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RESEARCH ARTICLE

Project BIS-IG: Prototyping of Wireless Irrigation Control System Using Arduino Microcontroller with SMS Notification

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Abstract

Objectives: This study aims to: 1. Improve water sustainability using automated water control systems and 2. Determine exact water requirement to irrigate on fine, medium and coarse soil type using drip irrigation technique. **Methods:** To work effectively with the Wireless Irrigation System, a sensor module was developed to sense out the soil humidity and water content of the soil. The system is designed using drip irrigation technique as a model for testing irrigation control. It will focus on three soil types which include fine, medium and coarse in determining the need of soil humidity level in the system. The developed technology was compared to the existing irrigation control system in terms of speed of irrigation and amount of water used in the irrigation procedure. **Findings :** In the existing irrigation system, continuous distribution of water to farmlands takes place. The water sustainability was not controlled. The proposed irrigation control system analyzes the soil humidity level of the farmland, and only applies irrigation when a specific soil which needs irrigation based on humidity level; when the soil humidity is below normal, the reservoir will release water to plants. After a series of testing and comparing of the two-irrigation control system during testing, it is proven that the developed irrigation control system can be used to improve water sustainability in irrigation. An average of 52.777777775% of water from the reservoir was saved using the automatic irrigation control system. **Novelty:** The proposed system was used as a prototype material or model in testing lowland areas for a bigger wireless irrigation control system that can be used in automation of irrigating farmlands through drip irrigation technique. The developed system was tested in a farm land miniature where soil types are in different stations. The developed system can reduce the use of water in irrigation.

Keywords: Arduino; drip irrigation; wireless communication; desktop application; embedded system

1 Introduction

The rate of irrigation development in the Philippines has been alarmingly slow. The level of irrigation development in terms of the ratio of actual to the total potential irrigable area of 3,019,609 hectares increased from 45.2% in 1985 to only 60.35% in 2017 (NIA, 2017). As a result, the country has resorted to rice importation for many years to address food security instead of boosting self-sufficiency for a more inclusive economic growth.

National Irrigation Administration is looking for options that may help the farmers in the province improve their irrigation control system. The need of increasing plants production entails great water supply throughout farming season. This would mean that water supply is very important in the agricultural sector specifically in rice farming. Challenge lies on the proper, adequate and up-to-date irrigation system that will answer the premise of the country.

In the existing manual irrigation control system, the water continues to distribute water from the reservoir to rice fields in real time without considering the humidity and type of soils. The water distribution is not controlled and the water from the reservoir are wasted. Figure 1 shows the flowchart of the existing irrigation control system.

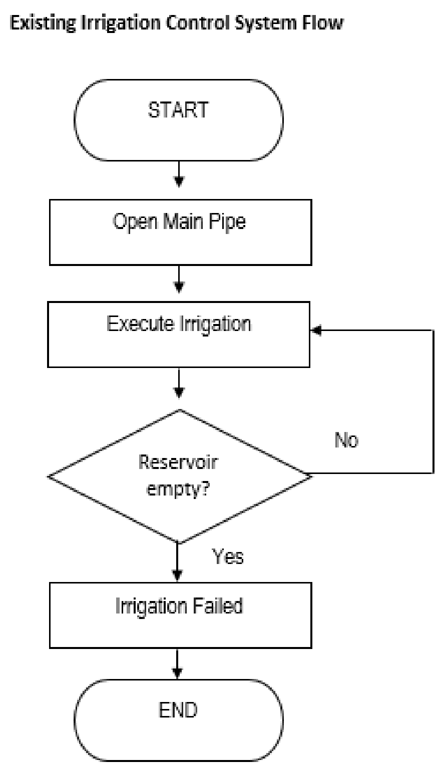

Fig 1. Flowchart of the existing manual irrigation system

Munir et al [1], proposed a solution for smart irrigation constitutes with three modules: first module is the sensor network, which is required to sense parameters influencing the water need. They used sensors DHT22, light sensor BH1750, and HL-69 hygrometer to sense temperature, soil moisture, light, and humidity in air. In the third module, edge and main IoT servers are used to transfer and receive data via HTTP requests. In the second module, KNN are applied on the sample dataset to train the model and used it for efficient decision-making of water requirements. The trained model classifies the input into five possible classes based on input values such as highly not required, not required, average, required, and highly required.

Lloret et al [2], designed a user application that displays the information gathered by the sensors and to allow the farmer to control the irrigation system. Tests were performed by the researcher in the environment to determine the coverage of the nodes with different deployments and to evaluate the correct performance of the system and the sensors. The researcher presented a system for flood irrigation that consisted of a sensor network that utilized WiFi as its communication protocol. Several atmospheric parameters such as temperature, humidity, and rain, soil parameters such as humidity, and water parameters such as water temperature, salinity, and water height were measured by different sensors.

In another study by Dahane et al [3], implemented a platform for precision agriculture which allows to collect fundamental physical phenomena (the moisture of the soil, air temperature, humidity, water level, water flow, luminous intensity) required for the precision agriculture, which will be treated to calculate the need for water needed for optimal irrigation. The platform consists of a sensor/actuator node, a desktop application and a gateway switches relay which controls water pump according to the requirement. The researchers concluded that the system developed is a good starting point for a smart irrigator. Arduino were used as the microcontroller of the prototype.

Fragaria et al [4], developed a systemtah monitors the humidity levels, moisture content of the soil and surrounding temperature. Parameter values such as maximum and minimum temperature, maximum and minimum humidity values can be monitored accordingly by sending an sms to the system monitors and control the water content of the soil using a moisture sensor which runs under the control of a microcontroller. The device has been successfully tested under simulated conditions and showed the ability of controlling temperature, humidity and soil moisture. The device showed the capability of sending sms holding the latest temperature and humidity information and also the status of the greenhouse.

Garcia et al [5], provided an overview of the actual state of the art regarding IoT irrigation systems for agriculture. They identified the most monitored parameters to characterize water quality for irrigation, soil and weather conditions. They have also identified the most utilized nodes to implement IoT and WSN systems for the irrigation of crops and the most popular wireless technologies. Finally, they have provided a 4-layer architecture proposal as well for the management of crop irrigation.

Jain et al [6], developed an IoT-based smart Irrigation system where soil, temperature, humidity sensors, submerged pump, and wireless camera are interfaced with a microcontroller with the cloud network system. In the cloud network system, the data is stored and can be accessed remotely. By operating submerged pumps, the plant/crop health can be improved by interfacing wireless cameras, the plant/crop health can be monitored anywhere. By conducting different experiments, it provides a remote monitoring solution to find the plant condition. By using the system, the users like farmers can monitor the plantation condition which improves the yielding of plantation towards enhancing overall production.

Drip irrigation is ideal for a wide variety of soil types. Water must be administered gently on clay soils to avoid surface water ponding and runoff. Higher emitter discharge rates will be required on sandy soils to guarantee appropriate lateral wetting of the soil.

Reddy et al [7], associated drip irrigation system on the basis of IOT technology. A Wi-Fi enabled microcontroller NODEMCU was used to inflict the data from the server. They developed a system that can access the microcontroller through the web application or an android application. Through the developed application, water level can be controlled by checking the soil status and data from microcontroller used in the garden.

Parimala et al [8], developed an Intelligent IoT based Automated Irrigation system where sensor data pertaining to soil moisture and temperature captured and accordingly KNN (K- Nearest Neighbor) classification machine learning algorithm deployed for analyzing the sensor data for prediction towards irrigating the soil with water. This is a fully automated where devices communicate among themselves and apply the intelligence in irrigating. This has been developed using low cost embedded devices like Arduino Uno, Raspberry Pi3.

From the above findings, it is investigated that the existing irrigation control system of NIA can be improved through:

- Developing a device that can sense the farmlands/rice field's soil moisture and the reservoir's water level.
- Developing a device that can determine appropriate water amount needed of a specific soil type.
- Transmit and receive data and instructions through wireless communication protocol.
- Update farmers the rice field's/ farmlands soil humidity status and reservoir's water level through SMS.
- Store rice field's/ farmlands soil humidity status in a real-time to a desktop application database.
- Apply Drip Irrigation Technique through the developed device.

To achieve these possible improvements, the researcher developed a device that will primarily track the plants' water consumption by calculating the water content of the soil using a soil moisture sensor, transmitting it through a wireless protocol and displaying in a desktop application. The moisture level measured by the sensor is compared to the value set in the Arduino. If the plant's moisture content is too low, the Arduino will send a command to water it, and vice versa. Water will be turned off until the sensor reading reaches the programmable value defined for the farm soil. As a result, this technology enables reports to be delivered directly to the consumer via their cellular phone in an easily understandable format.

2 Proposed Work

This presents a detailed discussion of the methods, techniques, and tools the researchers used to satisfy the identified objectives. This includes Conceptual Framework, Context Diagram, Entity Relationship Diagram, System Architecture, Hierarchical Input Process Output and Block Diagram, Hardware and software.

2.1 Conceptual Framework

The study was guided by the researcher's conceptual framework developed. To work effectively with the Wireless Irrigation System, a sensor module will be developed to sense out the soil humidity and water content of the soil. As the humidity of the soil decreases, automatically the Irrigation System will flow out water to irrigate the rice fields. Two sensors are connected to Arduino ATMega to get soil humidity data and water level data, these are soil humidity sensor and water level sensor. These data are transmitted to another Arduino-based device through a transceiver. Received data are displayed graphically and numerically in a desktop application. This desktop application can be accessed after entering valid user data from the database. The system requires the user to select the soil type of the farmland. Figure 2 represents the researcher's conceptual framework of the study.

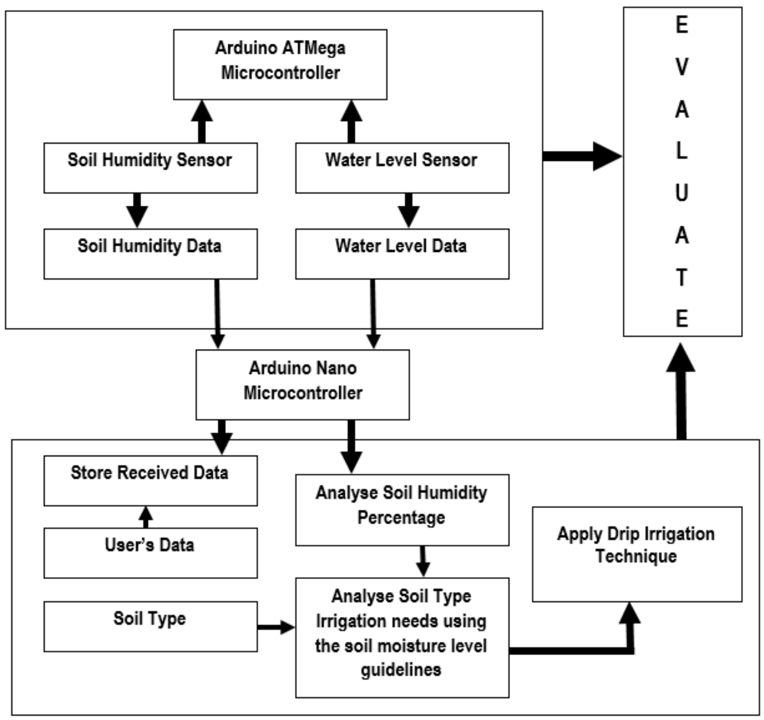

Fig 2. Conceptual Framework

2.2 Entity Relationship Diagram

This study used snowflake schema to identify relationships between tables of the system's database. Figure 3 shows the snowflake schema of the system. A single account can view many soil humidity and water level records.

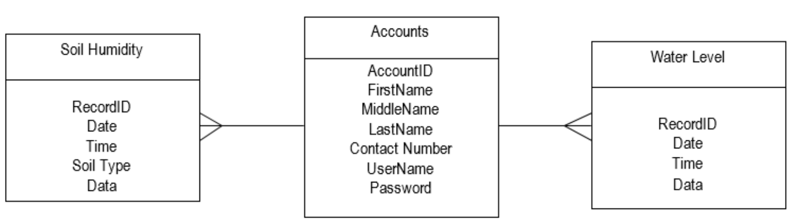

Fig 3. Snowflake Schema

2.3 System Architecture

Figure 4 represents the system architecture of the system. A device will be installed in the rice field. This device has a soil humidity sensor to monitor the rice field's soil humidity attached to the rice field and a water level sensor to monitor the water level attached to the water source. Water level and soil humidity data are transmitted to the server which is the desktop application when a connection between the device and the app is stable. The system sends water level and soil humidity through SMS to a mobile phone registered in the system.

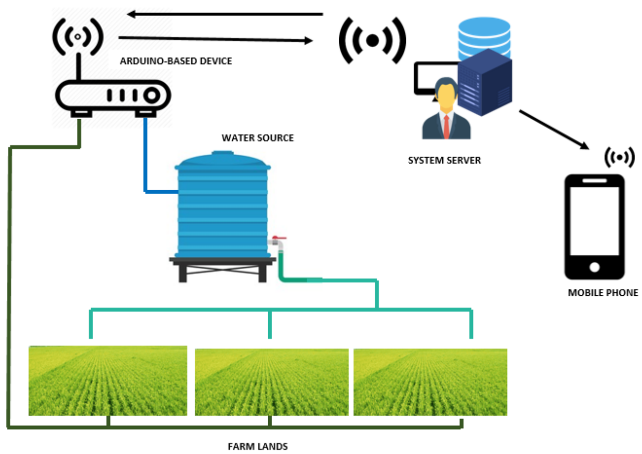

Fig 4. System Architecture

2.4 Block Diagram

Figure 5 represents a block diagram of the system. The device installed in the farmland needs to be powered with a 12 volts electric supply. Two sensors are connected to a microcontroller (Arduino ATMega) which captures the soil humidity percentage and water level. These data are transmitted to another microcontroller (Arduino Nano) through a transceiver module. This data now is transmitted to a desktop application for analysis and displayed. The irrigation command will be sent back to Arduino ATMega to perform irrigation.

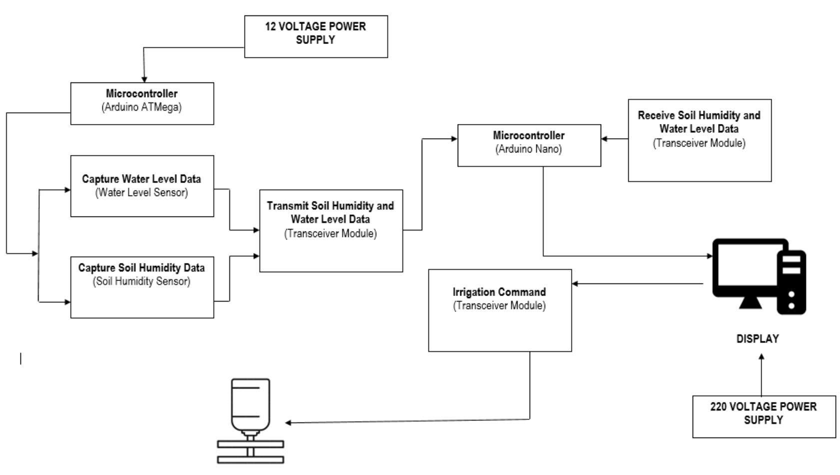

Fig 5. Block Diagram of the proposed irrigation control system

2.5 Hardware

The researcher used the drip irrigation technique which is ideal for a wide variety of soil types where ideal moisture levels for the three major types of soil are applied. This technique served as the model in developing the prototype of the irrigation device and desktop application. After series of testing, the device can perform irrigation with exact water requirement depending on the soil type set in the desktop application. The researcher used Microsoft Visual Studio and XAMPP in the development of the desktop application. Figure 6 shows the drip irrigation model in a farmland miniature. The main line is connected to the reservoir. The end stop is where the distribution of water stops. Drippers/emitters are where the water is released.

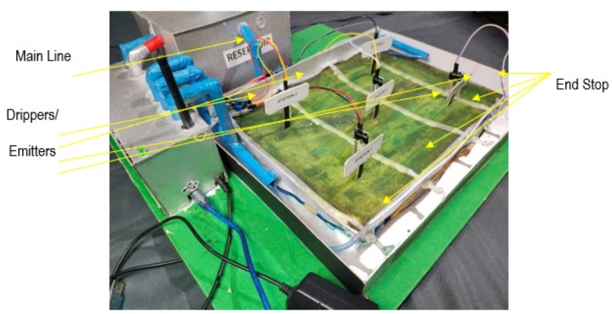

Fig 6. Automated Drip Irrigation System Model

2.6 Software

Figure 7 shows the home screen of the system when the application is already connected and communicating with the transmitter and receiver device. The water level and soil humidity display automatically changes based on the data received by the system. A real time graphing of the data can also be seen on this page. The user has an option to choose soil type between coarse, medium and fine. The distribution of water during irrigation depends on the selected soil type in the system.

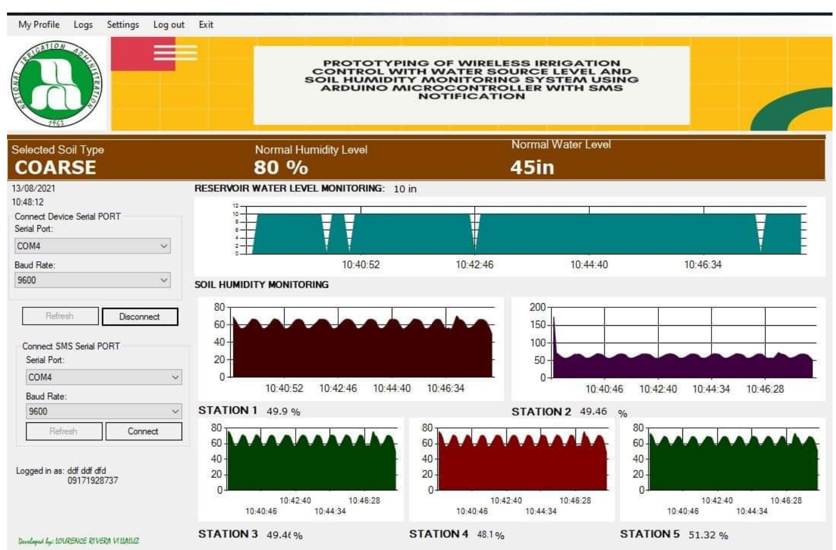

Fig 7. Desktop application of the irrigation control system

3 Result Analysis

The researchers performed a series of testing and evaluation of the existing and proposed irrigation control system during the development, the researcher able to identify which part of the existing irrigation system can be improved. At the end of the development, the researcher able to meet and satisfy the needs of the client in terms of the irrigation control system. This means that the developed prototype can be used to improve water sustainability in irrigation systems. A detailed discussion with supporting data follows.

3.1 Comparison of the existing and proposed irrigation control system flow

The researchers performed a series of testing and evaluation of the existing and proposed irrigation control system during the development, the researcher able to identify which part of the existing irrigation system can be improved. At the end of the development, the researcher able to meet and satisfy the needs of the client in terms of the irrigation control system. This means that the developed prototype can be used to improve water sustainability in irrigation systems. A detailed discussion with supporting data follows.

Figure 8 shows flowcharts of the existing irrigation control system and the proposed irrigation control system. On the left side, a flowchart illustrates the existing irrigation control system. When the main pipe from the reservoir is opened, irrigation automatically starts and is executed. Continuous distribution of water to farmlands take place. 0n the right side, a flowchart of the proposed irrigation control system is illustrated, when the system is initialized, the system analyses the soil humidity level of the farmland, and only applies irrigation when a specific soil humidity level which needs irrigation is realized. After a series of testing and comparing of the two irrigation control system during testing, it is proven that the developed irrigation control system can be used to improve water sustainability in irrigation systems.

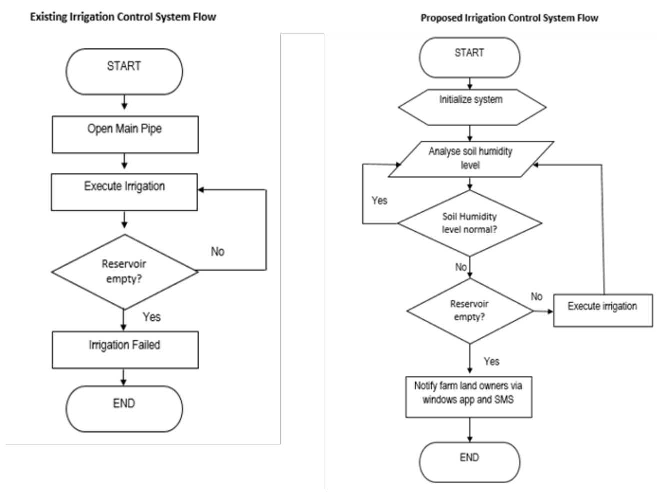

Fig 8. Flowchart of existing irrigation control system and the automated irrigation control system

3.2 Comparison of existing irrigation control system and the proposed irrigation in terms of water sustainability of three different soil types

Table 1 shows a unit testing result comparing the existing irrigation control system and the proposed irrigation in terms of water sustainability of the three different soil types. For each soil type, the date and time of the experiment were recorded in the date and time column followed by the existing soil humidity level and water level in the reservoir. In the existing irrigation control system, it is shown in the table that regardless of the soil humidity level, the irrigation is continuous. In fine soil type, the soil humidity during testing is 50.08%, this is below the soil type normal humidity which is sixty percent (60%). After the reservoir released water which measured 0.044 cubic inch per second within three minutes, the reservoir with a total of 12 cubic inches (12 in^3) became empty.

In the developed system, when the soil humidity is below normal, the reservoir will release water to plants. When the soil type turns its humidity to normal, irrigation will automatically stop. The table shows that after 4 minutes and 30 seconds the reservoir still have 8 cubic inches (12 in^3) water content. Similar to medium and coarse soil type, the table shows that the developed system can improve water sustainability.

Table 1. Recorded data during systemtesting

Soil Type	Control System	Date and Time	Soil Humidity Level	Reservoir Water Level	Action Taken	Water Released per second	Total Water Released
Fine (Station1)	Existing Irrigation Control System	July 23, 2021 10:15:00 AM	50.08%	12 cubic inches (12 in^3)	Irrigation	0.044 cubic inch per second	4 cubic inches (4 in^3)
		July 23, 2021 10:16:30 AM	60.10%	8 cubic inches (8 in^3)	Irrigation	0.044 cubic inch per second	4 cubic inches (4 in^3)
		July 23, 2021 10:18:00 AM	90.80%	4 cubic inches (8 in^3)	Irrigation	0.044 cubic inch per second	4 cubic inches (4 in^3)
		August 15, 2021 10:19:30 AM	100%	0 cubic inches (8 in^3)	Irrigation	0.00 cubic inch per second	None
	Automatic Irrigation Control System	July 23, 2021 10:20:00 AM	40.08%	12 cubic inches (12 in^3)	Irrigation	0.044 cubic inch per second	4 cubic inches (4 in^3)
		July 23, 2021 10:21:30 AM	60.10%	8 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
		July 23, 2021 10:23:00 AM	60.10%	8 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
		July 23, 2021 10:23:30 AM	60.10%	8 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
Medium (Station 2)	Existing Irrigation Control System	July 23, 2021 11:00:00 AM	30.76%	12 cubic inches (12 in^3)	Irrigation	0.055 cubic inch per second	5 cubic inches (5 in^3)
		July 23, 2021 11:01:30 AM	70.30%	8 cubic inches (8 in^3)	Irrigation	0.055 cubic inch per second	5 cubic inches (5 in^3)
		July 23, 2021 11:03:00 AM	87.00%	4 cubic inches (8 in^3)	Irrigation	0.022 cubic inch per second	2 cubic inches (2 in^3)
		July 23, 2021 11:04:30 AM	91.08%	0 cubic inches (8 in^3)	Irrigation	0.00 cubic inch per second	None
	Automatic Irrigation Control System	July 23, 2021 11:10:00 AM	30.76%	12 cubic inches (12 in^3)	Irrigation	0.055 cubic inch per second	5 cubic inches (5 in^3)
		July 23, 2021 11:11:30 AM	70.10%	7 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
		July 23, 2021 11:13:00 AM	70.30%	7 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
		July 23, 2021 11:14:30 AM	70.30%	7 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
Coarse (Station3)	Existing Irrigation Control System	July 23, 2021 11:30:00 AM	60.76%	12 cubic inches (12 in^3)	Irrigation	0.055 cubic inch per second	5 cubic inches (5 in^3)
		July 23, 2021 11:31:30 AM	84.20%	8 cubic inches (8 in^3)	Irrigation	0.055 cubic inch per second	5 cubic inches (5 in^3)
		July 23, 2021 11:33:00 AM	93.00%	4 cubic inches (8 in^3)	Irrigation	0.022 cubic inch per second	2 cubic inches (2 in^3)
		July 23, 2021 11:34:30 AM	93.00%	0 cubic inches (8 in^3)	Irrigation	0.00 cubic inch per second	None
	Automatic Irrigation Control System	July 23, 2021 11:40:00 AM	60.00%	12 cubic inches (12 in^3)	Irrigation	0.025 cubic inch per second	1.5 cubic inches (5 in^3)
		July 23, 2021 11:41:30 AM	80.10%	10.5 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
		July 23, 2021 11:43:00 AM	80.10%	4 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None
		July 23, 2021 11:44:30 AM	80.10%	4 cubic inches (8 in^3)	No Irrigation	0.00 cubic inch per second	None

3.3 Comparison of the existing irrigation control system and the proposed irrigation of coarse soil in terms of water sustainability.

Figure 9 shows a comparison of existing irrigation control system and the proposed irrigation in terms of water sustainability of coarse soil type. During testing, the reservoir were filled with 12 inches high water level. In the existing irrigation control system, after the soil humidity changed four times, the water level continuously decreased, while in the automated irrigation control system, after the second soil humidity level changed, the water level were maintained.

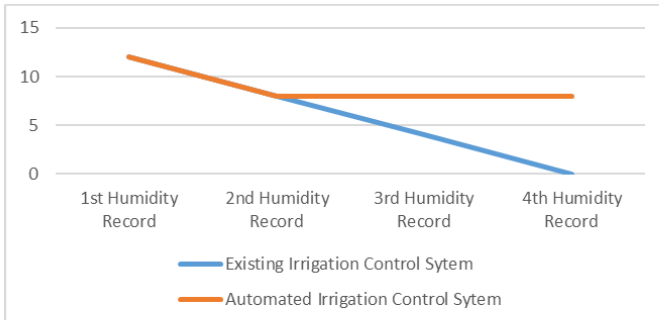

Fig 9. Comparison of irrigation systems in terms of water level data in coarse soil type

Compared to the existing studies, the developed technology can also enhance the water sustainability in the farmland that is using irrigation system. A platform that can be used in the monitoring of the water level in the reservoir and soil humidity was provided in this study which can be used in real time irrigation monitoring. To calculate the volume of the water saved in the automatic irrigation control system, a formula was provided by the researcher using SW = N*A where:

S1 = saved water in the irrigation of FINE Soil
S2 = saved water in the irrigation of COARSE Soil
S3 = saved water in the irrigation of MEDIUM Soil
N = (S1+S2+S3)/3
A = average volume of the water on the reservoir before automatic irrigation
SW = N % A
Actual values during system testing
S1 = $4in^3$
S2 = $7in^3$
S3 = $8in^3$
N = $(4in^3+7in^3+8in^3)/3$
N = $6.3333\ in^3$
A = $(12\ in^3+ 12in^3+ 12in^3)/3$
A = $12\ in^3$
SW = $6.3333\ in^3$ % $12\ in^3$
SW = 52.777777775%

4 Conclusion and Future Enhancement

The existing irrigation was evaluated using a questionnaire adopted from ISO 9126 - Software Product Quality Model and resulted a mean of 1.82 which is interpreted as slightly effective, and the developed device resulted a mean of 4.54. The developed prototype shows a potential of saving water sources for the irrigation of rice fields and farmlands. As shown in table 1.0, the use of water from the reservoir can be minimized depending on the moisture and the soil type. This means that the developed automated water control system can be used to improve water sustainability in farm lands. This can help the farmers conserve their water sustainability in the farmlands. The developed desktop application and irrigation device can irrigate and sustain exact water requirement on fine, medium and coarse soil type using drip irrigation technique. Based on the testing done, it is concluded that the water requirement depends on the soil humidity level. The researchers recommend to implement the developed system and device with the following considerations:

1. The prototypes will be implemented where calibration should be done with the sensors;

2. Replace transceivers with higher specifications since the maximum range used in the prototype is only 1000 meters;
3. Finally, the researcher vest to implement the system in places where there is an irrigation control system.

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