

A Farming System with Automatic Irrigation, Fertilization and Crop Protection

**Gowthami D.¹, Rama Lakshmi Sravya B.², Poojitha K.³,
Yaswanth D.⁴, Hari Kumar CH.⁵**

¹Assistant Professor, ²⁻⁵UG Student, Department of Electronics and Communication Engineering, PSCMR College of Engineering and Technology, Vijayawada, Andhra Pradesh, India.

E-mail: ¹dukkagowthami@gmail.com, ²sravyabijnepalli12@gmail.com, ³kakumanupoojitha.k@gmail.com, ⁴yaswanthd78@gmail.com, ⁵harikumarchejarla93@gmail.com

Abstract

This paper presents a smart agricultural system with the purpose of transforming agriculture through the integration of an automatic fertilization and irrigation system and a crop protection system. This system works with the recent IoT technology, Blynk App, sensor automation and smart pesticide spraying systems to increase agriculture productivity, save chemicals and water, and use available resources. Automatic crop protection system applies a microcontroller-based system for monitoring environmental parameters and providing selective pesticide sprinkling when needed to avoid wastage of chemicals and their impact on the environment. The automatic fertilization and irrigation systems constantly monitor soil moisture, temperature, pH and water level with sensors to ensure maximum growth of plants by providing precise irrigation and nutrient supply and combining this system as a cost-efficient solution for modern smart farming.

Keywords: Smart Agricultural System, IoT Technology, Sensor Automation, Automatic Fertilization, Irrigation System, Crop Protection System.

1. Introduction

The growth of world population makes it difficult to produce sufficient food to meet demand, creating additional strain on traditional agricultural methods. Traditional agriculture

customs many resources, such as land/labour/water, to produce crops, and produces crops with great variation in yield due to several external factors, such as climate changes, soil degradation, and poor water management. As a result, farmers use more than essential for each crop (water, fertiliser, pesticides) which leads to higher costs and negative effects on the environment. Therefore, agricultural systems must be developed not only economically viable intelligent and sustainable way to improve agriculture production while decreasing the use of resources.

The recent integrations of IoT technology, automation, and smart systems into agriculture demonstrates how many traditional farming barriers can be overcome by enabling precision agriculture and real-time decision-making [1],[2]. Smart Agriculture involves the use of interconnected sensor networks, actuator devices, and communication platforms for enabling the monitoring of environmental conditions and automating key farming operations. In IoT-based smart agriculture systems enhance the agricultural management by providing enhanced monitoring capabilities to farmers, reducing their reliance on physical labour, and supporting the data driven farming techniques [3].

Moreover, the recent computing paradigms like edge computing enables the IoT agricultural systems to perform more efficiently with greater speed and accuracy. Because, they allow localized processing of data and lower latency [4]. These interventions by the user (e.g., farmer) in sensitive agricultural conditions thereby increase efficiency in applications involving irrigation, fertilization, pest control, etc. [5]. The Agricultural information engineering has been defined as an essential component of contemporary farming systems, providing efficient means of acquiring, processing, and controlling agricultural data for better farming results.

The paper presents a smart agricultural system using IoT technology, which consists of two modules: The automated crop protection module and automated irrigation and fertilizer module. The crop protection module uses IoT sensors, automated spraying technology, and the Blynk application to monitor real-time field conditions and control the application of pesticides accordingly. This approach will help us to eliminate excessive chemical use and reduce the impact of pesticides on the environment while providing effective crop protection. The irrigation and fertilizer module continuously monitors critical environmental factors (e.g. soil

moisture content, water availability) so that it can manage the application of water and fertilizer to support optimal crop growth and reduce wasted resources.

The proposed system integrates with the Blynk mobile application, to provide farmers to monitor and control their farm remotely through a smart-phone interface. Farmers will be able to monitor their crops and schedule their agricultural activities in real-time. They will receive notifications when certain conditions are present on the farm (i.e., water levels drop below a certain threshold or intruders enter the farm). The main goal of our research is to create an IoT-based framework for automatic irrigation, fertilization, and pest management, therefore, enhancing agricultural productivity and reducing the use of agricultural resources. Major contributions of the work are as follows: (1) environmental monitoring, (2) automated processing logic, (3) mobile alerts, and (4) testing of improved resource efficiency and reduced manual labour associated with using the IoT-enabled system versus conventional farming. The results have shown that the implementation of IoT will provide a means for modern agriculture to become greater at producing hybrid and environmentally-friendly products while reducing resource requirements.

2. Related Work

Smart agriculture has emerged as a promising approach to address challenges related to food security, efficient resource utilization, and environmental sustainability. Recent research has focused on integrating advanced technologies such as the Internet of Things (IoT), edge computing, and automation to improve agricultural productivity. Aqeel-ur-Rehman et al. [3] discussed the adoption of smart agriculture systems for improved farm management, emphasizing their role in enhancing operational efficiency and informed decision-making. Cheng et al. [4] investigated the application of edge computing in IoT-based agricultural systems, demonstrating reduced latency and improved support for intelligent and environmentally friendly farming practices. Liu et al. [5] presented agricultural information engineering models that leverage data-driven approaches to optimize farming operations.

Sensor-based monitoring and IoT-integrated solutions play a crucial role in precision agriculture. Visconti et al. [6] proposed a sensor-based agri-food traceability system managed through a remote software platform, enabling real-time monitoring and improved farm operation efficiency. Villahenriksen et al. [7] reviewed IoT applications in arable farming,

highlighting implementation challenges such as interoperability and scalability, along with potential benefits including yield optimization and resource efficiency. Yang et al. [8] provided a comprehensive survey of smart agriculture technologies, discussing development models, enabling technologies, and security and privacy issues in IoT-based agricultural environments.

Several studies have emphasized automation and environmental control systems in agriculture. Huh [9] designed a PLC-based monitoring and control system for ICT-integrated vertical fish farms, demonstrating the effectiveness of automation in controlled farming environments. Chaudhary et al. [10] implemented a wireless sensor network-based greenhouse monitoring system to regulate environmental parameters such as temperature and humidity. Navarro et al. [11] conducted a systematic review of IoT-based smart farming solutions, focusing on monitoring, automation, and decision-support capabilities. Dagar et al. [12] further highlighted the role of IoT technologies in enhancing agricultural operations through remote monitoring and intelligent analytics.

Efficient water management has been identified as a critical component of smart agriculture, particularly under climate change conditions. Chartzoulakis and Bertaki [13] analyzed sustainable water management strategies to mitigate water scarcity in agriculture. Ye et al. [14] developed a low-power LoRa-based smart water metering system to enable long-range and energy-efficient water usage monitoring. Similarly, Yoon et al. [15] proposed a smart farm system based on LoRa and MQTT protocols, offering reliable communication for real-time monitoring and control.

3. Design and Methodology

The automatic fertilisation and irrigation system aims to increase the efficient use of water and nutrients in growing plants by monitoring the plant environment. Additionally, by utilising real-time sensing and control along with remote monitoring, the system will allow farmers to improve plant growth. The closed loop process of monitoring, analysing, controlling and monitoring reflects the system's efficiency and accuracy. The physical properties such as soil moisture content, soil temperature, soil pH, and soil water availability are all collected by field sensors and sent regularly to the central microcontroller (the system's main control unit) to process all data collected.

Sensor data is processed by the microcontroller to create a comparison against crop specific threshold values. When the soil moisture content falls below the moisture threshold, the irrigation pump and solenoid valves will automatically turn ON to deliver the required amount of water to the soil. Fertilizer dispensing is also determined by pH and specific nutrient levels. The way in which the water and fertilizer are dispatched is determined by decision logic to ensure that they are applied at the proper time, thereby minimizing waste of both resources. There are two ways to operate this system, either automatically (the user allows the system to make decisions based on sensor controls) or manually (the user controls the delivery of irrigation and fertilization through a mobile app). Figure 1 represents the working design of FSAI

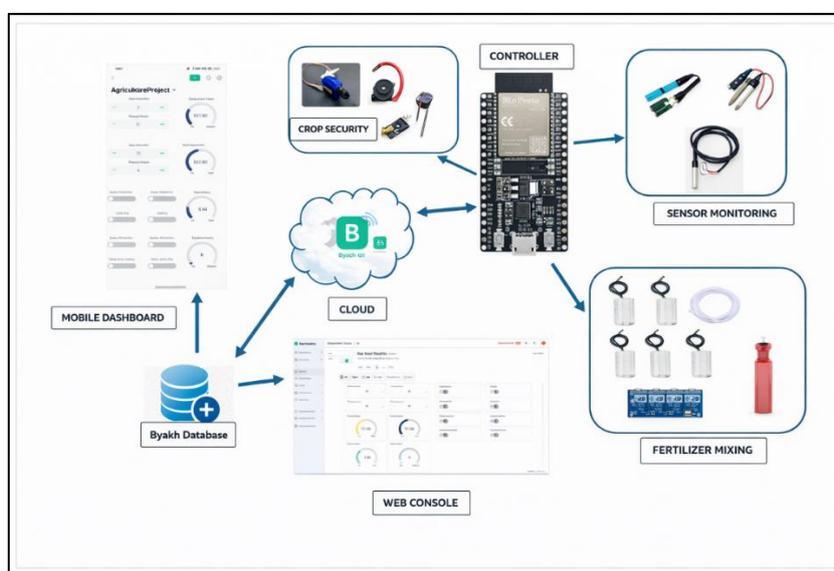


Figure 1. Working Design (FSAI)

The system hardware implementation includes a capacitive soil moisture sensor, temperature sensor (either DHT11 or DS18B20), a pH sensor, and a water level sensor. The capacitive soil moisture sensor produces accurate, stable, and a very little corrosion for a long period when deployed for agricultural applications approximately $\pm 3\%$ accuracy. Additionally, the digital output of the temperature sensor offers $\pm 1^\circ\text{C}$ accuracy approximately and allows continuous monitoring of ambient temperature. The pH sensor provides an output range of pH 0-14, with an accuracy approximately ± 0.1 . Determining the availability of nutrients in the soil is dependent on the pH of the soil, as it indicates how well nutrients are available to plants, and what fertilizers are best based on the pH level. Thus, a reliable pH sensor is crucial. The water

level sensor is to ensure water availability in the water reservoir and to protect pump dry-run conditions.

Calibration methods were developed for monitoring devices prior to ensure the measurement. The process of soil moisture sensor calibration consisted using dry and fully saturated soils for the calibration of sensor output under these two extreme conditions with the verification of readings taken under intermediate moisture conditions using standard gravimetric techniques. For the calibration of the pH Sensor, a series of standard buffer solutions were used at three different concentrations pH 4.0, 7.0, and 9.2 to prevent measurement drift and to maintain the accuracy of sensor readings. The reading temperature sensors were calibrated for accuracy by comparing this reading from a laboratory grade Digital Thermometer under controlled conditions. The effects of these calibration processes help to improve sensor accuracy and the enhance the reliability of control decisions.

Real-time data transmission from the microcontroller to the Blynk cloud platform uses Wi-Fi for the wireless communication. The Blynk mobile app allows real-time viewing of sensor information, the current status of the system, and control options. Users may set threshold values, choose among pre-configured fertilizer blends, and toggle between manual/automatic operation. Historical sensor data stored in the cloud, allowing the users to study historical data trends in order to refine and improve irrigation and fertilization strategies over time.

The system uses both irrigation and fertilizer application, and also integrated a laser intruder detection system. If someone tries to enter the property without authorization, they will receive an alert through the app on their phone notifying them, allowing for immediate action by the user. The system has an automatic alarm feature that alerts users when the sensor readings are abnormal, or identifying the false in the system, which helps to improve its reliability and security.

The proposed system was evaluated under predefined irrigation schedules and nutrient levels across different agricultural environments, including home gardens, farms, and crop fields. Experimental observations indicate the improved plant growth, efficient utilization of water and fertilizers, and reduced human intervention. These results confirm the effectiveness of the proposed IoT-based fertilization and irrigation system in improving crop productivity while promoting sustainable resource management.

4. Results and Discussion

In an open field farming environment, testing and implementation of automatic irrigation and fertilization systems are used. The performance evaluation of the Automatic irrigation and fertilization systems based on water efficiency, nutrient optimization, reliability of automation and responsiveness to security alerts. The experimental data indicate that watering and fertilising wastage has been reduced in enhanced crop growth and increased convenience of operations by including Blynk IoT for automation and remote monitoring (Figures 2–4).



Figure 2. Nutrients Tanks

The open field deployment preparation is presented in figure 2 below. It shows where soil moisture sensors, water level sensors, nutrient dispensing units and irrigation pumps are placed within the test plots. This set-up was created to provide real-time monitoring of the amount of water and fertilizer supplied to each plot, as well as the ability to control the amount of water and fertilizer supplied to each plot.

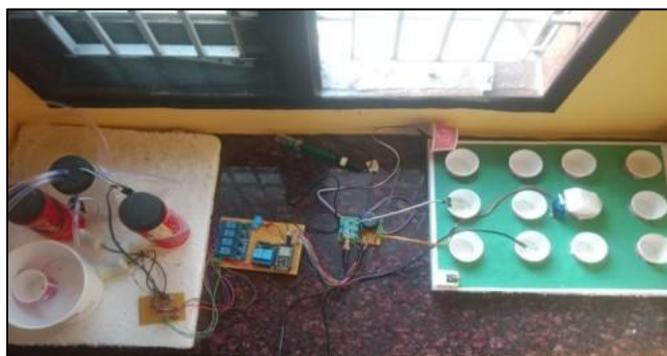


Figure 3. Circuit Board

The decrease in water consumption (40-60%) associated with the implementation of automated irrigation is illustrated in Figure 3. The soil moisture was monitored in real time to trigger irrigation, which is activated when soil moisture was below the desired threshold, optimizing water usage.



Figure 4. Laser Fencing

Figure 4 demonstrates the fertilizer optimization and alert system utilizes an automated method to dispense the precise amount of fertiliser that is needed to grow a certain type of crop, resulting in between 5% and 30% less fertiliser. Blynk has developed a system that sends out push notifications when the water level is low, the soil has too little moisture, or there is a potential security breach (e.g., a laser fence intrusion). By allowing farmers to receive push notifications from the Blynk app, the ability to quickly make corrections and improve field safety and system reliability can be maximized.

Table 1. Quantitative Performance Evaluation of the Proposed System

Parameter	Manual Farming System	Proposed Automated System
Average Water Consumption	18–22 L/plot/day	9–12 L/plot/day
Water Saving	—	40–60%
Fertilizer Usage	120 g/week/plot	85 g/week/plot
Fertilizer Reduction	—	5–30%
Irrigation Response Time	Manual delay	2.8 s
Soil Moisture Sensor Accuracy	—	±3%

Temperature Sensor Accuracy	—	±1 °C
pH Sensor Accuracy	—	±0.1
Water Level Sensor Accuracy	—	±2%
System Reliability	—	96.5%
Intrusion Detection Accuracy	—	100%
Alert Notification Delay	—	3–5 s
Monitoring Method	Manual	Real-time IoT
Labor Requirement	High	Low

Table 1 describes the quantitative assessment of the new IoT-enabled automatic irrigation and fertilisation system as tested in an open field. In comparison to traditional hand watering practices, the amount and frequency of both water and fertilizer use were reduced using the automated control method. When irrigation was applied, the time to respond to make changes in soil moisture was 2.8 seconds, meaning that irrigation can be applied at the appropriate time based on wet or dry soil. These benefits of the system provided with high levels of accuracy and reliability of sensor readings, leading to consistent and stable operation of the system. Finally, the addition of integrated security and alert systems, rapid detection and reporting of unauthorized access could be firewalls, enabling a higher level of safety on-site. Therefore, these findings confirm that an IoT-enabled automatic irrigation and fertilisation system is a reliable, efficient and sustainable solution for the agricultural sectors.

Table 2. Comparison Between Manual and Automated Farming Systems

Parameter	Manual System	Proposed System
Water Usage	High	Low
Fertilizer Usage	High	Low
Labor Requirement	High	Low
Uniformity	Inconsistent	Uniform
Monitoring	Manual	Real-time IoT
Alerts	Not available	Instant

Table 2 compares manual farming systems with automated farming by reducing less water and fertilizer usage, ensuring the irrigation and fertilizer will be applied uniformly across the entire farm, and farmers will be able to monitor their intervention levels in real-time,

receiving immediate alerts when conditions change. In conventional manual farming systems, these benefits are not available to the farmers.

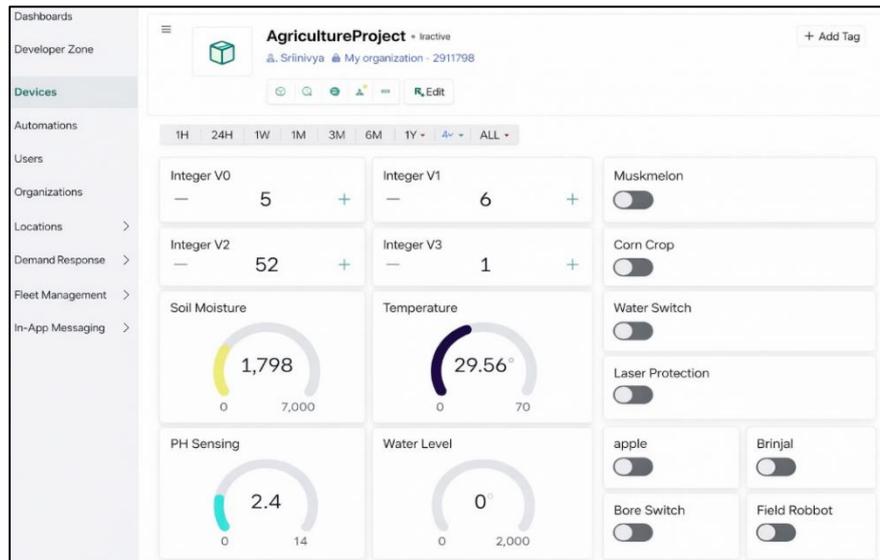


Figure 5. Web Interface

The use of automatic detection of unauthorized access and live monitoring of essential field parameters (see Figure 5), the increased performance and ability to adapt with changing conditions that the system offers improved field security and resource management. By utilizing an integrated security function for field protection detects the presence of unauthorized persons, including through fences or open fields, it is provided for the protection of both crops and irrigation equipment during abnormal incidents. By continuously monitoring soil moisture, water level, and nutrient distribution, the System enabled more effective Resource Management to reduce the possibility of crop water stress (Water Stress) and/or nutrient deficiency.

As shown by Figure 5, the security and adaptive control module operates both manual and automatic modes. When in automatic mode, the irrigation and fertilization schedules are managed by the system itself, based on live sensor data, along with using Blynk mobile app to provide instant notifications when low water level, unusual soil characteristics or unauthorized access were detected. In manual mode, the farmer has complete ability to bypass override automated event functions and this system is suitable to accommodate various types of agricultural settings and crops.

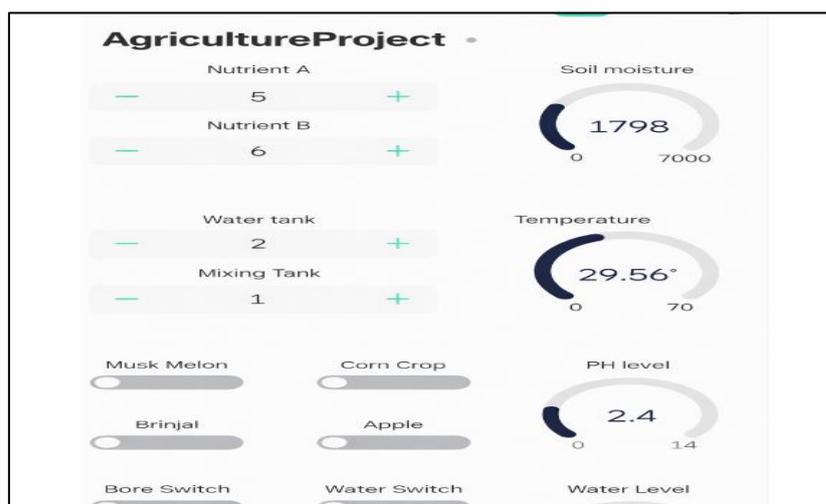


Figure 6. Mobile Application Interface

Using Blynk's historical data-log and visualization tools will help us with farm management decisions (Figure 6). The continuous monitoring of soil moisture, temperature, pH level and nutrient application enables farmers to track crop conditions through the seasons, allowing them to predict irrigation and fertilization practices. By analysing this historical data, farmers are able to adopt precision farming practices and reduce their wastage of both water and nutrients. This results in an increase in efficiency when using both water and nutrients.

The Blynk Internet of Things (IoT) dashboard can be viewed in Figure 6. It allows farmers to monitor their systems through a visual interface that includes live sensor readings and the timing of any irrigation or fertilisation activities. With this simple and user-friendly interface, the farmers with little or no technical expertise can know about their systems are performing and adjustments to their fertiliser and irrigation schedules based on the information provided, enabling them to improve their farming management efficiencies.

Figure 6 highlights the integration of how the IoT system is capable of making decisions based on both historical and real-time data. By integrating these types of data, the IoT system enables farmers to make better use of their resources, maintain the health of their soil and improves the uniform growth with their possible crops, without having any advanced technical backgrounds or experience with agricultural technologies.

5. Conclusion

The concept of using an IoT based automated system to enhance water efficiency, fertilizer management and farming security was implemented in this research study. The system offers successful automatic irrigation, fertilization and crop protection implemented in an open field farm. The system expands the scope of crop protection by providing background information on the crop's environment that includes sensors that detect cycle moisture, cycle temperature changes and detecting physical security breaches using laser barriers. Through the automated system, the farmers can respond immediately to security threats or extreme weather circumstances such as flooding or prolonged drought to minimize crop losses and maximize yield and able to respond to the issues like pest pressure or security risks. Network connectivity issues can potentially affect automation reliability by causing delays in real-time data transmission, especially at distant locations. With the passage of time, accurate readings require sensor calibration and maintenance, and that comes with a cost of operation. The reliance on electricity for off-grid regions can impact the performance of the overall system, and alternative energy sources must be developed, such as solar energy or other renewable resources. The operating conditions of soil type and terrain, crop development, and climate/weather variables may also vary with their location. These differing variables, the system may require individual customizations, which will create additional complexities in the initial setup process. Cybersecurity issues must also be addressed to protect the agricultural data from potential cyberattacks. However, future work is needed to enhance system stability and flexibility through AI-driven predictive analytics, adaptive irrigation management and improved offline capabilities and the implementation of advanced cybersecurity protection.

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