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AUTOMATIC IRRIGATION USING SOIL MOISTURE CONTENT CONTROL

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Abstract-Efficient water management is essential in agriculture to optimize crop growth and conserve water resources. Traditional irrigation methods often result in over-irrigation or under-irrigation, leading to reduced crop yield, soil degradation and excessive water wastage. To address these challenges, this project proposes an Automatic Irrigation Control System that continuously monitors soil moisture levels and regulates water supply accordingly. The system consists of soil moisture sensors, micro-controllers (such as Nodemcu), a relay module, and an electric water pump. The sensors measure the moisture content in the soil in real-time, and when the moisture level drops below a predefined threshold, the micro-controller triggers the water pump to irrigate the field. Once the soil reaches the required moisture level, the pump is automatically turned off, preventing waterlogging and optimizing water usage. Additionally, the system can be enhanced by integrating Internet of Things (IOT) technology, allowing farmers to monitor and control irrigation remotely through a mobile application or web interface. By incorporating machine learning algorithms, the system can predict irrigation needs based on weather conditions, soil type, and crop requirements, further improving efficiency.This automated irrigation system provides several benefits, including water conservation, reduced labor costs, improved crop health and increased agricultural productivity. It is a cost-effective and scalabe solution suitable for small-scale farmers and large agricultural fields. With climate change and increasing water scarcity, such smart irrigation systems play a crucial role in sustainable agriculture and resource management.

Keywords: Moisture sensor, DHT11 sensor, Nodemcu micro-controller, Blynk Web Interface (IoT)

1. Introduction

Agriculture is one of the most critical sectors worldwide, playing a fundamental role in ensuring food security. However, traditional irrigation methods, which often rely on manual intervention, pose several challenges that affect crop productivity and resource efficiency. In conventional irrigation, farmers must monitor soil moisture levels manually and decide when and how much water to apply. This process is not only labour-intensive but also prone to inefficiencies such as over-irrigation or under-irrigation. Over-irrigation results in water wastage and can lead to soil degradation nutrient leaching and increased salinity. On the other hand, under-irrigation leads to water stress in plants, reducing crop yield and quality. Automatic irrigation systems have emerged as a promising solution to address these challenges. These systems leverage advancements in technology, particularly in sensors, microcontrollers, and the Internet of Things (IoT), to optimize water distribution. ByIncorporating soil moisture sensors, micro-controllers, and the Internet of Things (Iot), to optimize water distribution. By incorporating soil moisture sensors, temperature sensors, humidity sensors, and weather forecasting tools, automatic irrigation systems can monitor environmental conditions in real time. Based on the data collected, these systems use predefined algorithms to regulate water flow, ensuring that crops receive an adequate amount of water precisely when needed the adoption of automatic irrigation system has increased due to the growing emphasis on water conservation and sustainable agricultural practices. Many regions worldwide face water scarcity issues, making efficient water use a priority for both large-scale commercial farms and smallholder farmers. Furthermore, advancements in wireless communication and cloud computing have enhanced the capabilities of automated irrigation system, allowing remote monitoring and control via smartphones and computers. This integration of technology in irrigation not only reduces human intervention but also improves the overall efficiency of agricultural operations. Despite these advantages, the implementation of automatic irrigation systems presents certain challenges. High initial setup costs, maintenance requirements, and the need for the technical expertise may hinder widespread adoption, especially in developing regions. Additionally, variations in soil types, crop water requirements, and environmental conditions necessitate customized solutions for different agricultural settings. Therefore, research and development efforts continue to focus on improving the affordability, reliability, and adaptability of automatic irrigation systems to ensure broader implementation.

Water is a finite and precious resource and Efficient utilization in agriculture is crucial for sustaining food productions. Inefficient irrigations practices contribute significally to water wastage, soil degradation, and inconsistent crop yields. Traditional irrigation methods rely on manual operation, which not only demands significant labour but also lacks precision in water application. This imprecise approach results in either over-watering, both of which have determined effects on plant health and agricultural productivity. Over-watering leads to excess water percolation beyond the root zone, causing the leaching of essential nutrients from the soil. This not only affects plant growth but also results in groundwater contamination due to the runoff of fertilizers and pesticides. Moreover, excessive water application can create anaerobic soil conditions, leading to root rot and other plant diseases. Conversely, under-watering results in water stress, reducing plant growth and yield. Crops subjected to prolonged water deficiency may experience stunted growth, poor flowering, and lower fruit set, ultimately impacting agricultural output and profitability. Given the global concerns surrounding climate change and water scarcity, there is an urgent need for sustainable irrigation solutions that optimize water usage while maintaining or enhancing crop yields. Automatic irrigation systems provide a viable approach to addressing these issues by integrating technology to regulate water application efficiency. However, the high costs of advanced irrigation technologies and the complexity of their operation pose significant barriers to their adoption, particularly among small and medium-scale farmers. There is a critical need for the development of cost-effective, user friendly and adaptable automatic irrigation systems that can widely developed across diverse agricultural landscapes. To bridge the gap, the proposed project aims to design and implement an intelligent irrigation system that utilize IoT components for real time soil moisture monitoring and automated water control. By leveraging affordable sensors, micro-controllers and communication technology the system will provide an efficient and sustainable solution to irrigation management. The ultimate goal is to reduce water wastage, improve crop health, and minimize human intervention in Irrigation techniques.

Table 1.1 Water Requirement for Various types of soil

SOIL TYPE	**WATER REQUIREMENT (mm/year)**
Red Soil	600 - 800
Black Soil	500 - 700
Alluvial Soil	1000-1500
Laterite Soil	700 - 1000
Saline/Alkaline Soil	1200 - 1500
Sandy Soil	800 - 1200

Table 1.2 Water Requirement for Various types of crops

Crop	**Water Requirement (mm/Year)**
Rice (Paddy)	1000-1500
Groundnut (Peanut)	450-600
Cotton	600-800

Sugarcane	1500-2500
Maize (Corn)	500-800
Pulses (Chickpea, Red Gram, Green Gram)	300-500
Banana	1500-2000
Mango	500-800
Vegetables (Tomato, Chilli,)	400-800
Tobacco	600-800
Sorghum (jowar)	400-600
Sunflower	400-600
Pearl millet (bajra)	400-600
Oilseeds (soybean, Sunflower, etc.)	400-600

2. Literature Review

The field of automated irrigation systems has evolved significally over the years, driven by the need to improve water efficiency and reduce manual labour in agricultural operations. Traditional irrigation methods, such as flood irrigation and sprinkler systems, often result in water wastage due to insufficient distribution and evaporation losses. As a result, researchers and engineers have found on developing automated irrigation techniques that integrate sensors, controllers, and wireless communication technologies to optimize water use. One of the earliest approaches to automated irrigation involved timer-based systems. These systems operate on a pre-defined schedule, delivering water to crops at specific intervals regardless of real-time soil moisture levels. While timer-based systems reduce human intervention, they lack adaptability to changing environmental conditions. As a result, crops may still receive excessive or insufficient water, leading to potential stress and reduced yields.

1. **A Study On Smart Irrigation System Using Iot**R.Subalaxmi and Anu Amal, (2016).

The highlighted feature of this paper is how smartly and automatically supply the water to the agriculture fields without any obstruction and conveniently according to their need. For this, sensors used are soil moisture sensor and DHT11 humidity& temperature sensor. All the information is sent on the farmer mobile application using Wi-Fi Relay Module and Arduino UNO R3.

2. **Arduino Based Smart Irrigation System Using Iot**Karan Kanasara and Vishal Zaweri (2015)

The main objective of the smart irrigation system is to make it as innovative, user friendly, more efficient and time as well as cost saving than the existing system. By measuring the four parameters soil moisture, temperature, humidity and pH values and it also includes an intruder detecting system and by server updates farmers can know about their crop whenever they want.

3. **Smart Irrigation System**Archana and Priya, (2016)

This paper tells about using automatic micro-controller based rain gun irrigation system. In this system the irrigation will take place only when there will be intense requirement of water that will reduce water wastage and save a large quantity of water. These types of systems will bring a change in management of field resource where they can develop a software stack called Android. It is used for devices that include an operating system, middleware and key applications. The Android SDK will provide the tools and APIs which are necessary for developing applications on Android Platforms by using programming languages like Java. Now-a-days mobile phones have become an integral part, serving multiple needs of humans. This application uses GPRS feature of mobile phone for irrigation control system as solution. These systems can cover lower range of agriculture land and they economically not affordable.

4. **Monitoring Temperature and Humidity using Arduino Nano and Module-DHT11 Sensor with Real Time DS3231 Data Logger and LCD Display** Srivastava, D., Kesarwani, A., Dubey, S., Paul Kuria, K., Ochieng Robinson, O., Mutava Gabriel, M., & Shrestha, R. (2020).

The main objective of this project is to monitor humidity and temperature by using sensors like DHT11 sensor and micro-controllers like Arduino and it also includes an piezo buzzer which helps farmers to identify the temperature and humidity and this shows real time values through an LCD display.

5. **Crop Evapotranspiration** Allen, R. G., Pereira, S., Raes, D., & Smith, M. (1990).

This paper tells about the crop factors and weather parameters and environmental conditions and forecasts the requirement of water for different types of crops and tells about weathers suitable for crops and quantity of water required and different factors required for the crop to the farmer.

6. **Evaluation of Soil Moisture Sensors under Intelligent Irrigation Systems for Economical Crops**Marazky, A. E., Mohammad, F. S., & Al-Ghobari, H. M. (2011).

This paper maintains about the moisture content of the soil in different regions and different types of soils in arid regions by using soil moisture sensors which helps for better irrigation of the soils in arid regions and suitable for economical crops and it evaluate the soil moisture content by collecting data from other sites by installing soil moisture collecting sensors and intimate farmers about the soil moisture and suitable crop for that land.

7. **Crop response to climate change**Zinyengere, N., Crespo, O., &Hachigonta, S. (2013).

This paper tells us about the change of humidity and temperature in crop field during sudden climate change and tells us the response of the crop towards the climate change and intimate the farmer about the crop and precautions what should be taken for the betterment of the crop.

8. **Design of Remote Monitoring and Control System with Automatic Irrigation System using GSM-Bluetooth** Purnima, S.R.N. Reddy (2012)

This paper talks about controlling and monitoring of automatic irrigation without any human intervention by using some devices such as GSM (Global Systems for Mobile Communications), Bluetooth, remote monitoring, sensors, micro-controllers. This monitors the moisture content of the soil and collects the data with the help of micro-controllers and sends the data to the farmer through wireless communication with the help of GSM module it is connected to the Bluetooth of the mobile device or pc where the data can be visualized and the farmer can control the system from the mobile only can monitor the field remotely through the device with the help of GSM module.

9. **Irrigation Water Management: Irrigation Water Needs** Brouwer, C., &Heibloem, M. (1986).

This paper talks about how to manage the water required for irrigation and tells us the quantity of water required for the crop or field and reduces water shortage or scarcity by managing the quanity of water required for the field.

In contrast, sensor-based irrigation systems have gained prominence due to their ability to monitor soil and atmospheric parameters in real-time. These systems use soil moisture sensors, temperature sensors, and humidity sensors to collect data on environmentConditions.

The collected data is processed by a micro-controller, which then determines whether irrigation is necessary. Such systems have been shown to improve water use efficiency by applying water only when needed. However, many sensors-based systems still operate in isolation, lacking real-time optimization and data-driven decision-making capabilities.

Recent advancements in the Internet of Things (IoT) have introduced smart irrigation systems that leverage cloud computing, wireless communication, and data analytics. These systems enable remote monitoring and control, allowing farmers to access real-time information and make informed irrigation decisions. Despite these advancements, challenges remain in ensuring cost-effective implementations, seamless data transmission, and user-friendly interfaces.

3. Experimental Methodology

The automatic irrigation system was designed to continuously sense the moisture level of the soil. The system responds appropriately by watering the soil with the exact required amount of water and then shuts down the water supply when the required level of soil moisture is achieved. The reference level of soil moisture content was made to be adjustable for the three most common soil samples. The moisture sensors were designed using probes made from corrosion-resistant material which can be stuck into soil sample. Voltage levels corresponding to the wet and dry states of the soil sample were computed by measuring the resistance between the moisture detector probes and matching them to output voltages of a comparator circuit. A submersible low-noise micro water pump was developed to deliver the water to the appropriate parts of the soil.

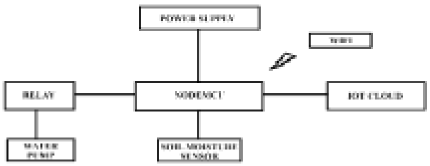

Fig 3.1 Flow chart of automatic irrigation

3.1 Materials and Equipment's

The implementation of an automatic irrigation system requires a combination of hardware and software components that work together to monitor environmental conditions and control water distribution efficiently. The key materials and equipment used in this project include the following:

i. Nodemcu Microcontroller

The **Nodemcu ESP8266** is a low-cost, WI-FI enabled microcontroller used for handling data processing and system control. It serves as the central unit responsible for collecting sensor data, processing it, and making decisions on irrigation scheduling.

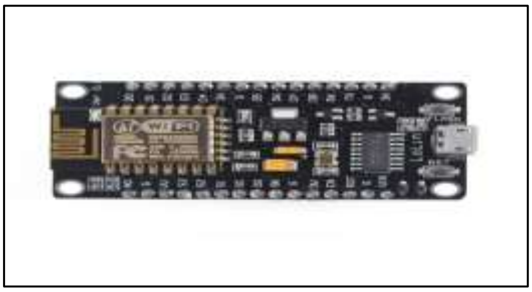

Fig 3.2 NodeMCU

ii. DHT11 Sensor (Temperature & Humidity monitoring):

The **DHT11 sensor** is used to measure **temperature and humidity** levels in the agriculture environment. These parameters influence soil moisture levels andplanttranspiration rates affecting irrigation requirements.

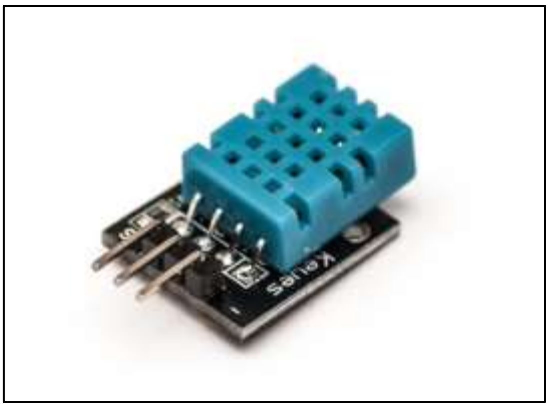

Fig 3.3DHT11 Sensor (Humidity&Temparature)

iii. Soil Moisture Sensor:

The **Soil Moisture Sensor** is a critical component that monitors soil moisture levels to determine when irrigation needed. This sensor operates based on changes in soil resistance or capacitance.

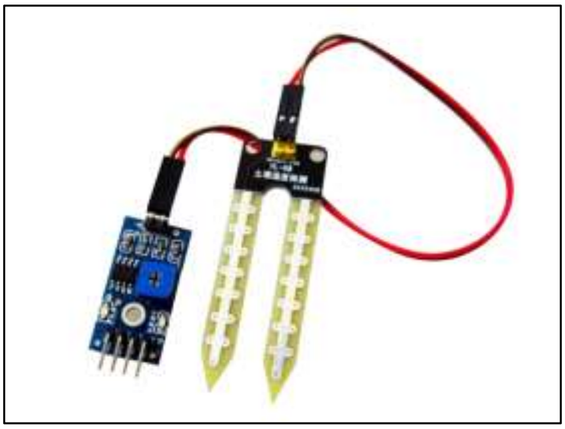

Fig 3.4 Soil moisture sensor

iv. Water Pump and Relay Module:

A DC water pump is integrated into the system to supply water when needed. The relay module acts as a switch to turn the pump on and off based on sensor readings.

Fig 3.5 Water pump

v. Blynk App (Real-Time Monitoring and User Control):

The **Blynk App** is an **IoT-based platform** that facilitates remote monitoring and control of the irrigation system. It enables real-time visualization of sensor data and allows users to adjust irrigation settings remotely.

3.2 Setup and Configuration

The hardware and software components are interconnected and configured to ensure accurate data collection and efficient irrigation control.

Hardware Setup:

The physical setup of the automatic irrigation involves the following steps:

i. Connecting Sensors to the Nodemcu Micro-controllers:

The DHT11sensor is connected to GPIO pins of the Nodemcu for temperature and humidity readings and the soil moisture sensor is connected to an analog pin, allowing continuous monitoring of soil conditions. The relay module is wired to the micro-controller and the water pump to enable automatic switching.

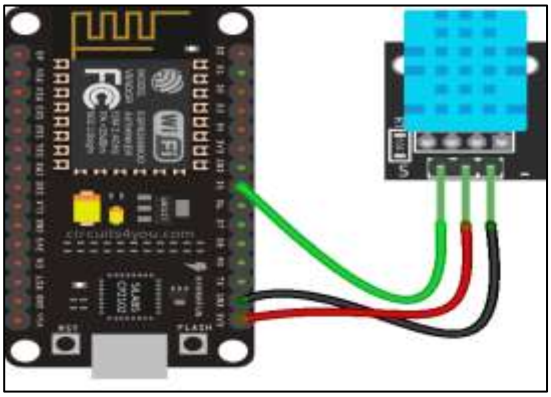

Fig 3.6 Connecting sensors

ii. Power Supply Configuration:

A 5V DC power source is used to power the Nodemcu and the water pump requires a 12V power supply, which is controlled via the relay module.

iii. Calibrating Sensors for Accuracy:

The soil moisture sensor is calibrated for different soil types to establish appropriate moisture thresholds. The DHT11 sensor is tested in controlled to verify accuracy.

iv. Relay Module and Pump Integration:

The relay is programmed to activate the pump when soil moisture levels drop below a defined threshold. And a delay mechanism prevents rapid switching, ensuring smooth operation.

Software Configuration:

The system is programmed using Arduino IDE with embedded C++ code to manage sensor readings, decision-making algorithms, and IoT connectivity.

i. Micro-controller Programming:

The Nodemcu reads sensor values at defined intervals and triggers the water pump with the help of relay if the soil moisture falls below the set threshold and the system logs all sensor data for future analysis.

ii. Blynk App Integration:

The micro-controller communicates with the Blynk cloud via WI-FI and displays live sensor readings on the app interface which can be manually override the automatic irrigation by the users if needed.

iii. WI-FI and Cloud Communication:

The system is connected to a local WI-FI network for enabling remote access. After the connection enabled the data is sent to the Blynk cloud for storage and visualization for the user.

3.3 Data collection and analysis

Data Acquisition Process:

i. Sensor Data Collection:

It takes readings from the DHT11 sensor and the soil moisture sensor which are recorded at 10-minute intervals and collects the status of water pump activation for monitoring the irrigation cycles.

ii. Environmental Monitoring:

In this data is collected under different weather conditions to observe variations in irrigation demand and weather conditions like rainfall and wind speeds.

iii. Data Storage and Logging:

The sensor readings are stored in the Blynk cloud for remote access and stores in local storage

on the micro-controller logs in case of any network failures.

Data Analysis Methodology:

The collected data is analyzed to identify trends and optimize irrigation efficiency.

i. Trend Analysis:

It examines variations in soil moisture levels for better understanding of different irrigation patterns and also anlyzes the correlations between temperatures, humidity, and water consumption.

ii. System Performance Evaluation:

The effectiveness of the automatic irrigation system is assessed based on water savings and plant health improvements. It compares pump activation with soil moisture levels for optimizing water usage.

iii. Error Detection and Troubleshooting:

It examines any anomalies in data transmission for identifying any connectivity issues, and calibration adjustments are made when sensor readings deviate from expected values.

4. Algorithms

Algorithms play a crucial role in ensuring the efficiency of an automatic irrigation soil moisture content control system. These algorithms help manage water distribution effectively by analyzing sensor data, adjusting irrigation schedules, and responding to environmental changes. These includes two major algorithms that are:

BMR Algorithm (Balanced Moisture Regulation Algorithm):

The **Balanced moisture Regulation (BMR)** Algorithm is a real-time optimization technique that calculates the optimal irrigation levels based on soil moisture sensor readings. It continuously monitors environmental conditions and dynamically adjusts water flow to prevent excessive or insufficient irrigation.

4.1 Working of BMR Algorithm:

I. Data collection from Soil Moisture Sensors:

Sensors are placed at different points in the soil measure moisture levels at regular intervals and micro-controller (Nodemcu) retrieves these readings and sends them to the central system.

II. Optimal Water Level Calculation:

The system determines the required moisture level based on plant type, soil characteristics, and climate conditions. If the moisture level falls below the threshold, the irrigation system activates the water pump and when the moisture level of the soil comes within range no irrigation is performed reducing the water wastage.

III. Real-Time Adjustments Based on Environmental Changes:

The Algorithm modifies irrigation timing accordingly to the sudden weather changes like rainfall or extreme heat and prevents unnecessary watering during rainy conditions.

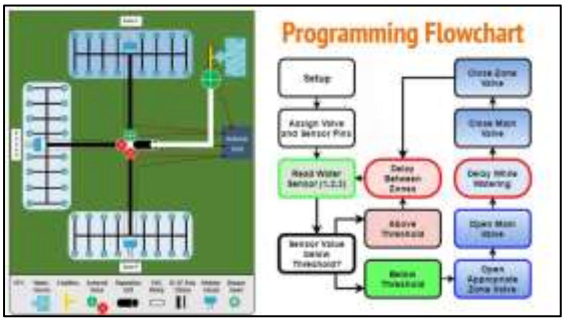

Fig 4.1BMR Algorithm (Balanced Moisture Regulation Algorithm)

BWR Algorithm (Balanced Water Regulation Algorithm):

The **Balanced Water Regulation (BWR)** Algorithm extends the functionality of BMR by incorporating a feedback loop that adjusts irrigation based on historical data and long-term moisture trends. Unlike BMR, which relies on real-time sensor readings, BWR optimizes water flow by considering past irrigation patterns and weather forecasts.

4.2 Working of BWR Algorithm:

The BWR algorithm follows an adaptive irrigation approach based on past data and prediction models:

i. Data Logging and Historical Analysis:

It records soil moisture levels and irrigation durations over weeks and months, and identifies trends in moisture retention and water absorption rates.

ii. Predictive Water Flow Adjustments:

It is based on past data; this system predicts future moisture fluctuations and continuous observe

Previous data. If there is any excessive watering is indicated in previous data, the algorithm reduces irrigation time, and the algorithm can increase irrigation frequency whenever the moisture retention is low.

iii. Feedback loop Optimization:

This system continuously learns from past irrigation cycles and adjust water distribution patterns to achieve optimal soil moisture levels.

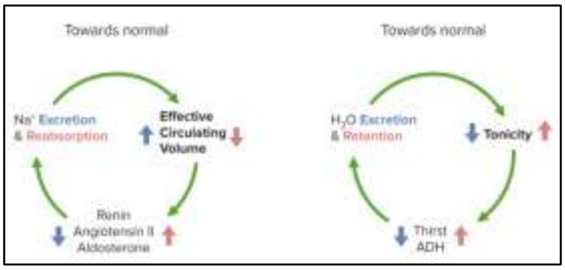

Fig 4.2BWR Algorithm (Balanced Water Regulation Algorithm)

5. Results and Discussions

Identified Patterns in Moisture Variation:

The soil moisture sensor played a crucial role in monitoring the moisture levels over time. Data collected at regular intervals important patterns in soil moisture fluctuations, including:

i. Moisture Levels Declining After Irrigation:

During this project we identified that the soil moisture level has increased significantly after irrigation and the rate of moisture loss varied depending on both the soil type and weather conditions. Different soil types, such as sandy or clay soils, impacted how quickly moisture was retained or drained. Additionally, factors like temperature, humidity and wind speed influenced the evaporation rate, further affecting the soil's moisture loss over time.

Irrigation Method	Average Water Usage per Week (Liters)	Reductionin Water Consumption (%)
Traditional Manual Irrigation	1000	0
Timer-Based Irrigation	850	15
Sensor-Based Automatic Irrigation (Proposed System)	750	25

ii. Daily Temperature and Humidity Effects on Soil Moisture:

Higher temperatures, particularly those above 30°C, led to faster evaporation, causing a grater decline in soil moisture levels. In contrast, lower temperatures at night helped reduce water loss, maintaining more stable moisture levels in the soil. Additionally, high humidity levels slowed down the rate of moisture depletion, which reduced the need for frequent irrigation.

iii. Influence of Rainfall on Moisture Content:

Rainfall events were automatically detected
By the system, which helped prevent unnecessary irrigation. When rain occurred, it significantly increased the soil's moisture content, thereby delaying the need for irrigation for several hours or even days.

iv. Variations in Moisture Retention Across Different Soil Depths:

The topsoil layer lost moisture rapidly, while the deeper layers retained it for a longer period. This pattern indicated that deep-rooted crops, which can access moisture from deeper soil layers, require less frequent irrigation compared to shallow-rooted crops that rely more on surface moisture.

parameter	Traditional irrigation	Automatic irrigation	improvement
Crop growth health	Inconsistent	Uniform	+30%
Water stress incidents	Frequent	Rare	-70%
Crop Yield (Kg per Hectare)	2500	3200	+28%

System Performance

The performance of the automatic irrigation system was evaluated based on three parameters:

5.1 Improved Water Efficiency:

One of the most significant benefits of the system was its ability to optimize water usage, leading to 25% reduction in water consumption compared to traditional irrigation methods. By ensuring that irrigation occurred only, when necessary, the system minimized water wastage. The integration of real-time monitoring and historical data analysis enabled precise irrigation scheduling, ensuring that water was applied efficiently and only when required.

Table 5.1 Water efficiency

The automatic system saved 250 litres of water per week, making it highly efficient for water-scarce regions.

5.2 Reduction in Human Intervention:

The system significantly reduced the need for manual monitoring and irrigation control.It resulted in a 40% reduction in manual intervention, as the system automatically managed irrigation based on soil conditions. Farmers no longer needed to manually check soil moisture levels or adjust irrigation schedules. Additionally, the Blynk App enabled remote monitoring, allowing farmers to control the system conveniently via a smartphone or tablet.

5.3 Enhancement in Crop Health:

Maintaining consistent soil moisture level is crucial for crop health, and the system was effectively ensured that crops received water at optimal times, preventing water stress. By preventing over-irrigation, the system reduced the risk of root and fungal infections. Additionally, uniform soil moisture distribution promoted better growth rates and higher yields, ultimately enhancing overall crop health and productivity.

Table 5.2 Crop Health Enhancement

These results confirm that the automatic irrigation system significally improved crop health and productivity.

6. Conclusion

The automatic irrigation system, utilizing real-time soil moisture sensors, significantly improves water use efficiency, reduces human intervention, and enhances crop health. Through data analysis, key patterns were identified, such as moisture levels declining after irrigation, with soil types and environmental factors like temperature, humidity, wind speed, and rainfall influencing moisture retention. The system reduced water consumption by 25% compared to traditional methods, minimized manual labour by 40%, and improved crop growth and yield by 28%, ensuring optimal irrigation schedules based on soil conditions. The integration of BMR and BWR optimization algorithms further enhances water distribution by minimizing over-irrigation and under-irrigation, adjusting to real-time environmental data. Additionally, the Blynk App enables remote monitoring and control, allowing for easy adjustments to irrigation schedules. Despite its success, recommendations include upgrading sensor accuracy, improving data transmission reliability, and customizing the system for different crop types. Future enhancements, such as integrating weather forecasting systems, implementing solar power, and incorporating multi-sensor capabilities, will optimize the system's performance. Overall, the system's efficiency, scalability, and ability to adapt to varying conditions position it as a promising solution for modern farming, promoting sustainable water use, improved crop productivity, and resource management.

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