International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 2, Mar-Apr 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

IoT-Enabled Crop and Soil-Aware Smart Irrigation System

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Abstract:

Agriculture is largest occupation in India; many peoples of India depend on agriculture for their living. But there are multiple problems that farmers faces in this era of technology such as unpredictable rain, inefficient irrigation practices, and no knowledge of soil and its nature. Most of methods that are used today are based on human judgment, which can cause many problems like insufficient watering, over watering which does effect in the crop health and overall yield.

This project is specifically made to address this problem with help of IoT-based devices that will read and make decision on basis of Realtime data from the fields. The project used soil moisture, temperature and humidity sensors with the weather API to get accurate data and decide the water requirement. This system is Crop-specific coefficient (Kc) is also used to increase the accuracy of the irrigation planning.

Because most of the farmers are situated in the rural area and there is very less connectivity, so this system supports both mode of communication like GSM for SMS and a mobile app which is connected with a cloud database to counter the communication problem in rural areas. A relay module is used to control the water pump so the farmer can control pump or whole irrigation system remotely.

More features like real-time monitoring, alert notifications, and dry soil alert are integrated for system reliability and safety. The prototype was tested under multiple different conditions, and it did show effective performance in reducing water wastage and improving irrigation efficiency. Overall, the system we have proposed provide a cost-effective, user-friendly, and more practical solution for modern agriculture, which will help farmers make better decisions.

Keywords — IoT, Smart Irrigation, ESP32, Soil Moisture Sensor, Automation, GSM Communication, Weather API, Precision Agriculture.

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I. INTRODUCTION

Agriculture is one of the most important sectors of India, it does contribute greatly to the economy and supports millions in India. Even though India is grown in the technology sector very much still in agriculture the irrigation in most of the region is done by manual methos. Farmers often depends on personal experience or judgement to decide whether to water the crop or not and also how much to irrigate, which may not always be accurate.

Multiple factors such as unpredictable rain, limited water in multiple regions, and inconsistent electricity make the irrigation very difficult and challenging. As a result, crop may suffer due to over-irrigation or insufficient watering, which leads to reducing the overall yield.

To overcome this problem, there is a need of a system that can assist the farmers to make decisions based of the data like weather, soil moisture and crops need of water. The integration of Internet of Things (IoT) technology will provide accurate and continuous monitoring of the soil and environment.

In this project, the sensors are used to collect the Realtime data like soil moisture, temperature and humidity also the crop-specific coefficient (Kc) and weather forecast are used to calculate accurate water requirement. Unlike older systems, which rely only on the moisture levels, this system considers multiple factors to improve the irrigation.

The system also use dual way of communication for better connectivity in rural areas where Wi-Fi or high-speed internet is not available in such region, we are going to use GSM module that will use SMS to send alerts and data to user's devices. This will help as a failsafe in case of there is a problem with network or internet.

The main goal of the project is to make a simple cost-effective and more practical solution to improve water management in agriculture and reduce farmers effort and improve overall crop productivity.

II. Literature Survey

Smart irrigation systems using IoT and cloud computing have been widely studied. In [1], a GSM-based irrigation system was proposed using sensors for real-time field monitoring. It enabled remote control and alerts but was limited to fixed soil moisture thresholds and lacked weather or crop-specific adaptability. Rezwan Hossain Naeem et al., "Smart Irrigation System Using IoT and Cloud Computing," IEEE ICREST, 2021.

In [2], a smart irrigation system integrating sensors with a cloud database was presented for automated irrigation and monitoring through a mobile application. However, it did not include crop coefficient (Kc) or evapotranspiration (ET) models for precise water prediction.

A crop-field monitoring and irrigation automation system using Arduino and GSM was introduced in [3]. The system improved automation but lacked weather data integration and scalability for different soil and crop conditions.

In [4], an automated irrigation system using IoT and wireless sensor networks was developed for large-scale irrigation. It reduced water usage but lacked real-time cloud integration and advanced scientific irrigation models.

Another system in [5] utilized Thing Speak and Blynk for cloud-based irrigation management. While it provided good automation, it relied heavily on internet connectivity, limiting its applicability in rural areas.

III. Related Work

In recent years, many systems have been developed to improve irrigation in agriculture. Some systems are very basic and use only soil moisture sensors. Other systems are more advanced and use IoT, cloud, and weather data.

From our study, we found that many existing systems work on simple logic. They turn the pump ON or OFF based on soil moisture values. This gives some level of automation, but it is not fully accurate. These systems do not consider crop type, weather changes, or future conditions.

Because of this, irrigation is not always correct. Sometimes more water is given and sometimes less. Also, performance can change depending on soil type and environment.

In our project, we tried to improve this. We used multiple sensors and also added crop-based calculation using FAO-56 ($ETc = ET_0 \times Kc$). This helps in calculating the actual water requirement.

We also added weather data and GSM support. So, the system can work even if internet is not available. This makes it more useful in rural areas.

Overall, compared to existing systems, our system is more practical. It considers multiple factors and is easier for farmers to use.

IV. Proposed System

We developed a smart irrigation system using IoT to improve the traditional irrigation methods.

Instead of relying only on experience or basic soil data such as soil moisture Our system uses multiple parameters including soil moisture temperature humidity to monitor the conditions. It also weather data and crop information.

The FAO-56 formula ($ET_c = ET_0 \times K_c$) Is also used to calculate exact water requirement for specific crop. Based on this the system automatically decides whether to irrigate or not and sets alert to the user this red over underwater and manual efforts.

The system proposed is also user-friendly allows farmers to control the pump through mobile application as well as SMS. It can also be used in the area where Internet connectivity is limited.

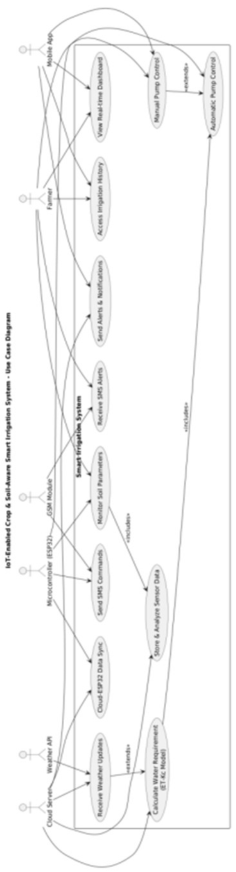


Fig 1. Use Case Model

The system works both online and offline. In the rural area Internet is not constantly available the system uses GSM module for SMS communication to transmit data directly to the user's device Other than that the data is also stored on cloud.

We used ESP32 as a main microcontroller It is connected with the sensors and relay. The data is transmitted through cloud or GSM the mobile application to display the data off sensors irrigation status and alerts in a user-friendly way.

In future the system can be extended with features like AI based prediction fertilizer control support of multiple fields add multiple languages We also include use case diagram to show purpose interaction and flow chart to explain the work process step by step

System Flowchart:

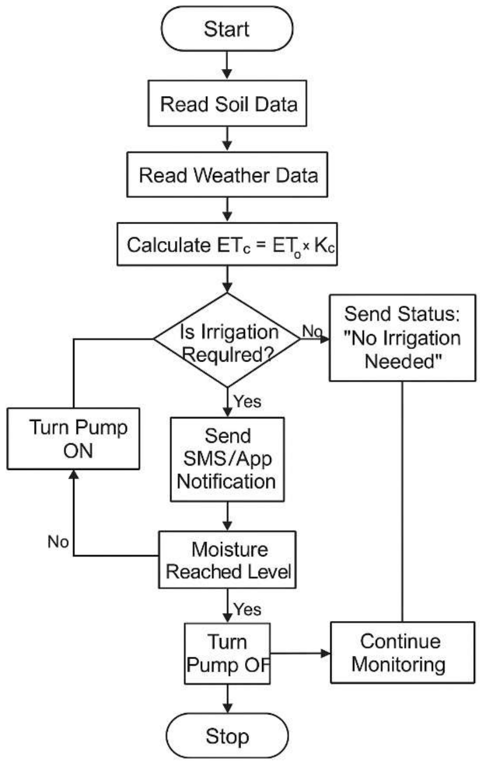


Fig 2. System Flowchart

V. FUNCTIONAL SCOPE

The main aim of our project is to automate and make irrigation process simpler. The system Collects filled data using sensors like soil moisture sensor, temperature sensor and humidity sensor.

This data along with crop value and data is used to calculate water requirement for a specific crop FAO-56 method. Based on this the ESP32 sets an alert to the farm then the farmer can act by turning ON or OFF pump.

The system supports both Wi-fi and GSM connectivity it allows users to send data to cloud directly through the Internet or the region where Internet is not available the data is set to the user's device directly through an SMS. The mobile device displays the data such as sensor values pump status and alerts.

Weather data is also included to avoid unnecessary irrigation It skips watering when rain is expected.

VI. COMPARISON WITH THE EXISTING SYSTEM.

There are multiple types of irrigation system used to each works different from the another.

- Manual Irrigation

The traditional method relays on the adjustment or experience it is required to be physically present at 1) the field, and this offer leads to over watering or underwater. 2)

- Timer-Based Irrigation

Water is supplied in fixed, but it doesn't submit take in consideration of soil condition or weather. So, the water is wasted in such conditions.

- Soil Moisture-Based Systems

Most of the systems designed for IoT based irrigation Based on soil moisture Which has a predefined threshold to activate or deactivate pump.

- Weather-Based Systems

In many systems it is based on weather API which only shows the if it's going to rain or not and based on that it doesn't decides whether to irritate or not.

- Proposed System

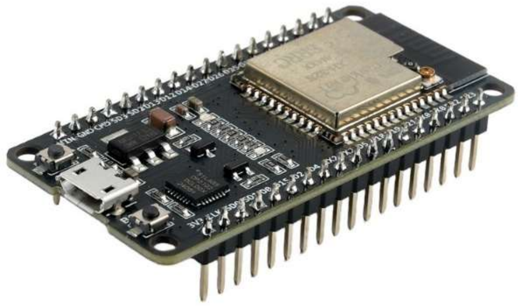
Our system combines multiple factors such Field data soil data, weather data (ET_0), crop value (Kc), using a FAO-56 method it calculates exact water requirements and when to water.

Our system also supports mobile application as well as SMS control, it works in both conditions if Internet is available and not because agriculture is done in a rural area where Internet connectivity is not always an option.

VII. HARDWARE USED

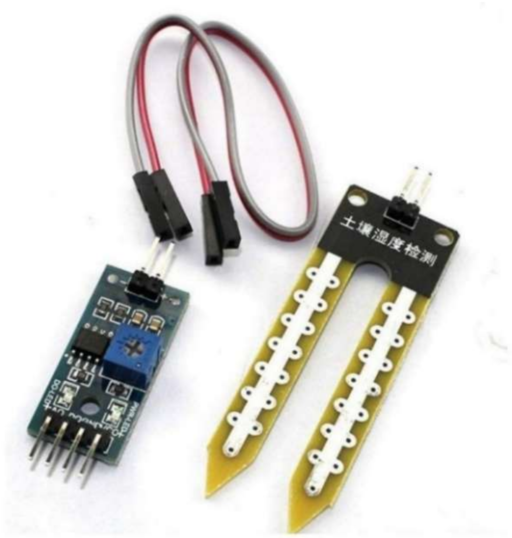
1. ESP32 Microcontroller

ESP32 microcontroller is the main part of the system It is used to control store and process data. Microcontroller is used to connect all the sensors and relay module together to control every aspect of the system.



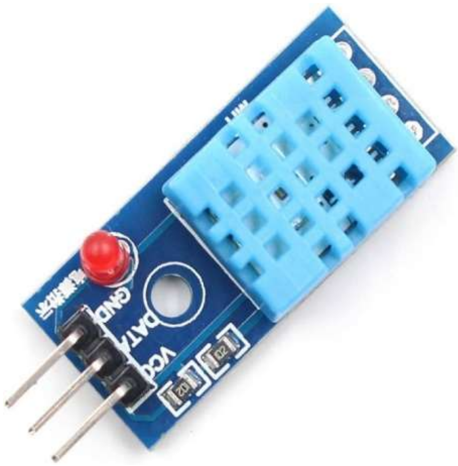
2. Soil Moisture Sensor

The soil moisture sensor is used to check the moisture level of the soil It is used to verify if the soil is dry or wet based on defined parameters



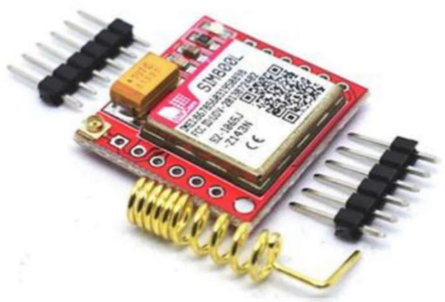
3. DHT11 Temperature & Humidity Sensor

The DHT 11 sensor is used to measure the temperature and humidity of the region it is used to calculate ET_0 value.



4. GSM Module (SIM800L)

The GSM module is used for communication via SMS or via Internet



5. Relay Module (5V)

A relay module is as a switch to turn ON or OFF pump the Relay audio receives the signal from the microcontroller and turn on or off the pump based the signal.

6. Water Pump

And this is a pump which is used to transfer water across the field.

VIII. CONCLUSION

In this project we have developed a smart irrigation system using IoT to improve the traditional method of irrigation and made it crop and soil away.

The system uses sensors such as Soil moisture humidity temperature along with weather API for weather forecast. Using the FAO-56 formula ($ETc = ET_0 \times Kc$), it calculates the required water and automatically sends the al two mobile devices.

We also added a GSM support allowing the user to control it from anywhere even from the area where Internet is not available such as rural areas where Internet connectivity is not constant The GSM module sends data from microcontroller to user via SMS and the data is processed locally in the mobile application.

Finally, the system was designed to be simple, practical and easier to use for every user.

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