Smart Drip Irrigation

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ABSTRACT

Zimbabwe experiences very high temperatures and decreasing water tables and this is the most challenging problem within the agricultural sector. Water conservation is a top priority especially in Zimbabwe’s region 2, where 70% of the farmers rely on irrigation. The El Nino drought which started in 2023, accompanied by very high temperatures, low rainfall and prolonged dryness is causing adverse effects on farming in the country. This event, being worse than the 2015-16 El Nino, has left the country with a crippling drought affecting over 60% of the seasonal crops. The long-term impact of this climatic event is bound to affect child nutrition by 2025, hence, the urgency to have sustainable measures of water management in place to curb the consequences of climate change. The system that was designed covers the implementation of Internet of Things technology, and the use of soil moisture sensors to measure soil moisture levels in real time and this measured data is used for analysis so that farmers can come up with better irrigation schedules for each crop and hence save water. The Blynk application is used to process the collected data and allow the farmer to control the irrigation remotely. The use of smart drip irrigation assists in water management and long term crop productivity mainly in drought stricken areas.

Keywords: Water optimisation, smart drip irrigation, irrigation solution, IoT, water conservation

INTRODUCTION

Advanced computerised smart drip irrigation is an innovative next-generation technique of land irrigation in farming to optimise the utilisation of water as well as the crop growth. Based on intelligent sensors, and mobile application collected data, soil moisture status can be correctly quantified, and drip irrigation can be set up independently when dry soil is identified. (Lioa, 2021). This process ensures that crops are provided with the precise amount of water needed to ensure healthy growth and maximum yield without wasting water in the process. In addition, by including the Internet of Things (IoT), soil moisture levels can be monitored and managed in real-time at a granular level. Collection of data and analysis through the Internet of Things, the system can distribute water strategically based on the crops’ requirements. This water saving technique does not manage water resources only but increases crop health and crop production by giving efficient irrigation. (Asres, 2023).

Low rainfall and drought are having a big impact on agricultural production and economic development. (Sharma, 2023). By using irrigation techniques like smart drip, farmers can improve their water management and increase crop yield and promote sustainable growth in plants. This movement towards the intelligent smart drip irrigation also works as a solution to climate change and water related challenges (Wei, 2024).

Drip irrigation and other micro irrigation systems are water saving methods that apply water directly to the plant’s roots, minimising water wastage and improving healthier growth. It is a better solution for water conservation, plant health, and weed suppression and fertilizer utilisation. Smart drip irrigation comes with an initial high cost of installation and maintenance, but provides water conservation methods. Traditional sprinkler systems provide uniform coverage but they are not conservative on water usage, and they are prone to overwatering thereby affecting the plant's growth rate. Drip irrigation systems are about 90% water usage efficient and traditional sprinkler irrigation is about is about 50 - 70% efficient (Wang, 2020).

Need of Smart Irrigation

Applies water directly to the roots of the plant minimising water runoff and evaporation.

Decreases the use of water and lowers water bills and operational costs.

Promotes health plant growth and high crop yields.

Reduces the need for labor-intensive cultivation because there will be fewer weeds in the fields.

Reduces soil erosion and nutrient leaching by reducing overwatering of plants

Can be used by different farmer scales, from small scales to large scales and also small to large gardens and lawns.

It uses sensors and data analytics for easy monitoring hence resulting in better informed decisions by the farmer.

Problem Statement

In Zimbabwe, the conservation of water is becoming vital, especially in region 2 where there is a larger number of farmers and about 70% of these farmers rely on irrigation. (Mwadzingeni, 2022). The regions in Zimbabwe are facing high temperatures, low rainfall and dry seasons due to the effects of El Nino drought which started in December 2023. (Aid, 2024).This drought event is similar to the severe drought that affected the country in 2015 to 2016 El Nino drought, which resulted in devastating effects, leading to the loss of over 55% of crops in that season. (Chidarikire, 2024)

RELATED WORK

The land reform program, which started in 2000, led to a decline in irrigation infrastructure, causing new landowners to rely heavily on rain for their crops, from 2020, the rain did not provide enough water for the farmers, hence a call to solutions that save water while producing enough food for Zimbabwe. (AgriculcutureSectors, 2024)

Agriculture serves as a central point of Zimbabwe's economy, despite contributing 11 to 14 percent of the country's GDP. This sector employs about 70% of the working population and supplies approximately 60 percent of raw materials to Zimbabwean industries. Zimbabwe experiences most of its rainfall during the summer months (November to March), but many regions of the country face challenges in this regard, especially region 2, where there is a larger number of farmers.

To mitigate the negative impacts of climate change and the induced droughts, a number of research initiatives have been done focusing on water management utilising Internet of Things based soil moisture sensors. Research was done that delved into the integration of agricultural progress with technological advancements, highlighting the immense potential of Internet of Things in farming. They presented a smart drip irrigation setup utilising ESP32, complete with sensors and managed through the Blynk app for data collection and manual adjustments. The ESP32 independent monitors soil conditions and triggers irrigation as needed based on sensor feedback. Successful trials underscore the system's effectiveness in successfully growing crops like green onions, underscoring how IoT innovations enhance operational efficiency and crop management in modern-day agriculture. (Pereira, 2023)

Another technology implemented a fuzzy logic method on herbal chili plants. Drip irrigation, is vital in the cultivation of herbal chili plants with efficiency. Combining this system with quick decision-making methods, such as fuzzy logic, demonstrated the optimisation of water supply for chili herbs based on temperature and soil moisture data. This research aimed at addressing water scarcity in arid regions, boost interest in herbal chili cultivation, and provide a framework for advancing agricultural information technology in areas like Madura. (Bhavsar, 2023)

A discussion on the vulnerability of food security due to climate change and inefficient irrigation practices was made, resulting in the proposal of smart irrigation systems that utilise cloud computing, embedded systems, and Internet of Things to enhance water resource management and ensure food security. (Morchid, 2024)

A technology that monitors environmental factors and automates irrigation was used by (Lean, 2024) and this system aimed at enhancing crop production efficiency while conserving water resources.

(EzekielChimana, 2024) Conducted a research at the Zimbabwe Open University where an irrigation system was developed for the university's greenhouse using soil moisture and light sensors to gather data for analysis.

(Machengete, 2017) Conducted a research at Midlands State University, Zimbabwe where an automated drip irrigation system that uses sprinklers and soil moisture sensors was developed. An SIM900 GSM module assisted in communicating with the developed mobile application.

Research Gap and Solutions

Most drip irrigation systems were implemented on a single plant, but in this research, the user or the farmer is allowed to select the plant that they want to irrigate on a particular day, and irrigation is triggered based on the plant's water needs, and notifications are delivered based on the selected plant. Current drip irrigation systems in other countries make use of sensors like soil moisture sensors to measure the level of moisture in the soil, temperature sensors to measure atmospheric temperature, humidity sensors to measure the amount of water in the air, and some integrate these sensors to communicate with micro-controllers such as Arduino Uno and ESP-32. In this study the researchers used soil moisture sensors to measure the level of moisture in the soil and ESP-32 as a microcontroller. In some regions of Zimbabwe, like Shangani which is between Gweru and Bulawayo, and region 2, they are already using manual drip irrigation, and they are not measuring the amount of moisture in the soil.

In the smart irrigation system, soil moisture sensors were connected to the input pins of the ESP32 microcontroller, and the electronic pump and the solenoid valve were connected to the GPIO (general purpose input output) pins of the ESP32 through the relay. If the value sensed by the soil moisture sensors is below the threshold, a notification is sent to the Blynk mobile application to switch on the pump and open the valve and if the moisture value is above the threshold a notification is sent to switch off the pump and to close the solenoid valve. Figure 2.1 shows the block diagram of the system.

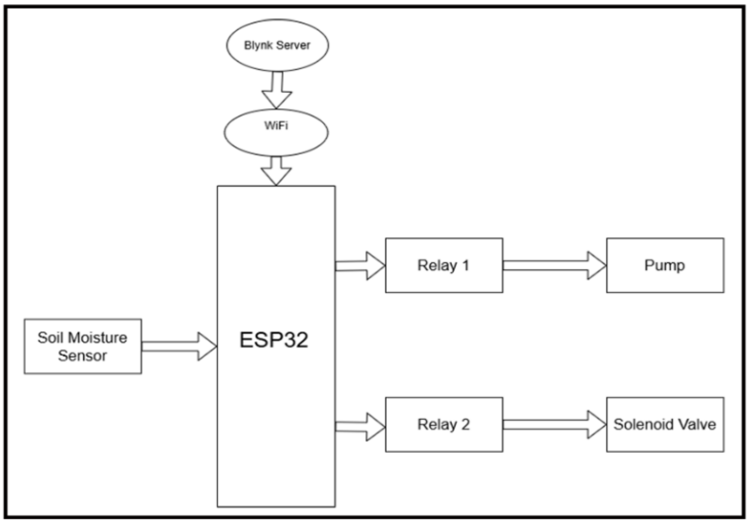

Figure 2.1 Block Diagram of the System

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The architecture in Figure 2.2 shows a complete diagrammatic view of every component that is connected to the ESP32 microcontroller. Code for every hardware component is written in the C++ programming language in the Arduino IDE, and then it is deployed to the ESP32 microcontroller, which will in turn relay the signals to other components like the soil moisture sensors and the water pump.

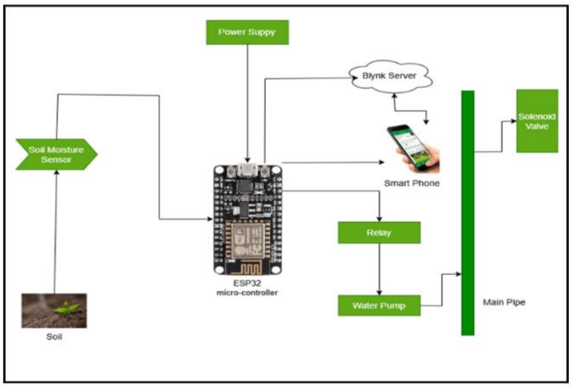

Figure 2.2 System architecture

Figure 2.3 shows an ESP32 microcontroller which is the central control system for the whole system. It receives input from the soil moisture sensors and sends signals to the relay to switch the pump on and off and to open and close the solenoid valve.

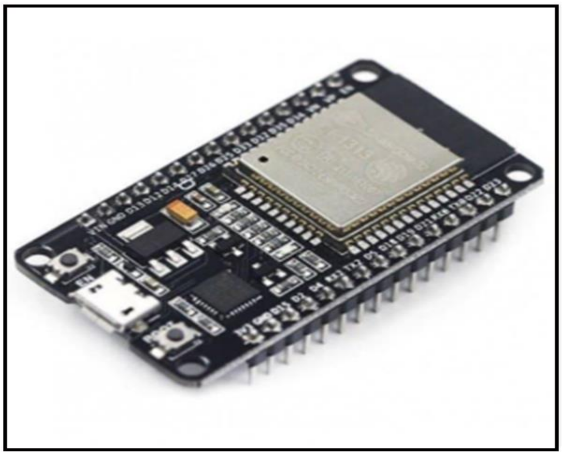

Figure 2.3 ESP32 Microcontroller

Figure 2.4 shows a soil moisture sensor which is used to detect the changes in the soil moisture level and then send the soil moisture figures to the ESP32 for processing and displaying the data on the Blynk application.

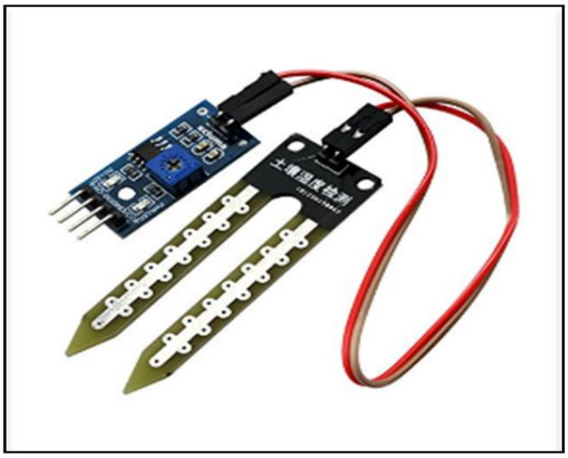

Figure 2.4 Soil Moisture Sensor

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Figure 2.5 shows a solenoid valve which is used for water flow control and it receives a signal from the ESP32 to open and close.

Figure 2.5 Solenoid Valve

Figure 2.6 shows an electronic pump that is used to pump water to different fields and it receives a command from the ESP32 to switch on and off through the relay.

Figure 2.6 Electronic Pump

METHODOLOGY

Quantitative research methodology was used since advanced technology sensors, data analysis and measurable impacts like water conservation, crop productivity and environmental outcomes were used. Descriptive research was used because there was a need for analysing data that was collected from the sensors and also observational studies that were carried out to see how different plants respond to certain quantities of water, depending on the soil type (Quemada, 2021). Experimental research was also used in the research because of the need to test different sensor types and also to test whether or not the smart drip irrigation is going to be efficient for the farmers. The Kanban agile software methodology was used as a software development methodology due to its flexibility, and workflow enhancement.

Sensor accuracy

$$\theta = a.V^2 + b.V + c$$

where

$\theta = \text{Volumetric Water Content}(\%)$

$v = \text{Sensor Output Voltage}(V)$

$$a, b, c = \text{Calibration Coefficients}$$

Table 3.1 Sensor Accuracy Analysis

Actual VWC(%)	Sensor reading(V)	Calibrated VWC(%)	Error(%)
10	1.2	9.8	2.0
20	1.8	19.5	2.5
30	2.4	29.1	3.0
40	3.0	38.7	3.3

Table 3.1 shows soil moisture sensors and how they improve volumetric water content due to voltage change and it shows that the higher the voltage the increase in volumetric water content.

Accuracy: The mean Absolute Error (MAE) = 2.7%

Precision: Standard Deviation(α) = 0.5%

Water Saving analysis

$$\text{Water saved} = \text{Traditional Usage} - \text{Smart System Usage}$$

Sample data was a 30 days trial on maize crop

Table 3.2 Water Saving analysis

Parameter	Sprinkler Irrigation	Smart Drip Irrigation	Savings(%)
Total water used	4500	3200	28.9%
Average daily usage	150	107	28.7%

Table 3.2 shows the difference between traditional sprinkler irrigation water saving and smart drip irrigation water saving and the results prove that the smart drip irrigation is a better approach when it comes to saving water.

The smart drip irrigation reduced water usage by 28.9% for the total water used and 28.7% for the average daily usage. Soil moisture levels of between 45% and 55% VWC (volumetric water content) sustains a plant for a number of days without being watered, and this range needs to be maintained at all times.

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RESULTS

Smart drip irrigation was tested and it displayed the expected results. Soil moisture level was efficiently detected, and every moisture drop or increase was displayed on the main screen. If the soil moisture level was below or above the threshold, notifications were delivered on the application notification screen as an alert to switch on and open the solenoid valve to start irrigating or to switch of and close the solenoid valve to stop irrigating.

Figure 4.1 shows the soil moisture reading and the switch for the solenoid valve and the switch for the pump, and also a menu showing a selection for the plant to be irrigated on a particular day, so that when notifications are generated according to the needs of that plant.

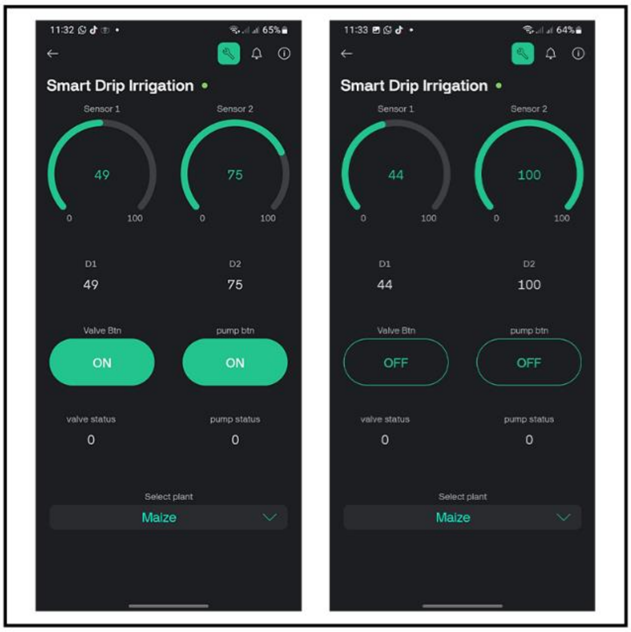

Figure 4.1 The Main Screen

Figure 4.2 shows the current status of soil moisture for different plants. The status is in the form of notifications sent to alert the user if a certain crop has had enough water.

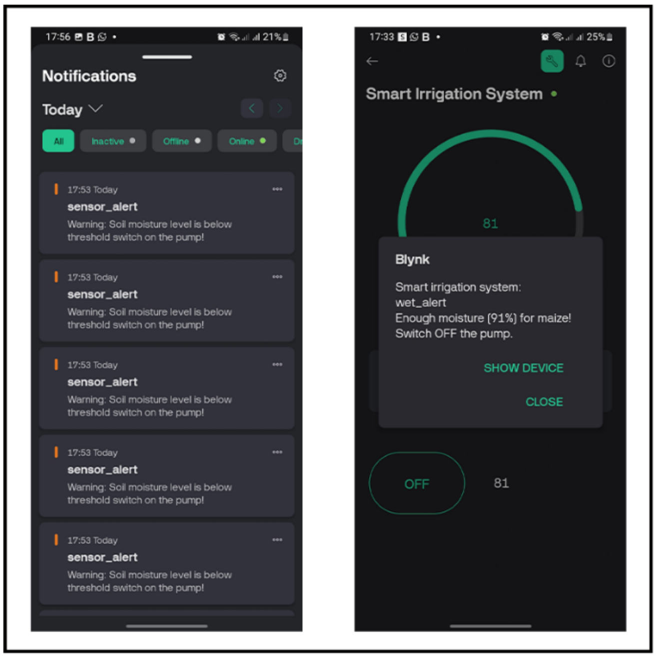

Figure 4.2 Notification Screen

Figure 4.3 shows how the soil was losing its moisture content, and the graph shows soil moisture against time. The voltage gain is measured against time and this voltage will determine the accuracy of our sensor especially the capacitive soil moisture sensors which are easily affected by a very low voltage supply. There will be a need of a pull up resistor to maintain the voltage supply to the soil moisture sensors.

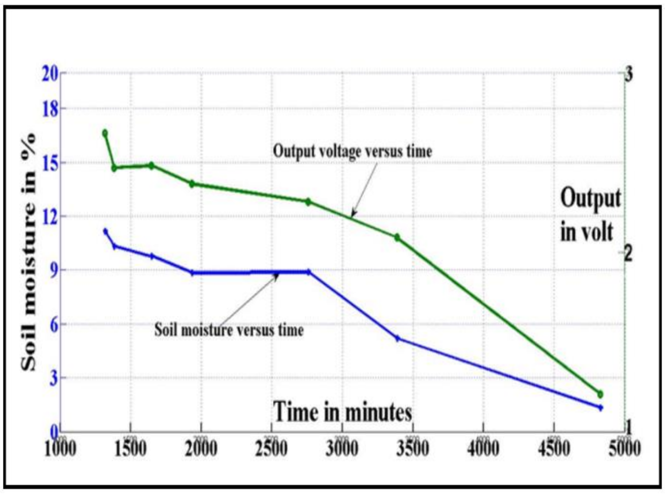

Figure 4.3 Soil Moisture Sensor Data

The system functionality and the coordination of the solenoid and the electronic pump were tested. The biggest challenge was the noise and the vibration of the pump which could affect the soil moisture sensors from reading accurate results but to avoid that a cushion was made to absorb the vibration. Figure 4.4 shows the irrigation system producing results on the mobile phone.

Figure 4.4 Components and Coordination

DISCUSSIONS AND FUTURE WORK

The descriptive and experimental research methodologies, assisted in the evaluation of soil moisture levels using different soil moisture sensors under different soil conditions and helped in checking how sensors responded to different conditions. This approach not only brings light into sensor performance but it also assesses the benefits of using smart drip irrigation. Which can be integrated with sprinkler irrigations to maximise cooling of the leaves if it is too hot. The system can further be improved by implementing a fault detection system in case there is a fault in the pump. There is a need of implementing PH sensors for a complete analysis.

CONCLUSION

This research addressed the potential of smart drip irrigation in addressing the challenges posed by climate change, induced El Niño drought and outdated irrigation schemes. The research advocates for a change to more sustainable and technology driven agricultural solutions, which will improve food security and contribute to the country's economic growth.

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