

IoT-based Crop Monitoring System

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Abstract—This paper proposes an innovative IoT-based crop monitoring system using the ESP8266 microcontroller along with a variety of sensors. Soil moisture, temperature, humidity, and light intensity sensors have been integrated for real-time environment data collection, essential for the growth of crops. Data processing occurs through the ESP8266, and the output is obtained on a screen with instant access. Besides, the Blynk cloud platform is used to provide distant monitoring and data analysis of the IoT system. This holistic approach will perhaps revolutionise agriculture through the accurate prediction of crops through inherent environmental factors, yielding vital time- sensitive inputs for significant influences in crop development processes.

Keywords—IoT, Crop monitoring, ESP8266, soil moisture Sensor, Temperature Sensor, Humidity Sensor, Light Intensity Sensor, Blynk, Cloud Computing, Precision Agriculture.

I. INTRODUCTION

The Internet of Things (IoT), which is a step forward in collecting data as well as in its processing and utilisation, revolutionises agricultural, environmental care, and urban planning. Amongst the most significant uses of IoT are setting up weather stations for the collection and provision of real-time data, together with geographical and environmental information. For this reason, smart agriculture solutions based on IoT technology are rapidly becoming widespread in the market.

Humidity and temperature information allow farmers to make more informed decisions on the timing of what is to be done at that time. Atmospheric and soil temperature information can be used to determine the best possible time to plant crops [1].



Figure 1: IoT Application in agriculture

In Figure 1, there is representation of a pictorial form of the applications of IoT in agriculture.

The initial methods used in agricultural monitoring systems depend on Wireless Sensor Networks (WSNs), which can be classified as either local or global. A local WSN connects to the Internet via a gateway to enable remote management of these systems. The main design goal of these solutions is to ensure energy efficiency. The integration of data from such sensors and the ESP8266 module will enable farmers to make informed decisions in real-time weather conditions by optimising yields and resource use. This data plays an important role in understanding the environmental conditions that show a significant impact on a crop's growth and yield. By displaying this information on an LCD screen and transmitting it to the Blynk IoT cloud platform, the system offers both local and remote access to critical agricultural data.

The kind of data-driven approach allows for effective management of conditions for environment-friendly and efficient agricultural practices. This model helps farmers reduce time wastage and lessen the environmental impacts while efficiently enhancing crop yields. These considerations of resource management are critical in ensuring food security and doing sustainable agriculture. Thus, the major goals of this project are as follows:

- Design and build a multisensor system that will accurately collect comprehensive environmental data.
- Utilise the ESP8266 microcontroller to process and stream data correctly.
- Integrate this system with the Blynk IoT cloud to see and analyse the sensor data gained remotely.

Therefore, the study contributes to some of the present concepts of precision agriculture by offering an economical and scalable framework for crop monitoring that may assist in improving crop yields and resource management in agriculture.

II. LITERATURE SURVEY

The integration of Internet of Things with machine learning and artificial intelligence profoundly renovates the agriculture sector by efficiency and sustainability, such as in this new approach through data-driven methods. This work jointly reviews the research and applications that are current in IoT-based agricultural systems, which brings emphasis on data acquisition in real-time, precision agriculture, and the ways of developing more advanced technologies to enhance farming practices.

Primarily, it was WSNs, and broadly, they can be categorized into two types: local and global systems. Local WSNs connect to the Internet via a gateway; hence, these agricultural systems can be monitored and operated from anywhere. As claimed by Yaqub et al. (2024), the primary need of these systems is energy efficiency, and therefore research has been gradually shifted toward networking protocols that could be designed for efficiency. Numerous standard and non-standard protocols have their application in enhancing connectivity and transfer in agricultural applications [1].

Precision agriculture, or PA, is a way of managing farming activities through the use of digital tools and methods to track agricultural production operations. In doing so, it promises to raise the quantity as well as the quality of outputs while lowering inputs and waste through the exploitation of data feeds from satellites, mobile devices, IoT, and technologies including cloud computing and artificial intelligence. The article by A. Ghilan, Y. E. AFOU, M. MERRAS, and N. E. Akkad will present a proposed irrigation system for PA under a smart farming aspect. This can help in the implementation of real-time and sustainable watering practices based on the data accumulation and evaluation of field-specific data along with weather forecasts. It also collects, analyzes, and visually plots the data stored in a ThingSpeak platform, so that actionable information about the amount of water to be used is provided to farmers [3].

The most important innovation that smart agriculture brings forward is the use of IoT techniques to monitor and regulate agricultural parameters in real time as mentioned by the author C. Prathap, S. Sivaranjani and M. Sathya (2018). Agriculture activities such as sowing and irrigation will be scheduled by proper decisions based on humidity and temperature data provided. For instance, in order to achieve proper planting timing along with maximal crop yield potential, atmospheric and soil temperatures will be measured [4].

It ranges from the soil, the irrigation systems, temperature, rainfall, water level, among others. Because the general health of the crop depends mainly on these parameters, then the agronomist should also be well-established and equipped with the exact or absolute values of these factors, rainfall conditions, or climate changes for proper crop growth to take place. In the opinion of Ruchi, V. Wasson, Muskan, and Gargi, sensors like other factors have a proper role in the development of crops by providing favorable conditions. [5].

Sensors are highly required in modern agriculture these days. The most widely applied ones include soil moisture and temperature sensors, humidity sensors, rain detectors, and light-dependent resistors. According to Uddin, Kumar Dey, and Akter (2024), among these, soil moisture sensors can identify excessive or insufficient availability of water by continuous level measurement, thus avoiding over- or under-watering conditions. All

these sensors record environmental factors that affect crop growth. Consequently, rain detectors could directly control irrigation systems, saving water and reducing losses in efficiency. Thanks to ESP8266 Wi-Fi module, which allows for connectivity and data transfer, the farmer's systems can be monitored and controlled from a laptop or mobile phone. The whole system demonstrates the possibility of effective resources management in agriculture with minimal costs [6].

Above all, IoT integration with edge and cloud computing increases the productivity of the farming process, even as it enhances the monitoring of various agricultural indicators, aquaculture sectors, farm animals, and the environment. According to Murugan et al. (2024), the system in consideration provides global accessibility of data and utilizes cloud services that produce automated notifications, emphasizing sustainability and flexibility. Further features related to machine learning will be implemented later to upgrade predictive analytics and improve precision in farming techniques [7].

Aggarwal and Singh (2024) examines how the use of ANNs (Artificial Neural Networks) in an Agriculture Farm Monitoring System schedules autonomous irrigation along with providing forecasts regarding weather. The system gathers time- series data from sensors that measure temperature, humidity, and rainfall to predict the most apt irrigation techniques for optimal resource usage.

Additionally, Qazi, Khawaja, and Farooq (2024) argues that IoT permits that smart communication of the connect devices by automatic collection of critical data to be used in agriculture. AI emergence enhances the skill of the farmer to make better choices on resource use concerning water management. These are the measures undertaken by the Indian Government towards the introduction of technology on agricultural land by introducing PMKSY or Pradhan Mantri Krishi Sinchayee Yojana besides eNAM or Electronic National Agriculture Market [9]. Combining accuracy with smart agriculture technology is of utmost importance to derive maximum profits by using the data to its fullest potential, despite challenges related to installation costs and low awareness, as said by Sharma (2024) [10]. AI and IoT can contribute decisively to the mechanization of agricultural pest control and soil management. Although the most important tools for crop management in high-tech agriculture are represented precisely by these technologies, their challenges remain unique. They are expensive to upkeep because of the high level of the problem and less efficient because of the non-standardized gathering of information and processing. This IoT, ML, and AI combo is dramatically raising the production and sustainability capabilities of the agro- food industry. We are increasingly making it possible to achieve better gains in agricultural methodologies that answer modern farming requirements due to continuous developments in data analysis, sensor technologies, and other real-time tracking systems. A review of this kind of literature itself shows large investment is essential for furthering and researching these areas to ensure increases in resource management, crop quality, and general agricultural output.

The structure, format, and flow of this paper for conference publication were influenced by the research conducted by Pallavi Deshpande and colleagues (2019) and (2021). Although their studies provided valuable insights for our organizational framework, we did not incorporate any direct content or references from their work, thereby maintaining the originality of this paper [11-12]

III. METHODOLOGY

In this project, the methodology is a heterogeneous approach for the system to be able to provide real- time, IoT-based solutions for farming. The methodology assimilates data collection from real field observations using environmental sensors in the system and is inclusive of farmer inputs gathered through surveys.



Figure 2: Field visit

Field visits and on-site observations: To understand the project practically, we visited different agricultural zones to evaluate numerous challenges, such as evaluating the regional climate, farming practices conducted by the farmers, and challenges and ultimatums that are applicable to each farmer individually within that region. The data obtained on evaluation was on temperature, humidity, soil moisture, and intensity of sunlight; this was the result of the manual data collection process at different places in the field (Fig.2).

Farmer Interviews- Questions and discussions were held with local farmers to prompt the facts on how farmers decide on which crops to farm. Questions asked included:

- What conditions do they look upon when choosing the crop to be grown?
- How do they react when the weather changes suddenly?
- What kind of technical solutions do they stretch out to adopting?

A. Sample Google Form survey for farmer input

We conducted a Google Form survey to supplement the field visits for a small population of farmers.

The Google Form was designed to interrogate: Trying to understand how farmers perceive the adaptation of the technology and sensor-based systems in real time farming. Information on common crops grown in a particular region and their respective

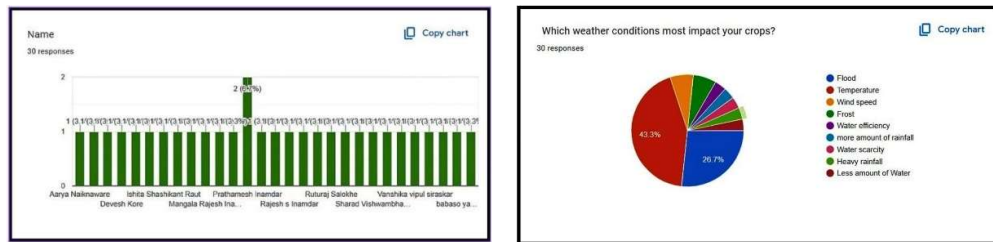


Fig. 3 Google Form Survey

B. Sensor Testing with Description

Individual sensors were thoroughly tested and calibrated to ensure accurate data collection in both indoor and outdoor environments. This form of calibration is crucial to the preservation of data integrity and optimal performance of entire IoT-based agricultural system.

- Soil Moisture Sensor: Connection with the analogue pin A0 of the ESP8266. The parameters for this sensor are measurements of the moisture in the soil.
- Temperature and Humidity Sensor: This digital sensor (e.g., DHT11 or DHT22) was used to measure real-time temperature and humidity.
- Light Intensity Sensor (LDR): A photoresistor was used to measure current sunlight levels, crucial for knowing the light exposure to the crops.

The sensor integration and testing phase played an important role in developing our IoT-based crop monitoring system, which gave us an assurance on the accuracy and reliability of the collected data. Each sensor was meticulously connected, calibrated, and tested individually before being incorporated into the complete system.

C. Components and description

- LCD Display and I2C Module: During testing process, we project data read from each sensor on a 16x2 I2C LCD screen (Fig 4) connected to the ESP8266. We were able to see real-time outputs and identify any discrepancies or errors in sensor measurements. We sent sensor's data to the Blynk cloud platform with specific virtual pins for reading soil moisture content, temperature, humidity, and light intensity. This enabled remote monitoring and checks on the accuracy of sensor measurements



Figure 4 LCD with I2C Module

- ESP8266: The ESP8266 (Fig5) is an low- cost microcontroller with Wi-Fi embedded. ESP8266 will be used to read sensor data-think of a soil moisture sensor and then transmit data to a web server or cloud computing platform for monitoring in real-time. ESP8266 contains an A0 as the analog input pin; however, most of the digital pins are free for use in communication with other peripherals.A0 is mainly used for reading analog sensor values.

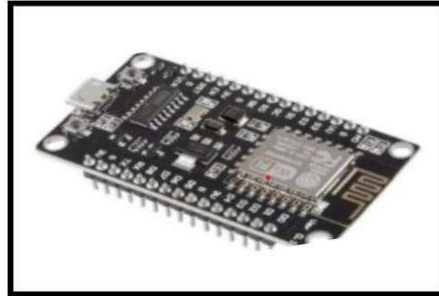


Figure 5 ESP8266 Model

- Soil Moisture Sensor: For the soil moisture sensor (Fig 6), this is a resistive-type device that measures volumetric water content in soil; it was connected to the analog pin A0 of the ESP8266. The operation of the sensor falls within the range of 3.3V to 5V and gives an analog output for $\pm 3\%$ accuracy. Testing involved putting the sensor into various samples of soil with different water contents levels ranging from dry to saturated.

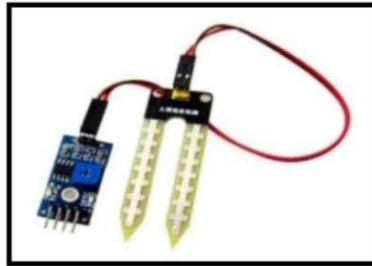


Figure 6 Soil Moisture Sensor

- DHT 22: Fig7 shows the picture of the DHT22 sensor. It was used for the measurements of temperature and humidity. The operating range of this sensor includes a temperature range of -40°C to 80°C at $\pm 0.5^{\circ}\text{C}$ and a humidity range of 0-100% RH at $\pm 2\%$ RH. This was connected to D2 pin of ESP8266 with use of a 10K pull-up resistor. Now, with DHT22 library installed in Arduino IDE, this is done by running successive measurements, testing the accuracy of equipment against one from a calibrated thermometer and hygrometer.

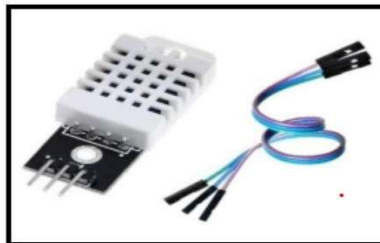


Figure 7 Temperature and Hmidity sensor

- LDR: The LDR (Fig8) measures the level of ambient light falling on crops. The resistance of the LDR is set between 1 K Ω under bright light and 1 M Ω in darkness, having a peak at 540nm. For this, we made the connection of A1 pin and GND through the voltage divider. Testing of the LDR was done under various lighting conditions

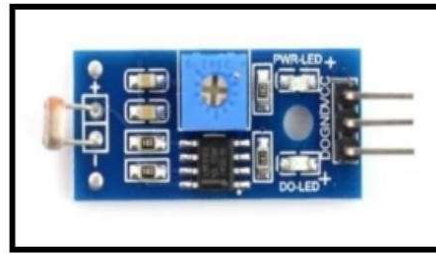


Figure 8 LDR (Light Dependent Resistor)

The rigorous testing and calibration ensured that each sensor, once integrated into the complete IoT-based crop monitoring system, was correctly working and actually providing valid data.

IV. IMPLEMENTATION

The block diagram shown in the below Figure 9 is a pictorial representation of the system implementation.

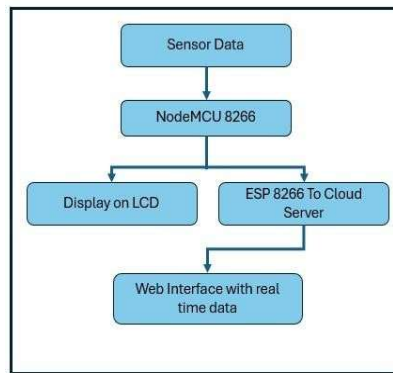


Figure 9 Block diagram of system

This block diagram shows the process of collecting and displaying sensor data using an Arduino IDE and ESP8266:

Sensor Data: The system collects data from sensors.

Arduino IDE Processing: The Arduino IDE processes the input from sensors.

Arduino IDE to ESP8266: Processed data is sent from the Arduino IDE to the ESP8266.

Output to LCD: Data is optionally displayed on an LCD.

Transmit to Cloud: The ESP8266 transmits the data to a cloud server.

Web Interface Access: The cloud server provides access to real- time sensor data via a web interface. A comprehensive environmental monitoring system is made of a DHT22 temperature and humidity sensor integrated together with a soil moisture sensor through an I2C LCD display in Arduino code. For this purpose, the necessary libraries available in the Arduino IDE are included in the code: DHT.h for interfacing with the DHT22 sensor, Wire.h for I2C communication, and LiquidCrystal_I2C.h to control the LCD display. There is DHT22 sensor connected to digital pin D4 and the soil moisture sensor is connected on analog pin A0.

Inside the setup() function, there would establish serial communication at a baud rate of 9600 for debugging purposes. DHT22 sensor would be initialized with dht.begin(). It would initiate the LCD with lcd.init(). It turns on the LCD backlight using lcd.backlight() and it displays with a message saying

"Initializing." on the screen before erasing the LCD screen for two seconds using lcd.clear(). The overall program function is contained in the loop() function, which runs forever as it reads data from sensors. Initially, it fetches the sensor reading of the soil moisture by using the analogRead(moisturePin) and then the temperature and humidity values with dht.readHumidity() and dht.readTemperature() respectively. To avoid errors in the data, the code has error checking on the DHT22 sensor reading. It makes use of the isnan() function to check if one of the values is not a NaN (Not a Number). Thus, if a reading has failed to return a valid value and, therefore, returns a NaN value, the code will print an error message to the Serial Monitor and write "Sensor Error!" into the lcd by lcd.print().

The values for temperature, humidity, and moisture are then printed to the Serial Monitor for monitoring if the readings are valid. The LCD is then updated, where it fills with the temperature and humidity values for five seconds by clearing the display using `lcd.clear()`, setting the cursor position with `lcd.setCursor()`, and printing the values. Then the display is cleared once again, and after showing temperature and humidity, the moisture level is shown for another five seconds. As a final delay of two seconds is added at the end of the `loop()` function, to not overload the sensors, and to have the system work in a manner suitable for something like an agricultural monitoring application or even a weather station. This code reads data from a DHT22 sensor (for temperature and humidity) and a soil moisture sensor, displaying the values on a 16x2 I2C LCD and printing them to the serial monitor.

Blynk IoT Cloud Platform Setup

A Blynk project was designed based on the modules outlined below:

- Virtual pins were configured to receive data from each sensor.
- Widgets were added to the Blynk app interface for visual representation of sensor data (e.g., gauges for temperature and humidity, charts for soil moisture trends).
- Notification systems were set up to alert users when sensor readings exceed predefined thresholds

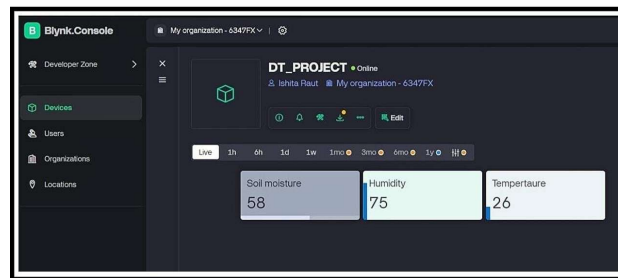


Fig.10 Blynk IoT Cloud Platform

Figure10 shows the implementation of BlynkIoT Cloud Platform

Configured the Blynk IoT Cloud Platform to receive, visualize, and manage data from the crop monitoring system based on ESP8266. The project was configured using the following credentials:

BLYNK_TEMPLATE_ID: "TMPL3mnOX5Vqc"

BLYNK_TEMPLATE_NAME: "Weather station" BLYNK_AUTH_TOKEN: "B3-OigzjaUDG9fw70MbZIOahJcnWSUPR"

These credentials are compulsory to the ESP8266 device in order to make a secure connection with the Blynk cloud in order to send data to the correct project with the correct device. Virtual pins were set to receive information from the sensors in the system. Specifically:

- V0: Soil Moisture Sensor
- V1: Temperature Sensor
- V2: Humidity Sensor
- V3: Light Intensity Sensor

Each virtual pin is a data stream, transmitting real- time sensor values coming from ESP8266 into the Blynk cloud. Applying different widgets on the Blynk app interface was customized to provide nice visual representations of the sensor readings. Added a gauge widget for the soil moisture sensor connected to V0, with values from 0 to 1023 as that is the range of the analog reading. For temperature and humidity (V1 and V2), two other gauge widgets were configured, with ranges set to 0-50°C and 0-100% respectively. A line graph soil moisture time trend chart widget was implemented to pull data from V0. This provides a capability to view the soil moisture variations on day to week.

Blynk's Event feature was used in the notification system to enhance proactive monitoring capabilities of the system. For instance, an event can be established to trigger when the soil moisture level (V0) drops below a specified threshold of 300 that is a threshold to show dry soil. After the trigger, it sends a push notification to the mobile device of an individual via the Blynk application reminding him or her to water crops. Similar conditions were set up for temperature extremes, for instance, below 10°C or above 35°C, as well as in low light conditions. The appliance instantly warns a user of any environmental condition that can harm the health of their crops.

A Super chart widget has also been utilized for adding the functionality of having all sensor data over time displayed on the Blynk dashboard. It was so arranged that soil moisture, temperature, humidity, and light

intensity will be presented in a graph so that the user could track the relation between environmental factors. Finally, the Table widget was implemented to present recent measurements from all sensors in tabular format for an easy overview of the current situations. This detailed setup of Blynk therefore makes sure that users get their real-time data, historical trends, and timely alerts. The three factors above are very integral in ensuring the management and even prediction of crop yield.



Fig. 11 Circuit Implementation

Hardware Implementation: Figure 11 shows the implementation of the project work

V. RESULT AND DISCUSSION

The system was deployed into a controlled agricultural environment and data taken from multiple sensors that monitor key environmental conditions controlling crop development. The principal purpose of this experiment was therefore meant to reveal the interrelation of environmental factors together with temperature, humidity, soil moisture, and light, as they relate to growth and development. Therefore, the strategy was to analyze the sensors in real time, thus providing highly valuable information on how conditions impact crop development, without requiring predictive modeling or platforms of complex data analytics. Rather, the experiment relied on direct interpretations of the data and practical agricultural strategies.



Fig. 12 Blynk IoT Cloud Platform Result

Fig.12 shows the Blynk IoT Cloud Platform implementation and its circuit result on LCD.

- **Soil Water Content Crop Yield:** The study demonstrated seemingly direct relation between the soil water content and crop yield. It was from the study that adequate levels of moisture in the soil are fundamental to the healthful development of roots, reduce the stress in crops and attain increased yields. Adequate moisture in the soil ensures that plants receive enough water, nutrients, and oxygen for optimal growth. On the other hand, overwatering causes reduction of soil oxygen that leads to water logging which causes diseases in roots and thus increases untimely crop productivity. It indicates an imperative for proper and accurate scheduling for irrigation that can provide the ideal levels of moisture in soils while avoiding cases of both over- watering and under-watering scenarios that lead to the impairment of crops.

- **Light Intensity and Photosynthesis:** Light is one of the important requirements for the process of photosynthesis that propels the growth process of the plants. Measurement data from LDR sensors revealed that at different development stages of the plants, light intensity was high enough to provoke rates of increased photosynthesis and biomass production.
Proper light management, like avoiding overheating when the plants receive enough sunlight, is fundamental in optimizing crop yields. The data showed that by controlling shading at peak times, agriculturalists could avoid exposing the crops to extra light, which was found to minimize damages from too much light exposure, while maximizing photosynthesis benefits.
- **Crop Health and Environmental Variation:** Crop health: Under environmental monitoring, crop health made an attempt to prove that variables such as temperature, humidity, and soil moisture were indeed changing, affecting crop productions in a very dramatic way. For instance, prolonged periods of high humidity augured for more chances of the outbreak of fungal diseases. Drought meant that plant growth was arrested, resulting in lower yields. It made possible monitoring various environmental condition's in real time to advise on the right time to take proper action in crop management. Monitoring environmental trends by farmers allows them to make informed decisions in how to irrigate, control pests and diseases hence healthy crops with no yield losses due to adverse conditions.
- **Precision Agriculture and Resource Optimization:** With the integration of multiple sensors, the system now understood how different factors of the environment correlated with each other and thus produced results concerning the nature of crop development. The continued monitoring of these factors by the system made it possible for farmers to optimize their applications of water and light. Since then, real-time monitoring led to quick intervention at needed times, which included prevention over- or under-watering due to changes in irrigation schedules, proper application of fertilizers at appropriate times, and control of light exposure for increased photosynthesis. This approach falls right under the dispensation of Precision Agriculture, directed toward resource efficiency and the reduction of waste, eventually making its way into better crop productivity and sustainability.
- **Success in the IoT-based monitoring system through Blynk Cloud:** The primary result of the experiment is the design of an IoT-based system that connects sensors with a Blynk Cloud platform. Real- time data concerning temperature, humidity, soil moisture, and light intensity were displayed remotely. Blynk integration allowed farmers to view their crops' environmental conditions from anywhere on earth by reporting any anomalies immediately. Such an ability to monitor remotely really helped them make timely decisions about matters such as irrigation scheduling and pest control while keeping tabs on their use of resources so that crops were always at the optimal growing condition.

VI. CONCLUSION

In conclusion, we demonstrated how the ESP8266 microcontroller combined with environmental sensors can be used to offer an IoT-based system in regard to monitoring agriculture. The key aspect of this system is giving farmers direct access to real- time data collection and sensor-based monitoring to allow optimization in crop management and their resource efficiency.

The monitoring of critical environmental variables such as moisture levels, temperature, humidity, and light intensity is quite crucial in understanding trends in crop growth performance and improving decisions.

This solution is scalable, adaptable to different farming conditions and types of crops, and it does not rely upon any machine learning models or complex web platforms, making it both cost-effective and very easy to implement. It helps the farmers take decisions that increase productivity and which make the use of resources more responsible and reduce impacts on the environment, thanks to very accurate and timely data. This system promises so much towards modernizing farming in an increasingly challenging rise situation and climate change and shrinkage of resources for small farmers' responses to increase yields with this altered landscape.

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FUTURE SCOPE

The developed IoT-based crop prediction system provides a wide variety of scopes in the field of future research and development:

- Integration of additional sensors (e.g., pH sensors, CO2 sensors) in order to monitor the environment more intensively.
- To develop an application for mobile, thereby providing farmers with actionable crop management recommendations.
- Designed integration with automated irrigation systems that manage exact water for the next days, based on predictions of soil moisture.

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