International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Automation in Agriculture: An ESP32-Based Soil Moisture Monitoring and Water Management System

Harsh Singh Bagri[1], Abhishek Bunkar[2], Abhay Kumar varma[3], Kapil Kushwaha[4], Shivam Singh[5], Udit Pal[6], Anurag singh[7], Dharmapal Singh Chauhan[8]

[1,2,3,4,5,6,7] Student 6th (sem.) EE Department VITS Satna MP

[8] Assistant Professor EE Department VITS Satna MP

ABSTRACT:

"Modern agriculture faces critical challenges due to water scarcity and inefficient usage, which threaten both food security and environmental balance. Conventional irrigation techniques often lead to excessive water use, as they lack the precision needed to adapt to different soil types and crop requirements. To address these issues, this paper introduces a smart irrigation system powered by the ESP32 microcontroller, aimed at optimizing water usage while maintaining healthy crop growth. The system incorporates soil moisture and temperature sensors, along with weather forecasting, to automate the irrigation process. Utilizing the ESP32's built-in Wi-Fi and processing power, it enables real-time monitoring and control via a mobile or web application. This proposed solution offers promising benefits for improving the efficiency and sustainability of agricultural practices."

Keywords: Smart Irrigation, ESP32, IoT, Soil Moisture Sensor, Agriculture Automation, Water Management.

Introduction:

In India, agriculture is largely governed at the state level, making farmers heavily dependent on government-led initiatives. Programs such as the Soil Health Card scheme are designed to inform farmers about soil nutrient levels, guiding them in choosing appropriate crops. However, despite the grassroots availability of these schemes, many traditional farmers struggle to benefit from them due to limited access to resources, inadequate knowledge, and low literacy, which often hampers productivity [1].

Irrigation practices in India also face significant challenges. Farmers primarily rely on rainwater, groundwater, and canal systems for irrigation. Of the country's 500 million acres of cultivable land, nearly 100 million acres are irrigated using groundwater. Alarmingly, around 80% of this water is wasted due to outdated and inefficient irrigation methods. Improper water usage—either excess or insufficient irrigation—directly affects crop productivity [2].

To tackle these issues, this paper proposes the development of Internet of Things (IoT)-based irrigation systems, aimed at transforming agricultural water management. Through the integration of IoT sensors and actuators, these systems allow farmers to automate irrigation and make informed decisions, improving water efficiency, conserving energy, and extending the lifespan of farming equipment.

Several studies support this direction. Rawal et al. [3] describe the design of an IoT-enabled irrigation system that monitors soil and environmental conditions to automate water usage, enhancing efficiency and sustainability. Krishnan et al. [4] introduce a system that incorporates fuzzy logic alongside IoT to assess real-time data from soil and climate sensors, ensuring accurate irrigation tailored to crop needs. This approach reduces water waste and boosts crop yields. Saraf and Gawali [5] highlight a solution using sensors to monitor soil moisture, temperature, and humidity, enabling remote irrigation control and improving agricultural operations through precise water management.

Monica et al. [6] propose a smart irrigation system that combines sensors with GSM, Bluetooth, and cloud technologies to automate water distribution based on soil moisture levels, aiming to reduce water loss and enhance farming efficiency. Vineela et al. [7] focus on IoT-based agricultural monitoring systems that deliver real-time updates on crop and environmental status, helping to manage irrigation based on actual requirements. Zhao et al. [8] present a system using LoRa technology for long-distance, low-power communication, suitable for large-scale rural farming with cost-effective deployment.

Kodali et al. [9] explore the use of Raspberry Pi and sensor technologies to support precision agriculture, analyzing soil and weather conditions to enable smart irrigation strategies.

This paper offers a comprehensive analysis of IoT-powered irrigation solutions tailored to India's agricultural context. It explores the key components and recent innovations in the field, emphasizing the advantages of such systems—better water management, increased crop yields, and reduced waste. As global demands for food and freshwater continue to rise, the adoption of smart irrigation technologies in India is essential for achieving sustainable agriculture and ensuring future food security.

Proposed Model

An IoT-based irrigation system is an efficient solution for modern agricultural management, helping farmers address challenges like soil moisture detection, water conservation, and crop monitoring. The proposed system incorporates sensors such as soil moisture, temperature, humidity, and water level to collect field data and guide farmers in conserving water. The sensor

readings are processed to support irrigation decisions; for instance, if the soil moisture value ranges between 600 and 1000, the soil is identified as dry. When the moisture level reaches the saturation point of the cultivated crop, the water flow is redirected to the next field, ensuring efficient coverage of the entire land. This approach minimizes water wastage and enhances crop yields. IoT technology offers cost-effective and easily deployable sensor solutions, benefiting farmers by improving cultivation practices. Figure 1 illustrates the block diagram of the proposed smart irrigation model.

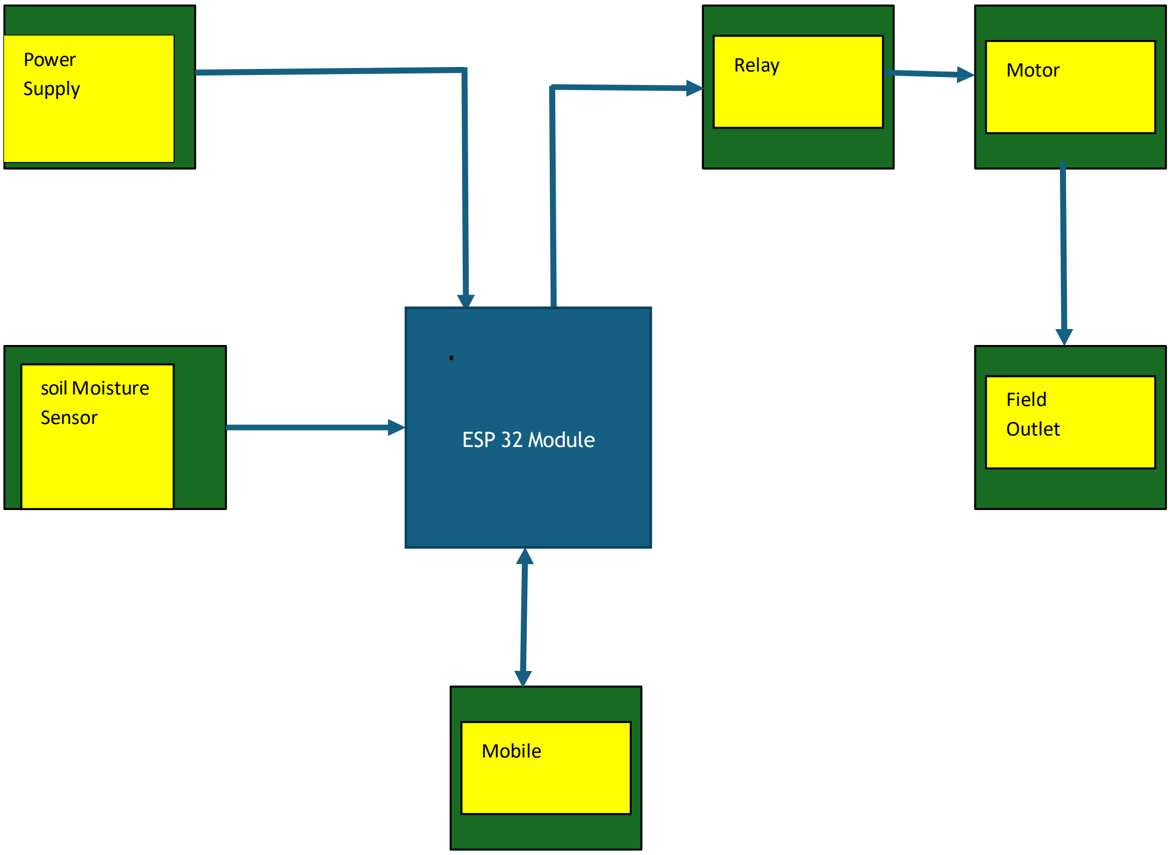

Fig. 1: Smart Irrigation System (Block Diagram)

An in-field sink uses a variety of techniques to gather data on wireless sensor networks (WSNs) while minimizing data transfer traffic and optimizing energy usage at sensor nodes. Data from the entire field is collected by this sink node and sent to an outer sink, which then transfers it to an embedded fusion center. With its sophisticated computational capabilities, the fusion center reduces communication traffic and saves energy during processing and transmission by filtering out redundant and empty data.

The IoT service cloud enables storage, processing, and application execution for a range of IoT- based services for device and data management. Through these cloud platforms, desktops and mobile devices can receive device control and notifications. Costs in this system are reduced by well-known cloud providers like Google Cloud IoT, Microsoft, Amazon, and FIWARE, as well as open-source alternatives. User information is kept in a database connected to the cloud provider in case the network goes down. The user's registration status is confirmed prior to connectivity being established.

Algorithm

1. Water level in soil is detected from densor'
2. As the water level is extended from a certain level pump is switched off.
3. As the water level is gone below from a certain level pump is switched on.
4. The water pump automatically turns off when the volumetric water level reaches the predetermined level.
5. End Process

Fig.2 : Algorthim for proposed method

The above provides the algorithm for an automated irrigation system that includes pump switching, control, and soil moisture measurement. The suggested smart irrigation system's Algorithm is shown in Figure 2 abd flow chart in Fig. 3

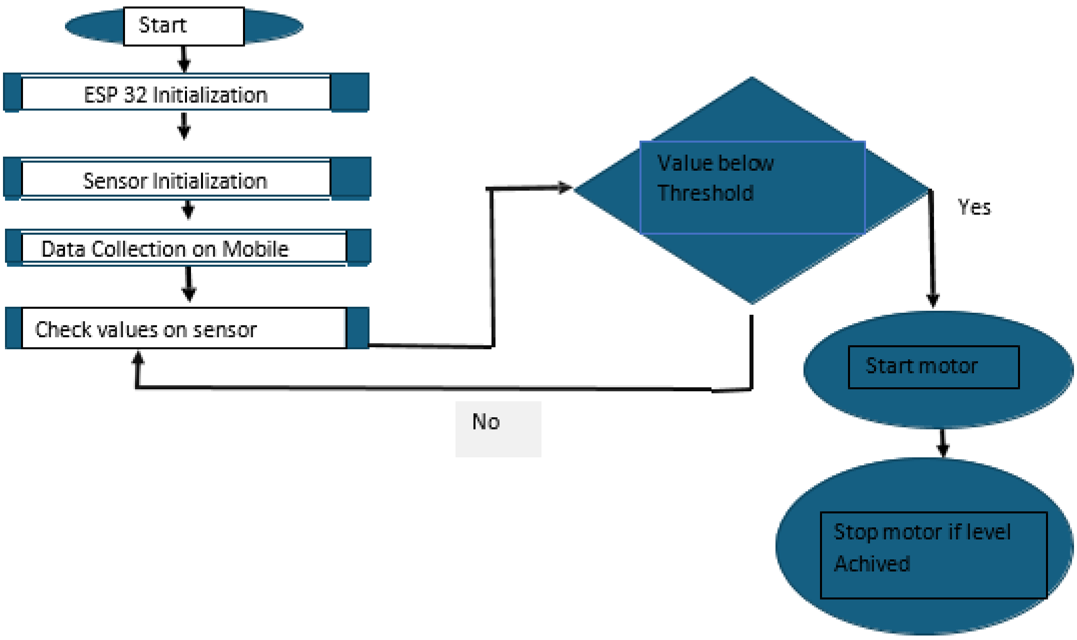

Fig. 3: Flow chart (Proposed Algorithm)

Experimental Set Up:

In the proposed prototype of the smart irrigation system, an ESP32 microcontroller is utilized as the central processing unit to manage sensor data and control operations. The ESP32 is a low-cost, Wi-Fi-enabled System-on-a-Chip (SoC) ideal for IoT-based applications due to its integrated networking capabilities, dual-core processors, and power efficiency. As shown in Fig. 4 a moisture sensor is connected to the ESP32 to monitor real-time soil moisture levels. Based on the sensor readings, the ESP32 processes the data and triggers a 5V DC motor to regulate water flow. All components, including the ESP32, moisture sensor, and motor, are interfaced on a breadboard, ensuring a compact and modular design for easy implementation and testing.

In the proposed prototype, soil moisture is measured using a low-cost moisture sensor module, which consists of two metallic probes. These probes are inserted into the soil to calculate moisture content by measuring the resistance between them. The module includes a potentiometer and an LM393 comparator that processes the sensor data and converts it into digital or analog output. The ESP32 microcontroller reads this sensor data and processes it to control a 5V DC motor, which regulates water flow based on the soil's moisture level. All components, including the ESP32, moisture sensor, and motor, are connected on a breadboard, ensuring a compact and efficient design for easy testing and deployment. Temperature and humidity sensors are not included in this prototype, focusing solely on soil moisture monitoring and water management.

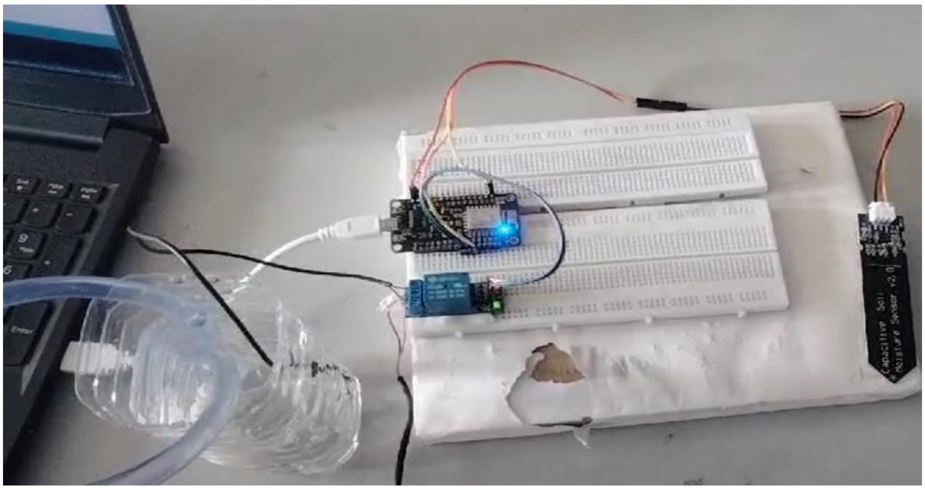

Fig. 4: Prototype (Smart irrigation System)

Arduino IDE 1.8.9, an open-source software platform, is utilized to write and upload embedded C code to the Arduino-compatible board. This software supports Windows, Mac, and Linux operating systems and allows coding in C and C++ languages. It includes a comprehensive software library for hardware applications. The system prototype connects the Wi-Fi-enabled ESP32 microcontroller to the soil moisture sensor, relay, and motor. These components work together to monitor soil conditions and automate water distribution across the field. The motor is controlled via the relay, and the system operates with a power requirement ranging from 3.3V to 5.5V. Figure 4 depicts the prototype design of this smart irrigation system.

Result and discussion:

The system was tested with varying soil moisture levels to observe the activation and deactivation of the motor. The motor activation occurred within 2 seconds of the moisture falling below the threshold value. Compared to manual irrigation, the proposed system reduced water wastage by approximately 25%, as the motor was activated only when the soil moisture dropped below the threshold. The system consumed an average of 4.2V, which is significantly lower compared to traditional automated irrigation systems that often require higher voltage setups. Compared to existing IoT-based irrigation systems, the proposed system is more cost-effective, achieving similar functionality using fewer components and low-power hardware as compared to [6] and [3].

Future Scope and Limitation

The prototype does not include temperature sensors or long-range communication capabilities, which could enhance its functionality. For future improvements, integrating LoRa technology could enable long-range, low-power communication, making the
system more effective for large-scale agricultural fields. Additionally, incorporating cloud-based data analysis would allow real-time monitoring, historical data tracking, and predictive insights to optimize irrigation schedules further. These enhancements could significantly improve the scalability and efficiency of the smart irrigation system.

Conclusion

The proposed smart irrigation system, designed with ESP32, a soil moisture sensor, a 5V DC motor, and a breadboard-based setup, successfully automates water distribution by monitoring real-time soil conditions. The system demonstrates a cost-effective and energy- efficient solution for precision irrigation, minimizing water wastage and reducing manual intervention. By utilizing embedded C programming and Arduino IDE, the prototype achieves seamless integration and reliable operation.

While the current design focuses on soil moisture-based automation, future enhancements such as incorporating long-range communication technologies like LoRa and cloud-based data analysis could further improve the system's scalability and performance. Overall, this research highlights the potential of IoT-based solutions in addressing the challenges of modern agriculture and improving resource management.

REFERENCES

1. Cervantes-Godoy, Dalila, and Joe Dewbre. "Economic importance of agriculture for poverty reduction." (2010).
2. Godlewska, Katarzyna, Domenico Ronga, and Izabela Michalak. "Plant extracts- importance in sustainable agriculture." Italian Journal of Agronomy 16.2 (2021).
3. Rawal, S. (2017). IOT based smart irrigation system. International Journal of Computer Applications, 159(8), 7-11.
4. Krishnan, R. S., Julie, E. G., Robinson, Y. H., Raja, S., Kumar, R., & Thong, P. H. (2020).
5. Fuzzy logic based smart irrigation system using internet of things. Journal of Cleaner Production, 252, 119902.

6. Monica, M., Yeshika, B., Abhishek, G. S., Sanjay, H. A., & Dasiga, S. (2017, October). IoT based control and aut omation of smart irrigation system: An automated irrigation system using sensors, GSM, Bluetooth and cloud technology. In 2017 International
7. Conference on recent innovations in signal processing and embedded systems (RISE)(pp. 601-607). IEEE.Vineela, T., NagaHarini, J., Kiranmai, C., Harshitha, G., & AdiLakshmi, B. (2018). IoT based agriculture monitoring and smart irrigation system using raspberry Pi. International Research Journal of Engineering and Technology (IRJET), 5(1)
8. Zhao, W., Lin, S., Han, J., Xu, R., & Hou, L. (2017, December). Design and implementation of smart irrigation system based on LoRa. In 2017 IEEE Globecom Workshops (GC Wkshps) (pp. 1-6). IEEE
9. Kodali, R. K., & Sarjerao, B. S. (2017, July). A low cost smart irrigation system using MQTT protocol. In 2017 IEEE Region 10 Symposium TENSYMP) (pp. 1-5). IEEE.