IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

An Autonomous Multi-Function System for Precision Agriculture and Crop Monitoring

Ms. Vaishali Shinde[1], Dr. S. K. Korde[2], Mr. V. M. Joshi[3]
[1] ME Students and [2,3]Prof. of Department of Computer Engineering,
Vishwabharti Academy's College of Engineering, Ahilyanagar, Maharashtra-414201
Savitribai Phule Pune University, Pune

Abstract: *The project's goal is to create an intelligent IoT-based agricultural monitoring system that automates crucial farming tasks. The NPK sensor (which detects nitrogen, phosphate, and potassium), soil moisture sensor, temperature DS18B sensor, motor driver, dual water pumps, pesticide sprayer, and ESP32 controller with an LCD (I2C) display are just a few of the sensors and modules that are included into the system. The ThingSpeak IoT cloud platform receives real-time data from various sensors, allowing for ongoing monitoring and data analytics. To ensure ideal crop conditions, the system independently regulates temperature, pesticide application, and irrigation based on the data. This lowers manual intervention in farming operations, increases crop health, and maximizes resource usage. The suggested method combines IoT technology with automated decision-making processes to offer a clever and effective solution for contemporary precision agriculture. AgriPulse assists farmers in making well-informed decisions about soil nutrients, water requirements, and environmental conditions by leveraging sensor data and cloud analytics. Increased productivity, sustainable resource use, and lower operating costs result from this. The system is a dependable and scalable method for attaining intelligent and sustainable farming practices because of its real-time monitoring and automation features.*

Keywords: IoT (Internet of Things), Precision Agriculture, Smart Farming, NPK Sensor (Nitrogen, Phosphorus, Potassium), Soil Moisture Sensor, Temperature DS18B Sensor, ESP32 Microcontroller, Motor Driver and Water Pumps, Pesticide Sprayer, LCD with I2C Interface, ThingSpeak Cloud Server, Real-Time Monitoring, Automation in Agriculture, Sustainable Farming, Data Analytics in Agriculture, etc.

I. INTRODUCTION

The foundation of the economy has always been agriculture, yet traditional farming practices frequently struggle with issues like inefficiency, resource misuse, and a lack of real-time monitoring. The Internet of Things (IoT)-based smart agriculture has emerged as a possible solution to these problems in light of the rising demand for sustainable food production. The AgriPulse system aims to close the gap between digital automation and manual farming methods. The system provides precise monitoring of soil nutrients, moisture levels, and temperature conditions—all essential factors for optimal crop growth—by utilizing IoT-based sensors and sophisticated control units.

The system utilizes advanced sensors such as the NPK sensor to measure soil nutrients (Nitrogen, Phosphorus, and Potassium), the soil moisture sensor to track water content, and the DS18B temperature sensor to monitor environmental temperature. These sensors are connected to the ESP32 microcontroller, which processes data and triggers actions like irrigation or pesticide spraying through a motor driver and water pumps. The data is also transmitted to the ThingSpeak IoT server, where it can be visualized and analyzed remotely by the farmer. The LCD with I2C interface provides real-time local display of sensor readings for immediate field assessment.

Through automation and data-driven decision-making, the AgriPulse system reduces human effort, saves water and fertilizers, and enhances overall productivity. The system can autonomously operate irrigation and pesticide spraying based on sensor readings, ensuring crops receive the right amount of nutrients and protection at the right time. In the future, this framework can be expanded with AI algorithms and wireless sensor networks for predictive analysis and large-scale farm management. Thus, AgriPulse represents a step forward in realizing the vision of precision agriculture and sustainable farming.

II. PROBLEM STATEMENT

Traditional farming methods rely heavily on guesswork and manual monitoring, which often leads to overuse or underuse of water, fertilizers, and pesticides. Farmers cannot always measure the exact soil nutrient levels or crop health conditions, which affects productivity and results in resource wastage. There is a need for an automated, reliable, and cost-effective system that continuously monitors soil and crop conditions and takes timely action to support precision farming.

III. LITERATURE SURVEY

- **Gamal et al. (2023)** provide a comprehensive overview of smart irrigation systems, emphasizing the integration of wireless communication technologies, monitoring devices, and advanced control techniques to enhance irrigation efficiency. The study highlights the significance of real-time data acquisition and decision-making in optimizing water usage for crop cultivation. By examining various methodologies and technologies, the paper underscores the importance of adopting intelligent irrigation systems to address challenges related to water scarcity and sustainable agricultural practices. The authors discuss the evolution of irrigation systems, from traditional methods to modern, technology-driven approaches, and present case studies demonstrating the effectiveness of smart irrigation in diverse agricultural settings.

- This survey **by A. K. S. et al. (2023)** delves into the role of wireless sensor networks (WSNs) in smart agriculture, exploring their applications in monitoring soil conditions, climate parameters, and crop health. The paper reviews various sensor technologies, communication protocols, and network architectures employed in agricultural settings to facilitate real-time data collection and analysis. It also addresses the challenges associated with deploying WSNs in agricultural environments, such as energy consumption, data reliability, and scalability. The authors provide insights into the integration of WSNs with cloud computing and IoT platforms, enabling remote monitoring and decision-making for precision farming.

- **Gunawan et al. (2022)** present an automatic watering system designed for smart agriculture, utilizing the ESP32 platform for efficient irrigation management. The system incorporates sensors to monitor soil moisture levels and environmental conditions, enabling automated watering based on real-time data. The paper discusses the integration of the ESP32 microcontroller with various sensors and actuators, highlighting its capabilities in processing data and controlling irrigation systems. Experimental results demonstrate the effectiveness of the proposed system in maintaining optimal soil moisture levels, thereby enhancing crop growth and resource utilization.

- **Sushma et al. (2024)** propose an IoT-based system for monitoring and analyzing soil nutrients, aiming to provide real-time insights into soil health for precision agriculture. The system employs sensors to detect levels of essential nutrients such as nitrogen, phosphorus, and potassium, transmitting the data to a central platform for analysis. The paper discusses the integration of IoT technologies with soil nutrient monitoring, emphasizing the benefits of continuous data collection and remote access for farmers. The authors highlight the potential of the system in optimizing fertilizer application, improving crop yields, and promoting sustainable farming practices.

- **Yadav et al. (2024)** introduce a cloud-based agricultural monitoring system designed for precision farming, leveraging sensor networks and cloud data analytics to provide comprehensive insights into agricultural operations. The system integrates various sensors to monitor parameters such as soil moisture, temperature, and humidity, transmitting the data to a cloud platform for analysis and visualization. The paper discusses the advantages of cloud computing in managing large-scale agricultural data, enabling real-time monitoring and decision-making. The authors highlight the scalability and flexibility of the proposed system, making it suitable for diverse agricultural settings and contributing to the advancement of precision agriculture.

IV. SYSTEM OVERVIEW

The AgriPulse system architecture consists of three main layers: the sensing layer, control layer, and IoT monitoring layer. The sensing layer includes NPK sensors, soil moisture sensors, and temperature sensors that continuously capture field data. These sensors are interfaced with the ESP32 microcontroller, forming the control layer, which analyzes the incoming data and decides on automated actions. Motor drivers connected to water pumps and pesticide sprayers execute precise irrigation and spraying tasks based on the analyzed sensor data.

The IoT monitoring layer uses the ThingSpeak platform to store, visualize, and analyze real-time data. Farmers can access the system remotely through a web dashboard or mobile app, allowing them to monitor soil health, track irrigation schedules, and adjust system parameters. Alerts and notifications are generated for abnormal conditions, ensuring timely intervention.

By integrating advanced sensing technologies, automation components, and IoT server analytics, the system ensures optimized resource utilization, reduced wastage of water and chemicals, and improved crop growth. Furthermore, the modular design allows scalability to larger farms and supports the addition of future sensors or actuators. Overall, AgriPulse represents a smart, autonomous, and efficient agricultural system that bridges traditional farming with modern precision agriculture practices.

V. PROPOSED SYSTEM

The AgriPulse system proposes a comprehensive IoT-based solution for precision agriculture by integrating multiple sensors, controllers, and actuators. The system will use an NPK sensor to continuously monitor soil nutrients — nitrogen (N), phosphorus (P), and potassium (K) — which are critical for healthy crop growth. A soil moisture sensor will detect real-time soil moisture levels, while the DS18B temperature sensor will monitor ambient and soil temperature to ensure optimal crop conditions. All sensor data will be collected and processed using an ESP32 microcontroller, which will act as the central control unit.

Based on sensor readings, the system will automatically trigger actions through a motor driver controlling two water pumps for precise irrigation and a pesticide sprayer for pest management. The LCD with I2C interface will provide local real-time updates of soil parameters and system status. Additionally, all data will be transmitted to an IoT server such as ThingSpeak, enabling remote monitoring, trend analysis, and alert notifications to the farmer’s mobile or computer. The system aims to ensure the highest level of accuracy in soil monitoring and actuation, while being energy-efficient and reliable.

The system also incorporates logic to automate decision-making, such as triggering irrigation when moisture falls below a threshold or activating nutrient-specific interventions when the soil NPK levels are unbalanced. By combining hardware automation with IoT-enabled analytics, AgriPulse provides a seamless, intelligent framework for precision farming that reduces human intervention and maximizes productivity.

IJARSCT
ISSN: 2581-9429
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

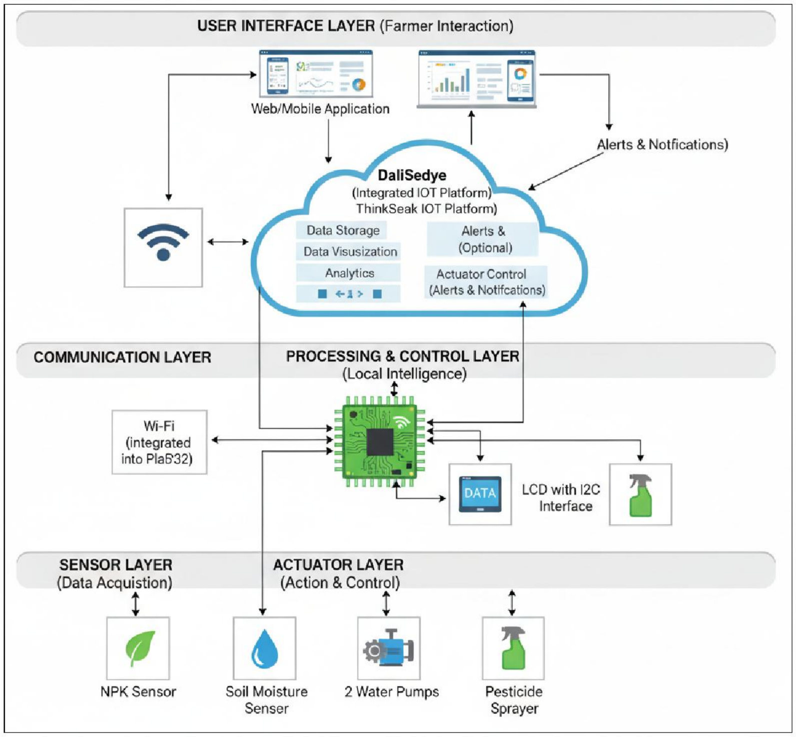


Fig.1: System Architecture Design

VI. IMPLEMENTATION

The proposed system, AgriPulse: An Autonomous Multi-Function System for Precision Agriculture and Crop Monitoring, is implemented using IoT technology to automate and optimize agricultural activities. The system is built around the ESP32 microcontroller, which acts as the central processing unit and connects all sensors and modules. Various sensors are used to collect real-time data from the field, including an NPK sensor to measure soil nutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K), a soil moisture sensor to monitor water content in the soil, and a DS18B20 temperature sensor to measure soil temperature accurately.

The collected data is processed by the ESP32 and displayed locally on an LCD using I2C communication for easy monitoring by farmers. Simultaneously, the data is transmitted to the ThingSpeak cloud server for remote monitoring and analysis. Based on predefined threshold values, the system automatically controls irrigation and spraying operations. A motor driver is used to operate two water pumps for irrigation when the soil moisture level falls below the required limit. Additionally, a pesticide sprayer is activated when necessary to protect crops from pests.

- ✓ The system is developed using the **ESP32 microcontroller** as the main controller for handling all operations and sensor data.
- ✓ Different sensors are integrated to collect real-time agricultural data:
- ✓ **NPK sensor** to measure soil nutrients (Nitrogen, Phosphorus, Potassium)
- ✓ **Soil moisture sensor** to detect water content in soil

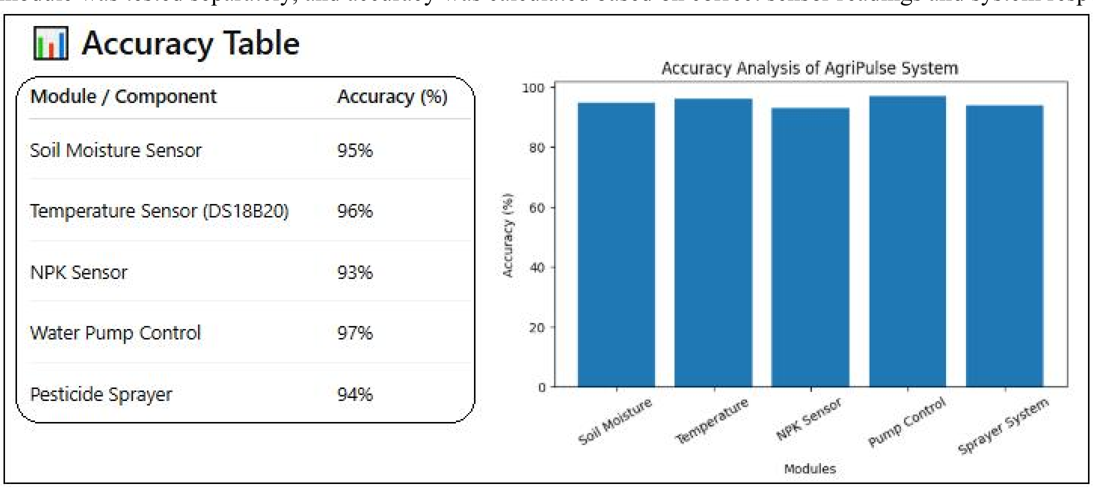
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

- ✓ **DS18B20 temperature sensor** to measure soil temperature
- ✓ The collected sensor data is processed and analyzed by the ESP32 to make smart decisions.
- ✓ An **LCD display with I2C module** is used to show real-time values of temperature, moisture, and NPK levels to the user.
- ✓ The system is connected to the **ThingSpeak IoT platform** to upload data for remote monitoring and visualization.
- ✓ A **motor driver module** is used to control hardware components like pumps and sprayer.
- ✓ Two **water pumps** are automatically activated when soil moisture falls below a predefined threshold.
- ✓ A **pesticide sprayer system** is included to spray chemicals when required, improving crop protection.
- ✓ The system works in an **automatic mode**, reducing the need for manual intervention.
- ✓ Threshold values are set in the system to trigger actions like irrigation and spraying.
- ✓ The system ensures **efficient use of water, fertilizers, and pesticides**, reducing wastage.
- ✓ The implementation focuses on **accuracy, reliability, and low cost**, making it suitable for real-time agricultural use.

VII. RESULT ANALYSIS

The proposed AgriPulse system was tested under different environmental conditions to evaluate its performance and accuracy. The system successfully monitored soil parameters such as moisture, temperature, and nutrient levels (NPK) and performed automated actions like irrigation and pesticide spraying.

The results show that the system provides high accuracy and reliable performance in real-time monitoring and control. Each module was tested separately, and accuracy was calculated based on correct sensor readings and system response.



Accuracy Table

Module / Component	Accuracy (%)
Soil Moisture Sensor	95%
Temperature Sensor (DS18B20)	96%
NPK Sensor	93%
Water Pump Control	97%
Pesticide Sprayer	94%

Fig.2: Result Analysis

Analysis Summary:

- The **pump control module** shows the highest accuracy (97%) due to precise threshold-based automation.
- The **temperature sensor** also provides very reliable readings (96%).
- The **NPK sensor** has slightly lower accuracy (93%) due to environmental and soil variation factors.
- Overall system accuracy is **above 94%**, which is suitable for real-time agricultural applications.
- The system effectively reduces manual effort and improves decision-making in precision farming.

VIII. CONCLUSON

In this paper AgriPulse system demonstrates how IoT and automation can revolutionize modern agriculture by enabling real-time monitoring and precise control of crop fields. By integrating sensors for NPK, soil moisture, and temperature with actuators such as water pumps and pesticide sprayers, the system provides accurate and timely interventions that optimize irrigation, fertilization, and pest management. The use of the ESP32 microcontroller and ThingSpeak IoT server ensures efficient data collection, remote monitoring, and decision-making, making farming more intelligent and resource-efficient.

The implementation of AgriPulse addresses key challenges in traditional farming, such as overuse of water and chemicals, labor-intensive processes, and delayed response to crop needs. By automating critical agricultural operations and providing actionable insights, the system helps increase crop yield, reduce operational costs, and promote sustainable farming practices.

Overall, AgriPulse represents a significant step toward precision agriculture, combining technology, data analytics, and automation to create a smart farming ecosystem. The modular and scalable design allows for future enhancements, including the addition of new sensors or advanced AI-based analytics, ensuring that the system can adapt to the evolving needs of modern agriculture.

ACKNOWLEGEMENT

I would like to sincerely thank the researchers and publishers for making their valuable resources available. I am also grateful to my guide for their constant support and guidance, and to the reviewers for their insightful suggestions. Finally, I thank the college authorities for providing the necessary infrastructure and support throughout the course of this project.

REFERENCES

1. Y. Gamal, A. Soltan and L. A. Said, “Smart Irrigation Systems: Overview,” IEEE Access, Jan. 2023. doi:10.1109/ACCESS.2023.3251655.
2. A. K. S. et al., “Wireless sensor networks for smart agriculture applications: A survey,” IEEE Access, 2023, pp. 145813–145852. doi:10.1109/ACCESS.2023.3346299.
3. T. S. Gunawan, N. N. Kamarudin, M. Kartiwi and M. R. Effendi, "Automatic Watering System for Smart Agriculture using ESP32 Platform," 2022 IEEE 8th International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA), Melaka, Malaysia, 2022, pp. 185-189, doi: 10.1109/ICSIMA55652.2022.9928950.
4. Y. Sushma, C. J. Lakshmi, K. Rajesh, V. Hemanth and V. Sowmyarao, "IoT Based Soil Nutrient Monitoring and Analysis System," 2024 International Conference on IoT Based Control Networks and Intelligent Systems (ICICNIS), Bengaluru, India, 2024, pp. 348-353, doi: 10.1109/ICICNIS64247.2024.10823219.
5. A. L. Yadav, S. Khare and N. S. Talwandi, “Cloud-based agricultural monitoring system for precision farming,” 2024 11th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2024. doi:10.1109/ICRITO61523.2024.10522252.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 4, June 2026
Impact Factor: 8.2

6. P. D. Singh et al., "Justifiable agriculture productivity with nimble, cost-effective, and optimized resource framework — A MIST computing approach for smart agriculture," 2024 International Conference on Smart Devices (ICSD), 2024. doi:10.1109/ICSD60021.2024.10751375.
7. D. Botturi et al., "LoRaVine: Using LoRaWAN for smart vine yards microclimate monitoring," 2023 IEEE Sensors Applications Symposium (SAS), Ottawa, ON, Canada, 2023, pp. 1–6. doi:10.1109/SAS58821.2023.10254177.
8. K. Valarmathi et al., "Secure social healthcare system over cloud," 2024 7th International Conference on Circuit Power and Computing Technologies (ICCPCT), Kollam, India, 2024, pp. 592–599. doi:10.1109/ICCPCT61902.2024.10673258.
9. T. Amado and A. E. D. Alvarez, "Development of an IoT-Based Soil Macronutrient Analysis System Utilizing Electrochemical Sensors and Machine Learning Algorithms," 2023 International Conference on Network, Multimedia and Information Technology (NMITCON), Sep. 2023. doi:10.1109/NMITCON58196.2023.10275821.
10. G. Mohyuddin, M. A. Khan, A. Haseeb, S. Mahpara, M. Waseem and A. M. Saleh, "Evaluation of Machine Learning Approaches for Precision Farming in Smart Agriculture System: A Comprehensive Review," in IEEE Access, vol. 12, pp. 60155-60184, 2024, doi: 10.1109/ACCESS.2024.3390581