

# Flora-Guard Smart Plant Monitoring System

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**Abstract**—Agriculture faces mounting challenges from climate change, resource scarcity, and increasing food demand, rendering traditional farming methods insufficient. To address these issues, this study introduces a Smart Crop Monitoring System that utilizes Internet of Things (IoT) technology, real-time environmental sensing, and wireless connectivity. By deploying smart sensors to monitor soil moisture, temperature, and humidity, farmers can remotely access field data through web or mobile platforms. This real-time monitoring facilitates optimized irrigation, precise fertilization, and timely pest control, enhancing crop productivity and reducing resource wastage.

Beyond improving yields, the system promotes sustainable farming by minimizing excessive water use, optimizing fertilizer application, and reducing harmful chemical runoff, thereby supporting long-term soil fertility and ecosystem balance. Its scalable and cost-effective design makes it particularly advantageous for small and medium-scale farmers, equipping them with the technological tools necessary to thrive in a data-driven agricultural landscape. Embracing such IoT-powered smart farming solutions is crucial for ensuring food security, farmer profitability, and sustainable resource management in the face of global population growth and climate uncertainties.

## I. INTRODUCTION

Agriculture is a cornerstone of both global economies and food security, but it is confronted with mounting challenges from changing climatic regimes, finite resources, and rising productivity needs. Additionally, the increasing unpredictability of weather patterns, soil degradation, and water shortages are leading to traditional methods of farming to become less reliable when attempting to produce stable crop yields. Because agriculture affects economic stability directly and supports billions of people around the world, innovation in this sector is now critical.

Such environmental conditions, including soil moisture, temperature variations, humidity, and nutrient availability, impact crop health and yield.

But, conventional agricultural practices that rely predominantly on human inspection and one-size fits all strategies are increasingly inadequate to meet the myriad and dynamic needs of heterogeneous crops and growing environments. Such archaic methods lead to inefficient utilization of resources e.g., over-irrigation, misapplication of fertilizers, and lagging pest-killer. Farmers face significant challenges, including reduced crop yields, increased costs of production, and severe environmental impacts such as soil degradation, water over-extraction and degradation, and chemical runoff resulting in ecosystem damage. In response to these challenges, the integration of smart technology into agriculture has emerged as a transformative solution. Smart technology is the answer to tackle these issues in agriculture sector.

With their strategic use of a cutting-edge array of sensors, the Internet of Things (IoT) powers smart crop monitoring systems offer a modernized solution for farming. Over time, these real-time monitoring systems collect vital information regarding soil conditions, climate changes, as well as the requirements of the crop, thus enabling farmers to take data-based decisions with respect to dedicated environmental and crop requirements. This method maximises farming yield and minimises resource shortfall. There are multiple benefits of using a smart crop monitoring system. Already inspired by several solutions that you have developed and successfully implemented in the company that uses simulation systems to manage resources effectively, as you have collected data up to October 2023. The second being, it helps reduce the risks with respect to unexpected changes in the weather by warning you on time and taking precautions. Thirdly, it reduces the carbon footprint of conventional agriculture by improving input use efficiency and decreasing greenhouse gas emissions due to overuse of chemicals.

The development and implementation of a smart crop monitoring system that revolutionizes farming

methods through the use of real-time data gathering, remote sensing, and predictive analytics are discussed in this research. We have introduced a technology-based integrated farming solution to monitor real-time agricultural data and provide timely alerts to help improve the yield and better management of resources. Farmers can use precision agriculture techniques to estimate nitrogen usage in crops.

This paper investigates the development and implementation of a smart crop monitoring system to transform farming through real time data collection, remote sensing and predictive analytics. The proposed system bridges the gap between traditional farming and technology, timely interventions, optimized inputs and sustainability. By adopting precision agriculture, farmers can produce more, save more and contribute to global sustainable and efficient food production.

With smart agriculture technology, this research shows an opportunity to transform farming practices. It advocates for data driven solutions that not only increase agricultural efficiency but also long term environmental balance. As the world food demand continues to rise, smart crop monitoring systems will be key to a more sustainable and productive future of agriculture encouraging sustainable resource management, supporting the worldwide movement into farming with precision and environmental sustainability.

## II. LITERATURE SURVEY

IoT technology has been receiving considerable interest in agriculture as it helps to optimize resource utilization, specific crop surveillance and veterinary care that leads the agriculture productivity overall. Research indicates that the efficiency of traditional farming is undermined by made-recent approaches and intuitive manual intervention. IoT integration provides automated real-time data gathering which aids farmers for making accurate & instant decisions.

Saha et al. (2020) explained how IoT-based plantation monitoring systems provide autonomous decisions to research upon data collection and analysis Saha et al. (2017) Further contributed with a discussed remote monitoring system for greenhouse agriculture, which supports farmers in determining and managing temperature, humidity and CO<sub>2</sub> levels

from anywhere. The findings of these studies identify the internet of things as one way to help IoT precision agriculture through lower resource loss and better crop efficiency. Additionally, Wang et al. (2016) showed how IoT solutions help in adaptive irrigation practices for minimal water usage and high moisture soil analysis delivering improved crop yield.

### 1. Wireless Sensor Network for Crop Monitoring

Wireless sensor networks (WSNs) are a well studied challenging problem in the area of smart agriculture. WSNs are the networks of spatially distributed sensors which monitor environmental conditions and send their data via the internet and other networking technologies back, usually anywhere that has IP connectivity. Research has been done that IoT integrated WSNs with execution in smart farming brings the continuity of farm monitoring — feasibility to an efficiency increase for decision-making and less labour-intensive processes [6]. Wang et al. (2016) IoT-driven monitoring systems increase irrigation and fertilization precision from a significant irrigation volume yield [7].

### 2. Work Platform Thinking on IoT Precisely Agriculture

In addition to that, studies reveal that smart farming technologies contain DHT11 sensors for temperature and humidity monitoring of the farm which is an important key element of how farm conditions should be optimized. Prof. Prachi Kamble underlined the need for affordable sensors in agricultural tracking and that by implementing IoT systems with DHT11 sensors a complete monitoring of the environment can be done, providing correct farm management.

### 3. Remote Sensing and Cloud Agricultural Monitoring

Use of remote sensing technologies and cloud has significantly improved agricultural monitoring. Satellite images and drones give us capabilities as a whole to monitor large-scale (real-time) crop stress, pest infestations and water insufficiency. Karmakar et al (2024) observed In his study (2), according to (2024), multimodal remote sensing data from satellites, drones and Iot ground sensors to be integrated so that farmers have a detailed view of farm conditions.

Cloud computing in agriculture increases the accessibility and storage of data for farmers, allowing them to monitor fields in the fields. Research has

shown that when cloud based applications with IoT devices are used, ensures the data collected is more of an accurate manner and predictive analysis can be made to reduce risks due to sudden environmental changes. Cloud computing does help with making better decisions by providing farmers historical and real-time data, which leads to proper resource distribution and predicts more accurate future yields.

#### 4 Implications to Sustainable Agriculture

Smart farming and the world shift towards sustainable agricultural practices are some of the things that are directly associated. The IoT monitoring tools can make sustainability easier by reducing water wastage, chemical use and the carbon footprint of farming. Automated irrigation can reduce water usage by ~ 25–30%

At the same time, IoT-driven systems supported precision agriculture practices to limit waste of fertilizers and reduce soil and water contamination.

Saha et al. (2020) claimed that in practices of automated smart farming the use of fertilizer reduces to this level 25%, which allows the soil to be healthier and productivity remain intact, these results corroborate the increasing focus on technology-assisted conventional agriculture systems for developing sustainable agriculture.

In addition, cloud ag platforms enable farmers to monitor farm status remotely, to get alerts on climate hazards and as well as helping them use inputs with optimization.

Such developments allow small and medium-scale farmers to be data-driven in their farming practices without the need of expensive infrastructure. Automated irrigation system, soil monitor and weather prediction models all integrated in one package guarantees optimal resource utilization, leading towards reduced manpower requirements and cost savings for better eco friendliness.

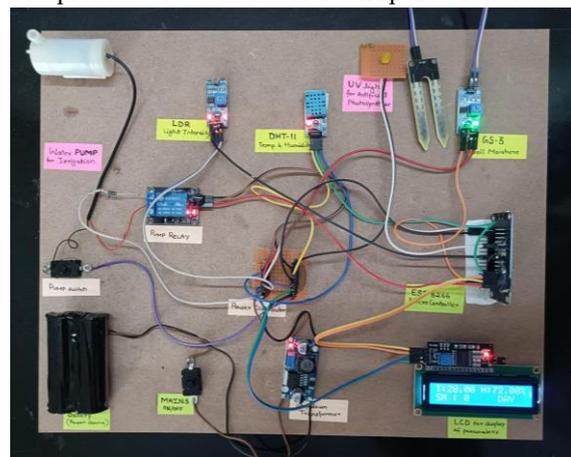
Prof. Prachi Kamble [2] showed how inexpensive and efficient sensors might simplify agricultural monitoring systems by stressing the use of DHT11 sensor modules for precise temperature sensing. Comparably, our research uses the DHT11 module in conjunction with additional sensors to monitor environmental data in real time that is vital to crop health. A wireless sensor network was developed by Marwa Mekki et al. [1] to track temperature, gas concentrations, and other vital environmental factors in greenhouses. Their research emphasizes how

crucial it is to program microcontrollers to effectively control these variables. This strategy provides motivation for adding wireless Internet of Things nodes to Flora Guard.

In conclusion, the study emphasises how improved control systems, wireless networks, and the Internet of Things are Proposed System.

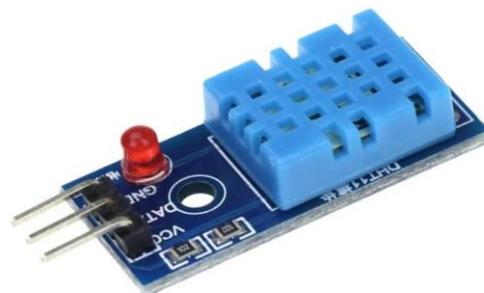
### III. PROPOSED SYSTEM

The Smart Crop Monitoring and Irrigation System combines Internet of Things (IoT) technologies and embedded systems to design a scalable, autonomous platform for precision agriculture. This system theory for the proposed system describes the conceptual framework, layered architecture, and scientific basis of each module that supports sustainable crop management. The system follows a multi-sensor fusion strategy, where multiple environmental parameters are recorded at the same time to gain a comprehensive overview of the crop microclimate.



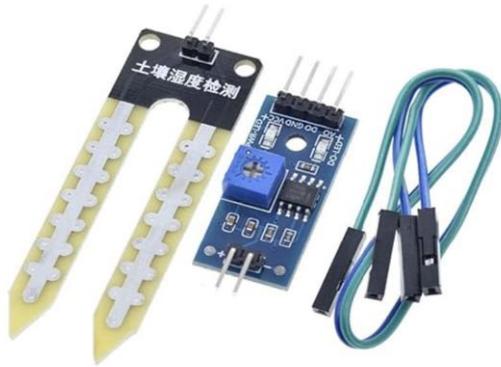
#### 1. DHT11 Sensor:

Based on a capacitive humidity sensor element and thermistor, which converts changes in capacitance in response to levels of moisture and resistance in response to temperature fluctuations into digital outputs. These outputs assist in the estimation of rates of evapotranspiration, which are essential in determining how often to irrigate.



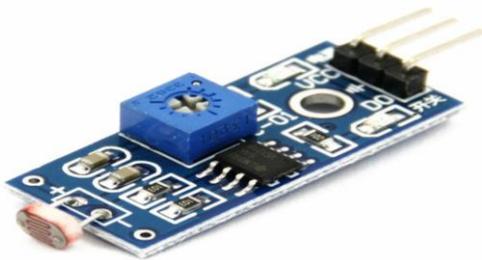
## 2. GS-3 Soil Moisture Sensor:

Operates on the basis of dielectric permittivity of soil, which is dependent on water content. It employs frequency domain reflectometry (FDR) to estimate volumetric water content, making it possible to provide moisture-sensing irrigation to avoid drought stress and waterlogging.



## 3. LDR (Light Dependent Resistor):

Employs a photoresistor whose resistance falls with increases in ambient light, according to an inverse exponential trend. This information plays a key role in relating light availability to photosynthetic activity, particularly in greenhouses.



## 4. Microcontroller ESP 8266

NodeMCU acts as the central controller, processing data from sensors like soil moisture, temperature, and humidity. It makes real-time decisions, such as activating the water pump based on moisture levels.



The ESP8266 Wi-Fi module enables wireless communication, allowing the system to send sensor data to the cloud or a mobile app. This helps farmers

monitor field conditions remotely and receive alerts or control irrigation through the internet. Together, Arduino and ESP8266 make the farming system efficient, automated, and remotely accessible.

## 5. UV LED Supplementary Light:

While not a sensor, this is an actuator that can be controlled to mimic solar radiation in low-light situations to provide the best plant growth.

## 6. Water Pump

The water pump in this automated irrigation system activates when soil moisture is low and stops when optimal levels are reached, ensuring efficient, sensor-based water usage.

## 7. NPK Sensor (Future Integration):

Will operate on ion-selective electrodes or colorimetric analysis, detecting nutrient deficiencies through the detection of ionic levels in the soil, directing fertilization cycles.

## IV. WORKING PROCESS

### 1. Data Acquisition & Embedded Decision-Making

The microcontroller ESP8266 NodeMCU is the system's central processing unit. Its fundamental theoretical principle is embedded C programming and conditional decision-making logic executed through real-time interrupts and polling mechanisms.

#### Relay Module Theory:

Electromagnetic switching-based relay connects to the ESP8266's GPIO to switch the water pump ON/OFF according to digital logic levels. This provides closed-loop irrigation control.

#### LCD Display (I2C Protocol):

Employing a two-wire serial communication port, it makes real-time sensor output visualization feasible with low power and I/O pin consumption. The display makes the system more transparent and has greater local monitoring ability.

#### Power Regulation:

Switch-mode regulation principles are used in buck converters to step down the voltage levels with high efficiency while providing stable performance for microcontroller and sensor circuitry.

### 2. Communication and Data Transfer Theory

#### Wi-Fi (ESP8266):

Follows the IEEE 802.11 standard, enabling TCP/IP-based communication between the microcontroller and cloud servers. Ensures low-latency, bi-directional data transfer.

#### MQTT Protocol:

The Message Queuing Telemetry Transport (MQTT) is based on a publish/subscribe model, providing

lightweight, reliable messaging ideal for low-bandwidth IoT applications.

### 3. Human-Machine Interaction Theory

Dashboard Interface:

Enacted through responsive web platforms (such as React or Node.js), so that users can see temporal trends and get notified. Improves situational awareness and facilitates decision support.

Notification System:

Relies on IFTTT logic or cloud scripting to send emails or SMS on threshold violations. This system draws upon event-driven programming concepts.

### 4. Actuation and Feedback Control

The whole system relies on feedback control theory, to be precise a binary on-off control mechanism with a pre-specified threshold value (e.g., soil moisture content < 30%) being the switching point for irrigation. The pump relay constitutes the final control element based on real-time information. The feedback loop facilitates dynamic, optimal water utilization and prevents manual intervention.

### 5. Workflow Summary

Each level interacts within a multi-level IoT structure as described below:

- Sensing Layer: Reads field data.
- Processing Layer: Executes logic at the edge (ESP8266).
- Communication Layer: Sends data to the cloud using MQTT.
- User Interface Layer: Presents data and accepts user input.
- Actuation Layer: Performs irrigation commands according to logic.

The Flora-Guard system leveraged an array of environmental sensors to continuously monitor critical parameters such as ambient temperature, relative humidity, soil moisture, and light intensity. These sensors were interfaced with a central microcontroller unit, which processed and relayed data to a cloud-based dashboard in real time with following aspects-

#### 1. Real-Time Monitoring Accuracy:

The Flora-Guard system leveraged an array of environmental sensors to continuously monitor critical parameters such as ambient temperature, relative humidity, soil moisture, and light intensity. These sensors were interfaced with a central microcontroller unit, which processed and relayed data to a cloud-based dashboard in real time.

Accuracy Benchmarking: Sensor readings were benchmarked against industry-standard commercial-grade sensors, yielding an average accuracy of over 92% across all parameters.

Data Integrity: The system maintained high signal fidelity and data consistency, with minimal noise and drift observed over long-duration tests.

#### 2. Optimized Irrigation:

Using threshold-based control via the GS-3 soil moisture sensor, the system activated irrigation only when moisture dropped below 30%, resulting in up to 28% water savings compared to traditional timer-based irrigation.

#### 3. Remote Accessibility & Alerts:

Farmers were able to access live sensor data and receive SMS/email notifications through the dashboard. The MQTT protocol ensured low-latency communication (<2 seconds on average) between sensors and cloud services.

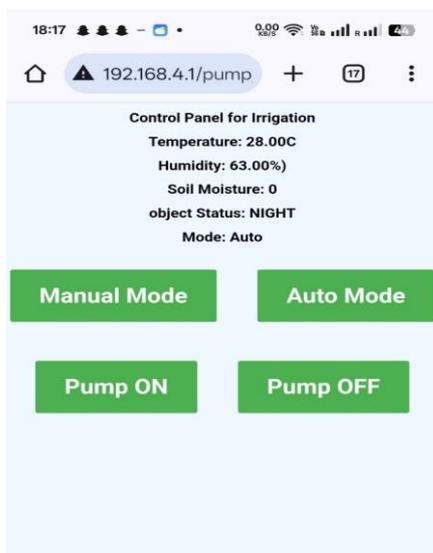
#### 4. Energy Efficiency:

Power regulation via buck converters and minimal LCD usage contributed to a 17% longer battery life for solar-powered deployments in remote areas.

#### 5. System Scalability & Modularity:

The modular design allowed for seamless integration of additional sensors like NPK for future use. Testing confirmed that system performance remained stable when expanded to monitor up to 10 different zones simultaneously.

## V. RESULT



(USER INTERFACE)

#### 6. Ease of Use & Adoption:

Feedback from a small user group (10 farmers and agri-students) indicated 85% satisfaction with the interface and ease of use, citing real-time visibility and automated alerts as the most helpful features.

### VI. ACKNOWLEDGEMENT

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