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Remotely monitored Web based Smart Hydroponics System for Crop Yield Prediction using IoT

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***Abstract*— Manures, pesticides, agricultural chemicals, small and fragmented land holdings, and other problems plague agriculture in developing nations like India. Consumers is also demanding a healthier diet that is high in quality and free of agricultural chemicals and pesticides. The above mentioned difficulties and demands are met by using the system of hydroponics, which can be organic. This kind of agriculture could result in a high yield if properly controlled and monitored. A smart agriculture system based on web application is proposed for remote monitoring by combining an appropriate IoT platform with the necessary sensor network. The proposed system controls the necessary conditions for the plant to grow hydroponically, and cultivators can remotely control agriculture using IoT. Various sensors are deployed in the field to collect parameters such as temperature, humidity, pH and water content. The sensor data that has been collected and the external input data such as the District Name, Crop Name, Area in acres and the Type of Hydroponics system is then sent to microcontroller, which in turn processes the data and then acts on it. The data that has been collected is sent to the cloud, processed and the notifications are delivered to the farmers. The proposed web application provides the farmers with an estimate of how much crop yield will be produced based on the given sensor and user input. The crop yield prediction is provided in tones and is estimated using Random Forest algorithm.**

Keywords—Agriculture, Hydroponics, Organic farming, sensors,Random Forest Algorithm.

I. INTRODUCTION

In recent years, the industrial and urbanization revolutions caused a reduction in the amount of fertile agricultural land in various parts of the world, and intensive research is being conducted to overcome the lack of fertilized soil farms. Hydroponics, Aquaponics, and Aeroponics are three technologies that have emerged as a result of such research. Hydroponics has the most impact because hydroponics provides the assurance of cultivation of plants without soil and with limited resources. It consequently had a significant impact on terrace farming in urban areas where hydroponics was feasible.

Hydroponics is a type of farming in which plants grow in a soilless medium that is supplied with a mix of water and nutrients. Hydroponics enables to create farms in areas where soil conditions are insufficient to support farming. The IoT system determine the pH, water level, temperature, and humidity in the hydroponic reservoir, which continuously monitors the farm and displays data about plant growth [1][2]. There are numerous uses for the Internet of Things (IoT) in daily life, including smart agriculture systems, wearable healthcare devices, and smart transportation systems [3].

The challenges start with integrating current technologies to establish an IoT ecosystem [4]. Nevertheless, farmers have recently benefited greatly from the role that technology has played in their favor. Through IoT, various methodologies are being used in the farming sector [5]. The results are as anticipated because true automation has been implemented. Farmers can increase their income by implementing technological advancements and smart farming practices rather than traditional ones [6].

The existing agriculture systems deal with monitoring the conditions like soil and water. But, there are several other factors that effects the agriculture such as lack of water facility, and utilization of proper pesticides in proper time, and also due to the low soil moisture content available in the soil. In order to predict the soil and water conditions with respect to time and without human intervention, there is a need for hardware and software integration [7]. The currently available systems fail in producing higher yields and predicting the plants that are more prone to diseases and soil rodents which can incur the growth of plants. This fact motivated on implementing a web based remote monitoring of Smart Hydroponics System [8] using IoT which can help farmers in increasing the quality of the crops and also protecting their financial investment and reducing the time [9][10].

The proposed system, gathers information about the environmental conditions that helps farmers to choose an ideal crop that works best for them. With this model, the risk of crop failure, low yield, excessive water usage, excessive fertilizer and use of pesticide, etc. can be significantly reduced, making it more effective than earlier techniques. The sensors deployed throughout the field collects data, which is then sent to the cloud where it is processed and analyzed and the results are displayed to the farmers to use. Using the data displayed, farmers can make informed decisions about the parameters that affects their crops.

II. RELATED WORKS

Chris Jordan G et.al [1] proposed a system that constantly monitors pH, water level, air temperature, and relative humidity which makes the ideal environment for the plants to grow in. Additionally, this system offers controlled water irrigation and nutrient solution intake through the use of basic mechanisms. Users can store, manage, use, and share information online by using the data collected from the sensors and the cloud-based technology is used as the backend.

Kunyanuth Kularbphettong et.al [2] demonstrates how effectively the automated agricultural system and hydro-cultured plants can be used to increase the stability of pH sensors. For users who need to plant hydroponic vegetables, it is practical and effective because it uses IoT and mobile phones to automatically control and monitor the automatic hydroponics vegetable system.

Srivastava et al., [3] provides a thorough analysis of the most recent developments and technologies in the field of IoT-based smart farming. The commercial IoT-based products created for smart farming are also discussed.

Hernández-Morales et al., [4] developed an IoT based system, experimentally tested, and validated by keeping track of the temperature and humidity of a commercial-size greenhouse in Mexico for six months in order to show that it is feasible. A data-driven predictive model for greenhouse microclimate conditions was also included. Within a 1°C error, 24-hour temperature predictions were made with accuracy. The results show that, the proposed IoT framework would help farmers in monitoring the crops and hence enable productivity gains.

Farooq, Hira et al., [5] suggested that by combining IoT-based farming with big data has the potential to offer a universal solution for indoor farming. It combines sensors, embedded computing, wireless communication, modern networks, and distributed information processing technologies that gives a new way to collect massive amounts of data for in-depth analysis and to automate the entire farming system for higher yields in terms of both quality and quantity.

Anurag Shrivastava et al., [6], utilized big data analytics in farming to reduce costs of farming and land needed to build smart farms while also recycling water usage. It keeps track of the water levels and other contaminants continuously and monitors them with a centralized server through an Android mobile app, an IoT platform. The farm owners are informed if the water level drops or the system runs out of water. In order to monitor the quantity and quality of water for plant growth, numerous sensors are used.

Kulkarni, Sambhaji et al., [7], proposed an effective hydroponics setup that has been automated to keep track of the health of the plants and to maintain ideal pH and temperature levels for root-system nutrients uptake. As the system's brain, the microcontroller will poll the sensors to gather data about the nutrient solution. The microcontroller will start the procedures to adjust the pH and temperature of the solution if it is out of range.

Usman Nurhasan et al., [8], was successful in developing a system that employs fuzzy Sugeno that uses a website interface to automatically monitor and control hydroponic water circulation. Given that water circulation can work more effectively in certain situations, this system is ideal and performs well with hydroponic deep flow technique (DFT).

Farooq, Muhammad Shoaib, et al., [9] demonstrated how IoT-based agriculture systems can be connected to pertinent technologies like cloud computing, big data storage, and analytics. Security concerns in IoT agriculture have also been brought up. A list of applications created for various facets of farm management using sensors and smart phones has also been provided.

Edwin, Bijolin, et al., [10] uses a global system for mobile communication in which the module is connected to an Arduino to transfer the data collected by the sensors to IoT. A form of cloud computing where the data can be analyzed and an alert SMS is sent to a mobile device. A group of technologies that work together to automatically send an SMS message to a mobile device when any sensor value that is being generated exceeds predetermined threshold values.

Susan Nnedimpka Nnad, et al., [11] developed a fully automated farming system that is remotely controllable, especially in greenhouses. The main goal is to make greenhouse technology available to non-farming or technologically oriented personas. It employs sensors, electrical devices, and actuators to regulate and continuously ensure ideal greenhouse conditions.

Ravi Lakshmanan et al., [12], designed and implemented an automated smart hydroponics system based on the internet of things. The challenges that this system overcomes include the need for a new, sustainable farming method using the Internet of Things and the growing global demand for food. NodeMcu, Node Red, MQTT, and sensors that were selected during component selection based on necessary parameters were used to implement the design, and it was uploaded to the cloud to be tracked and processed.

Shomefun, Tobi Emmanuel et al., [13] suggested that, drip irrigation system operations are efficiently monitored and managed by a microcontroller-based automated irrigation system. The microcontroller-based automated irrigation system is a helpful tool for precise soil moisture control in highly specialized greenhouse vegetable production. It is a straightforward, accurate method of irrigation. Additionally, it helps to maximize their net profits while saving time and removing human error in adjusting the amount of soil moisture that is available.

Nalwade, Rahul, and Tushar Mote et al., [14] discussed about Automation of water delivery, upkeep of farms' required temperatures, upkeep of nutrients' pH and EC, automation of required sunlight for farms, as well as alarms and indicators for unusual conditions for farms Additionally, related information will be sent to the owner of that specific farm and displayed on a display panel.

Abdul Raheman et al., [15] developed a system that helps the farmer to continuously check and monitor the crops and also automatically monitors the soil states. The farmer no longer needs to frequently visit the field to check the water levels because this system continuously monitors the condition of the soil. Given the quick depletion of water resources, this system also helps to reduce water waste.

III. SYSTEM OVERVIEW

A. Acquiring sensor data

The monitoring of indoor environmental parameters uses the sensing technology. Temperature and Humidity sensors are used for measuring the temperature and humidity. It is an integrated circuit with a temperature- proportional electrical output that can measure both humidity and temperature. It sends the information in real time in the form of analog signals [11].

Intruder Detector are used for intruder detection, an infrared sensor discharges or potentially recognizes infrared radiation to detect its environment [12]. It detects any object or obstacle in its vicinity and sends a signal to microcontroller for the same. The microcontroller is programmed to ring a buzzer when an intruder is detected.

Water level sensor has a small plastic ball that floats on water which gives two readings low and high. Low indicates that the tank is empty and high indicates the tank is full. The pH sensor is one of the most significant sensors used to measure water. This sensor aids in determining the water's alkalinity and acidity levels.

B. Processing through Microcontroller

ESP32 has wireless connectivity such as Wi-Fi and Bluetooth, whereas the majority of Arduino boards, with the exception of a few, lack wireless connectivity and demand external components. Bluetooth and Wi-Fi modules are external modules.

The ESP32 is made to offer wireless connectivity in an approachable manner. The 36 GPIO, is a high number compared to other boards and includes 18 Analog to Digital (ADC) pins. The ESP32 operates between 160 and 240 MHz, which is clearly audible during data transfer. The below Figure.1 gives the pin description of ESP32 Microcontroller Board [13]. The microcontroller process the values received from the sensors and provides recommendation to the farmer on the LCD display.

- It sends notification to the farmer when any of the parameters are not within the range of recommended value.
- NodeMCU decides whether to water the crop or not by controlling the relay [14].
- NodeMCU turns on the buzzer to scare off any intruder or rodents when detected.
- The data reaches the server from NodeMCU through Wifi.

C. Analog to Digital Converter

Analog to Digital Converter (ADC) is used to convert the analog signal into digital form. It has only one input pin to read the analog voltage from an external device. By using pulse code modulation (PCM) technique, the digital values are received.

D. Generated Output Actions

- LCD Display - The LCD screen is used to display the values obtained from various sensors connected to it. Itcan display up to one 8-character line or two 8- character lines. It can display both numbers and alphabets. This is the output device used to show the actions performed by the microcontroller. The I2C connected to the LCD frame converts the binary values to digital values which are displayed on the LCD screen.
- Relay - A relay is an electrically operated switch. It is used to control the water flow into the hydroponic tank.It is powered by a 12v battery.
- Buzzer - This is the output device for microcontroller, and it is used to scare the birds and rodents in the farm. The buzzer gives a sound whenever an intruder is detected.
- Water Pump - It is a submersible water pump. It receives the instructions from microcontroller to switchon and off the pump [15].

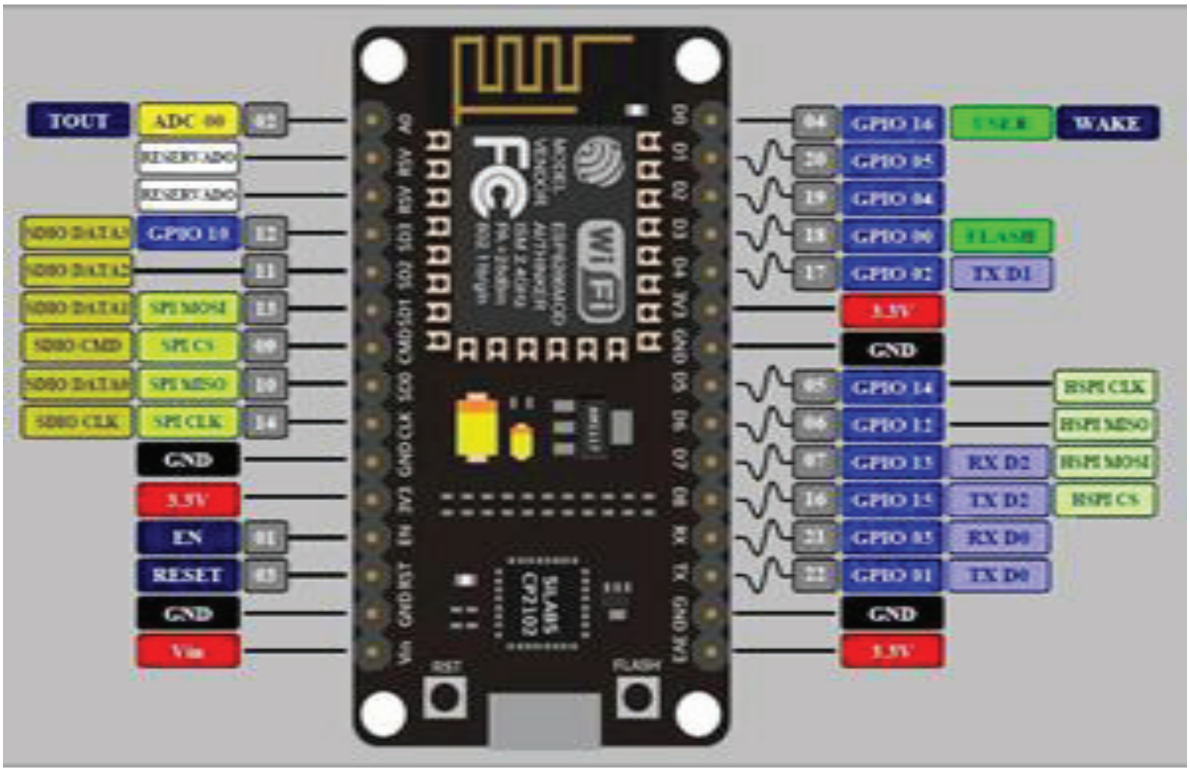

Fig. 1. Pin Description of ESP32 Microcontroller Board

IV. SYSTEM IMPLEMENTATION

In System implementation, the sensors that are set up on the field collects the values of various parameters such as water level, temperature, humidity, pH, intruderdetector from the hydroponic reservoir. The analog values collected is converted to digital values by Analog to Digital convertor which can be a separate device or can also be a container as an in-built utility in some microcontrollers.

In this set up, all the connections are made according to the system design. The sensors and the LCD display are connected to the microcontroller. The microcontroller now contains the digital values of the data collected from various sensors that have been deployed. The microcontroller after processing the values decides on the further actions that has to be taken. The LCD displays the values being read by the sensors. Over the Wi-Fi module alert messages are sent to the user if any of the parameter values exceeds the threshold. The relay is controlled by the microcontroller which switches in regard to pump the water into the tank. It sends signal to the buzzer to buzz in case of any intruder being detected on the field. LCD display displays the values of the sensors that was obtained using the sensors.

The below Figure. 2 shows the connection of the components.

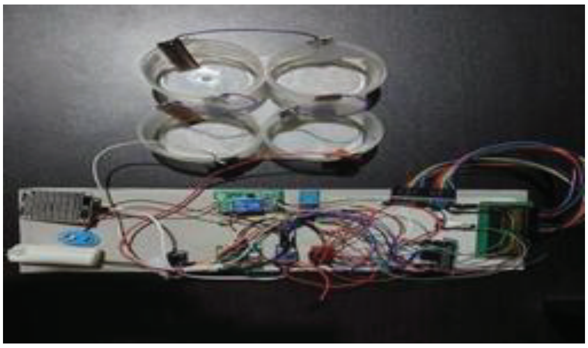

Fig. 2. System Implementation using the Connections

The below Figure.3 shows the proposed system design, the data flow happening of various gadgets put together on the agriculture field.

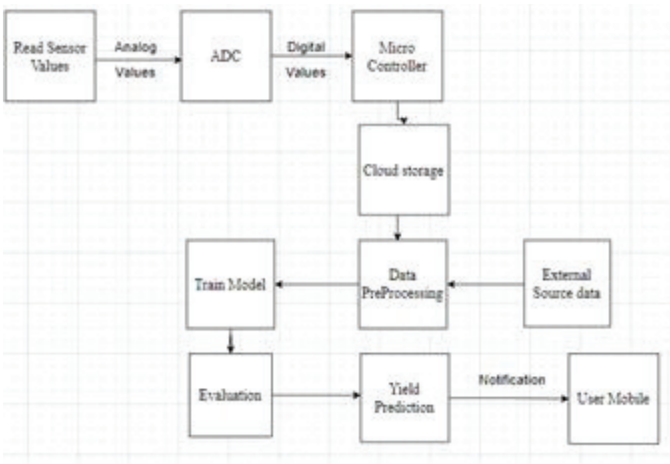

Fig. 3. Proposed System Design

The hydroponic reservoir's pH, water level, temperature, humidity, and intruder detector values are measured by a variety of sensors placed around the area.The Analog to Digital convertor, which can be a standalone device or an integrated utility in some microcontrollers, converts the collected analog values to digital values. The microcontroller is then connected to the server after receiving the digital values of the data gathered from the sensors. The collected values are saved to the cloud storage. The user can upload data values from any external sources and it is subjected to pre-processing. The missing data were handled and the data is then transformed into the necessary form, where the necessary attributes are extracted. The desired results are obtained by extracting the focus attributes and trained using the Random Forest model. The trained model is then fed to the testing phase to determine its performance. Notifications are then sent to the user's mobile device if the obtained sensor values do not fall within the threshold range or if the sensors detect some abnormality. A zonal representation of the crop yield is obtained and displayed using the user-specific data that has been entered. Farmers can decide on the factors that affect their crops which helps them in promoting the prediction of crop yield.

A. *Decision Support System*

The values of pH, humidity and temperature in the field are obtained from the sensors in real time and the data collected is given for preprocessing. The other parameters like year, area, temperature, precipitation, humidity, district and kind of crop are given as an external data input. The missing data is handled and transformed according to the model requirements before being fed into the model. The weighted attributes are extracted for the training of the machine learning model.

Random Forest algorithm is implemented to train the model. After training the model with the fed data, it will be tested with a set of test data to see the outcome and to check if the model holds good for the required outcome. The crop yield is then predicted in terms of tones for the specified crop. The following pseudocode is used to perform prediction using the trained random forest algorithm.

1. Each decision tree is generated using a subset of K data points that are taken in random.
2. When the test data is provided, the results are predicted by each of the decision tree independently.
3. The final prediction result is the outcome of the decision trees based on majority voting system.

B. *Performance Analysis*

Systematic observations are made as a part of performance analysis in order to improve the performance and decision-making and it is shown in the below Table 1. This service is primarily provided through the provision of objective statistical data analysis. The performance of machine learning models after training is determined using performance evaluation metrics. This aids in determining how well the machine learning model can execute on a dataset that it has never encountered before.

C. *Confusion Matrix:*

A confusion matrix, also known as an error matrix, is a particular table layout that allows visualization of the performance of an algorithm, typically a supervised learning one, in the field of machine learning and more specifically the problem of statistical classification. A table called a confusion matrix is used to describe how well a classification algorithm performs. The output of a classification algorithm is visualized and summarized in a confusion matrix.

TABLE I. ANALYSIS OF PREDICTION PERFORMANCE

		Predicted Class		
		Positive	Negative	
Actual Class	Positive	True Positive(TP)	False Negative(FN) Type II Error	Sensitivity $\frac{TP}{(TP+FN)}$
	Negative	False Positive(FP)	True Negative(TN)	Specificity $\frac{TN}{(TN+FP)}$
		Precision $\frac{TP}{(TP+FN)}$	Negative Predictive Value $\frac{TP}{(TP+FN)}$	Accuracy $\frac{TP+TN}{(TP+TN+FP+FN)}$

- The true positive rate (also called hit rate or recall) of a classifier can be determined by dividing the correctly classified positives (the true positive count) by the total positive count.
- The false positive rate, also known as the false alarm rate, of the classifier can be determined by dividing the total number of negatives by the number of negatives that were incorrectly classified (the false negative count).
- The recall formula is done by calculating correctly the number of positive classes' estimation.
- The precision formula is done while asking how many estimated classes estimated must be positive evidently.
- The overall accuracy of a classifier is determined by dividing the total number of positives and negatives that were correctly classified by the total number of samples.

V. INTERFACE DESIGN

A. User Interface Design

The below Figure.4 shows the design with respect to the login page. Once the user logs in he is directed to the home page.

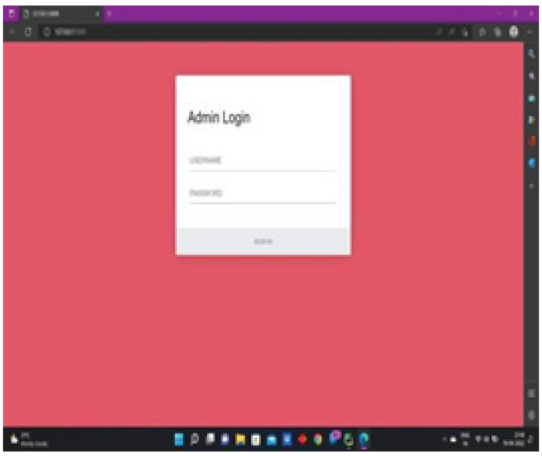

Fig. 4. User login and Sign-up page

The crop yield prediction is shown in the below Figure 5. The yield of a particular crop is predicted based on the information entered by the user. Real time values of various parameters obtained from the green house is displayed in the right.

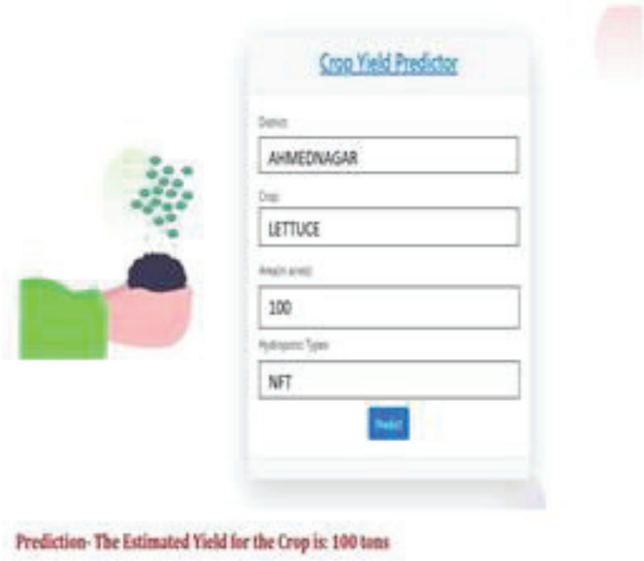

Fig. 5. Crop yield prediction

B. Results

1) Crop Prediction

Farmer can input the type of crop, the number of acres in which the user wants to grow and the location of the farm. The crop yield prediction is done based on the inputs of various parameters such as temperature, humidity and pH. The details are shown in the below Figure 6.

Fig. 6. Crop yield prediction based on various parameters

2) Notifications to the User

The below Figure.7 shows the notifications that are sent to the farmer's mobile phone. Whenever the temperature, pH and humidity exceeds the threshold, the user gets the notifications/alert messages along with voice alerts. Voice alerts are on a loop for one minute.

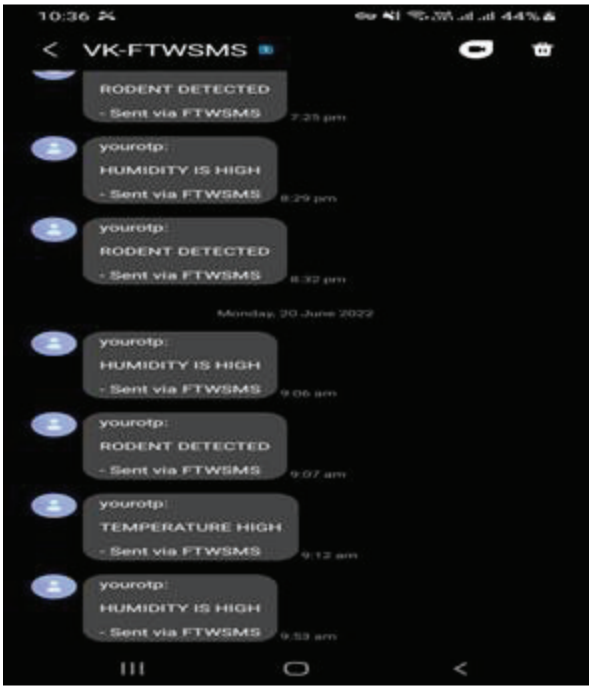

Fig. 7. Notifications sent to the user

VI. CONCLUSION

An intelligent hydroponic farming system is built, that communicates with a sensor network and provides the farmer with the information about the crop conditions. The proposed IoT system minimizes power consumption while serving as a watchful eye for farmers. The farmer can monitor the farm remotely and be aware of certain parameters. The system offers the assistance required to choose a crop, care for their land, and sell crops at a fair price. This system is easy to use, effective, and long-lasting. The proposed model makes farming easier and more appealing. It offers the support required to choose a crop based on the farmer's land. Farmers benefit from saving of time and financial investment. Additionally, it raises the crops' overall quality and the system can be upgraded to turn on an air conditioner and fans to lower the temperature in that area. The method's primary focus on microcontrollers is its biggest drawback. If the microcontroller breaks down, the system will not function. Based on the sensor values obtained, the web application predicts the crop yield using Random Forest Machine Learning algorithm. In future, improvement can be done by typically including more sensors such as Electrochemical sensors which possess the potential to systematically monitor the health of plants and help the artificial intelligence system predict outcomes better, and integrating data analytics system to predict outcomes for better crop health.

REFERENCES

[1] Aliac, Chris Jordan G., and Elmer Maravillas. "IOT hydroponics management system." 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM). IEEE, 2018.

[2] Kularbphettong, Kunyanuth, Udomlux Ampant, and Nutthaphol Kongrodj. "An automated hydroponics system based on mobile application." International Journal of Information and Education Technology 9.8 (2019): 548-552.

[3] Srivastava, Abhishek, and Dushmanta Kumar Das. "A comprehensive review on the application of Internet of Thing (IoT) in smart agriculture." Wireless Personal Communications 122.2 (2022): 1807-1837.

[4] Hernández-Morales, Carlos A., J. M. Luna-Rivera, and Rafael Perez-Jimenez. "Design and deployment of a practical IoT-based monitoring system forprotected cultivations." Computer Communications 186 (2022): 51-64.

[5] Farooq, Hira, et al. "A review on smart IoT based farming." Annals of Emerging Technologies in Computing (AETiC), Print ISSN (2020): 2516-0281.

[6] Anurag Shrivastava, Chinmaya Kumar Nayak, R. Dilip, Soumya Ranjan Samal, Sandeep Rout, Shaikh Mohd Ashfaque,"Automatic robotic system design and development for vertical hydroponic farming using IoT and big data analysis", International Journal of Engineering & Technology, vol. 12, no. 8, pages:1-7, 2019.

[7] Kulkarni, Sambhaji, et al. "Automation of hydroponic System." International Journal Of Science Technology & Engineering 3.9 (2017).

[8] Usman Nurhasan, Arief Prasetyo, Gilang Lazuardi, Erfan Rohadi, Hendra Pradibta, "Implementation IoT in System Monitoring Hydroponic Plant Water Circulation and Control", International Journal of Engineering & Technology, vol. 7, issue. 4, pages:122-126, Dec 2018.

[9] Farooq, Muhammad Shoaib, et al. "A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming." Ieee Access 7 (2019): 156237- 156271.

[10] Edwin, Bijolin, et al. "Smart agriculture monitoring system for outdoor and hydroponic environments." Indones. J. Electr. Eng. Comput. Sci 25.3 (2022): 1679-1687.

[11] Susan Nnedimpka Nnadi, Francis E Idachaba, "Design and Implementation of a Sustainable IOT Enabled Greenhouse Prototype", vol. 10, issue. 11, pages:457-461, 2018.

[12] Ravi Lakshmanan, Mohamed Djama, Sathish Kumar Selvaperumal, Raed Abdulla, "Automated smart hydroponics system using internet of things", 2020, International Journal of Electrical and Computer Engineering (IJECE), vol. 10, no. 6, pages:6389-6398, Dec 2020.

[13] Shomefun, Tobi Emmanuel, Awosope Claudius OA, and Ebenezer O. Diagi. "Microcontroller-based vertical farming automation system." International Journal of Electrical and Computer Engineering 8.4 (2018): 2046.

[14] Nalwade, Rahul, and Tushar Mote. "Hydroponics farming." 2017 International Conference on Trends in Electronics and Informatics (ICEI). IEEE, 2017.

[15] Abdul Raheman, M.Kameswara Rao , B. Vamsi Reddy , T. Ravi Kumar, "IOT based self-tracking solar powered smart irrigation system", International Journal of Engineering & Technology, vol. 2, issue. 7, pages:390-393, 2018.