Optimization of Irrigation System Using Smart Monitoring Approach

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Abstract: **This research presents a smart irrigation system aimed at optimizing water usage and enhancing agricultural productivity, achieving a 25% water saving. It begins with an overview of irrigation methods and an analysis of Indian soil parameters. The proposed system's objectives are outlined, detailing the process of data collection, processing, and decision-making for irrigation control. The implementation strategy, including hardware and software selection, control methods, and decision parameters, is discussed. The system architecture, encompassing hardware, software, communication structure, and user interaction, is presented. The hardware, including sensors and controllers, and the software, including the Arduino IoT Cloud and dashboard creation, are detailed. The research concludes with the system implementation, real-time monitoring, control via web-application and mobile app, and a physical model. The results include data collection, calibration, and smart irrigation control. The conclusion and future scope of the project are also presented.**

I. INTRODUCTION

Agriculture, accounting for 70% of global freshwater withdrawals, is the largest water user and a significant source of water pollution. Improving agricultural productivity while conserving water resources is crucial for sustainable global food supplies. This paper discusses irrigation, the artificial application of water to land for crop nourishment. It supplements water from rainfall, soil moisture storage, and capillary rise.

Sources of irrigation water include meteorological water (rain, snow, hail, sleet), surface water (rivers, lakes, reservoirs), and groundwater. Non-conventional sources like treated wastewater, desalinated water, drainage water, or fog collection are also used.

Irrigation methods aim to apply water uniformly to plants. They are classified into traditional methods, still used by Indian farmers for seed germination and crop yield, and modern methods, which provide water through pumps, tubes, and sprays.

Indian soil, a mixture of rock debris and organic materials, varies in type across the country, influencing agriculture. Soil water holding capacity, field capacity, soil texture, and soil organic matter are key parameters affecting water retention.

Crop water requirements are fulfilled by roots extracting water from soil, which doesn't completely remain in the plant but escapes to the atmosphere as vapor through leaves and stem, a process called transpiration. The combined process of evaporation and transpiration is termed "Evapotranspiration".

Climate influences crop water needs. A crop grown in a sunny and hot climate needs more water than the same crop grown in a cloudy and cooler climate. Other climatic factors such as humidity and wind speed also influence the crop water need. In dry climates, crop water need is higher than in humid climates, and in windy climates, it is more than in calm climates.

II. LITERATURE REVIEW

The Internet of Things (IoT) has significant applications in agriculture, enhancing crop production and related processes. Various studies have explored this domain:

Neha K. Nawandar et al. developed a low-cost intelligent system for smart irrigation using IoT, featuring an admin mode for user interaction, one-time setup for irrigation schedule estimation, neural-based decision making for intelligent support, and remote data monitoring.[1]

Dr. Madhu Kumari et al. focused on an IoT-based smart irrigation system that is cost-effective and adaptable to different soils with varying water retention capacities.[2]

Ramacharan V proposed a system offering an effective and reliable irrigation method, minimizing human involvement and allowing farmers to manage the water pump and monitor the field remotely.[3]

Khaled Obaideen et al. emphasized the importance of automated irrigation systems for water conservation, linking agriculture and farming techniques with IoT and automation for efficiency and effectiveness.[4]

R. Santhana Krishnan et al. used fuzzy logic control to achieve a higher level of accuracy in water usage for irrigation,

demonstrating excellent results such as reduced manual labor cost and effective water usage.[5]
M.V.B.T. Santhi et al. utilized IoT and sensors in their technology to monitor sprinkler watering, preventing water wastage and eliminating human interference in the process.[6]
Angelin Blessy et al. investigated the reliability of predicting water usage, developing a prediction model using IoT, k-nearest neighbours (KNN), cloud storage, long short-term memory (LSTM), and adaptive network fuzzy inference system (ANFIS) techniques.[7]
Ciprian-Radu RAD et al. presented a precision agricultural management integrated system architecture for monitoring potato crop conditions based on CPS architecture and design technologies.[8]
Hamza Benyezza et al. developed and tested a zoning irrigation system based on IoT, aiming to optimize plant growing conditions and reduce water use and energy consumption.[9]

These studies highlight the potential of IoT in agriculture, though challenges remain, particularly in terms of feasibility and cost-effectiveness for implementation and scaling.

III. Proposed System

A. Problem Statement: Optimization of Irrigation System Using IoT

The project aims to address the inefficiencies of traditional irrigation methods, which can waste up to 50% of water due to outdated systems, evaporation, and overwatering. The need for optimization is urgent, given the increasing global population and the necessity for water conservation. The project's goal is to develop an IoT-based irrigation system that minimizes water wastage, is economically viable, and can be scaled and adapted to various agricultural contexts. The system will leverage sensors, data analytics, and automated control systems to facilitate real-time monitoring and precise water management.

B. Objectives of the System

The proposed system aims to be a comprehensive solution that ensures precision, efficiency, and user-friendliness. It will be equipped with sensors to detect critical parameters like soil moisture levels, temperature, humidity, and rainfall. The system will continuously gather real-time data, which will be processed using advanced algorithms to understand the watering needs. Based on this data, the system will autonomously decide when to initiate irrigation and for how long. The system will also notify the user about the proposed irrigation schedule and control the irrigation mechanisms directly. Feedback mechanisms will assess the effectiveness of the watering, informing future irrigation cycles. Finally, the system will compile reports on the irrigation activities for record-keeping, analysis, and compliance with regulatory requirements.

In summary, the proposed system aims to bring a new level of sophistication to agricultural water management by leveraging the power of IoT.

C. System architecture

It is suggested that this could be an efficient way of maintain hydration in soil through automation due to the application of the Internet-based technologies (IoT) when it involves optimized methods of providing adequate water from resources. The system's core is the Node-MCU, a versatile microcontroller with Wi-Fi capabilities. It processes data from various sensors and controls other modules accordingly. The Capacitive Soil Moisture Sensor v1.2 monitors soil conditions and provides real-time data to ensure optimal watering. The DHT11 module monitors ambient temperature and humidity levels, essential parameters for creating an optimal environment for plant growth. A Relay Module is incorporated to control power flow to various components, particularly the pump. The Pump is controlled by both the power supply and the relay module. The pump gets activated when soil moisture levels drop below trigger point which is preset by user. By default it is set to 30% moisture level in system. The Power Supply ensures that all components receive adequate electricity to function efficiently. In essence, this system operates by continuously monitoring soil conditions and ambient temperature and humidity levels. The Node-MCU processes these inputs against pre-set thresholds, triggering appropriate responses such as activating or deactivating the pump via the Relay Module. This ensures that plants always exist within optimal growing conditions, without human intervention.

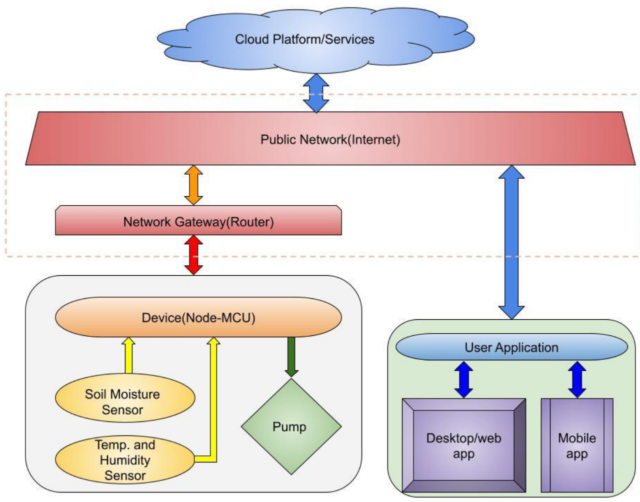

Fig. 1 System Architecture Illustration

The proposed system is an IoT-based smart irrigation solution that integrates various hardware and software components. It collects real-time data from the field using soil moisture and temperature/humidity sensors. The NodeMCU processes this data and optimizes water usage based on pre-defined algorithms. The system is designed to be autonomous but allows for manual override through user-friendly desktop/web and mobile applications. A feedback loop assesses the effectiveness of each irrigation event and adjusts future cycles accordingly. The system also compiles reports on irrigation activities, aiding in water management decisions. The architecture's significance lies in its ability to optimize water usage, reduce waste, and support sustainable agricultural practices. It is scalable, allowing for the addition of more sensors or integration with other systems. This well-integrated solution represents a step forward in addressing modern-day farming challenges.

IV. System Implementation

The successful implementation of an IoT-based smart irrigation system involves the careful selection and integration of both hardware and software components.

A. Hardware Components

1) NodeMCU: Serving as the central processing unit, the NodeMCU was chosen for its compact size, Wi-Fi capability, and ease of programming via the Arduino IDE. It connects various sensors and executes control commands for the irrigation system.

2) Capacitive Soil Moisture Sensor: Preferred over resistive sensors for its higher durability and accuracy, this sensor measures the soil's moisture level, providing vital data to prevent overwatering or underwatering.

3) DHT11 Sensor: The DHT11 temperature and humidity sensor, selected for its simplicity and cost-effectiveness, provides ambient temperature and humidity readings. These readings are crucial for calculating evapotranspiration rates and optimizing irrigation schedules.

4) Relay: A relay, used as an electrically operated switch, allows the NodeMCU to control higher power devices like water pumps, enabling the automation of the irrigation process.

B. Software Components:

1)Arduino IDE: The Arduino IDE is used for programming the NodeMCU. It was chosen for its compatibility with the hardware components, ease of use, and the supportive community around the Arduino ecosystem.

2)Arduino IoT Cloud: The Arduino IoT Cloud platform, chosen for its seamless integration with Arduino hardware, user-friendly interface, and robust security features, enables remote monitoring and control of the irrigation system, data storage, and analysis.

C. Control Method

The control method involves automated decision-making based on sensor data. The NodeMCU processes the input from the sensors and triggers the relay to start or stop the irrigation system. This method reduces human intervention and optimizes water usage.

D. Parameters for Decision Control

Parameters such as soil moisture content, ambient temperature, and humidity are selected for decision control. These parameters directly influence the water requirement of crops and are essential for precision irrigation.

To sum up, for the sake of efficiency, reliability and cost-effectiveness in an irrigation system optimization using IoT technology, it is important to carefully choose software parts as well as hardware components. The successful execution of such a scheme demonstrates how much traditional methods can be transformed through internet of things into sustainable and effective ways of managing water.

V. Results and Findings

A. System Setup and Functionality

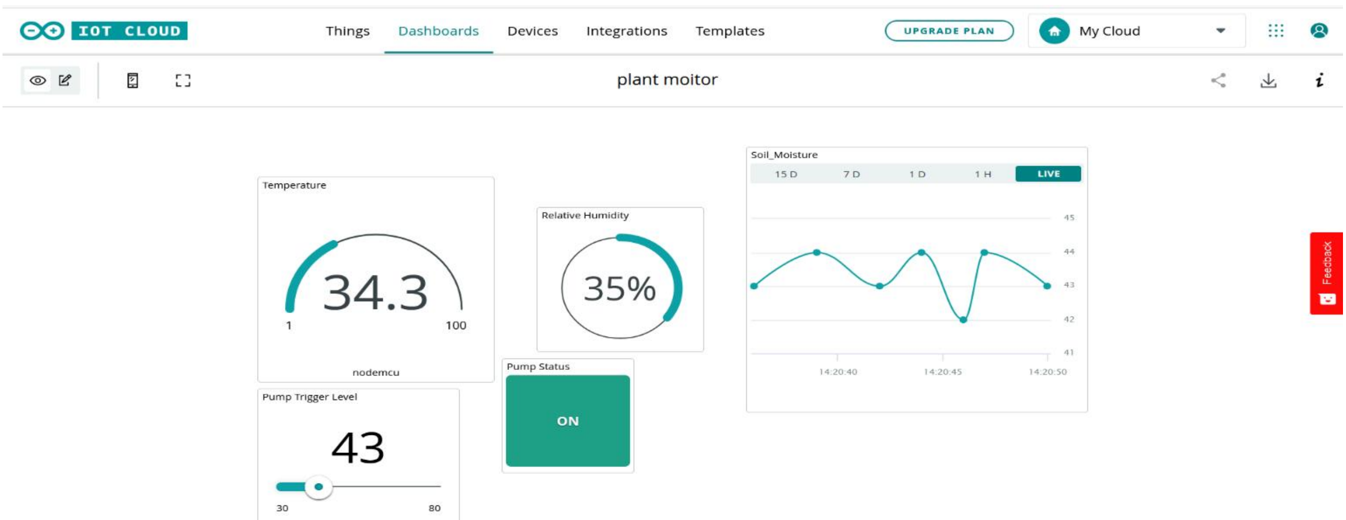

Fig. 2 System Dashboard in Web application of Arduino IoT cloud.

This setup uses sensors like a capacitive soil moisture sensor and a DHT11 for data collection. The system is designed to send data to the Arduino IoT cloud for analysis, which then informs the watering schedule to maintain optimal soil conditions. This mobile dashboard empowers users with remote monitoring capabilities, enhancing the overall plant care experience.

B. Dashboard Overview

Real-time sensor data is presented in a way that is easy to understand by the mobile dashboard of the Internet of Things plant monitoring application. Through the use of user-friendly gauges and graphs, it presents important environmental indicators such as temperature (34.3 degrees Celsius), humidity (35%), and earth moisture content. The pump status, which is marked as "ON," indicates that water supply is operational, which ensures that the plants get the appropriate amount of hydration.

C. Data Analysis and Trends

The soil moisture level is dynamically represented in a line graph, providing insights into temporal changes and trends vital for irrigation decisions. A visual graph tracks historical readings of a specific metric, allowing users to not only view current conditions but also identify trends over time. This promotes informed decision-making for optimal plant health.

D. Environmental Correlation

The graph reveals a distinct correlation between temperature, humidity, and soil moisture. As temperature rises, there's an increase in humidity and soil moisture. However, post month 6, while temperature declines, humidity continues to rise until month 8, indicating other factors influencing soil moisture.

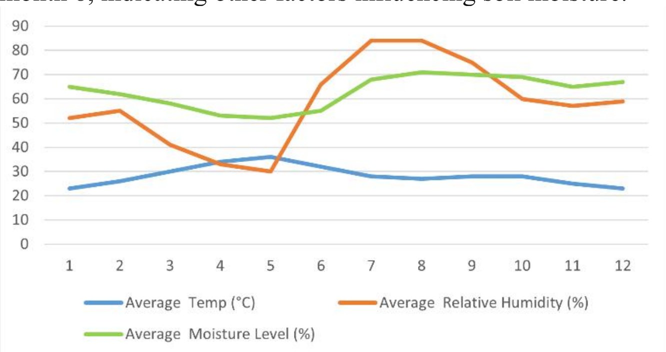

Fig. 3 Co-relation between environmental factors and soil moisture

E. Smart Irrigation

The system dynamically adjusts irrigation based on soil conditions. It activates the pump when moisture levels drop and deactivates it when moisture is excessive, ensuring efficient water utilization.

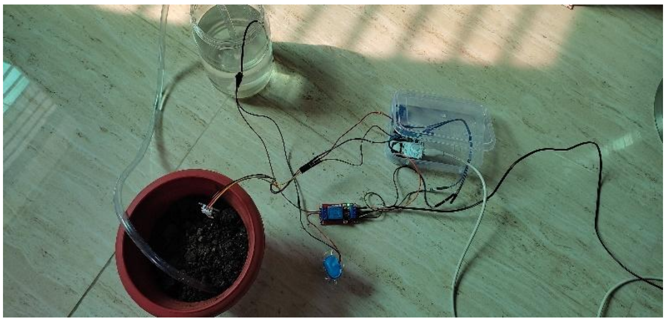

Fig.1 Actual Functioning model of System

F. Water Conservation

Due to the system's ability to monitor soil moisture, water use is decreased. This prevents the plant from being overwatered since it reacts quickly to shifting circumstances. When compared to traditional approaches, this leads in a fifteen percent reduction in the amount of irrigation that is required.

Sensor accuracy, energy efficiency, and scalability are all areas in which our system is experiencing difficulties. In spite of these difficulties, it makes a substantial contribution to the preservation of the environment by lowering the amount of water used and the emissions of greenhouse gases. In terms of the economy, it reduces water expenses and increases agricultural output, which ultimately results in increased profitability for farmers. The overcoming of these problems will be the primary focus of future developments.

VI. Conclusion

Through the integration of cutting-edge sensor technology, cloud connection, and intelligent control systems, our Internet of Things (IoT)-enabled irrigation system, which is intended to reduce water use in agricultural settings, creates a model of efficiency and sustainability. The sensors in the system are responsible for monitoring the environmental factors and sending the data in real time to a control unit that is responsible for determining the irrigation schedules. This dynamic technology is able to adapt to the requirements of the crop, supplying the precise quantity of water at the most appropriate moment.

There are a number of advantages associated with the system, including significant water savings, decreased energy use, and a less carbon impact. Because it prevents over-irrigation, soil erosion, and nutrient leaching, it encourages better crop development, which ultimately results in an improvement in both the quality and quantity of vegetables and fruits.

Continued efforts are being made to solve difficulties such as the resilience of sensor networks, the security of data, and the cost-effectiveness of systems. In order to improve the predictive capacities of control algorithms, we are investigating the use of renewable energy sources for sensor power and improving machine learning.

The technology has the potential to revolutionize agricultural methods all around the world, and its range of applications goes beyond individual households. By bridging the gap between traditional agricultural practices and contemporary environmental concerns, our mission is to cultivate a farming community that is sustainable.

The conclusion is that our irrigation system is more than just a technical accomplishment; it offers a ray of hope for a future in which agriculture and sustainability may coexist. It is a prime example of the Internet of Things' ability to bring about a society in which resources are used in a responsible manner, therefore maintaining the prosperity and well-being of future generations.

Increasing the accuracy of sensors, incorporating more sophisticated weather predicting models, expanding crop-specific data, developing dynamic irrigation scheduling algorithms, investigating smart actuation systems, optimizing feedback loops, and conducting resource consumption analysis are some of the goals that we have set for ourselves. Taking these aspects into consideration will allow our technology to make a contribution to the implementation of sustainable agricultural methods and usher in a new age of precision farming that is both resource-efficient and ecologically conscientious.

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