Hydrosense: Pioneering Iot for Precision Drip Irrigation and Sustainable Water Management

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ABSTRACT

A smart irrigation system using real-time sensors can greatly improve water efficiency and resource management. Traditional farming often struggles with inefficient water use, which affects crop growth. To address this issue, a drip irrigation system powered by IoT was designed and evaluated, with its performance compared to an evapotranspiration-based system. The system includes sensors and microcontrollers that track Soil Water Content (SWC), soil temperature, humidity, and air temperature. Irrigation was scheduled based on predefined upper and lower moisture thresholds (half of the farm area's capacity). Watering started when soil moisture dropped to 35% and stopped when it reached 85%. Sensor data was sent wirelessly to a cloud server, allowing farmers to access it from anywhere. The results showed that brinjal plants under the IoT-based system expanded by 1.3 cm more than those in the crop Evapotranspiration -based system. The leaves were also larger, both in length and width. The system was built to withstand outdoor conditions, with a water resistant enclosure ensuring durability.

Keywords: IoT, Smart Irrigation, Crop Evapotranspiration, Drip Irrigation, SWC.

INTRODUCTION

The advancement of the agriculture sector is impeded by water limitations. Agricultural development is often used as a measure to evaluate each nation's progress. Water use is essential in agricultural activities. Farmers can improve their agricultural practices through the use of precipitation forecasts. Environmental factors such as the greenhouse effect, river desiccation, high temperatures, and global warming have recently altered weather patterns [1–4]. Precipitation patterns are changing due to climate change, and the amount of rainfall directly influences groundwater levels. Agriculturists generally have two options for irrigating their crops: irrigation and rain-fed agriculture. Direct precipitation, which has a lower risk of contamination, is essential for rain-fed agriculture. Nevertheless, it faces water shortages during periods of minimal or absent precipitation. Irrigation refers to the artificial application of water using various methods. A well-designed irrigation system can protect plants from harsh winter conditions, prevent rapid desiccation, and reduce the amount of water required for agricultural cultivation [5]. Prompt action is necessary to optimize resource utilization, especially in light of the adverse effects of technological advancement and the significant decline in available physical labor on agricultural production.

The Internet of Things (IoT) is transforming agriculture by providing farmers with a wide range of innovative tools, including weather forecasts, soil moisture and temperature measurements, and fertility assessments. Online crop monitoring includes weed detection, water availability assessment, insect identification, animal intrusion detection, and various other indicators of plant health. IoT technology enables farmers to enhance productivity while reducing operating expenses. A typical smart irrigation system includes soil moisture sensors, a control unit, valves, a water source (such as a pump), optional weather sensors for monitoring precipitation and temperature, and a communication network that facilitates remote monitoring and control—often utilizing IoT technology.

Analysis of Sensor Components

Soil moisture sensors: The primary instrument that identifies the need for irrigation by assessing the soil water content at multiple depths.

Rain sensors: They can identify impending rainfall and adjust the irrigation plan accordingly.

Temperature sensors: Monitor external temperatures to assess their impact on irrigation decisions, especially during inclement weather.

Sensors that gauge leaf moisture: These devices can assist in preventing unnecessary watering of plants.

Advantages of An Intelligent Irrigation System:

Water conservation: One major advantage is that it drastically cuts down on water consumption. Soil moisture levels determine when irrigation is needed; thus, there are huge savings of water, which is especially important in locations where water is scarce [6–9].

Improved harvest quality: Plants flourish and provide more harvest when precise water delivery is ensured at the ideal moment.

Farmers and property owners may save money by reducing water usage, which leads to decreased water costs.

Protection of water resources and mitigation of irrigation's negative effects on the environment are two aspects of water conservation that contribute to environmental sustainability [10-14].

Smart systems can adapt to changing weather conditions by tracking data like temperature and rainfall and adjusting watering schedules appropriately.

Using a smart phone app, owners of many smart irrigation systems may remotely check the system's status and change the watering schedule as needed.

Enhanced soil health: By avoiding overwatering and soil erosion, precise watering helps to preserve the structure of good soil.

Sensing soil water content, temperature, and other environmental factors allows for data-driven insights, which in turn enable improved irrigation management.

MATERIALS AND METHOD

The Smart Drip Irrigation System's IoT Components: Hardware Implementation

The solenoid valve regulating the water supply to the raised garden beds is electrically connected to soil moisture sensors. The solenoid valve is programmed to open and close automatically during irrigation events according to a soil moisture threshold. [15–17] The data gathering system for the Internet of Things was powered by a transportable solar panel, control module, and solar charging unit served as the primary power source. The 12V DC motor/actuator and receiver were seamlessly integrated into the power system. This setup ensured efficient energy distribution for operation. The receiver is made up of a motor driver module and a CPU that has an ESP8266 Wi-Fi module built in. The receiver's internal components were protected from water and other environmental hazards by use of an IP-65 casing. You can activate and deactivate the power on the receiving device with one button, and choose between automatic and manual modes with the other. A 5.5W solar panel charged the 12V 7Ah battery, which served as the system's power source [18-20]. The ESP-WROOM-32 microcontroller from the Chinese company Espress if was employed. This model features an integrated Wi-Fi, Bluetooth, and BLE MCU module, together with 34 conventional digital GPIO pins and 12 analogue input channels, each with 18 bits of resolution. Due to its integrated Wi-Fi module, the microcontroller (ESP-WROOM32) transfers sensor data to the cloud server wirelessly. We may effortlessly

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connect to the Internet utilizing the receiver's rapid processing capabilities and included ESP8266 Wi-Fi module/Bluetooth. The DHT11 sensor was employed to measure temperature and relative humidity. Fig 1 show the Circuit diagram of developed Irrigation System.

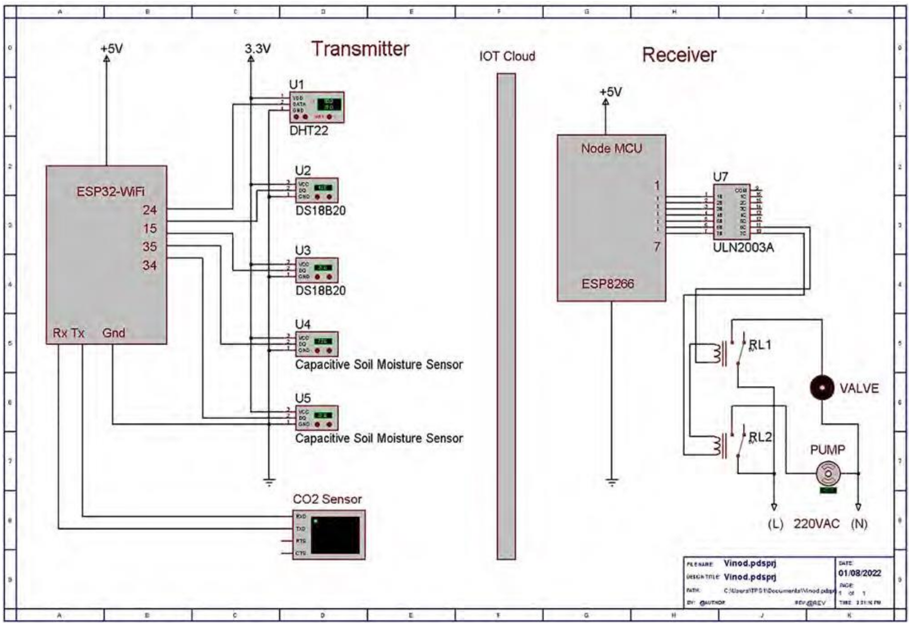

Fig 1 Circuit diagram of developed Irrigation System

Software Module

To function, the solenoid valve depends on the soil water content level as it is right now (if the measured SWC is less than 35.5%), and continues to do so until it hits a predefined threshold value (SWC more than85.5%). The ESP8266 Wi-Fi module transmits data on the soil's temperature, relative humidity, moisture content, and frequency to the ThinkSpeak IoT platform every two minutes. [21–23] Still, the user is free to adjust the interval as needed. More power is used up as the duration is shortened. With the integrated ESP8266 Wi-Fi module, You can monitor system data remotely at any time using a smartphone app or an internet connection. Schedules for irrigation were developed after careful consideration of the soil's water availability, taking into account both its upper (field capacity) and lower (plant allowed water) constraints.

The solenoid valves were opened by the motor driver module as soon as the soil moisture level reached a certain threshold. Fig 2 represent the Channel Creation for Thing Speak.

Fig 2 Channel Creation for Thing Speak

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Experimental Setup and Procedure:

The raised planter beds in the design of the IoT drip irrigation system. To establish an Evapotranspiration-based system drip irrigation planner that considers the crop's water needs, a second, identical planter bed was established outside. Daily, the quantity of irrigation water for crops was assessed using meteorological data. The actuators of the receiver system were autonomously, Triggered and shut off by relays based on user-specified conditions. utilizing soil moisture data[24]. the created IoT & Evapotranspiration-based drip irrigation system equipped in terms of their performance. For thirty-one days, testing of the control and monitoring system were carried out at 10 AM, 2 PM, and 6PM. The findings were recorded three times daily

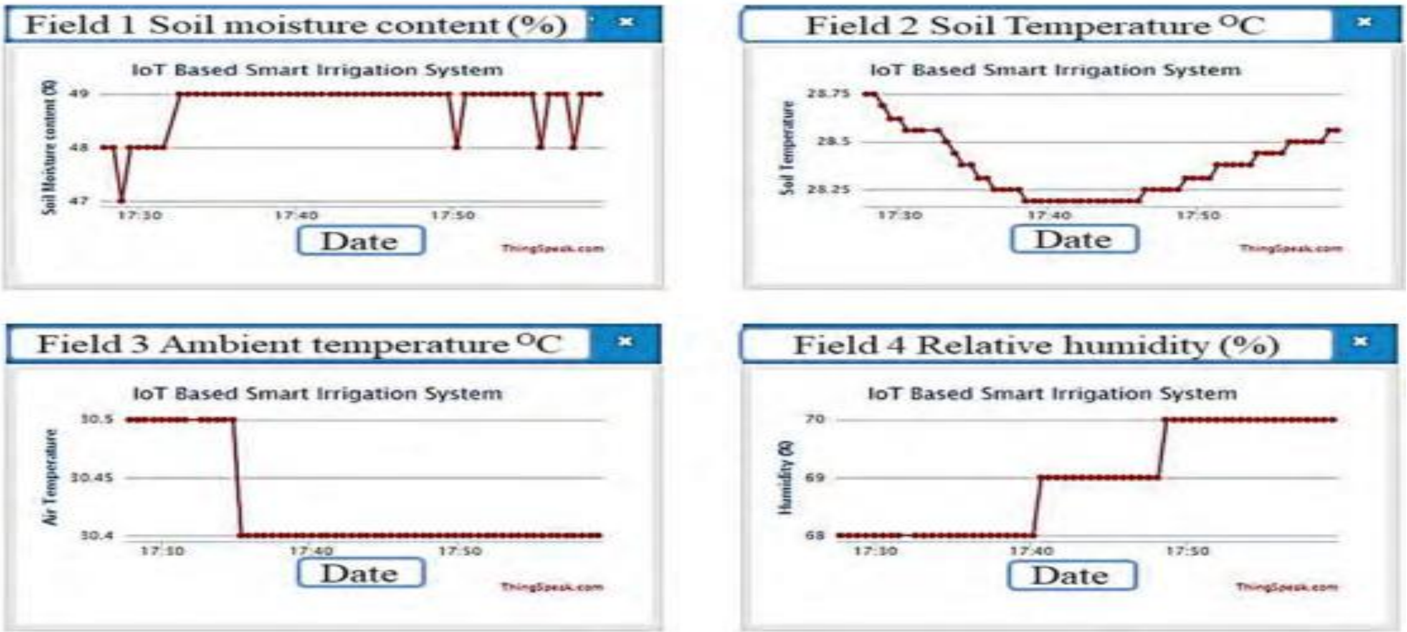

Fig 3 Created a test bed for smart irrigation system based on IoT

to Consider the substantial variations in environmental conditions at different times. A solenoid valve turned on and off according to threshold values calculated from a curve representing the soil water properties. We spent 45 days testing the system, solar panels, and monitoring system, control system Evapotranspiration-Grounded on drip irrigation, and how well the plants grew [25]. Fig 3 Shows the Created a test bed for smart irrigation system based on IoT.

The study involved selected brinjal plants, because of their vulnerability to conditions including extremely moist soil, water stress, high temperatures, and severe salt. Over the course of 45 days, measured at 2-day intervals. After two weeks of transplanting, the crop development characteristics were assessed. Use of these three metrics allowed for the evaluation of the built-in IoT and Evapotranspiration - Grounded on drip irrigation systems [26-27]. These little raised garden beds were IoT drip-watered by the monitoring and control system. Drip irrigation with ETc required human intervention to regulate watering according to the rate of

Fig 4 visual representation of environmental parameter data

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evaporation each day. During the testing phase of the monitoring system, we compared the results from several sensors that measured soil water content, soil_temp, relative humidity, and temperature to those from separately marketed sensors. The accuracy and dependability of the data collecting tools were confirmed by this test. An ICT with a 12-bit resolution, the MPM-160-B, was used to measure soil Water content. At the same depth, we monitored soil water content using sensors linked with IoT & Evapotranspiration Grounded on drip irrigation to evaluate the dependability of the prototype IoT. The soil temperature was measured with soil thermometers, and the relative humidity with a test 623 thermohygrometer [28-31]**.**

RESULTS

In accordance with the established protocol, the sensors were calibrated. Also, the gravimetric method's representative moisture content was compared to the sensor's % readouts at various moisture levels for sensor calibration [32]. Assessment of the data collecting system's efficiency :We put the gadget through its paces to see if it could gather data about its surroundings using its sensors and send it to an Internet of Things platform. In order to test the data-gathering gadget, a local WiFi network was attached to it. The field data generated by the sensors was viewed using the Thing Speak IoT platform. Several hours were spent operating the system for several data input. From what we can tell, the sensors successfully transmitted the data they collected about the surrounding environment to the web app. Soil_temp, relative humidity, soil water content, and temperature graphs provide the data access observations based on the relevant sensor data. The data was transferred to the IoT platform every fifteen to twenty seconds [33-35].

As shown in Fig 4, the data visualization capabilities of Thing Speak enhance our understanding of the connection between our physical world and the passage of time. Humidity increases as the temperature decreases. Farmers may enhance their precision irrigation methods by tracking these changes over time and using that information to make more informed decisions about their crops in relation to environmental factors. Consequently, we put the Think Speak platform through its paces to see if it could record and display the cloud-based data on environmental parameters in an understandable manner. Thanks to the application, the document's exact details were exposed. The data gathering module was subsequently tested for its ability to withstand water. This was done to make sure the gear could be utilized outside, on wide fields. When first tested under running water from the tap, the gadget did not leak. Extensive evaluation and validation was conducted in two areas: the monitoring system and the control system. The data collecting device collected a variety of environmental variables for the monitoring system test.

Performance study

Fig 5 sensor placed in crop field after transplantation

In order to test how well the IoT-based irrigation system can monitor field conditions through data collection and manage environmental factors using automated control systems, small-scale raised planter beds were constructed. This test was conducted to ensure that the data acquisition equipment is reliable and accurate. The sensors were buried 15 centimeters below ground level throughout the cultivation period. The water pump was configured to activate when the soil water content fell below 35.3%. The monitoring system test demonstrated that the IoT values for soil water content, temperature, and humidity closely matched the accurate baseline measurements. Although there were slight differences between the IoT test and baseline measurements, they were minimal. Therefore, it is reasonable to conclude that the data collection system is reliable and sufficiently precise. The control system's ability to maintain optimal environmental conditions for plant growth is a crucial component. If the monitoring system were to fail, it could result in unfavorable conditions for plant development the average amount of water consumed by the IoT system over the course of 45 days was determined to be 2.1 liters every two days. This indicates that the water pump was functioning as intended, activating only when the relative humidity fell below a certain threshold. Otherwise, the water in the tank could have evaporated quickly if the pump had run continuously regardless of sensor data. Consequently, the autonomous control system successfully maintained acceptable levels for all environmental parameters. The findings show that the new system consumes less potable water than the ETc-based drip irrigation method. Over the 45-day period, the total pumping time of irrigation systems was compared. The results demonstrate that soil moisture sensors, in combination with recent advancements in IoT and wireless sensor network (WSN) technologies, are effective tools for accurately monitoring soil water content under various field conditions and for scheduling irrigation more efficiently. Fig 5 shows the transplanted plants with sensors placed in crop field.

Traditional irrigation systems can result in some areas of a field receiving excessive amounts of water, while other areas remain under-irrigated. To enhance efficiency, productivity, and profitability in farming, smart irrigation techniques are essential for real-time irrigation management. The outcomes of the trials demonstrate significant benefits, including reduced labor costs and more efficient use of irrigation water. Scientifically advanced and technologically improved soil water content-based irrigation scheduling methods aim to enhance irrigation efficiency 20%, plant growth 20-25%, and crop yields. To gather data, field characteristics are wirelessly transmitted to a cloud platform via LoRa or Wi-Fi protocols. This provides a promising solution by enabling decision-makers to access real-time data on soil water content, temperature, relative humidity, and soil temperature. Based on experimental results, the prototype data collection system performed as expected in small-scale raised garden beds, offering a potential solution to the challenges of water shortages and low agricultural yields.

CONCLUSION

This project focused on developing a wireless IoT-driven drip irrigation system to address the limitations of existing systems in terms of cost, range, self-sufficiency, weather resistance, and outdoor functionality. The system's sensors and microprocessor efficiently collected environmental data using IoT technologies. A cloud server (Thing Speak) wirelessly received data from the sensors, allowing users with Internet-enabled devices to access it remotely. The developed method was effectively tested on Vertisols for brinjal cultivation, and the results confirmed its reliability and efficiency in the field. Drip irrigation systems based on IoT and Evapotranspiration were employed for irrigation scheduling. The IoT-based drip irrigation system outperformed the Evapotranspiration-based drip irrigation system in both water conservation and enhanced plant growth performance 20 to 25%. Furthermore, comparative measurements of the IoT and Evapotranspiration-based drip irrigation systems revealed a significant difference in pumping operation duration and water consumption rate. The key insight from these initial findings is that IoT-based drip irrigation systems can help farmers optimize water usage and determine the appropriate timing for crop watering.

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