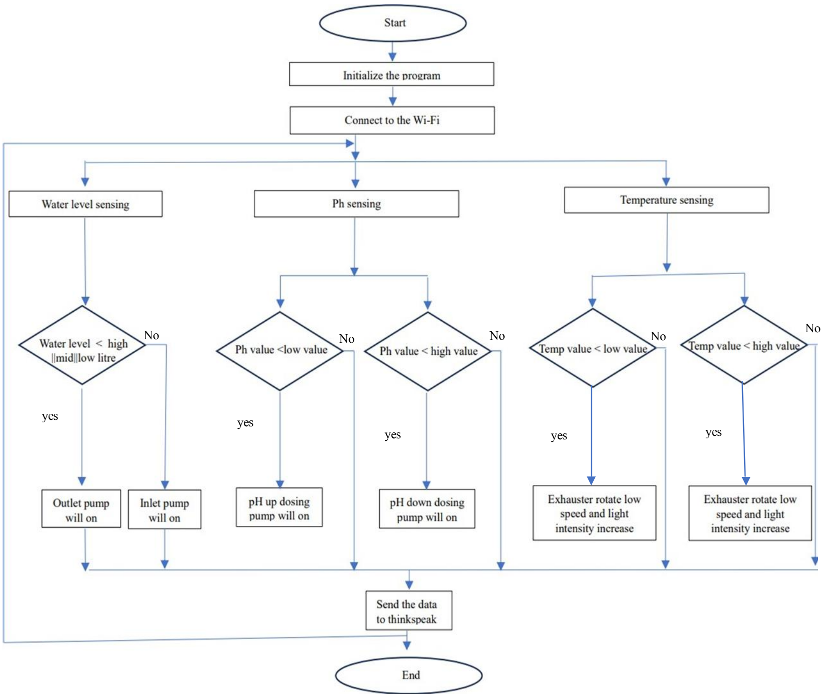
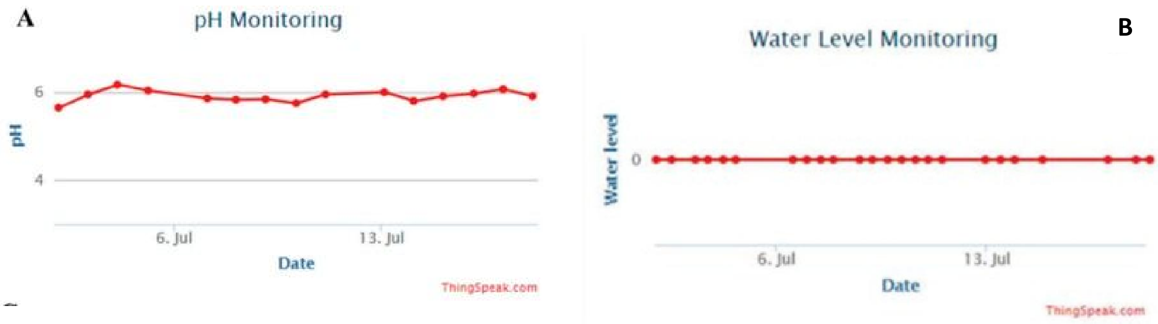


Fig 5: flow chart of the Automated hydroponics system

V. INTERNET OF THINGS (IOT) PLATFORM

The system was designed to get the data from the sensors and collected in a central microcontrollerand send it to IoT platform. IoT platform is capable to store, analyse and preview microcontroller Userin private or public web-interface and also in a mobile application. The web-interface can be Visualizedanytime from smart phone or computer and the mobile application is also simple and easily Accessible solution. In Figure 6, a sample Thingspeak web-interface is shown. However, Thingspeak Web- interface can show several days' data at a time while the mobile application can Show for a shorter duration with last data-point highlighted.



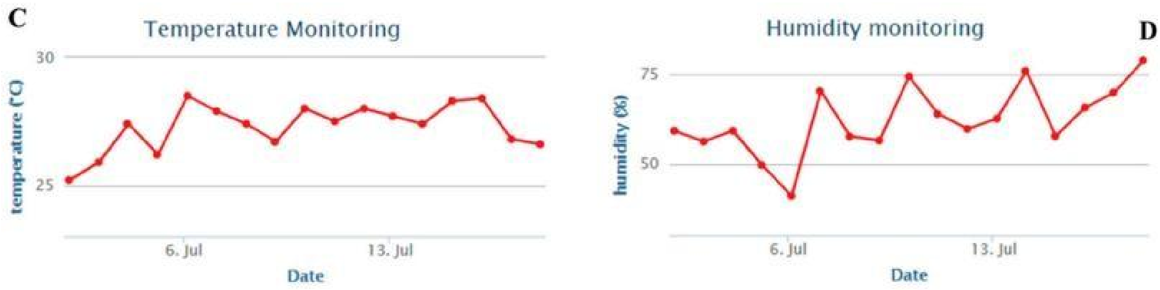


Fig 6: Sample graphs of the Thingspeak Web-interface of IoT platform

VI. DISCUSSION

The logic described in the Nutrient Film Technique (NFT) vertical hydroponic system using PVC pipes and stepper motor-operated valves at each layer is not directly based on fuzzy logic, but it does involve precise control and regulation of water and nutrient delivery in the described system, a pump circulates nutrient-rich water from a reservoir through the different layers of PVC pipes, feeding plantsin a vertical setup. The use of stepper motor-operated valves at each layer allows for precise regulationof water and nutrient delivery. This precise control supports efficient plant growth by optimizing waterand nutrient usage and enabling the system to recirculate water and nutrients effectively.

While the logic used here involves a control system that adjusts the flow of water and nutrients based on specific conditions, it may use a more traditional rule-based or PID (Proportional-Integral-Derivative) control approach. This differs from fuzzy logic, which typically involves handling imprecise, uncertain, or vague data through linguistic variables and membership functions to make decisions and adjustments. The system described can still achieve efficient and precise control over water and nutrient delivery, similar to what fuzzy logic would aim for, but the underlying control mechanism may differ in methodology

VII. CONCLUSION

The core of a hydroponic system is to maintain and control the environmental parameters and the efficient supply of nutrition and water for healthy growth of the plants. In this paper, a cost effective automated vertical hydroponic system using IoT platform has been implemented. The design of the vertical hydroponic system was selected based on a comparison with other designs in terms of costs, efficiency, and suitability to build in small indoor space. The primary structure design of the system has been assembled and the required parameters to build an automatic system were planned in order to select the required components. The parameters of the system were studied and calculated such as the suitable temperature, light wavelength, pH and the required amount of water for the system. Finally, the parameters were displayed in Thingspeak IoT platform web-interface and mobile application to provide easily accessible user interface. The IoT platform allows to extract data in a CSV file which can help in machine learning algorithm development while the system can produce a large amount data suitable for training classical and deep learning algorithms to enhance the performance of the automated system for controlling. This study has opened up the possibility of carrying out several other potential studies. Moreover, the hydroponically grown plants, organic plants,and field plants can be studied and their comparative growth can be monitored through this wireless platform.

REFERENCES

[1]. Resh, H.M. Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Grower; 19 April 2016; CRC Press: Boca Raton, FL, USA,2016; ISBN 1439878676.

[2]. Abdullah, N.-O. Vertical-horizontal regulated soilless farming via advanced hydroponics for domestic food production in Doha, Qatar. Res. Ideas Outcomes 2016, 2, e8134.

[3]. Crisnapati, P.N.; Wardana, I.N.K.; Aryanto, I.K.A.A.; Hermawan, A. Hommons: Hydroponic management and monitoring system for an IOT based NFT farm using web technology. In Proceedings of the 2017 5th International Conference on Cyber and IT Service Management (CITSM), Denpasar, Indonesia, 8–10 August 2017; pp. 1–6.

[4]. Mehra, M.; Saxena, S.; Sankaranarayanan, S.; Tom, R.J.; Veeramanikandan, M. IoT based hydroponics system using Deep Neural Networks. Comput. Electron. Agric. 2018, 155, 473–486.

[5]. Baabood, A. Qatar's Resilience Strategy and Implications for State-Society Relations; Istituto Affari Internazionali (IAI): Rome, Italy, 2017.

[6]. Chowdhury, M.E.; Khandakar, A.; Hossain, B.; Abouhasera, R. A low-cost closed-loop solar tracking system based on the sun position algorithm. J. Sens. 2019, 2019, 1–11.

[7]. Khandakar, A.; EH Chowdhury, M.; Khoda Kazi, M.; Benhmed, K.; Touati, F.; Al-Hitmi, M.; Gonzales, J.S.Machine learning based photovoltaics (PV) power prediction using different environmental parameters of Qatar. Energies 2019, 12, 2782.

[8]. Ahmad, N.; Khandakar, A.; El-Tayeb, A.; Benhmed, K.; Iqbal, A.; Touati, F. Novel design for thermal management of PV cells in harsh environmental conditions. Energies 2018, 11, 3231

DOI: 10.48175/IJARSCT-17860