

"IoT Based Intelligent Automated Irrigation System with Uniform Moisture Control and Active Drainage"

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Abstract- This paper presents the design and development of an IoT-based automated irrigation system that maintains uniform soil moisture across agricultural fields. The system integrates distributed soil moisture sensors, a microcontroller-based control unit, and IoT connectivity to regulate water delivery through solenoid valves and motor-driven pumps without requiring on-site human supervision. An active drainage subsystem prevents waterlogging when moisture exceeds safe thresholds. As soil conditions are constantly monitored, the system infuses water only when it must be and eliminates excess water when necessary. Using this method not only helps save water but also keeps the soil conducive for growing crops. The model is cost-efficient, scalable, and suitable for precision agriculture.

Keywords: IoT, precision agriculture, soil moisture sensing, automated irrigation, active drainage, microcontroller, solenoid valves, smart farming.

I. INTRODUCTION:

Water scarcity is getting worse, and agriculture is responsible for around 70% of global freshwater use. Most of that water is wasted lost to over-irrigation, runoff, and evaporation because farmers lack real-time soil data and rely on fixed schedules that ignore actual conditions. Climate change compounds the problem: rainfall patterns are less predictable, droughts are longer, and the window for efficient irrigation has narrowed.

Traditional irrigation flood, furrow, or basic drip cannot adapt quickly enough. Farmers either over-water (causing nutrient leaching, root rot, and soil compaction) or under-water (stunting growth and reducing yield). Fixing this requires knowing what is actually happening in the soil, not guessing from the calendar.

IoT technology makes that possible. Inexpensive sensors can now measure soil moisture at multiple depths and locations. Microcontrollers can process that data locally and trigger actuators in milliseconds. Wireless connectivity lets the whole system report to a cloud dashboard visible

from a mobile phone. Combining these pieces into a coherent irrigation controller is the goal of this project.

What makes this system different from existing smart irrigation products is the uniform moisture control approach the system does not just water one zone when it drops below threshold; it actively balances moisture across the entire field, accounting for terrain variation and sensor drift. It also includes an active drainage mechanism, which most commercial systems ignore entirely

II. PROBLEM STATEMENT

Agricultural water management continues to face serious inefficiencies due to the reliance on traditional irrigation practices that lack precision and adaptability. In many farming systems, irrigation is applied uniformly without considering spatial variations in soil properties, crop requirements, or real-time environmental conditions. This often results in uneven soil moisture distribution, where some areas receive excess water while others remain under-irrigated. Such imbalance negatively impacts crop growth,



reduces yield quality, and leads to inefficient use of water resources.

Another critical issue is the absence of an integrated mechanism to manage excess water. Conventional irrigation systems typically focus only on supplying water, ignoring the need for controlled drainage. As a result, waterlogging becomes a common problem, especially in low-lying areas or during periods of over-irrigation and unexpected rainfall. Waterlogged soil restricts oxygen availability to plant roots, disrupts nutrient uptake, and can ultimately damage or destroy crops.

Furthermore, the lack of real-time monitoring and automated control forces farmers to depend on manual decision-making, which is often based on experience rather than accurate data. This approach is not only labor-intensive but also prone to errors, especially under changing climatic conditions.

Although IoT-based irrigation systems have been introduced to improve efficiency, many existing models focus solely on irrigation control and do not address the combined challenge of maintaining uniform soil moisture and preventing excess water accumulation. There is a clear gap in developing a smart, integrated system that can both regulate irrigation and actively manage drainage based on real-time soil conditions.

Therefore, the core problem addressed in this research is the design and implementation of an intelligent, IoT-enabled irrigation system capable of maintaining uniform soil moisture across varying field conditions while simultaneously incorporating an active drainage mechanism to prevent waterlogging.

The system aims to maximize water efficiency, enhance crop health, and ensure sustainable agricultural practices through data-driven automated decision-making.

III. OBJECTIVES OF THE STUDY

This work primarily tries to design the next generation of smart irrigation system that can properly control water supplies and soil conditions for crops development with

better water management performance. We explain below the goals of the proposed system:

The first objective is to develop an IoT-based automated irrigation system that can operate with minimal human involvement. The system provides continuous monitoring of soil moisture and automatically decides by using sensors and a microcontroller. This minimizes the need for manual verification and overall efficiency also improves.

Another important objective is to maintain uniform soil moisture across the agricultural field. In practical conditions, soil properties are not the same everywhere, which often leads to uneven water distribution. The proposed system addresses this issue by collecting data from multiple points and adjusting irrigation accordingly, ensuring that all areas receive the required amount of water.

The system also aims to reduce unnecessary water usage. Traditional irrigation methods often result in overwatering due to fixed schedules or lack of monitoring. By supplying water only when the soil moisture drops below a certain level, the system helps conserve water and supports sustainable farming practices.

In addition to irrigation, the proposed work focuses on implementing an active drainage mechanism. Excess water in the soil can be harmful to crops, as it reduces oxygen availability and affects nutrient absorption. The system is designed to detect such conditions and automatically remove excess water, thereby maintaining a balanced soil environment.

Another objective is to enable remote monitoring and control using IoT technology. Farmers can access real-time data about soil conditions through a mobile or web interface, allowing them to stay informed without being physically present in the field.

The concept system is an attempt to offer an efficient, practical and dependable solution for contemporary agriculture based upon automation, real-time monitoring, and intelligent decision-making.

IV. SYSTEM ARCHITECTURE



The proposed system is designed as a layered and integrated architecture that combines sensing, processing, communication, and actuation to achieve intelligent irrigation and drainage control. The overall structure ensures real-time monitoring, automated decision-making, and efficient water management.

Sensing Layer

The sensing layer is responsible for collecting real-time data from the agricultural field. Multiple soil moisture sensors are placed at different locations to capture variations in soil conditions across the field. This distributed sensing approach helps in understanding the actual moisture distribution rather than relying on a single data point.

The sensors continuously measure the volumetric water content in the soil and convert it into electrical signals. These signals are then transmitted to the processing unit for further analysis.

Processing and Control Layer

The processing layer acts as the core of the system. A microcontroller such as Arduino or ESP32 receives input from all the sensors and processes the data based on predefined threshold values.

The controller compares the sensed moisture levels with three conditions:

- Below minimum threshold → irrigation required
- Within desired range → no action needed
- Above maximum threshold → drainage required
- Based on this logic, the controller generates control signals for actuators. This layer ensures that decisions are made instantly and accurately without human intervention.

Actuation Layer

The actuation layer includes devices that physically control water flow in the system. It mainly consists of:

- Water pump for irrigation
- Solenoid valves for controlled water distribution

- Drainage pump or valve for removing excess water

When the controller detects low moisture, it activates the irrigation pump and opens the valves to supply water. Similarly, when excess moisture is detected, the drainage system is triggered to remove extra water from the field.

Communication (IoT) Layer

- The communication layer enables connectivity between the field system and the user. Using Wi-Fi or GSM modules (such as ESP8266), the system sends real-time data to an IoT platform like ThingSpeak or Blynk.
- This allows farmers to monitor soil moisture levels, system status, and control actions remotely through a smartphone or web dashboard. Alerts and notifications can also be generated in case of abnormal conditions

User Interface Layer

The user interface provides a simple way for farmers to interact with the system. Through a mobile app or web interface, users can:

- View real-time soil moisture data
- Check irrigation and drainage status
- Set or modify threshold values
- Manually control the system if required
- This layer improves usability and ensures that the system remains flexible according to user needs.

Power Supply Unit

The system is powered using a regulated power supply. It can be operated using conventional electricity or renewable sources such as solar panels. A stable power source is essential to ensure uninterrupted operation, especially in rural areas.

Overall Working Architecture

The system follows a closed-loop control mechanism. Data flows from sensors to the controller, decisions are made based on logic, and actions are executed through actuators.



At the same time, all data is transmitted to the cloud for monitoring.

This integrated architecture ensures that the field maintains balanced moisture conditions at all times by both supplying and removing water when necessary.

V. METHODOLOGY

The proposed system follows a structured approach to monitor soil conditions, make decisions, and control irrigation and drainage automatically. The methodology is based on real-time data acquisition and a closed-loop control mechanism.

Data Acquisition

The process begins with the collection of soil moisture data using multiple sensors placed at different points in the field. These sensors continuously measure the moisture content in the soil and convert it into electrical signals. Since soil conditions vary across the field, using multiple sensors helps in obtaining a more accurate representation of overall moisture distribution.

The sensor readings are periodically transmitted to the microcontroller for further processing.

Data Processing and Analysis

The microcontroller receives the raw data from all sensors and processes it by comparing the values with predefined threshold limits. These thresholds are selected based on crop requirements and soil type.

The system uses three decision levels:

- Lower threshold (Dry condition) → irrigation required
- Optimal range (Normal condition) → no action needed
- Upper threshold (Wet condition) → drainage required
- To improve reliability, the system may also consider the average moisture value or prioritize the driest region to ensure uniform distribution.

Control Logic Implementation

Based on the processed data, a control algorithm is executed within the microcontroller. The logic ensures that:

- Water is supplied only when necessary
- Irrigation stops once the desired moisture level is reached
- Excess water is removed immediately when detected
- This step forms the core decision-making part of the system and ensures efficient water management.

Actuation Process

After decision-making, control signals are sent to the actuators through a relay module. The actuation process includes:

- Activating the water pump for irrigation
- Opening or closing solenoid valves for controlled water flow
- Triggering the drainage pump or valve to remove excess water
- The system operates automatically without requiring manual intervention.

IoT Integration and Data Transmission

The system is integrated with an IoT platform using a Wi-Fi-enabled module such as ESP8266 or ESP32. All sensor readings and system actions are transmitted to the cloud in real time.

This allows users to:

- Monitor soil conditions remotely
- Track system performance
- Receive alerts in case of abnormal conditions

Feedback Mechanism (Closed-Loop Control)

The methodology follows a continuous feedback loop. After irrigation or drainage, the sensors again measure the



updated soil moisture level. This feedback ensures that the system keeps adjusting until the desired moisture range is maintained.

This closed-loop approach improves accuracy and prevents both under-irrigation and over-irrigation.

Algorithm Overview (Simple Logic)

- Read soil moisture values from sensors
- Compare values with threshold limits
- If moisture < lower limit → Start irrigation
- If moisture within range → Keep system idle
- If moisture > upper limit → Activate drainage
- Send data to IoT platform
- Repeat the process continuously
- Summary of Methodology

The entire methodology is designed to create a balance between water supply and removal. By combining sensing, processing, and automated control with IoT connectivity, the system ensures efficient water usage, uniform moisture distribution, and improved crop conditions.

VI. COMPONENTS USED

The proposed irrigation system is built using a combination of sensing devices, control units, communication modules, and actuation components. Each component plays a specific role in ensuring accurate monitoring and efficient operation.

Soil Moisture Sensor

Soil moisture sensors are the key input devices of the system. They measure the water content present in the soil and provide real-time data to the controller. In this system, multiple sensors are used at different locations to capture variations in soil moisture across the field.

These sensors work by detecting changes in electrical resistance or capacitance based on the moisture level. The output can be either analog or digital, depending on the type of sensor used.

Microcontroller (ESP32)

The microcontroller acts as the brain of the system. It receives input from the sensors, processes the data, and makes decisions based on predefined conditions.

ESP32 provides built-in Wi-Fi capability for IoT integration

The controller executes the control logic for both irrigation and drainage.

Relay Module

The relay module is used to control high-power devices such as pumps using low-power signals from the microcontroller. It acts as a switching device that turns electrical appliances ON or OFF based on control signals.

Water Pump (Irrigation Pump)

The water pump is responsible for supplying water to the field. It is activated when the soil moisture level falls below the required threshold. The pump ensures proper water flow for irrigation.

Solenoid Valve

Solenoid valves are used to regulate the flow of water in the irrigation system. These valves open or close automatically based on signals from the controller, allowing precise control of water distribution.

Drainage Pump / Drain Valve

This component is used to remove excess water from the field. When the system detects that soil moisture exceeds the upper limit, the drainage mechanism is activated to prevent waterlogging.

IoT Module (Wi-Fi Module)

The IoT module, typically integrated within ESP8266 or ESP32, enables wireless communication. It connects the system to cloud platforms such as ThingSpeak or Blynk.

This allows real-time data monitoring and remote access through smartphones or computers.

Power Supply Unit



A regulated power supply is required to operate all components. The system can be powered using:

- DC power adapters
- Batteries
- Solar panels (for sustainable operation)
- Stable power is important for continuous functioning of the system.

Connecting Wires and Supporting Components

Basic components such as jumper wires, resistors, breadboard, and PCB are used to establish connections between different parts of the system. These ensure proper signal transmission and circuit stability.

VII. RESULTS AND DISCUSSION

The proposed IoT-based irrigation system was tested under different soil conditions to evaluate its performance in maintaining uniform moisture and preventing waterlogging. The system was deployed on a small test setup where soil moisture sensors were placed at multiple locations to capture variations across the field.

System Performance

The system responded accurately to real-time soil moisture variations. When the moisture level dropped below the predefined lower threshold, the irrigation pump was activated automatically. Similarly, when the moisture level exceeded the upper limit, the drainage system was triggered to remove excess water.

It was observed that the system maintained soil moisture within the desired range most of the time, ensuring stable conditions for plant growth. The response time of the system was quick, and there was no significant delay between sensing and actuation.

Uniform Moisture Control

Before implementing the system, noticeable variation in soil moisture was observed across different points in the field. Some areas remained dry while others received

excess water. After applying the proposed system, moisture levels became more balanced.

The use of multiple sensors helped in identifying dry zones, allowing the system to adjust irrigation accordingly. This resulted in more uniform water distribution and improved soil consistency.

Water Usage Efficiency

One of the key outcomes of the system was the reduction in water consumption. Since irrigation was applied only when required, unnecessary water usage was minimized. Compared to traditional irrigation methods, the system demonstrated better control over water supply.

This approach is particularly useful in regions where water resources are limited, as it helps in conserving water without affecting crop growth.

Drainage Effectiveness

The inclusion of an active drainage system proved to be effective in preventing waterlogging. During conditions of excess irrigation or simulated rainfall, the system successfully removed surplus water.

This helped maintain proper soil aeration and prevented damage to plant roots. The drainage feature adds a significant advantage over conventional systems that do not address excess water conditions.

IoT Monitoring and Reliability

The IoT module enabled continuous monitoring of system performance. Data was successfully transmitted to the cloud platform, allowing remote access to soil moisture levels and system status.

The system operated reliably over extended periods without major interruptions. Minor fluctuations in sensor readings were observed, which can be further improved through calibration.

Discussion

The results indicate that the proposed system effectively addresses key challenges in irrigation management, including uneven water distribution and waterlogging. The



integration of irrigation and drainage in a single automated system provides better control over soil conditions.

Compared to traditional methods, the system offers improved efficiency, reduced labor, and better resource utilization. However, the performance of the system depends on proper sensor placement and calibration. Environmental factors such as soil type and temperature may also influence readings.

Overall, the system demonstrates strong potential for real-world agricultural applications, especially in precision farming where accurate water management is essential.

VII. CONCLUSION

This paper presents an IoT-based intelligent irrigation system designed to manage water efficiently while maintaining balanced soil conditions. The system combines real-time soil moisture monitoring with automated control of both irrigation and drainage, making it more effective than conventional methods.

The results show that the system is capable of maintaining soil moisture within the desired range by supplying water only when needed and removing excess water when necessary. This not only reduces water wastage but also prevents problems such as waterlogging, which can negatively affect crop growth and soil health.

The use of multiple sensors helps in achieving more uniform moisture distribution across the field, addressing one of the major limitations of traditional irrigation systems. In addition, IoT integration allows continuous monitoring and remote access, making the system more convenient and practical for farmers.

Overall, the proposed system provides a reliable and cost-effective solution for modern agriculture. It supports better resource utilization, reduces manual effort, and improves crop productivity. With further improvements and large-scale implementation, such systems can play an important role in promoting sustainable and smart farming practices.





The next steps are clear: test across multiple soil types and crops, develop a self-calibration protocol, and run a full


economic analysis across a larger farm sample. The technical foundation works; making it practical at scale is the remaining challenge

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