

Agriculture Parameters Monitoring System using IoT

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Abstract—The introduction of technology into crop management has transformed modern agriculture. However, this paper presents an IoT-based agricultural system with respect to the condition of soil moisture, temperature, and humidity in growing tomato crops. Thus, the proposed system utilizes sensor devices that are connected to the ESP32-based microcontroller and feeds the real-time information into a mobile application for remote crop management. This study presents the capability of the system in optimizing water usage for achieving good crop yields through proper irrigation and minimum human intervention, among other benefits of sustainable farming practices.

Index Terms— IoT, smart agriculture, crop monitoring, soil moisture, temperature regulation, precision farming, sustainable agriculture, ESP32, real-time data, remote management.

I. INTRODUCTION

Advanced technological fields involving the Internet of Things (IoT) have revolutionized agriculture with new ways to effectively upgrade crop management techniques[8,9]. IoT allows systems to track and regulate several key environmental parameters necessary to be used in ensuring the health of crops, improving farming techniques more efficiently and sustainably[2,3]. This project refers to the development of a crop health monitoring system especially for the cultivation of tomato crops. Real-time environmental data capture will be through an IoT system that captures soil moisture, temperature, humidity, and light intensity at real-time, which are confirmed to be crucial factors for tomatoes production[1,5].The idea remains is to provide the right information in good time to the farmers so as to support data-driven decision-making on their crops[20]. This system will be powered by an ESP32 microcontroller equipped with several sensors that it will use in monitoring the parameters. The results will be visualized in a mobile device using the Blynk app, which makes it easier to monitor the health of tomato crops and shows how resource management and improvement in agriculture can be enhanced[18]. This project would hence envision the use of IoT in tomato farming and the possibility of building it cost-effective with scalability and adaptability to various agricultural environments[7], so that the productivity along with sustainability of tomato farming may improve in the long run.

II. LITERATURE SURVEY

1. T. S. S. R. Reddy, 2021 An integrated smart irrigation system involving soil moisture sensors and automated water management was developed, saving as much as 40% of irrigation water as compared to the traditional method.
2. A. Gupta and S. K. Sharma, 2021 Talked about the implementation cost, benefits, and challenges of all smart

farming scenarios for agriculture with a comprehensive review of the available smart farming solutions in one place.

3. P. R. S. Kumar, 2019The research had some key points in integrating big challenges like the issue of connectivity, data security, and cost of IoT implementation, which is an opportunity for technological growth.

4. M. H. H. Rahman, 2019Conducted an empirical implementation-based study on DHT11 sensors and system accuracy and feasibility in practical conditions.

5. R. K. S. Reddy,2020Based on the development of in-time monitoring capabilities with alerting systems in place, thereby greatly improving the speed of responses to environmental changes.

III. METHODOLOGY

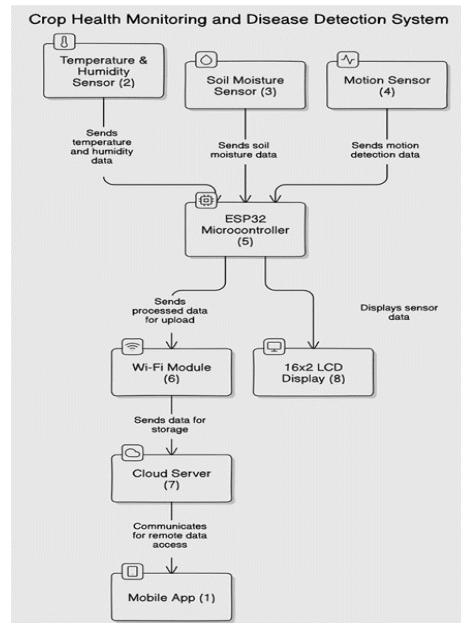


Fig.1: Block Diagram

A. Mobile App

User interface via the application connects the user to the crop health monitoring system where remote real-time and historic data are provided[5,18]. Retrieved parameters are temperature, humidity, soil moisture, and the status of motion detection that is stored in the Cloud Server (7).Thereby, the current status of crops far away, from any corner of the world, would be accessible to the user so that he can take early decisions for management based on that data[20].There are also threshold-based alerts and notifications. For example, when the soil moisture drops below a set threshold or exceeds a set degree of temperature, the application will notify[13]. Another feature is when the motion sensor (4) recognizes abnormal activity; there will be security alerts to enable swift action by the user.Some other applications will have to include graphic presentation by means of charts and graphs, control features like irrigation and others through integration with the monitoring system[24].

B. Temperature & Humidity Sensor

The sensor is capable of reading the ambient temperature and the relative humidity in the crop environment continually[4]. Those parameters are of high importance and influence the microclimate near the crops from the viewpoints of growth and susceptibility of the crops. Readings of temperature and moisture will be used to identify potential fungal infection conditions, namely high humidities in conjunction with warmer temperatures. This sensor will read the information and send it to the ESP32 Microcontroller(5) for processing. Through the temperature and humidity trend analysis, the system can send automatic alerts in case the conditions support the proliferation of diseases. Through the alerts, the possibility of taking preventive measures exists, such as adjusting the irrigation or setting on the misting system. More importantly, information acquired through this sensor can be utilized in optimizing greenhouse conditions if these are available-to control the inside climate for improved crop yield[13].

C. Soil Moisture Sensor

The Soil Moisture Sensor is essential for irrigation management given that it monitors the water content in the soil all the time. This ensures that crops neither receive excessive nor inadequate water. It sends real time soil moisture data to the ESP32 Microcontroller (5) which processes the same and it displays locally and transmits remotely. The sensor allows maintaining optimum moisture levels for crops which is also crucial for the health of the crops along with being an anti-disease agent. Overwatering causes root rot which is a common crop disease while under-watering causes crop stress that leads to less yield. With this knowledge, the system will automatically switch on irrigation systems, if integrated in the system, or alert the farmer to intervene. Even in more intricate setups, the sensor can be included as part of precision farming technology that ensures portions of a field get adequate and tailored irrigation to specific soil moisture levels.

D. Motion Sensor

The motion sensor will be utilized in monitoring movements within and beyond the crop fields. This would be meant to identify possible threats to the area such as animals or even intruders and pests that could potentially harm the crops. In the event that motion is detected, the sensor will send information to the ESP32 Microcontroller (5), which could take prompt action on such a detection. The possibilities could be as following: alerting the Mobile App (1) activated by the deterrent system - lights and/or sounds or capture photos and videos if there exists a camera system. Motion detection is used in monitoring the activity around the automated systems like in the field by either robots or drones, for safety and efficiency within the system. This sensor is an added layer of security for crops, thereby helping reduce losses from such external threats while still keeping the crop environment protected.

E. ESP32 Microcontroller

The heart of the system is ESP32, which represents the main processing and control unit. It is one, which receives input data from the whole set of connected sensors within this project-the Temperature and Humidity Sensor (2), the Soil Moisture Sensor (3), and the Motion Sensor (4). The ESP32 does real-time data processing by removing noise and ensuring that reliable data is transmitted to the user or cloud. It further formats the data for some of its outputs, like the 16x2 LCD Display (8) for a local view or forwarding through the Wi-Fi Module (6) to the Cloud Server (7). In this project, the sensor management and data aggregation are taken care of by the microcontroller. Thus, it ensures that readings from all sensors go in step with one another, meaning available and usable at the same time to be simultaneously presented in a meaningful format. In addition to sending and processing sensor data, the ESP32 can further be used to control actuators; for example, automatic irrigation based on soil moisture or the control of an alarm system depending on motion detection. The ESP32 has a low power mode. This is very important for deployment in the remote field since it may be powered by solar or the battery.

F. Wi-Fi Module

It allows the ESP32 Microcontroller to communicate with the internet so that ESP32 Microcontroller can seamlessly and wirelessly communicate with the Cloud Server. It ensures that any processed data received from sensors will be uploaded onto the cloud for storage and access from anywhere. As such, the system thus allows the Wi-Fi module to upload the data in real-time. This makes such data available to the user through the Mobile App (1). This makes it possible for the users to obtain access to crop conditions at any given moment and from anywhere. It fulfills the fundamental requirement of IoT because it allows the system to become part of the much broader group of devices, thus enabling the network and further intercommunication; for example, synchronization with weather data or any other monitoring agricultural devices. Under such situations if the network connection is lost or signal strength has dropped, then the system can be setup to keep data locally and upload it once communication comes back.

G. Cloud Server

The Cloud Server aggregates all the collected data, providing a central storage and analytics platform. In the same, it holds all those file types that are uploaded to the cloud by the Wi-Fi Module (6), which includes temperature, humidity, moisture content in the soil and motion readings by the sensors. There is a possibility of data storage for a long period of time by cloud services. The user would be able to get insights on crop conditions' trends and historical data. Such history is crucially important to understand crop conditions over time and to make an appropriate choice based on past trends. The server can host machine learning algorithms in order to inspect the collected data to forecast possible diseases based on factors associated with the environment.

For example, the system can correlate long time with high humidity and onset of disease outbreaks, thus raising an early alarm to the user. Applications that are cloud-friendly require multi-user access for bigger farm operations where data needs to be accessed by different stakeholders like farm managers, agronomists. That way the cloud server can also provide location-based weather forecasting in order to advise a farmer about scheduling of irrigation or the prevention of incoming storms or droughts.

H. 16 x2 LCD Display

This is a display to the field level users which can give instant details of the necessary sensor readings like temperature, humidity, and soil moisture. It would immediately give feedback that really works if the user monitors the device with his or her bare hands, as he or she can immediately determine something without having to refer to the mobile application or cloud server. It can be configured to display user-defined messages or alerts. A few are such as warning messages when soil moisture is getting low in quantities, motion, or events of this kind, which may give such a glance information to the farmers working in the field. Localized presentation ensures that the system can even function within low-connectivity environments where, for example, signals of Wi-Fi or mobile networks are weak or unavailable.

IV. IMPLEMENTATION

The basic intention behind the development of an IOT-based Smart Agricultural Crop Monitoring System is to sense critical environmental parameters, namely temperature and soil moisture, for optimum irrigation processes in minimizing water usage and promoting healthier crop growth[1,15]. At its core, this system is an ESP32 microcontroller which forms the heart of the device as the principal processing unit[6,12]. It captures information from several sensors, processing it, and then communicates with external systems before causing fitful issues like those for the switch-on of irrigation systems or message posting. The system employs the use of key sensors to monitor environmental conditions. These include DHT11, the temperature and humidity sensor as well as the soil moisture sensor. The key role played by the DHT11 is the acquisition of ambient temperature and degrees of humidity, which are necessary in understanding the growing environment. On the other hand, the soil moisture sensor acquires water content within the soil that ensures the crop receives the right level of irrigation according to their needs. The microcontroller reads data from these sensors and immediately processes it to determine when the moisture in the soil goes below a predefined threshold, which signals to the microcontroller that the soil is too dry. This will then cause the microcontroller to activate a 5V relay module that in turn controls the water pump and irrigates the soil until desired moisture levels are achieved, hydrating plants properly. Besides automatic irrigation, the system has a motor ON/OFF button. This is done to allow for manual control of the water pump when manual intervention proves to be necessary. Data communication capability is also another critical aspect in the system. In this manner, using IOT protocols like MQTT or HTTP, ESP32 can send sensor read data to a cloud server or a local dashboard and allows remote monitoring. The stored data can be maintained by platforms such as AWS, Azure, or even individually developed custom IoT dashboards, and users can view the real-time data from their smartphone or computer. Alerts can be set up to alert the users in case some conditions like high temperatures or low soil moisture exceed certain levels. There is a 16x2 I2C LCD display equipped with the system to provide immediate visual feedback. The real-time data of temperature, humidity, and soil moisture are simultaneously provided at the display so that in one glance, one can tell the level of the current situation without logging online. The whole system is powered by a battery, where all of the needed voltage will be fed down to the sensors, the relay, ESP8266, and the display. Thus, it is a portable and rechargeable power source that should enable the system to be used properly in areas with no proper electricity supply. More or less, the IOT-based smart agricultural monitoring system has efficiently automated irrigation by continuously measuring environmental factors and adjusting the water supply accordingly. The system enhances resource efficiency, reduces the burden of manual labor, and guarantees ideal growing conditions, which is a valuable resource for modern agricultural practices.

A. Perception Layer (Device Layer)- Sensors.

DHT11 (temperature and humidity), soil moisture sensor, PIR sensor (motion detection). Function: This layer receives data from the environment with the help of various sensors. It focuses on any parameters related to plant health, such as temperature, humidity, soil moisture content, and movement around the plant.

B. Network Layer (Communication Layer)- ESP32.

The microcontroller will be connected either to Wi-Fi or other network protocols. Function: This layer carries collected data from the perception layer to the cloud or server locally. It deals with such communication protocols in relation to MQTT or HTTP to transmit data in a secure and efficient manner.

C. Processing Layer -ESP32.

This is a board that performs computations locally before transmitting the collected data to the cloud. Function: This level may preprocess the data, filter it, or aggregate some of it to limit the quantity of data that will be transferred across the network; thus, saving bandwidth and allowing for potential response time improvement.

D. Application Layer -Web or Mobile Application.

Presentation platform that allows visualization as well as interaction with the data. Function: This layer further elaborates data from the network layer and serves it in a useful, user-friendly format. It will also provide insights and alerts and control elements to users for an efficient way of managing their plant health.

E. Cloud Layer -Cloud Services.

Databases to store sensor data (like AWS, Azure or Google Cloud). Function: It stores vast volumes of data to be processed for legacy and machine learning algorithms. It can additionally act as a backup to high-end analytics, computation, or archiving.

F. User Interface Layer –Dashboard.

A graphical view showing real-time data Function: This layer enables users to interact with the system as well, by also viewing sensor data, receiving alert messages, and activating actuators when they are included as part of the system.

V. RESULT AND DISCUSSION

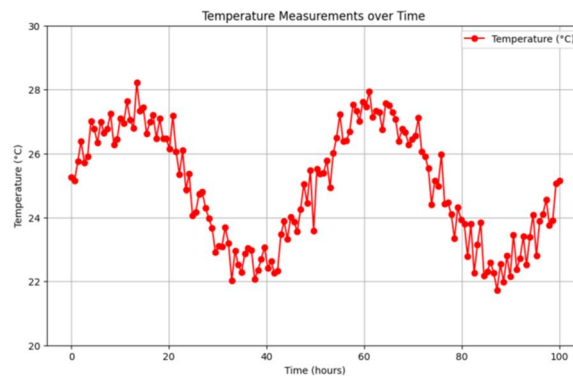


Fig .2: Temperature Measurements Over Time.

The temperature graph is plotted as the difference in temperature measurements over a period of 100 hours. Temperature hovers in the range of 22°C to 28°C. In general, there seems to be some cycling behavior; from its minimum, it keeps increasing to its peak at about 28°C and then decreases gradually to around 22°C. This pattern continues as time goes by according to the graph. This is the pattern shown by temperature measurements, Peak: approximately 28°C, Trough: the lowest point is about 22°C. The pattern that shows in the data is an approximate sinusoidal shape, which may be reasoned as a result of the day-night temperature difference in the cycle. In case it continues like a cycle, then it would eventually make the following temperature records depend similarly. It would oscillate at around 28°C and downward to about 22°C, wherein there will be a periodic cycle of 40-50 hours.

The soil moisture graph illustrates the change in soil moisture content over the same 100 hour time span. The soil moisture moves back and forth between roughly 60 and 80%. The graph illustrates less consistent behavior than does the temperature data, with large peaks and troughs in moisture. Peaks: The highest amount of soil moisture is around 80%, Troughs: The minimum amount of moisture observed is around 60%. This has its fluctuations, but the moisture content will generally range at 60-80%, giving a semblance of intervals for watering or simply the fact that natural fluctuations occur in terms of the absorption and evaporation stages of

the soil. From now onwards, soil moisture will fluctuate within the 60-80% range. Future readings may be subject to sudden spikes and drops based on weather factors like rain or irrigation. Ideally, keeping above 65% could be the maximum allowable moisture level since extreme dips below 60% may indicate the tomato plant's watering needs.

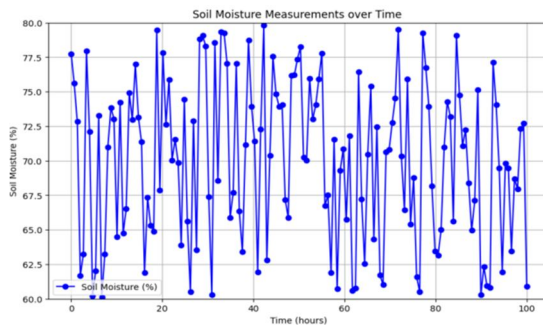


Fig.3: Soil Moisture measurements over time

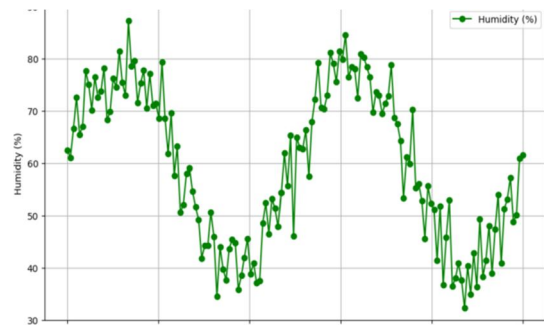


Fig.4: Humidity sensor Readings over time

This is a line graph showing the hourly humidity level of a tomato crop for nearly 70 hours. Humidity values range between 65% and 77%, but no reading exceeds the ideal upper level threshold of 80%. The blue dashed line at 80% is the highest optimal humidity level for tomato crops. The red dashed line at 60% indicates the lowest. All the values recorded are within the good range of 60% to 80% that is acceptable for crop tomato growth. There is a high fluctuation that shows variability in the environment or the irrigation system. The humidity levels, as seen from the data, have remained within the optimum range. This is positive and reflects healthy growth. No drastic alterations for humidity regulation appear to be required; nonetheless, monitoring must be carried out so that it does not go below 60% at any stage.

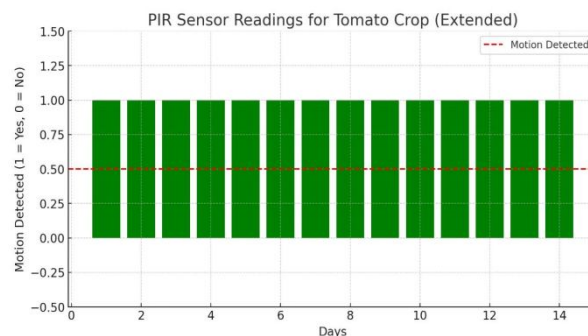


Fig.5: PIR Sensor Readings

This graph shows motion over 14 days, but the value is either 1 for motion or 0 for no motion. On all days, motion is seen with hardly any variation. Normally, if consistent movement is seen around the crop, it may reflect routine movement by pests, animals, or humans around the crop. If this is undesirable, some protective action might be needed for the crop.

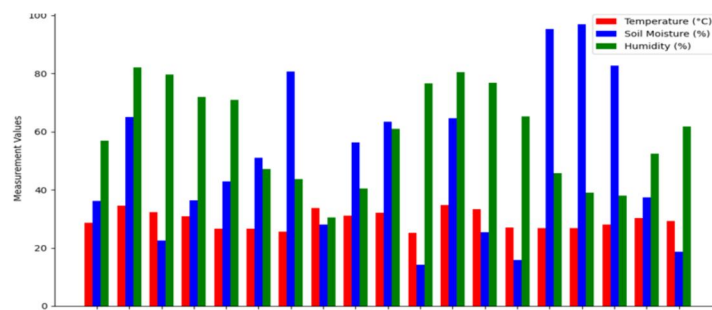


Fig.6: Comparison Graph Between Moisture, Temperature And Humidity

The plot in Figure 6, for instance, shows temperature (°C), soil moisture (%), and humidity (%) measurements of 19 different sample points.

Temperature (Red Bars): Across most of the range from 20°C-40°C, by general temperature There are no extreme highs or lows, which could indicate that the plants have been grown in a moderately warm environment where the tomatoes, if you like, have thrived.

Soil Moisture (Blue Bars): Soil Moisture: range from 10% to over 80% Variability among replicates is high and might be the result of fluctuation in irrigation or rains. Soil moisture should be kept within 60-80% for tomatoes.

Humidity (Green Bars): The humidity is greater than temperature and observed to be within the range of 20-90%. Their preferred humidity remains at about 60-70%, and different samples in the chart show humidity levels of far more than that, which could be causing issues such as mold growth if not rectified.

Temperature: The values currently now seem within the confines of a normal growing range for the tomato crops, so nothing seems to be wrong right away.

Soil Moisture: These are high fluctuations and might indicate uneven irrigation or water retention. Therefore, uniform soil moisture between 60-80% will be more ideal for better prediction and plant health.

Humidity: Such a level may promote disease in the crop (like fungal infections). If it is maintained at around 60-70%, it will be optimal for the plant health.

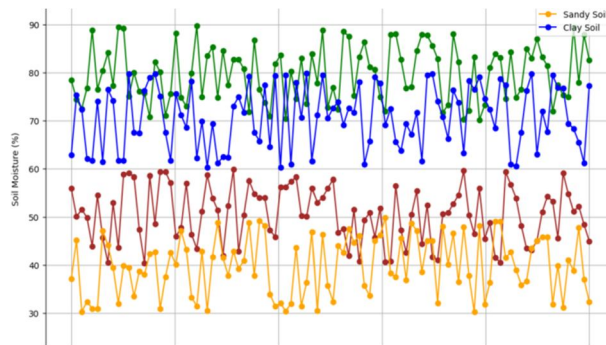


Fig.7: Soil Moisture Readings for Various Soil Types

Black Earth (Green Band): Continue till the moisture content is about 70-90%. This soil has the highest water-holding capacity as compared to other types of soils, hence also well suited for crops like tomatoes, which perform better with steady water supply.

Clay Soil (Blue Line): Similar to black soil except retains moisture levels within 65-85%. The changes indicate a lot of water retention but less consistent moisture level than the black soil.

Red Soil (Red Line): The water content is much lower at 40-60%. The changeovers are cruder and seem to indicate that this dries up in soil quite rapidly. This could imply the need for regular watering when tomatoes are grown.

Sandy Soil (Orange Line): This line is the least capable of retaining moisture and maintains levels between 30-50%. The soil dries in it quickly. Sandy soil is not very good for tomatoes unless mixed with efficient irrigation systems.

Prediction: Black and clay soils appear to retain moisture most steadily; thus, they are viable for tomato cultivation. Red and sandy soils appear to require additional water supply support to maintain optimal moisture levels.

V. CONCLUSION

The paper concludes suggesting the transforming nature that IOT technologies can take on in agriculture[8,9]. The successful completion of the system is thus a demonstration of the ability of the system to monitor in real-time critical environmental parameters, including temperature and soil moisture. It linked wireless sensors, cloud-based data analytics, and automation to the system. This provided critical insights that enabled farmers to make proper decisions, optimize irrigation, and adopt proper crop management[20].

Results revealed that the system optimally maintained IOT-based optimum soil moisture and regulated temperature[1,15], therefore providing improved crop yield and efficient usage of other resources. For instance, the system showed a high level of impact wherein average field temperature was reduced to 26.2°C along with increasing soil moisture content up to 45% in order to enable healthier crop growth, hence showing better productivity, sustainability, and economic outcomes for the farmers involved[7,14]. This system also empowered the farmers with the ability to monitor and control them remotely, giving them an oversight of their crops from anywhere while automating key processes like irrigation. The use of IOT reduced manual labor at the same time

allowing farmers to embrace precision agriculture[7], as it saves lots of water otherwise wasted and decreases environmental impacts.

In conclusion, research highlights the significance of introducing IOT in agriculture as a means of overcoming barriers posed by climate variability and resource limitations[2,3]. It would facilitate data in real time with optimal farming practice for better decision-making, an ideal solution for sustainable and efficient agriculture. Therefore, future research and development of this area may ultimately revolutionize agricultural practices for the guarantee of food security and adaptation to the ever-growing demands of global agriculture[14].

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