# Agri-Water: An IoT-based System for Sustainable Agriculture

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**Abstract.** Climatic conditions intricately influence agriculture, impacting optimal crop growth and reproduction through environmental factors. This study introduces a technological solution leveraging the Internet of Things (IoT), with Raspberry Pi 3 as the central controller. The system systematically collects crucial data on temperature, humidity, and soil moisture, ensuring the quality of crops. Subsequently, this information is used to formulate systematic crop watering plans. By efficiently using Raspberry Pi, the system regulates and monitors crops, contributing to water conservation by directing it precisely to the crops. This technology offers a practical and efficient approach to crop management, especially during challenging agricultural periods.

## 1 Introduction

The Food and Agricultural Organization [1] that not keeping track of crops well enough leads to losing 20–40% of them each year due to pests, diseases, and other reasons. To tackle this issue, sensors and smart systems are used to monitor things like weather, soil fertility, and the right amount of fertilizers needed for crops to grow. Using too much fertilizer harms the soil's fertility. Recently, Farooq and colleagues reviewed 67 research papers on the use of the Internet of Things (IoT) in farming [2]. They found that about 16% of the papers were about precision agriculture, 16% focused on monitoring irrigation, 13% on soil monitoring, 12% on temperature, 11% each for animal and humidity monitoring, 5% each for air and disease monitoring, and 7% for water monitoring. Interestingly, only 4% of the papers discussed monitoring fertilization.

A wireless sensor network helps farmers make better decisions by overseeing different farm tasks and providing useful information about the temperature, humidity, and soil moisture. Weather changes affect water levels, which can be distracting for farmers and harm agriculture. To tackle this, farmers use a smartphone app to control water usage for plants, both automatically and manually. This makes it easier for farmers who spend a lot of time on agriculture tasks. Using a sensor microcontroller system, this application accurately

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manages the water system for gardens. It is accomplished by placing sensors in the field to monitor soil temperature and moisture, and then transmitting the data to a microcontroller for plant water need estimation [3].

The study focuses on three main objectives to enhance its overall organization and efficiency. Firstly, the aim is to design an IoT-based system for controlling and monitoring smart agricultural technology. Second, we plan to develop and implement a Smart Agriculture prototype that enables users to observe soil conditions, ensuring optimal plant growth. Lastly, we intend to assess the system's website and mobile app, allowing users to effortlessly record and manage humidity, soil moisture, and temperature levels, as well as control the irrigation system pump. These objectives work together to achieve the project's overarching goal of advancing smart agricultural practices.

The second section explores other researchers' discoveries, explaining different methods and their results. The third section discusses how we plan to conduct our study. In the fourth section, we share our findings and discuss them. Finally, the last section concludes the paper.

## 2 Related Works

This section investigates the agricultural aspects overseen by IoT. The initial step towards reducing water usage involves the monitoring of soil moisture. Crops necessitate light, carbon dioxide, and water for growth, with a particular emphasis on water conservation due to the substantial water consumption in agriculture.

The Internet of Things (IoT) is a network interconnecting digital, mechanical, and computational machines. Within the realm of IoT, the term "Thing" denotes any device equipped with a sensor capable of autonomously collecting and transmitting data across the network without human intervention [4]. The embedded technology facilitates interaction with internal conditions and the surrounding environment, aiding decision-making. In their research, [3] developed an application that efficiently manages garden water systems utilizing a sensor microcontroller system. This process entails strategically placing sensors in the field to monitor soil temperature and moisture. The collected data is subsequently transmitted to a microcontroller, enabling an accurate estimation of plant water needs. However, the study primarily collected data for research purposes. Another scholarly work by [5] discusses a system incorporating a CPU, IC-S8817BS, and a wireless transceiver module with ZigBee protocol. This system utilizes sensors to monitor diverse environmental variables, including water level, humidity, and temperature. The collected data is disseminated to farmers through mobile text messages and emails, informing specialists about field conditions. The review underscores the system's emphasis on addressing sensor node failure and energy efficiency issues. Nonetheless, the application is constrained by ZigBee technology, resulting in a limited communication range.

The significance of hydro-meteorological data is underscored by [7] in estimating crop water requirements and scheduling irrigation. The daily assessment of tank water balance is crucial for effective tank operation, particularly in managing irrigation releases during normal, flood, and drought seasons. Nevertheless, the monitoring and provision of such data for tank systems often need to be improved. In their research, [8] employed a technique to directly supply water to plant roots, which is particularly advantageous in arid regions and low rainfall seasons. This approach supports the growth of crops, maintains landscapes, and facilitates soil re-vegetation in disturbed areas. Irrigation during crop production serves various purposes, including protecting plants from frost, controlling plant growth in grain fields, and preventing soil consolidation. The implementation of an intelligent watering system was achieved [9] through the integration of the Internet of

Things (IoT) and Information and Communication Technology (ICT). Intelligent watering software was developed by integrating suitable sensor components, control panels, and systems. This innovation enables agricultural producers to engage in automatic and smart watering, providing a solution to challenges associated with the aging population and labor shortages in rural areas of Taiwan. Nevertheless, data concerning the optimal quantity and timing of watering can be systematically gathered and analyzed. Study [9] looks at ways IoT is used in precision farming, focusing on improved sensor technologies and data analytics. However, the study might need to examine IoT implementation challenges in precision agriculture thoroughly. In [10], the paper discusses using wireless sensor networks for monitoring the environment in agriculture, including soil quality and climate conditions. Yet, it may need to detail the challenges of scaling up these networks or their cost implications.

[11] presents a case study on sustainable farming practices with IoT, especially in organic farming. Despite valuable insights, the study may need to discuss how applicable its findings are to different types of agriculture. Discussing real-time data analysis for better farming practices, [12] explores IoT-based crop monitoring for precision agriculture. However, the paper might need to examine challenges like data privacy and IoT device reliability thoroughly. [13] focuses on smart watering systems in sustainable farming, using IoT to optimize water use and improve crop yield. While the study collects water use and crop health data, it may not deeply explore challenges for small-scale farmers or the scalability of these systems. In improving agricultural sustainability, [14] discusses using IoT for crop disease monitoring, emphasizing early detection and proactive management. Although the paper involves experiments, challenges related to accurate disease detection or false positives might need to be thoroughly discussed.

In summary, this research aims to enhance and employ a specialized soil sensor, specifically the single sensor, DHT11, to mitigate corrosion problems induced by fertilizers. The approach involves data manipulation to enable automated irrigation based on the insights gained from humidity and temperature data collected during the study.

# 3 Methodology

This section outlines the development of the application, which entails four phases emphasizing water conservation.

## 3.1 Requirement Planning

Requirement planning for this study involves outlining the specific needs and criteria that must be met for the successful development and implementation of the project. Gathering user requirements is crucial to ensuring the final product aligns with user expectations. The process involves directly collecting input from end-users and stakeholders to comprehend their expectations, needs, and how they envision interacting with the IoT system. Technical requirements covered hardware specifications (sensors, devices), software requirements (applications, platforms), and network infrastructure.

## 3.2 User Design

In this stage, the application develops its architecture and user interface, encompassing the creation of both a webpage and mobile apps. It is imperative to distinctly outline all hardware and software requirements to guarantee the system structure's optimal functioning, including the sensors.

### 3.3 Rapid Construction

Through application coding, system testing, and unit integration, prototypes and beta systems evolve into functional models in a swift construction process. A comprehensive usability test ensures the smooth operation of each module, with continuous observation and documentation of the process at every stage. Automatic and manual watering methods are analyzed, measuring soil moisture and water consumption. The sensor readings are presented visually on the webpage and mobile app interface. As per the specifications, the application's operational flow is depicted in Figure 1, a graphical activity diagram. The process starts with a field search, and upon detecting the range, the designated range is inputted, initiating the retrieval of sensor data. This retrieval facilitates the adjustment of the water pumping amount, ranging from 100% to 50% until the pump is deactivated. The 100% to 50% range for water pumping provides a balance between meeting peak demand when necessary and optimizing operational efficiency during periods of lower demand. It considers energy efficiency, equipment longevity, water conservation, and overall system stability.

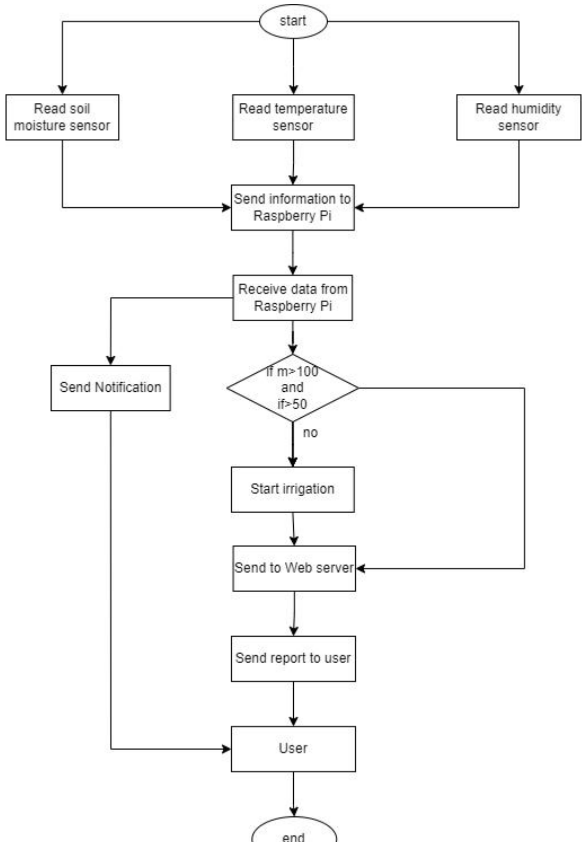


**Fig. 1.** System graphical activity flowchart

### 3.4 Cutover

The completed product is now prepared for dissemination following necessary enhancements. This phase will rigorously examine the project's outcomes and analysis, accompanied by a logical graphical representation of testing data.

## 4 Result and Discussion

This section discusses the outcome of the study and shows it in graphs. Following a specific process, this study tests the integration of the Raspberry Pi, DHT11 sensor, and soil sensor. The primary objective is to ensure the accuracy of the collected data. The study compiles all data regarding water usage on a server to analyze the impact of various watering methods. We performed two testing approaches: one involves automated watering, while the other entails manual watering. The process guarantees that the plant receives sufficient water, retains the appropriate pH level, and monitors the temperature and humidity in the surrounding area. The study conducted rigorous checks to ensure the consistency of the data collected. This involved cross-verifying the recorded water usage, pH levels, and environmental parameters to identify any discrepancies or outliers.

### 4.1 Connectivity Test: Assessing the Link Between Internet and Raspberry Pi

The Raspberry Pi is connected to Wi-Fi and displays the result on the webpage and mobile app interfaces, as shown in Figures 2 and 3. A prerequisite for the sensor to transmit the accumulated data to the server is an internet connection on the Raspberry Pi. Nonetheless, the execution of the test remains imperative as it verifies Raspberry Pi's capacity to access the mobile website and app for the intelligent agricultural system.

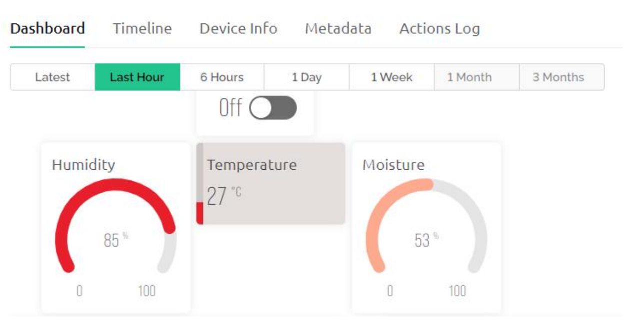


**Fig. 2.** Webpage User Interface


**Fig. 3.** Mobile Apps User Interface

### 4.2 Connectivity Test: Assessing the Link between DHT11 and Raspberry Pi

Figure 4 illustrates the interconnection between the Raspberry Pi and the DHT11. On the Raspberry Pi, affix the red jumper wire to the 5-volt pin, link the black jumper wire to the ground pin, and connect the yellow jumper wire to GPIO 12. Conversely, Figure 5 presents the data acquired from the sensors, affirming the test's success, with data captured for the latest hour depicted in Figure 6 and a span of six hours shown in Figure 7 below.

**Fig. 4.** Webpage User Interface

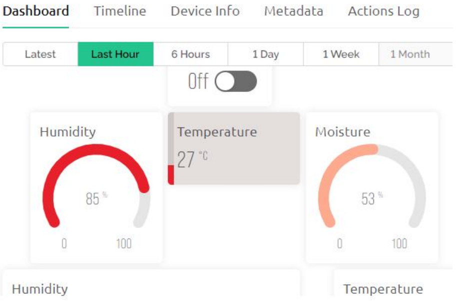


**Fig. 5.** Mobile Apps User Interface

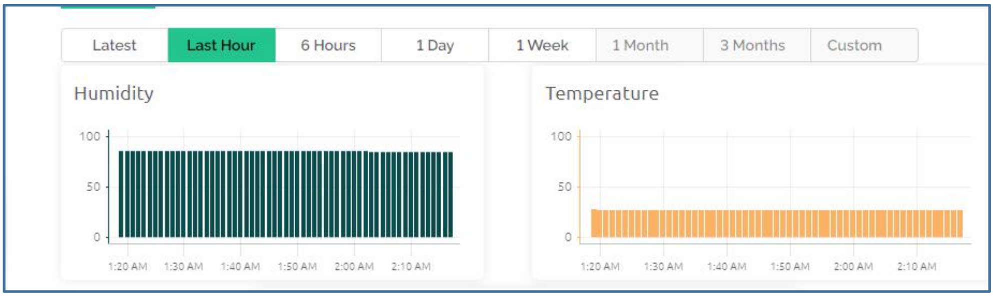


**Fig. 6.** DHT11 data capture for last hour

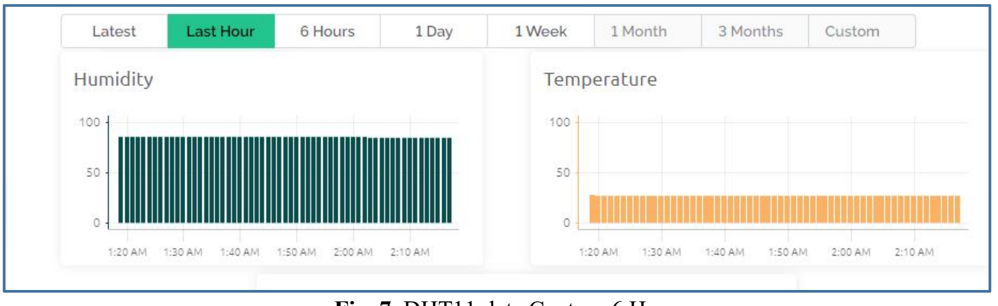


**Fig. 7.** DHT11 data Capture 6 Hour

### 4.3 Connectivity Test: Assessing the Link between Soil Moisture Sensor and Raspberry Pi

Figure 8 displays the connection between the capacitive soil moisture sensor and the Raspberry Pi. The output of the capacitive soil sensor, as depicted in Figure 9, confirms the success of the testing, with data captured for the latest hour in Figure 10 and over six hours in Figure 11.

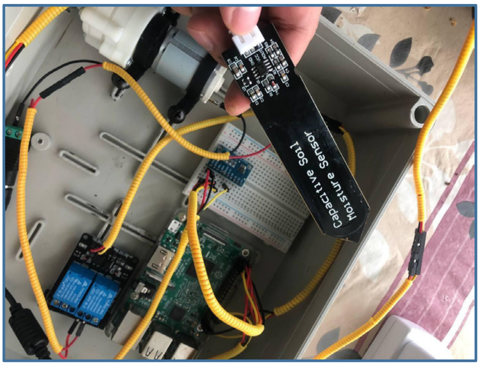


**Fig. 8.** Soil Moisture Setup

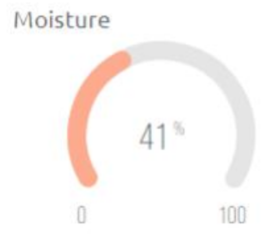


**Fig. 9.** Output Capacitive Soil Sensor

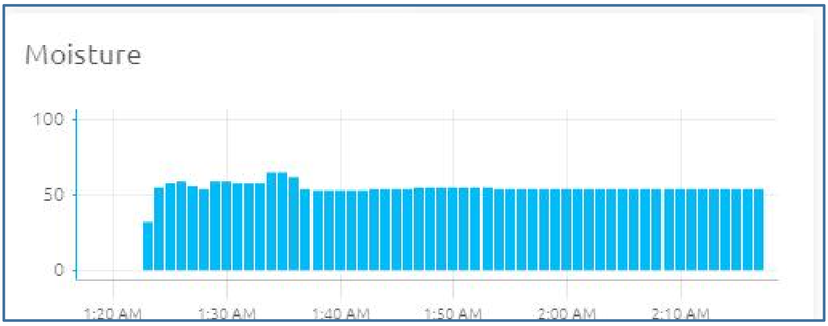


**Fig. 10.** Soil moisture sensor data capture for last hour

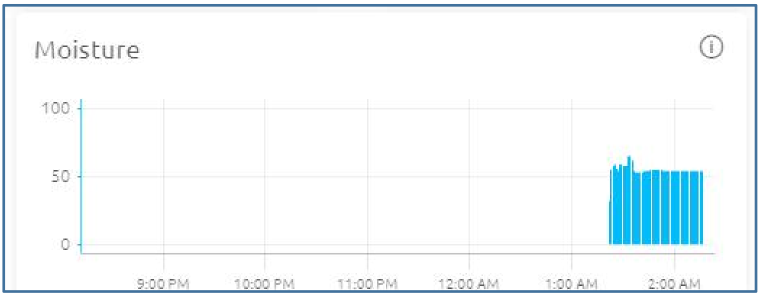


**Fig. 11.** Soil moisture sensor data capture for 6 hour

### 4.4 Connectivity Test: Assessing the Link between Relay and Raspberry Pi

Figure 12 below illustrates the connectivity between the Raspberry Pi, relay, power supply, and water pump. Furthermore, Figure 13 demonstrates the successful flow of water from the pump. The 12-volt power supply and the relay receive a signal from the Raspberry Pi to activate the water pump.

**Fig. 12.** Relay Setup

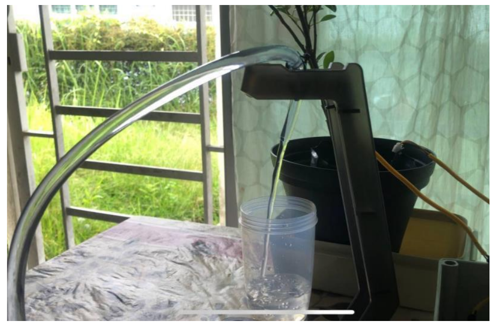

**Fig. 13.** Water Output

## 5 Conclusion and Future Works

This study utilizes a Raspberry Pi 3 Internet of Things device seamlessly integrated with an online server. Incorporating two distinct sensors—a soil sensor measuring soil moisture and a DHT11 gauging temperature and humidity—the system adeptly regulates the irrigation system. The connectivity ensures timely plant watering while monitoring critical parameters such as humidity, temperature, and soil moisture. The 12V power adapter orchestrates the activation of the water pump, triggering it through a signal sent from the Raspberry Pi to the relay. Real-time data, updated every minute, is accessible to users through the website interface. Weekly reports provide a comprehensive overview of statistics throughout the entire week. The study has achieved all its objectives, benefiting farmers nationwide. A proposed enhancement involves automating water usage calculations for precise monitoring, allowing for visualizing trends in watering methods through graphical representation. Concurrently, the development and implementation of advanced analytics tools, including artificial intelligence and machine learning, will be crucial for extracting actionable insights and optimizing decision-making processes. Finally, maintaining a strong focus on data security, encompassing encryption for both in transit and at rest, along with compliance with data protection regulations, will be fundamental for the success of future data-driven technologies.

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