

# IoT-Based Groundwater and Irrigation Resource Management System

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**Abstract**—Efficient management of groundwater resources is essential for sustainable agriculture, particularly in regions experiencing increasing water scarcity. This paper presents an IoT-Based Groundwater and Irrigation Resource Management System designed to monitor borewell water levels and irrigation flow rates in real time. The proposed system utilizes sensors to continuously collect data related to groundwater availability and irrigation usage. These sensor readings are transmitted through an IoT-enabled microcontroller to a cloud-based platform for monitoring and analysis. The collected data is analyzed using data analytics techniques to identify water consumption patterns and predict groundwater depletion trends. Based on these insights, the system can optimize water allocation and support farmers in making informed irrigation decisions. The system also provides real-time monitoring and automated alerts to notify users about critical water levels or abnormal irrigation activity. By integrating IoT sensing technologies with data-driven analysis, the proposed system improves irrigation efficiency, reduces excessive groundwater extraction, and enhances water resource management. This approach contributes to long-term water conservation strategies and promotes sustainable agricultural practices.

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**Keywords**—Internet of Things (IoT); Groundwater Monitoring; Smart Irrigation; Water Resource Management; Flow Rate Monitoring; Sustainable Agriculture

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## I. Introduction

Water is one of the most essential resources for agricultural productivity and food security. In many developing regions, agriculture heavily depends on groundwater resources obtained through borewells for irrigation. However, excessive and unregulated extraction of groundwater has led to a significant decline in water tables, creating serious concerns about long-term water availability. Traditional irrigation practices often rely on manual observation and fixed irrigation schedules, which may result in inefficient water usage and wastage.

Recent advancements in the Internet of Things (IoT) have enabled the development of smart monitoring systems that can improve water management in agriculture. IoT technology allows sensors, communication modules, and cloud platforms to work together in collecting and transmitting environmental data in real time. By integrating sensors for monitoring borewell water levels and irrigation flow rates, it becomes possible to track water usage accurately and make better irrigation decisions.

The proposed IoT-Based Groundwater and Irrigation Resource Management System aims to address these challenges by continuously monitoring groundwater levels and irrigation flow through smart sensors. The system collects real-time data and sends it to a cloud platform using an IoT-enabled controller such as

ESP8266 or NodeMCU. The data can then be analyzed to detect patterns of water consumption and predict potential groundwater depletion trends.

Furthermore, data analytics can assist in optimizing irrigation schedules and water allocation based on actual field requirements. Farmers can access real-time information through a dashboard or mobile application, enabling them to take timely actions to conserve water and improve irrigation efficiency. Alerts and notifications can also be generated when groundwater levels drop below a critical threshold. By providing continuous monitoring and intelligent analysis of water resources, this system supports sustainable water management practices in agriculture.

## II. Literature Review

Several researchers have explored the application of Internet of Things (IoT) technologies to improve water management and irrigation efficiency in agriculture. Patel et al. proposed an IoT-based irrigation monitoring system that utilized soil moisture sensors and wireless communication modules to automate irrigation processes. The system reduced water wastage by activating irrigation only when soil moisture levels dropped below a predefined threshold. However, the system mainly focused on soil conditions and did not consider groundwater availability, which is an important factor in sustainable irrigation planning [5].

In another study, Kumar and Singh developed a groundwater monitoring system using ultrasonic sensors and GSM communication to measure borewell water levels and transmit data to farmers through mobile alerts. Although the system enabled remote monitoring of water levels, it lacked integration with irrigation management systems and did not provide predictive analysis for groundwater depletion. As a result, farmers could monitor water levels but were unable to optimize irrigation based on long-term water availability trends [12].

Rao et al. implemented a wireless fertigation system integrating soil moisture sensors and automated valves. Although the system improved irrigation accuracy, it lacked cloud-based analytics for long-term data evaluation and predictive nutrient management. More recent research has begun incorporating machine learning techniques to estimate nutrient requirements based on historical crop performance. While these approaches show promise, many systems require high computational resources and remain unsuitable for small-scale or resource-limited farming environments [4].

Similarly, Sharma et al. proposed a smart irrigation framework that combines IoT sensors with cloud computing to monitor soil moisture, temperature, and water flow. The system provides real-time monitoring through a mobile dashboard and helps farmers manage irrigation more efficiently. However, the framework mainly focuses on surface irrigation parameters and does not include groundwater depletion analysis or water resource forecasting [7].

Gupta and Verma developed a water management framework using IoT and cloud computing to monitor irrigation flow rates and environmental conditions. The system allowed real-time data visualization and provided alerts when abnormal water usage was detected. However, the system mainly focused on irrigation flow monitoring and lacked mechanisms for predicting groundwater depletion trends [2].

Recent studies have also explored the integration of data analytics and artificial intelligence techniques for agricultural water management. Li et al. proposed a smart irrigation decision support system that analyzes historical environmental data to optimize irrigation schedules. Although the system demonstrated improved water efficiency, its implementation required advanced computational infrastructure, making it less practical for small-scale farmers [10]. Therefore, there is a need for an integrated solution that combines groundwater monitoring, irrigation flow measurement, and data-driven analytics to support efficient water management.

## III. Existing System

Traditional irrigation systems generally rely on manual monitoring and fixed irrigation schedules. Farmers typically operate irrigation pumps based on experience or visual observation of soil conditions. In some modern implementations, basic automation systems are used where soil moisture sensors detect the moisture level in the soil and control irrigation pumps automatically through a microcontroller.

In the existing IoT-based irrigation systems, sensors such as soil moisture sensors, temperature sensors, and humidity sensors are connected to a microcontroller like Arduino or NodeMCU. These sensors collect

environmental data from the agricultural field and transmit the information to a cloud platform through wireless communication. Based on the sensor readings, the system can automatically switch the irrigation pump on or off using a relay module.

Although these systems improve irrigation efficiency compared to traditional methods, most existing systems mainly focus on soil moisture monitoring and basic irrigation automation. They often do not monitor groundwater availability in borewells or analyze long-term water usage trends. As a result, farmers may still extract groundwater without understanding its depletion patterns.

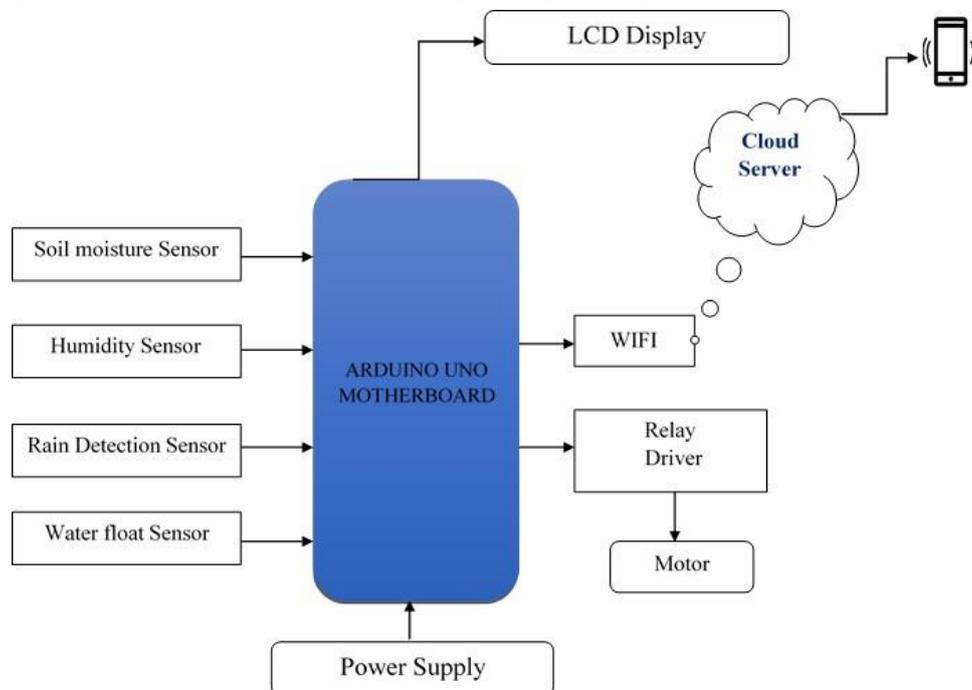


Fig. 1. Block diagram of existing system.

The existing irrigation monitoring system typically consists of the following components: (1) Sensors — soil moisture sensors and environmental sensors measure soil water content and environmental conditions; (2) Microcontroller Unit — a controller such as Arduino or NodeMCU processes the sensor data; (3) Communication Module — Wi-Fi or GSM modules transmit the collected data to a cloud server or mobile application; (4) Relay Module — used to control the irrigation pump based on sensor readings; (5) Water Pump/Irrigation System — supplies water to crops when irrigation is required; and (6) Cloud Server/Mobile Application — displays real-time data and allows farmers to monitor irrigation status remotely.

The typical outputs produced by existing irrigation systems include soil moisture level readings displayed on a mobile application or dashboard, automatic ON/OFF control of irrigation pumps based on moisture thresholds, real-time monitoring of environmental conditions such as temperature and humidity, and basic alerts or notifications sent to farmers when irrigation is activated. However, the system generally does not provide groundwater level monitoring, predictive analytics for water depletion, or optimized water allocation strategies, which limits its effectiveness in long-term water conservation.

#### IV. Proposed System Methodology

The proposed IoT-Based Groundwater and Irrigation Resource Management System is designed to monitor groundwater levels and irrigation flow in real time while optimizing water usage in agricultural fields. The system integrates multiple sensors, an IoT-enabled microcontroller, and cloud-based data analytics to support efficient water management and sustainable irrigation practices.

In this system, sensors continuously measure parameters such as borewell water level, soil moisture, and irrigation flow rate. These sensor readings are processed by an IoT microcontroller such as ESP8266 or NodeMCU, which transmits the data to a cloud platform through wireless communication. Farmers can access this information through a web dashboard or mobile application. The system also analyzes collected data to detect water usage patterns and predict possible groundwater depletion trends. Based on these insights, the system can recommend optimal irrigation schedules or automatically control irrigation pumps

using a relay module. Alerts can also be generated when groundwater levels fall below a predefined threshold, helping farmers take preventive actions.

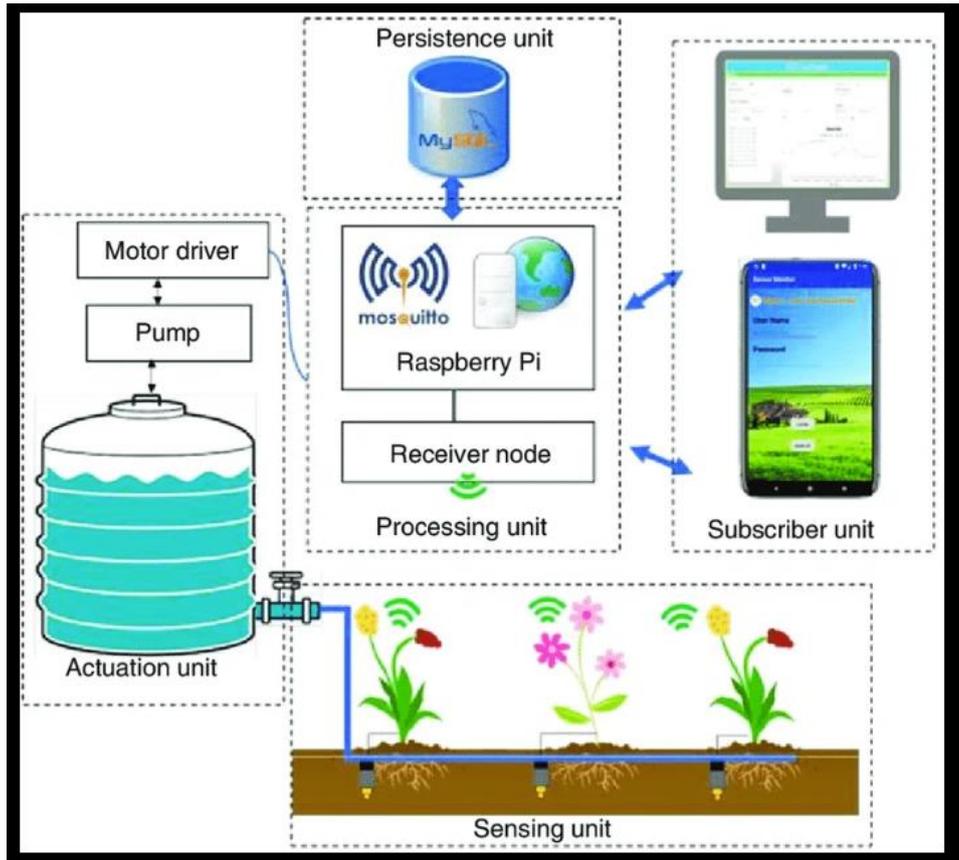


Fig. 2. Existing system setup.

The system workflow is as follows: (1) Sensors continuously collect data on groundwater level, soil moisture, and water flow rate; (2) The ESP8266 microcontroller processes the sensor data; (3) The collected data is transmitted to the cloud platform via Wi-Fi; (4) Data analytics evaluate historical and real-time data to identify water usage patterns and groundwater depletion trends; (5) If soil moisture is low, the system automatically activates the irrigation pump through a relay; (6) Farmers receive alerts and monitoring updates through a mobile application or dashboard; and (7) Data analytics facilitate predicting groundwater depletion trends.

## V. Results and Discussion

The developed IoT-Based Groundwater and Irrigation Resource Management System was tested under prototype conditions to evaluate its performance in monitoring water resources and controlling irrigation automatically. The system successfully collected data from sensors such as the soil moisture sensor, water level sensor, and water flow sensor and transmitted the information to the cloud platform through the ESP8266 module.

During the testing phase, the soil moisture sensor accurately detected variations in soil moisture levels. When the moisture level dropped below the predefined threshold, the microcontroller activated the relay module, which turned on the irrigation pump. Once the soil moisture reached the required level, the pump was automatically turned off. This automated process helped maintain optimal soil moisture for crop growth while preventing unnecessary water usage.

The ultrasonic water level sensor was used to monitor the borewell or water tank level. The system successfully detected changes in water levels and generated alerts when the water level dropped below a safe limit. This feature helps prevent excessive groundwater extraction and encourages efficient water management practices. The water flow sensor measured the amount of water supplied during irrigation. The collected data helped in estimating water consumption and identifying irrigation patterns. This information can be further used for analyzing irrigation efficiency and planning better water allocation strategies.

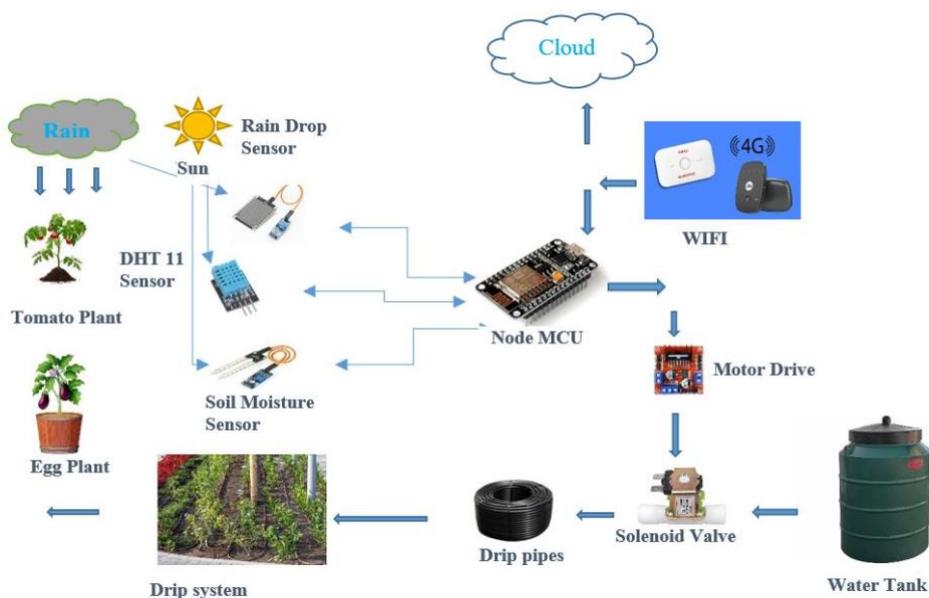


Fig. 3. Proposed system setup.

### 5.1 Experimental Setup

The proposed IoT-Based Groundwater and Irrigation Resource Management System was implemented using an IoT-enabled microcontroller and multiple sensors to monitor irrigation and groundwater parameters. The prototype includes sensors for measuring soil moisture, borewell water level, and irrigation water flow rate. These sensors are connected to a microcontroller such as ESP8266/NodeMCU, which collects sensor data and transmits it to a cloud-based platform through Wi-Fi connectivity.

A relay module is used to control the irrigation pump automatically based on soil moisture conditions. When the soil moisture level falls below the predefined threshold, the relay activates the pump to start irrigation. Once sufficient moisture is detected, the pump is automatically turned off. At the same time, the water level sensor monitors groundwater availability to prevent excessive extraction.

### 5.2 System Output

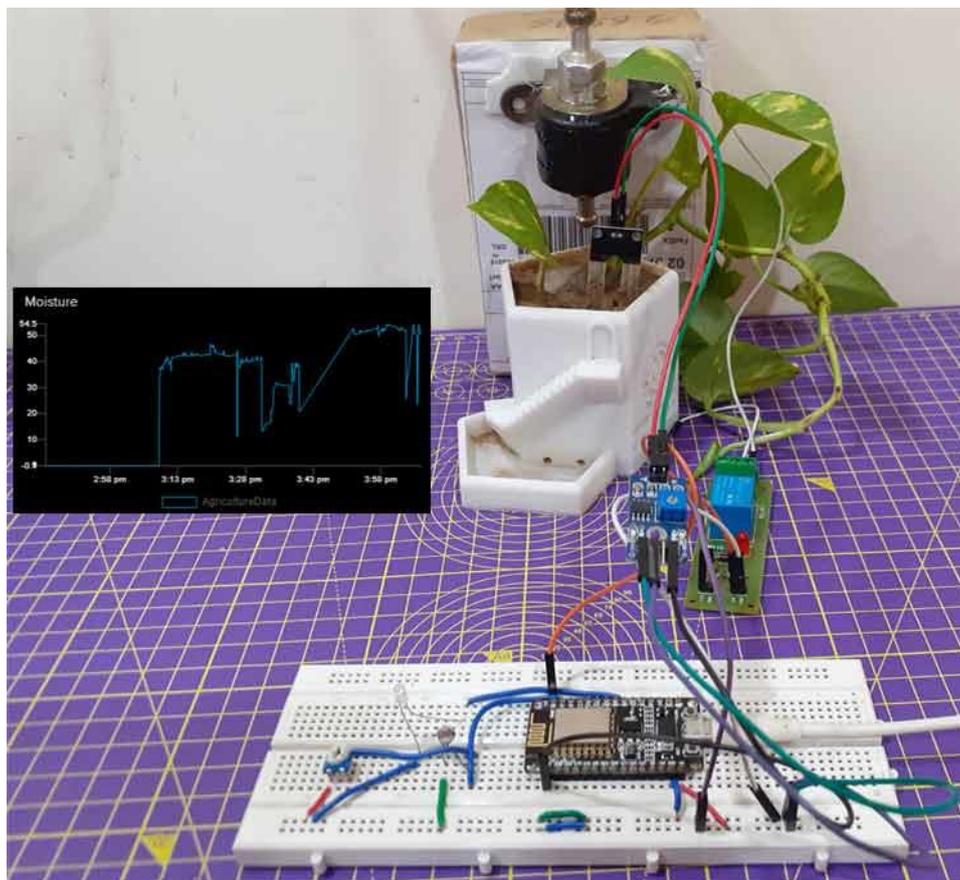


Fig. 4. Output setup connecting with software.

The prototype system generates the following outputs: (1) Real-Time Sensor Monitoring — the system continuously measures soil moisture, water level, and irrigation flow rate, which are transmitted to a cloud platform viewable through a dashboard or mobile application; (2) Automatic Pump Control — when soil moisture falls below the threshold value, the system automatically activates the irrigation pump using the relay module, and turns it off when adequate moisture is detected; (3) Groundwater Level Monitoring — the ultrasonic water level sensor monitors the borewell water level and prevents excessive extraction by providing alerts when levels fall below a critical limit; (4) Water Usage Analysis — the flow sensor measures the amount of water used for irrigation, enabling evaluation of irrigation efficiency and optimization of water usage; and (5) Alert and Notification System — farmers receive notifications when groundwater levels are low or when irrigation is activated, allowing better decision-making and monitoring.

### 5.3 Discussion

The experimental results demonstrate that the proposed system effectively monitors groundwater levels and irrigation parameters in real time. By integrating IoT sensors with wireless communication and cloud monitoring, the system enables farmers to track water usage and irrigation status remotely. The automatic pump control mechanism helps reduce water wastage and improves irrigation efficiency.

Additionally, the continuous monitoring of groundwater levels provides valuable insights into water availability and depletion trends. This information can assist farmers and agricultural planners in implementing sustainable water management strategies. Compared with traditional irrigation methods, the proposed system offers improved efficiency, automation, and long-term water conservation benefits. Overall, the prototype successfully validates the feasibility of an IoT-based approach for groundwater monitoring and irrigation resource management in modern agriculture.

## VI. Conclusion

The proposed IoT-Based Groundwater and Irrigation Resource Management System provides an efficient and reliable solution for monitoring and managing water resources in agricultural environments. The system integrates various sensors, an IoT-enabled microcontroller, and wireless communication technology to continuously monitor important parameters such as soil moisture levels, groundwater

availability, and irrigation flow rate. By collecting and transmitting real-time data to a cloud-based platform, the system enables farmers to monitor field conditions remotely and make informed decisions regarding irrigation practices.

The experimental results from the prototype implementation demonstrate that the system can effectively automate irrigation processes by activating the water pump only when soil moisture levels fall below a defined threshold. This automated control helps in reducing water wastage and ensures that crops receive the required amount of water at the right time. Additionally, the groundwater monitoring feature provides early warnings when borewell water levels decrease, helping prevent over-extraction of groundwater resources.

Another important advantage of the proposed system is its ability to record irrigation data over time. This data can be used to analyze water usage patterns and identify trends in groundwater consumption. Such information is valuable for improving irrigation scheduling and developing long-term water conservation strategies. Compared with traditional irrigation systems, the proposed IoT-based approach offers better monitoring, improved efficiency, and reduced manual intervention.

Furthermore, the system is designed to be cost-effective and scalable, making it suitable for small and medium-scale farmers. With the integration of future technologies such as machine learning, predictive analytics, and advanced IoT platforms, the system can further enhance water management by predicting irrigation requirements and optimizing resource allocation. In conclusion, the proposed system plays a significant role in promoting smart agriculture, sustainable groundwater management, and efficient irrigation practices, ultimately contributing to improved agricultural productivity and long-term environmental sustainability.

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