PAPER ID: 20260201038

# IoT-Based Smart Agriculture for Soil, Water, and Crop Monitoring

**Dr. Kavita Mittal[1], Esha Chauhan[2] and Prabhjot Singh Chadha[2]**
[1]Professor, Jagannath University, Delhi NCR, Bahadurgarh
kavita.mittal@jagannathuniversityncr.ac.in
[2]Student of Masters of Computer Applications, Department of IT, Jagannath University, Delhi NCR, Bahadurgarh

**Abstract:** Smart agriculture, also known as precision farming, has emerged as a transformative approach to improve agricultural productivity and enhance sustainability through the integration of Internet of Things (IoT) technologies. This paper presents the design, modelling, and analysis of an IoT-enabled smart agriculture system for real-time monitoring of soil, water, and crop parameters. The proposed model consists of soil moisture sensors, temperature and humidity sensors, and crop monitoring mechanisms interfaced with an Arduino Uno microcontroller device to automate irrigation system and provide real-time feedback via an LCD display. Sensor data is processed to trigger automated irrigation through a relay-controlled pump when soil moisture falls below a predefined threshold, thereby optimizing water usage and improving crop health. The system is simulated and validated using Proteus software, ensuring reliability prior to deployment. Results and recent survey-based analyses indicate that IoT-driven precision farming can achieve up to 40% water savings, 15–22% yield improvement, and reduced labour dependency. The proposed integration of IoT communication technologies further enables scalability and remote monitoring. Overall, the proposed approach demonstrates an efficient, cost-effective, and sustainable solution for smart agriculture, significantly contributing to resource conservation, enhanced productivity, and long-term food security.

## I. INTRODUCTION

Smart agriculture, also known as precision farming, is transforming conventional farming practices through the integration of advanced digital technologies. Among these technologies, the Internet of Things (IoT) plays a pivotal role by enabling continuous monitoring and intelligent decision-making across farm environments. IoT-based systems deploy interconnected sensors that collect, process, and transmit real-time data related to soil conditions, water availability, and crop health, thereby improving productivity and sustainability.

Soil sensors are widely used to measure critical parameters such as moisture content, temperature, pH levels, and nutrient availability. These measurements allow farmers to make precise irrigation and fertilization decisions, reducing dependency on guesswork and fixed schedules. Water sensors further optimize irrigation systems by monitoring water levels, flow rates, and potential leakage, ensuring efficient water usage and conservation. Additionally, crop sensors track plant growth patterns, detect diseases, and assess overall crop health, enabling early intervention and minimizing yield losses.

The IoT sensors integrated with mobile applications and cloud-computing based dashboards allows farmers and agricultural researchers to remotely access field data using smartphones or computers. This real-time visibility leads to faster, data-driven decisions that enhance crop yield, reduce resource wastage, and promote environmentally responsible farming practices. Ultimately, the adoption of IoT-enabled smart agriculture supports sustainable food production, improves farm profitability, and strengthens food security for a rapidly growing global population.

## II. METHODOLOGY AND COMPONENT DESCRIPTION

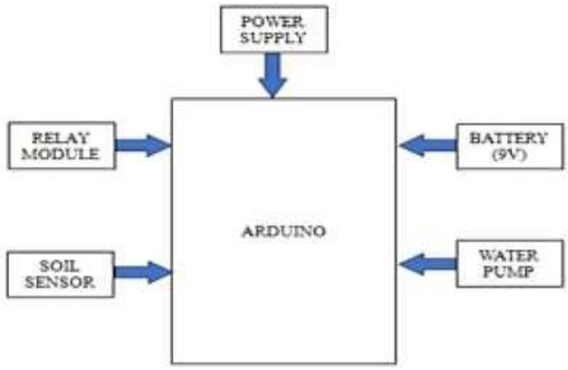
A typical IoT-enabled modern agriculture system follows a layered architecture consisting of sensing, processing, communication, and actuation layers. Each layer plays a crucial role in acquiring field data, analysing it, and executing automated responses to environmental conditions [1].

In the proposed system, soil moisture sensors continuously monitor the moisture content of the soil, while the DHT11 sensor measures ambient temperature and humidity. The collected sensor data is processed by an Arduino Uno microcontroller, which serves as the central control unit. The processed information is displayed in real time on a 16×2 LCD screen, providing immediate feedback to the user.

When the soil moisture measure drops below a predefined threshold, the Arduino triggers a buzzer alert, thereby activating a relay module that switches on the water pump motor. This automated irrigation mechanism ensures that crops receive adequate water precisely when needed. The LCD displays environmental parameters and irrigation status, such as soil condition and pump operation.

This smart irrigation system offers multiple advantages, including significant water conservation, improved energy efficiency, and improved plant health. By IoT based irrigation based on real-time sensor data, the system attempts to minimize water wastage and supports optimal crop growth. Temperature and humidity monitoring further contribute to effective microclimate management, improving overall agricultural efficiency [2].

**Fig. 1. Block Diagram of Smart Agriculture System**




**A. Proteus Software**

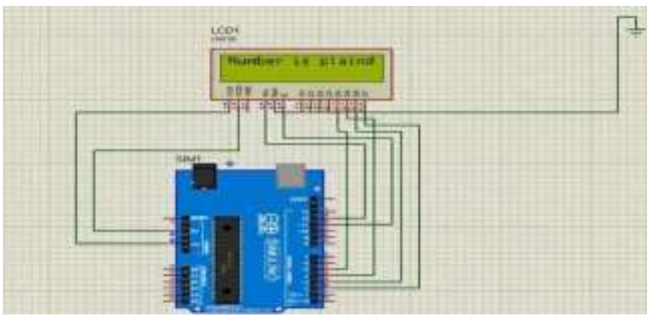
Proteus is a user friendly simulation platform for designing, testing, and validating electronic circuits and embedded systems. It provides an extensive library of electronic components and allows easy creation of schematic designs and simulations. Proteus supports analog and digital circuit simulation, microcontroller-based system modeling, RS232 communication, I2C and SPI debugging, LCD simulation, and virtual instruments such as oscilloscopes and logic analysers [3]. The ARES module of Proteus facilitates PCB design and routing, making it a comprehensive EDA tool. Owing to its versatility and cost-effectiveness, Proteus is extensively used in academic institutions for teaching microcontrollers, embedded systems, and project development [4], [5].

**B. Arduino Uno**

Arduino Uno is an open-source microcontroller board designed for simplicity, flexibility, and ease of programming. It enables direct interfacing with sensors, actuators, and communication modules. Programmed using C/C++ in the Arduino IDE, the Arduino Uno functions as a compact processing device that receives inputs from sensors and generates appropriate outputs. Since its introduction, Arduino has gained widespread adoption in educational and industrial projects. In India, its application has increased at s faster pace due to affordability and community support. In this project, the Arduino Uno is used as the main controller to integrate soil, water, and crop monitoring sensors with display and actuation units.

**III. MODELLING AND ANALYSIS**

**A. Arduino-Based Field Monitoring and Automation**



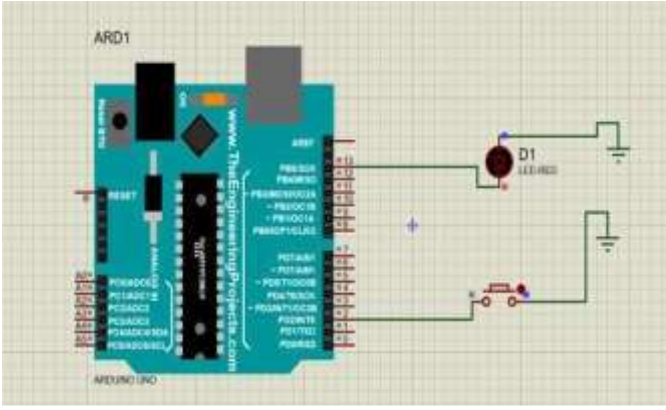



Figure 2 illustrates the initial electronic configuration using an Arduino Uno connected to an LED and a push-button switch. This basic setup forms the foundation for sensor-based monitoring and automation in agricultural applications.

**Fig. 2. Connecting Components**

**Roles in Soil, Water, and Crop Monitoring:**

- **Arduino Uno:** Acts as the central controller interfacing with sensors like water level sensors soil moisture sensors, and crop monitoring devices.
- **LED (D1):** Serves as a visual indicator representing system status, such as dry or moist soil conditions.
- **Push Button:** Simulates user input for system activation, testing, or manual override.

In precision farming applications, multiple sensors like temperature, humidity, soil moisture, and light sensors are connected to the Arduino's analog (A0–A5) and digital (D2–D13) input pins.

**B. Real-Time Monitoring Using Arduino and LCD Interface**

Figure 3 shows the Arduino Uno interfaced with an LCD display for real-time visualization of sensor data.

**Fig. 3. Real-Time Water, Soil, and Crop Monitoring**

**System Description:**

- **Arduino Uno:** Collects and processes sensor data for irrigation and crop management decisions.
- **LCD Display:** Displays real-time values and alerts, such as "Soil Dry – Irrigation ON" or "Water Tank Low."

**Practical Implementation:**

- Sensor readings are updated at regular intervals and displayed on the LCD.
- Alerts are raised for abnormal or unwanted conditions such as excessive dryness or insufficient water supply.
- Optional wireless modules (Wi-Fi or GSM) can transmit data to cloud platforms for remote monitoring, though the LCD provides immediate on-site visualization.

**C. IoT Communication Technologies in Agriculture**

IoT enables undisturbed communication among devices, making agricultural systems more intelligent and responsive. IoT-based agriculture utilizes embedded systems, wireless sensor networks (WSNs), communication protocols, and cloud computing to enable remote monitoring and control [6]. Applications include precision farming, livestock monitoring, and greenhouse management.

Different wireless technologies vary in communication range and data rate, as summarized in Table I.

**TABLE I. Data Rate and Range of IoT Communication Technologies**

| Technology | Range | Data Rate |
|---|---|---|
| Bluetooth | Short | Low |
| BLE | Short | Low |
| Zigbee | Short | Low |
| 6LoWPAN | Short | Low |
| NFC/RFID | Short | Low |
| LPWAN | Long | Low |
| VSAT | Long | Low |
| Wi-Fi | Low | High |
| 4G | Moderate | High |
| 5G | Moderate | High |

## IV. RESULTS AND DISCUSSION

Recent studies and surveys conducted up to 2025 indicate that IoT-enabled precision farming significantly enhances agricultural efficiency. Smart agriculture systems integrating soil moisture, nutrient, and crop health sensors enable real-time data acquisition, automated irrigation, and predictive analytics through AI and cloud platforms.

Reported outcomes include up to 40% reduction in water usage, 22% improvement in crop yields, and substantial reduction in labor requirements [7]. Adoption rates are higher in regions with advanced connectivity and technical infrastructure, such as North America and Europe, while emerging economies like India and China are witnessing rapid growth.

**Regional Performance Summary**

| Region | IoT Adoption (%) | Water Reduction (%) | Yield Improvement (%) | Labor Reduction (%) |
|---|---|---|---|---|
| North America | 50 | 40 | 22 | 18 |
| Europe | 48 | 38 | 21 | 17 |
| Asia (India, China) | 35 | 30 | 18 | 15 |
| Australia | 45 | 36 | 20 | 16 |
| South America | 28 | 25 | 15 | 12 |

Emerging trends include AI-driven analytics, satellite integration, autonomous machinery, and sustainability assessment tools, making smart agriculture more resilient and adaptive.

## V. CONCLUSION

IoT-enabled smart agriculture represents a transformative shift in modern farming by combining technological intelligence with traditional agricultural practices. Continuous real-time monitoring of soil, water, and crop parameters enables precise irrigation, optimized fertilization, and early detection of crop stress. These capabilities significantly reduce resource wastage, enhance productivity, and minimize environmental impact.

Automated irrigation systems enable efficient water usage saving up to 40%, while crop monitoring technologies contribute to yield improvements of 15–22%. Integration with AI and cloud computing further empowers farmers with predictive insights and remote decision-making tools. Despite challenges such as initial costs, connectivity limitations, and skill requirements, ongoing innovation is making IoT solutions more affordable and accessible.

In conclusion, IoT-based precision farming is a critical enabler of sustainable agriculture, offering economic, environmental, and social benefits. Widespread adoption of these technologies will play a vital role in ensuring food security, climate resilience, and agricultural sustainability in the future.

## REFERENCES


[1] Y. S. Chung, “Integration of Smart Sensors and IoT in Precision Agriculture: Trends, Challenges and Future Prospects.”

[2] K. A. and R. Vadivel, “Optimized Water Management for Precision Agriculture Using IoT-Based Smart Irrigation System.”

[3] D. J. Cook et al., “An Agent-Based Smart Home,” Arlington, VA.

[4] C. Fan, X. Li, and B. Sun, “Application of Proteus in Experimental Teaching,” vol. 215, pp. 512–516, 2018.

[5] H. Wang et al., “Construction and Practice of Virtual Simulation Experimental Teaching Center,” *Computer Teaching*, vol. 9, pp. 5–11, 2015.

[6] R. dos Santos et al., “Agri Prediction: A Proactive Internet of Things Model to Anticipate Problems and Improve Agricultural Production,” *Computers and Electronics in Agriculture*, vol. 161, pp. 202–213, 2019.

[7] S. M. Kim et al., “Integration of Smart Sensors and IoT in Precision Agriculture: Trends, Challenges, and Future Prospects.”