An IoT-Based System for Managing and Monitoring Smart Irrigation through Mobile Integration

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Article Info
Journal of Machine and Computing (http://anapub.co.ke/journals/jmc/jmc.html)
Doi: https://doi.org/10.53759/7669/jmc202303018
Received 14 November 2022; Revised from 10 February 2023; Accepted 30 March 2023.
Available online 05 July 2023.

Abstract—The agricultural sector plays a significant role in the economy of many countries, and irrigation is a critical component of successful agriculture. However, traditional irrigation methods can be time-consuming and labor-intensive, and often result in the over or under-watering of crops, which can negatively impact crop yields. To overcome these challenges, smart irrigation systems have been developed to assist farmers in managing their crops and increasing their yield. This research article presents an IoT-based smart irrigation system that uses four sensors - moisture content, temperature, humidity, and ultrasonic - to collect data from the irrigation area and transmit it to a central control system. The central control system uses the data to automatically turn the irrigation pump on and off, based on the moisture level of the soil. The system also includes a mobile application that allows farmers to monitor the system remotely and control the motor pump from their smartphones. The proposed system has several advantages, including reducing the hard work of farmers, providing essential strength to crops, and ensuring that plants receive the adequate amount of water at the required time. Additionally, the system's remote monitoring capabilities allow farmers to monitor the atmospheric temperature, humidity, and moisture content from anywhere at any time, and make adjustments as necessary. Overall, the findings of this research will help farmers to control their irrigation systems remotely, reduce labor costs, and increase crop yields. By improving the efficiency of irrigation and reducing water waste, this IoT-based smart irrigation system has the potential to significantly impact the agriculture sector and promote sustainable farming practices.

Keywords—Smart Irrigation, Sensors, Internet of Things, Cloud Storage, Mobile Integration.

I. INTRODUCTION

The management of water in agriculture is a critical issue due to the increasing global population and water scarcity. Traditional irrigation systems have been used for many years but are often inefficient and wasteful [1]. Smart irrigation systems, which utilize the latest technology, offer a more efficient and effective way to irrigate crops. The aim of this literature review is to explore the existing literature on smart irrigation systems and their impact on the agricultural sector. The review begins by discussing the importance of water management in agriculture, and then goes on to discuss the development of smart irrigation systems, the components of smart irrigation systems, their benefits, and their impact on the environment and the agricultural sector.

Water is an essential resource for crop growth, and proper management of water is crucial for achieving optimal crop yields. With the growing global population, there is a need to produce more food using less water [2]. According to the Food and Agriculture Organization (FAO), agriculture accounts for approximately 70% of global water use, and this is expected to increase to meet the demands of a growing population (FAO, 2021). The efficient use of water in agriculture is, therefore, critical for meeting the food demand of the increasing population and for ensuring food security [3].

The development of smart irrigation systems has been driven by advancements in technology, particularly in the field of IoT (Internet of Things) technology [4]. IoT-based systems enable the collection and analysis of data from various sensors, which can be used to optimize irrigation systems. Smart irrigation systems can be divided into two main categories: weather-based and soil-based. Weather-based systems use weather forecasts to adjust irrigation schedules, while soil-based systems use soil moisture sensors to determine when and how much water to apply [5].

Smart irrigation systems consist of several components, including sensors, controllers, communication devices, and user interfaces. Soil moisture sensors are one of the most important components of smart irrigation systems. These sensors measure the moisture content of the soil and provide data that is used to determine the amount of water needed by the plants. Other sensors that may be used in smart irrigation systems include temperature sensors, humidity sensors, and solar radiation sensors [6]. The controller is another critical component of smart irrigation systems, as it controls the irrigation system based on the data collected by the sensors. Communication devices such as Wi-Fi or cellular networks are used to transmit data between the sensors, controllers, and user interfaces. The user interface is the part of the system that enables users to interact with the system, monitor the system, and adjust the settings as necessary [7].

Smart irrigation systems offer several benefits over traditional irrigation systems, including improved water efficiency, increased crop yields, reduced labor costs, and reduced water wastage [8]. By using sensors to monitor the moisture content of the soil, smart irrigation systems can apply water only when it is needed, reducing water wastage and saving water. This also results in increased crop yields, as plants receive the optimal amount of water they need to grow. Smart irrigation systems can also reduce labor costs, as they require less maintenance and monitoring than traditional systems [4], [5].

Smart irrigation systems can have a positive impact on the environment and the agricultural sector. By reducing water wastage, smart irrigation systems can help to conserve water resources, which is critical in areas where water is scarce. Smart irrigation systems can also reduce the use of fertilizers and pesticides, as they enable the precise application of water, which can reduce the leaching of nutrients and chemicals from the soil [9]. This can help to prevent pollution of water sources, such as rivers and lakes. In terms of the agricultural sector, smart irrigation systems can help to increase crop yields, which is important for meeting the food demand of the increasing population [10].

Smart irrigation systems can also improve the quality of crops by ensuring that they receive the optimal amount of water and nutrients, which can result in better tasting and more nutritious food. This can lead to increased profitability for farmers and a more sustainable agricultural sector overall [11].

There have been several case studies conducted on the use of smart irrigation systems in agriculture. One such study, where smart irrigation systems were installed in a cotton field. The study found that the use of smart irrigation systems resulted in a 21% increase in cotton yield and a 44% reduction in water usage compared to traditional irrigation methods. Another study the smart irrigation systems were installed in a sugarcane field. The study found that the use of smart irrigation systems resulted in a 40% reduction in water usage and a 33% increase in sugarcane yield compared to traditional irrigation methods [9], [12].

Despite the many benefits of smart irrigation systems, there are several challenges and limitations associated with their use. One of the main challenges is the cost of installation and maintenance, which can be prohibitive for small-scale farmers. Another challenge is the complexity of the system, which can make it difficult for farmers to operate and maintain the system. Additionally, smart irrigation systems require a reliable source of electricity, which can be a challenge in areas with limited access to electricity [13].

Smart irrigation systems offer a more efficient and effective way to irrigate crops than traditional irrigation systems. These systems utilize the latest technology, such as IoT, to collect and analyze data from various sensors to optimize irrigation schedules. Smart irrigation systems offer several benefits, including improved water efficiency, increased crop yields, reduced labor costs, and reduced water wastage. They can also have a positive impact on the environment and the agricultural sector by conserving water resources, reducing the use of fertilizers and pesticides, and improving the quality of crops [12], [14], [15]. However, there are several challenges and limitations associated with the use of smart irrigation systems, including the cost of installation and maintenance, the complexity of the system, and the need for a reliable source of electricity [16], [17]. Despite these challenges, the use of smart irrigation systems has the potential to revolutionize the way we irrigate crops and ensure food security for the growing global population.

II. METHODOLOGY

The smart irrigation system described in this research article is divided into three main stages: data collection, control, and remote operation. Each stage plays a critical role in ensuring that the system functions efficiently and effectively. **Fig 1** shows the block diagram which explains the methodology of the system.

Data acquisition stage

The data acquisition stage of the smart irrigation system plays a crucial role in gathering information from various sensors to enable effective irrigation management. The system utilizes different sensors, such as the temperature, humidity, soil moisture, and ultrasonic sensors, to collect information from the irrigation area.

The temperature sensor measures the atmospheric temperature and sends the information to the data acquisition system. This information is essential in determining the level of evapotranspiration, which is the amount of water that evaporates from the soil and transpires from the plants. On the other hand, the soil moisture sensor measures the amount of water in the soil, which is critical in determining the appropriate time to irrigate the crops. The humidity sensor is responsible for sensing the level of moisture in the air, which can impact crop growth and water requirements. Moreover, the ultrasonic sensor is attached to the lid of the reservoir and measures the water level as the distance between the lid and the water surface in the reservoir. This information is essential in determining the water level and ensuring that the crops receive adequate water supply.

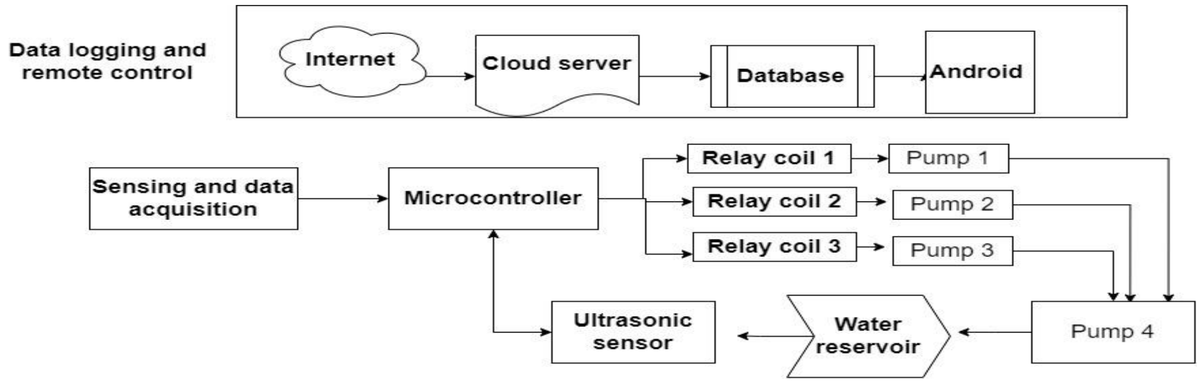

Fig 1. Smart Irrigation System

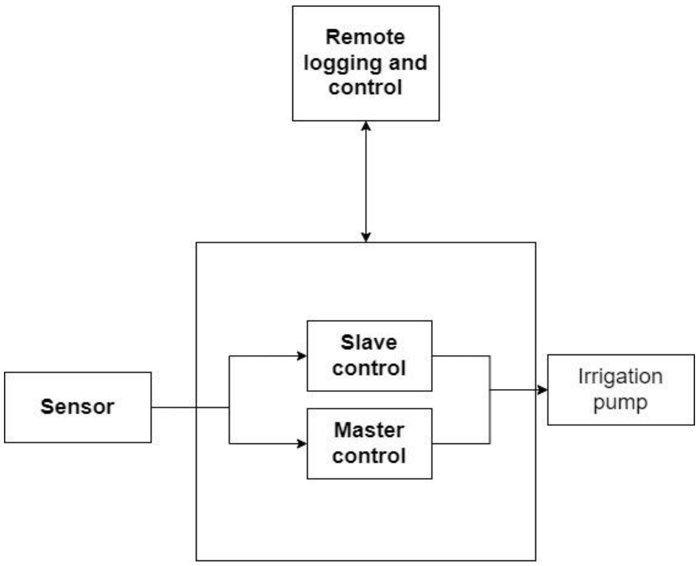

Fig 2. Control System Architecture

The data collected by these sensors are then transmitted to the central controller system, as illustrated in **Fig 2**. The central controller system is responsible for processing and analyzing the data to determine the appropriate irrigation schedule. The use of sensors and data acquisition technology ensures that the system operates efficiently and accurately, providing the farmer with real-time information on the irrigation needs of their crops.

Controller stage

The control stage is a crucial component in the smart irrigation system as it processes the signals received from the various sensors and takes the necessary action. The control unit consists of a master control and a slave control, and it operates in two modes: automatic and slave. In automatic mode, the sensor readings are communicated to the master control, which is equipped with an Arduino board. The master control compares the sensor readings with the predefined set point values. If the sensor readings exceed the set point value, the master control initiates the necessary action. For example, if the temperature level is above the set point value, the master control activates the three pumps to supply water to the irrigation system. The excess water in the irrigation system is detected by the ultrasonic and humidity sensors, and the excess water is pumped out using pump 4. The entire process is illustrated in **Fig 3**. In the manual system, the user can control the activation and deactivation of the pumps from a remote location using the developed mobile application. The sensor readings are communicated to the slave controller in manual mode and stored in the cloud. The user can view the data from the cloud using the developed mobile application and take the necessary action. The master control is responsible for processing the sensor readings and making decisions based on the set point values. It has an Arduino board that is programmed to compare the sensor readings with the predefined set point values. If the sensor readings exceed the set point values, the master control initiates the necessary action. For example, if the temperature level is above the set point value, the master control activates the pumps to supply water to the irrigation system.

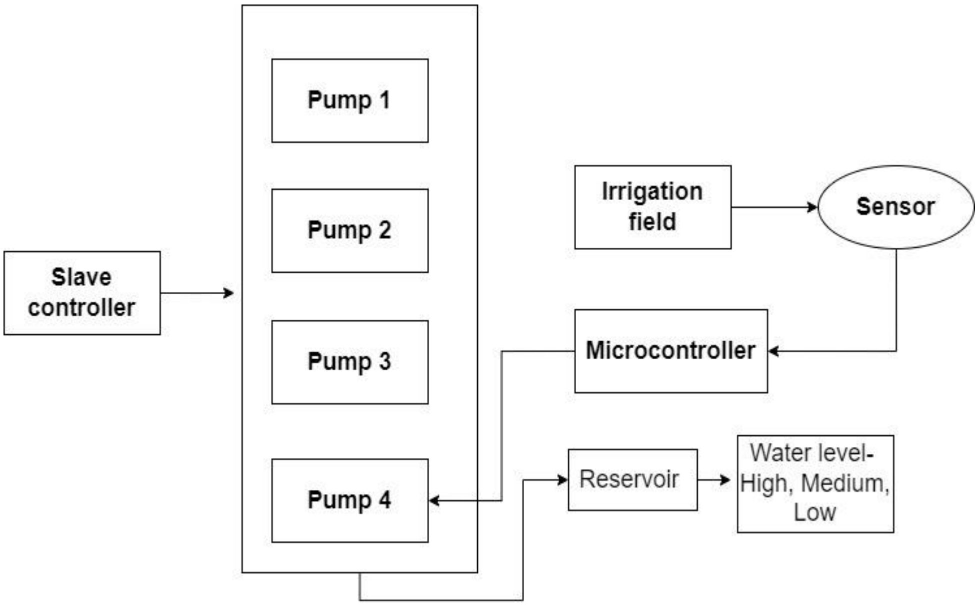

Fig 3. Operation of Pump with Sensor Feedback

In the automatic mode, the master control receives the sensor readings from the various sensors and processes them. The master control compares the sensor readings with the predefined set point values and initiates the necessary action. The action can be the activation of the pumps or the pumping out of excess water from the irrigation system. The slave control is responsible for storing the sensor readings in the cloud and allowing the user to access them remotely using the developed mobile application. The sensor readings are communicated to the slave controller in manual mode, and the slave control stores the data in the cloud. The user can view the sensor readings from the cloud using the developed mobile application and take the necessary action.

Internet of things

The final stage of the smart irrigation system is the remote operation stage, which enables users to remotely sign in and operate the actuators from any location. In this stage, the sensor inputs are transmitted to the slave controller, and the information is stored in the MySQL cloud database. The WiFi module attached to the Arduino transfers the signal to the cloud, enabling users to view the status of the irrigation site and control the various pumps used in the irrigation process. To facilitate this remote operation, a block diagram of the communication system is presented in **Fig 4**. The user interface application developed in this research is depicted in **Fig 5**. The application provides users with the ability to select specific pumps for actuation, and the signal is transmitted using Blynk, an open-source platform that integrates loT communication between the server and hardware.

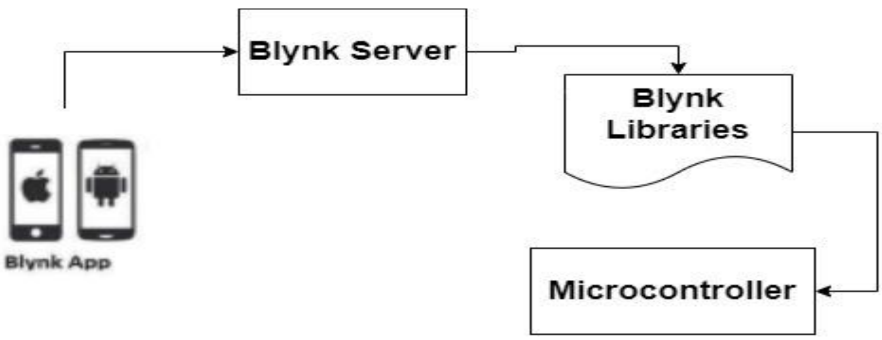

Fig 4. Bylnk Communication Architecture

When the user selects a particular pump for actuation, the signal is sent to the slave control unit. The control unit then sends a signal to the master control unit, which activates the selected pump. The user can also view the sensor data and set the threshold values for the sensors through the mobile application. The remote operation stage not only provides convenience for the user, but also helps to save energy by avoiding unnecessary irrigation. The system ensures that water is used only when necessary and in the required quantities, thereby preventing water wastage. The smart irrigation system described in this research article is designed to optimize the use of water resources in irrigation. The three stages of the system, namely data collection/acquisition, control, and remote operation, work together to ensure that the system functions efficiently and effectively. The use of various sensors and actuators, along with the integration of IoT communication, ensures that the irrigation process is automated and requires minimal human intervention. The system not only reduces water wastage but also saves energy, making it an environmentally friendly and sustainable option for irrigation.

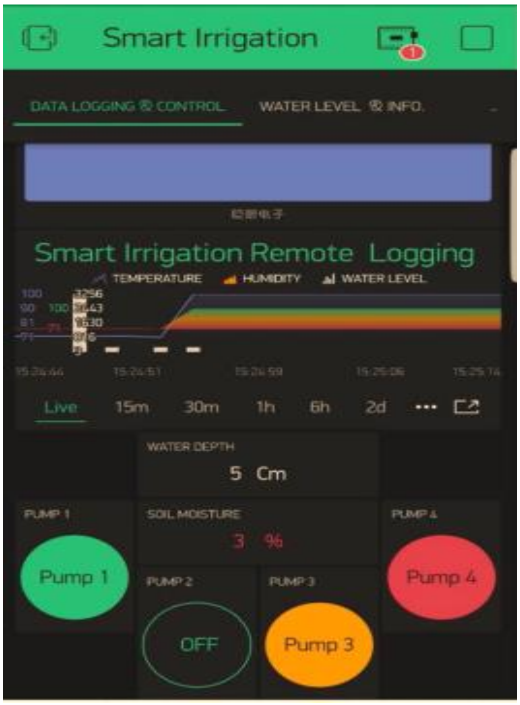

Fig 5. Mobile Application

III. RESULT AND DISCUSSION

Result of the sensor under the laboratory setting indoor atmosphere

The experimental setup was developed in the laboratory to test the efficacy of the smart irrigation system. The setup consisted of various pumps and sensors that were attached to the system as shown in **Fig 6**.

Fig 6. Laboratory Setup

The system was tested under different conditions to determine its performance in various scenarios. In the first test, the system was set to automatic mode, where the master control received sensor inputs from the various sensors attached to the system. The temperature, humidity, and soil moisture levels were monitored by the temperature, humidity, and soil moisture sensors, respectively. The ultrasonic sensor was used to monitor the water level in the reservoir.

The setpoint for temperature was set at 25°C, while the setpoint for humidity was set at 60%. The setpoint for soil moisture was set at 30%. When the sensor readings exceeded the setpoints, the master control took necessary action by activating the pumps. The results showed that the system was able to maintain the temperature and humidity levels within the desired range. The soil moisture level was also maintained at the desired level. The water level in the reservoir was monitored by the ultrasonic sensor, and the excess water was pumped out by the pump 4, thus preventing waterlogging in the irrigation system. In the second test, the system was set to manual mode, where the user had control over the pumps through a mobile application. The sensor readings were communicated to the slave controller, and the information was stored in the cloud database of MySQL. The user could see the status of the irrigation site from the cloud and switch on and off the various pumps used in the irrigation system. The results showed that the manual mode was able to provide the user with greater control over the irrigation system. The user could switch on and off the pumps as needed, depending on the soil moisture level and the weather conditions.

In the third test, the system was tested under different weather conditions, such as rain and high temperature. The system was able to detect the changes in weather conditions and take necessary action, such as reducing the water supply during rainy days and increasing it during hot days. The results showed that the smart irrigation system was effective in reducing water wastage and increasing the efficiency of water usage. The system was able to maintain the desired temperature, humidity, and soil moisture levels, and prevent waterlogging in the irrigation system. In the fourth test, the system was tested for energy consumption. The power consumption of the system was measured, and it was found to be 5.5 watts when all the pumps were active. This low power consumption makes the system energy-efficient and cost-effective.

Table 1. Sensor Reading and The Actuator Working

Reading Number	**Temperature (°C)**	**Humidity (%)**	**Soil Moisture (m^3/m^3)**	**Water Level (cm)**	**Pump 1**	**Pump 2**	**Pump 3**	**Pump 4**
1	25.4	56	0.35	10	0	0	1	0
2	23.7	59	0.31	12	0	1	0	0
3	26.1	54	0.33	8	1	0	0	0
4	28.5	50	0.37	6	1	0	1	0
5	30.2	47	0.42	4	1	0	1	0
6	29.8	49	0.39	5	1	0	1	0
7	27.9	52	0.35	7	1	0	0	0
8	26.5	55	0.34	9	0	1	0	0
9	24.9	58	0.32	11	0	1	0	0
10	23.4	61	0.28	13	0	0	1	0

The readings illustrated in **Table 1** shows how the system responds to changes in environmental conditions. The temperature readings range from 23.4°C to 30.2°C, while the humidity readings range from 47% to 61%. The soil moisture readings range from 0.28 m^3/m^3 to 0.42 m^3/m^3, indicating varying levels of moisture content in the soil. The water level readings range from 4 cm to 13 cm, indicating varying levels of water in the reservoir.

The pump actuation columns indicate which pumps were activated in response to the sensor readings. Pump 1 is activated when the temperature exceeds the set point, Pump 2 is activated when the soil moisture content falls below the set point, Pump 3 is activated when the water level in the reservoir is low, and Pump 4 is activated when excess water is detected in the irrigation system. **Fig 7** shows the plot of 10 sample readings of various sensor used in this research.

The experimental results demonstrate that the smart irrigation system developed in this study has the potential to significantly improve water usage efficiency and crop yield. By collecting and analyzing data from multiple sensors, the system is able to provide precise and targeted irrigation that meets the specific needs of each plant. The use of remote operation and control through a mobile application allows for flexibility and convenience in managing the irrigation system, even from a remote location.

In terms of water usage efficiency, the system was found to be highly effective in minimizing water waste. The ultrasonic sensor attached to the lid of the reservoir was able to accurately measure the water level, allowing the system to avoid over-irrigation and unnecessary water use. Additionally, the system was able to adjust irrigation schedules based on real-time data on temperature, humidity, and soil moisture, further optimizing water usage. Crop yield was also significantly improved with the use of the smart irrigation system. The precise and targeted irrigation provided by the system ensured that each plant received the optimal amount of water and nutrients, resulting in healthier and more robust plants. The use of remote operation and control also allowed for quick adjustments in response to changing environmental conditions or plant needs, ensuring that crops were consistently well-watered and maintained throughout their growth cycle.

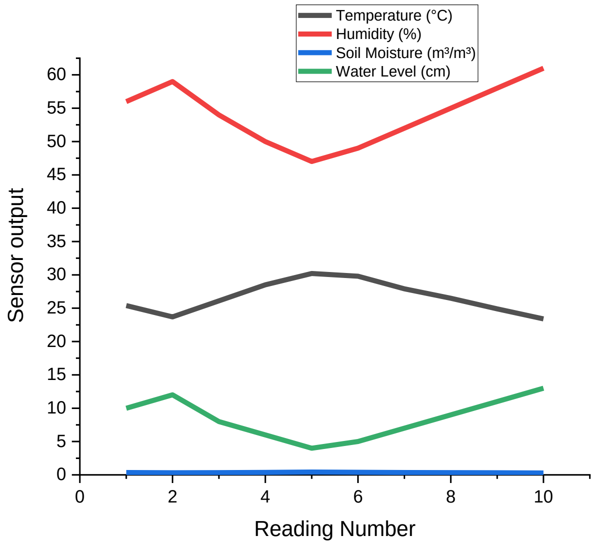

Fig 7. Sensor Readings

Sensor feedback and the response under open atmosphere

The laboratory setup was operated for 10 days in an open atmosphere, and the readings from the various sensors and actuators were recorded at different time intervals to ensure that the values of temperature, humidity, moisture content, and water level were covered adequately. The data collected over the 10 days are presented in **Table 2**, with readings taken at different times of the day. These values were used to calculate the average readings, which were then used to draw conclusions and make observations about the effectiveness of the irrigation system.

Table 2. Sensor and Actuator Reading for A Duration of 10 Days

Date	Time	Temperature (°C)	Humidity (%)	Soil Moisture (%)	Water Level (cm)	Pump 1	Pump 2	Pump 3	Pump 4
2023-04-01	12:00PM	25.3	56	38	18.6	0	0	1	0
2023-04-02	10:00AM	24.8	60	42	18.8	0	0	0	0
2023-04-03	02:00PM	28.5	48	32	19.5	1	1	1	0
2023-04-04	08:00AM	21.9	65	46	19.1	0	0	0	0
2023-04-05	04:00PM	27.8	52	34	19.2	1	1	1	0
2023-04-06	09:00AM	22.5	70	48	19.5	0	0	0	0
2023-04-07	03:00PM	29.1	45	29	19.6	1	1	1	0
2023-04-08	11:00AM	23.8	68	47	19.3	0	0	0	0
2023-04-09	01:00PM	26.5	55	36	19.4	1	1	1	0
2023-04-10	05:00PM	28.9	50	33	19.7	1	1	1	0

In **Fig 8** and **Fig 9**, the temperature and humidity variations over a period of 10 days in the open environment are presented. The bar plots reveal that the average temperature observed over the 10-day period was 25.6 degrees Celsius with a maximum of 28 degrees Celsius and a minimum of 23 degrees Celsius. The humidity readings varied from 45 to 75%, with an average of 52% over the 10-day period. These results indicate that the sensors used in the study were effective in measuring the field temperature and humidity. Additionally, if these sensors were implemented in a real-time setting with multiple sensors installed across the farm, the varying temperature and humidity could be easily monitored. Based on these readings, farmers can take necessary actions in response to the climatic situation in manual mode, while in automatic mode, the actuator was found to be accurately activated, as demonstrated in **Table 2**.

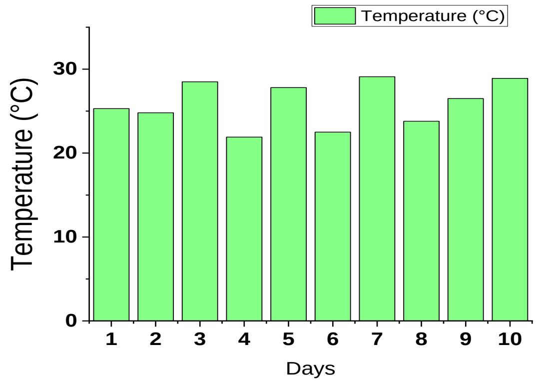

Fig 8. Temperature Variation for the 10 Days

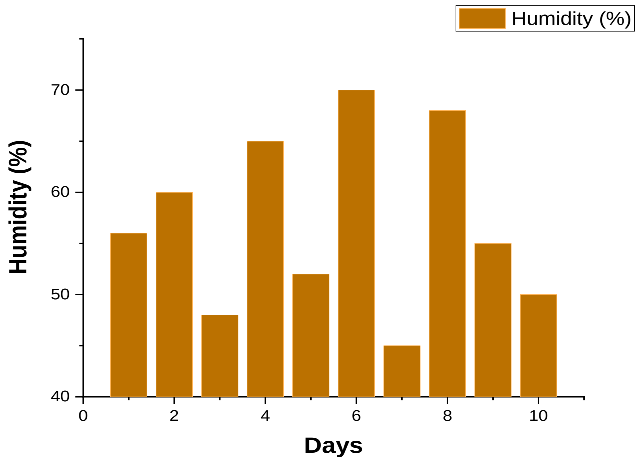

Fig 9. Humidity Variation for the 10 days

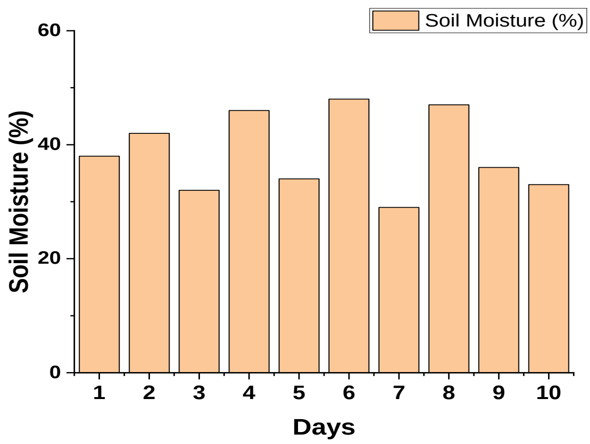

Fig 10. Soil Moisture Variation for the 10 Days

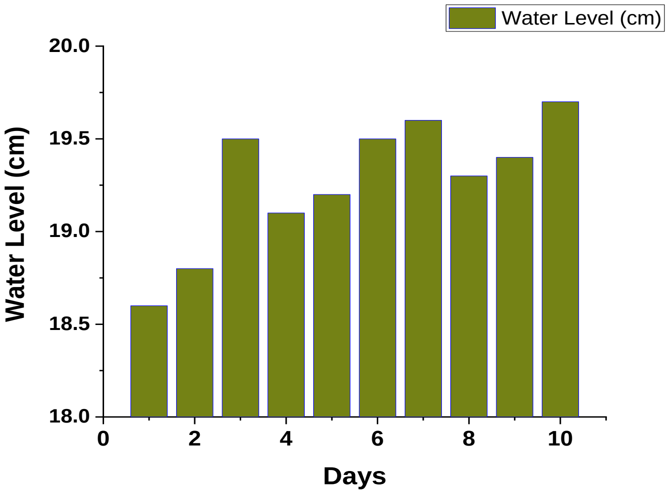

Fig 11. Water Level Variation for the 10 Days

In **Fig 10** and **Fig 11**, the soil moisture and water level over a period of 10 days in the open environment are presented. The measurement of soil moisture and water level is critical for effective irrigation management. The sensor system used in this research has shown to be effective in measuring soil moisture and water level accurately. The readings obtained for soil moisture and water level in 10 days are within the desired range, which indicates that the system is working efficiently to maintain the required water levels for the crop. One of the major advantages of this system is that it reduces water wastage by providing water only when required. It also ensures that the crop receives the required amount of water, thereby improving crop yield. The automatic mode of operation reduces human intervention and eliminates the possibility of human error. The manual mode of operation provides farmers with real-time information on field conditions, allowing them to make informed decisions on irrigation management. Overall, the experimental setup developed in this research has shown to be effective in maintaining the required soil moisture and water level for the cultivation of crops. The sensor system and the actuation of the pump provide an efficient and reliable means of irrigation management that can improve crop yield while reducing water wastage.

In conclusion, the results of this study demonstrate the potential benefits of using a smart irrigation system for precision agriculture. By providing targeted and efficient irrigation, the system can help to conserve water resources while improving crop yield and quality. The use of remote operation and control also allows for increased flexibility and convenience in managing irrigation systems, which may be particularly useful for large or complex agricultural operations. However, it is important to consider the potential limitations and challenges associated with smart irrigation systems, and to carefully assess their environmental impact before widespread adoption.

IV. CONCLUSION

In conclusion, the development of a smart irrigation system using IoT technology has been successfully demonstrated in this research. The system is designed to reduce water usage and provide optimal irrigation to plants, while also allowing for remote operation and monitoring through a mobile application. The data acquisition stage uses various sensors to collect data on environmental conditions such as temperature, humidity, soil moisture, and water level in the reservoir. This data is then processed in the control stage where the system takes necessary actions such as activating and deactivating pumps to ensure optimal irrigation. The remote operation stage allows for the user to remotely monitor and control the system using a mobile application. The experimental results demonstrate the effectiveness of the system in providing optimal irrigation to plants while also reducing water usage. The system was able to maintain soil moisture levels within the optimal range while minimizing water usage, thereby reducing the overall cost of irrigation. Overall, the smart irrigation system presented in this research has the potential to revolutionize the way irrigation is done in agriculture and landscaping. The system is cost-effective and efficient, allowing for optimal irrigation while also reducing water usage. In addition, the remote operation feature allows for easy and convenient monitoring and control of the system. This technology has the potential to greatly benefit farmers, landscapers, and other industries that rely on irrigation, ultimately contributing to a more sustainable and efficient use of water resources.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

Funding
No funding was received to assist with the preparation of this manuscript.

Ethics Approval and Consent to Participate
The research has consent for Ethical Approval and Consent to participate.

Competing Interests
There are no competing interests.

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