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Smart Water-Irrigated Management System (SWIMS): Automated Water Level Monitoring, Notification, and Irrigation Control for Enhanced Crop Cultivation

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***Abstract* - Provinces in the Philippines, such as Ilocos Norte, have areas that struggle to manage water efficiently and mitigate disasters brought on by numerous annual storms despite existing irrigation designs. A more pragmatic approach to irrigation designs is needed to resolve this issue. This study aimed to design and develop a miniature smart water management prototype that combines irrigation and floodwater systems featuring disaster preparedness that the country could implement. The study employed an operational research design to construct a scaled-down smart and autonomous water management system with Internet of Things (IoT) capabilities. The prototype featured contingency measures, irrigation control, and short message services (SMS) through ultrasonic sensors, a soil moisture sensor, and actuators. The results showed that the precision tests of ultrasonic sensors and the soil moisture sensor were precise between readings. All components were functional and in good condition. Acceptability and adaptability tests yielded a weighted mean of 4.07 and 4.13, respectively, translating high levels in each. Ultrasonic and soil moisture sensors have minimal variations in each reading, inferring reliability and consistency. Every constituent component is functional, and the prototype is highly acceptable in design. The prototype is capable of being adapted for modifications and upgrades to accommodate larger scales, suggesting implementation near areas experiencing agricultural challenges.**

Keywords: Agricultural challenges, Contingency measure, Disaster preparedness, Internet of Things, Irrigation design, Sensor, Short message service, Storm, Water management.

I. INTRODUCTION

Storms persist as one of the most lethal forms of weather-related catastrophes worldwide, with the Philippines emerging as among the nation’s most vulnerable to such calamities (Gray *et al.*, 2022). The Philippines experiences approximately 20 storms annually and faces recurring challenges, necessitating a comprehensive approach to disaster risk reduction and management (Holden & Marshall, 2018). According to Barbetta *et al.* (2022), flooding adversely affects the quality of groundwater and surface water, leading to potential service interruptions and overflow due to damaged infrastructure. Minimal interactions between irrigation designs and operation engineers in Ilocos Norte result in impractical designs that limit water management efficiency (David *et al.*, 2012). With this, recognizing the need for effective water resource management is crucial for sustainable development (Mushtaq *et al.*, 2020), as the water industry's future relies on integrating sustainability into its operations (Silva, 2022). Consequently, the modernization of water management systems is essential to ensure protection against flooding resulting from aging infrastructure, population growth, and increasing urbanization (Larsen *et al.*, 2016). Bekic *et al.* (2019) emphasized the need for technological water management systems as they enhance the accuracy, security, and quality of water management. Innovative technologies such as the Internet of Things (IoT), wireless sensor networks, and Cloud computing have played a pivotal role in ameliorating water management in agriculture, optimizing water usage, and improving crop quality (Saad *et al.*, 2020). Furthermore, Obaideen *et al.* (2022) and Tangadi *et al*. (2018) claim that IoT-based efficient water distribution systems enhance water management, conservation, and irrigation efficiency, reducing water waste and improving soil quality. Farmers can now affordably utilize smart irrigation systems, enabling efficient water management and agriculture monitoring (Kamienski *et al*., 2019). These systems not only address challenges but also promote best practices for implementation, as García *et al.* (2020) highlighted.

Prakash *et al*. (2023) introduced an IoT-based prototype for advanced hydrological data collection, addressing water flow, level, and discharge. The study proposes a novel approach to improve water discharge determination, considering factors like flow, sectional area width, and average depth, and the developed system demonstrates

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remarkable performance with an F1-score of 97% for "no alert," 97% for "yellow alert," 96% for "orange alert," and 98% for "red alert.". Drawing parallels with existing studies, Priya and Chekuri (2017) proposed an IoT-based Water Level Monitoring system to prevent container overflow, utilizing ultrasonic sensors to detect liquid levels. This system helped prevent water wastage by informing about the fluid levels of the containers. In contrast, Hassan *et al.* (2020) emphasized real-time measurements and short message service (SMS) notifications for flood management. The system's precise real-time water height measurements enable prompt SMS notifications to alert authorities about potential flood disasters, reducing flooding risks. Kenyon *et al.* (2008) research revealed the potential integration of sustainable flood management into policy agendas, emphasizing the necessity to enhance government policies against flooding and provide adequate education for farmers. The study ensured that government policies prevented the worsening of flooding and offered accessible flood management advice for farmers to address flood risk in future agricultural policies.

Furthermore, Ward *et al.* (2020) highlighted the need to broaden the focus of hydrological risk research beyond individual flood or drought risks and emphasize the interconnectedness of these phenomena within the hydrological cycle. The study provides examples illustrating how disaster risk reduction measures for floods or droughts can unintentionally affect the risk of the opposite hazard. Correspondingly, a study by Dzulkarnain *et al.* (2019) utilized a system dynamics approach to create a comprehensive flood mitigation model to reduce the impact on agricultural production. Information from interviews with government officials and existing research reports is incorporated, providing district governments with a valuable tool to minimize the risk of flooding in agriculture. De Wrachien and Mambretti (2015) also investigated the challenges associated with expanding agricultural areas, specifically focusing on the scarcity of economically viable sites for large-scale irrigation and drainage projects in flood-prone regions. The study underscored an escalating flood risk due to population growth, urbanization, land subsidence, and climate change, emphasizing the pivotal role of flood modeling for effective risk management in agriculture.

Integrating irrigation systems for agriculture and floodwater systems for disaster preparedness is a relatively underexplored area, with few studies addressing this issue. Studies conducted by Kenyon *et al*. (2008) and Ward *et al*. (2020) emphasize the potential for agriculture to contribute to sustainable flood management; however, the analyses of these studies need more specific attention to integrating irrigation and floodwater systems. Additionally, studies conducted by Dzulkarnain *et al.* (2019) and De Wrachien and Mambretti (2015) focused on flood mitigation in agriculture and the role of mathematical models in flood-prone areas but need to address the integration of irrigation and floodwater systems directly. Thus, this study designed and developed a miniature water management system that integrates irrigation and floodwater systems which feature disaster preparedness.

Specifically, this study (a) designed a smart water-irrigated management system with automated water level monitoring, notification, and irrigation control; (b) developed a program logic for the prototype; (c) tested the functionality of the prototype; (d) tested the precision of the measurements of the water levels and soil moisture; and (e) determined the level of acceptability and adaptability of the prototype. An IoT-based water level monitoring and notification system enables real-time data collection and analysis, providing early warning for residents to evacuate the vicinity in the event of flooding or overflow. Furthermore, farmers can strategically and readily allocate water resources, minimizing waste and ensuring optimal crop growth.

II. MATERIALS AND METHODS

2.1 Materials

This research project employed a comprehensive set of materials to develop and implement an automated irrigation system. The key components included one (1) 28BYJ-48 stepper motor, one (1) ULN2003 stepper motor driver, one (1) ESP32 DEVKIT DOIT V1 microcontroller unit (MCU) for efficient processing, one (1) Arduino Uno, three (3) HC-SMR04 ultrasonic sensors, three (3) circular plastic floaters of 2.8 inches in diameter for water level monitoring, one (1) power supply, one (1) buck converter, and two (2) peristaltic water pumps with tubes for irrigation. Additionally, the system utilized three (3) light-emitting diodes or LEDs (green, amber, red) for status indication, one (1) switch, one (1) soil moisture sensor, one (1) two-channel relay, PVCs of three inches (3 inches) in diameter, cement, plywoods, and wires.

2.2 Research Design

The research employed an operational approach to meet project objectives by meticulously planning and designing. A customized program was created for the prototype, integrating with specific sensors. The construction phase involved assembling hardware components and implementing the program. Pilot testing assessed performance and gathered user feedback. Necessary adjustments and refinements were made during the finalization stage to meet defined criteria. The evaluation phase determined the prototype's acceptability for monitoring water levels and soil moisture.

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2.3 Procedure

This part of the paper explains how the project's systems were set up, including instrumentation, logic, diagrams, and analysis. It gives detailed insights into how components were integrated. It also describes tests done to ensure the systems are reliable and functional.

2.3.1 Designing the smart water-irrigated management system with automated water level monitoring, notification, and irrigation control

In establishing the smart water-irrigated management system, various components and sensors were required, including ultrasonic sensors for water level monitoring, a soil moisture sensor for measuring moisture in the crop field, peristaltic water pumps for irrigation, and the ESP32 model, which featured integrated Wi-Fi and dual-mode Bluetooth capabilities. The ESP32 Micro Controller Unit employed a system/mechanism control, facilitating seamless communication of data within the network. The project used a router to connect to the autonomous system, allowing data to flow smoothly between computer networks. This ensured that commands were carried out correctly. Additionally, the router helped direct internet traffic, making it possible to connect the autonomous system using IoT technology.

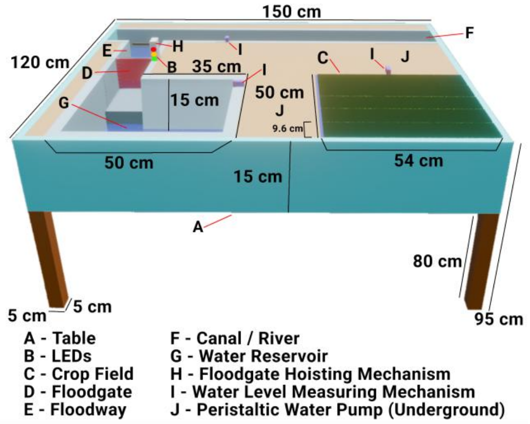

Figure 1: Design of the SWIMS

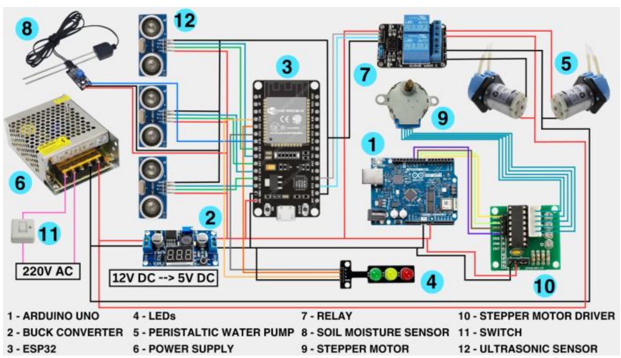

Figure 2: Wiring Diagram

2.3.1.1 Water Level Monitoring System

Each ultrasonic sensor was strategically positioned by the water level monitoring system to detect the water level in the river, reservoir, and crop field by measuring the distance between it and a floating device, both of which were trapped inside a pipe. This setup rendered the water level sensors. The pipe was stripped in such a way that the entry and exit of water was enabled for the floating device to change in elevation. Four ranges were defined that would light up solely one of three LEDs (green, amber, and red) corresponding to its respective range as the water level deviated, starting with the second range with the first skipped. The ESP32 was configured to collect sensor data and transmit it to the Blynk server, an IoT Cloud platform utilized to process and store data. This was exemplified by the phrase "real-time event processing engine with massive scalability." While the complete process was controlled, the object that spoke was utilized as an IoT Cloud platform by this system.

2.3.1.2 Automated Gate System

A gate from the river water was constructed for the automated gate system, positioned between the reservoir. A stepper motor was employed to open and close the gate to permit or stop the water flow due to its precise control and ability to move in discrete steps, ensuring accurate and reliable gate positioning for security and access control systems.

2.3.1.3 Irrigation Control System

The irrigation control system was implemented by connecting the soil moisture sensor to the microcontroller (ESP32). The microcontroller was programmed to read moisture levels and set threshold values for irrigation. A relay was between the peristaltic water pump and ESP32, activating automatically when soil moisture fell below the threshold and deactivating when the desired moisture level was reached. The data collected was sent to the Blynk server to view the sensed values. The Blynk platform displayed real-time data and system status, accessible remotely. The data was stored in the Blynk server for analysis, and a mobile Blynk app was utilized for convenient monitoring and access through smartphones or tablets.

2.3.1.4 Notification system or Alert system

In implementing notifications or alerts using the Blynk server, the ESP32 was integrated with the Blynk platform in ensuring seamless communication between the device and the platform. A robust data collection and monitoring system was developed on the ESP32 for constant monitoring of water levels in the river. A warning message of increasing urgency

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was programmed, which remained consistent for each predefined range.

Upon detecting such a shift between ranges, notification protocols were set up within the platform to alert via Gmail or the Blynk mobile app on the user's devices corresponding to that specific warning message.

2.3.2 Developing the System Flow

The system was programmed through Arduino, an open-source integrated development environment (IDE), user-friendly software for programming and uploading code to Arduino microcontroller boards such as ESP32 using a computer.

The program measured four variables: river water level % (*x*), reservoir water level % (*y*), crop field water level % (*z*), and crop field moisture level % (*m*). Each variable had its parts in the prototype, was independent, and did a specific function if it satisfied a condition (excluding *y*).

The system was initiated by initializing the ESP32, ultrasonic sensors, and soil moisture sensor. It initially checked the analog value of *x* using the ultrasonic sensor for river water.

If *x* was greater than 50%, it sent "NOTICE: NORMAL RIVER WATER LEVEL" to users. The default setting was to lower the reservoir dam gate. If *x* was greater than or equal to 50% but less than 70%, only the green LED activated with the message "WARNING: HIGH RIVER WATER LEVEL" sent to users. If *x* was greater than or equal to 70% but less than 85%, the reservoir dam gate was raised, activating the amber LED with the message "WARNING: PREPARE TO EVACUATE. NOW RAISING RESERVOIR DAM." If *x* was greater than or equal to 85%, the reservoir dam gate was lowered to store excess water, activating the red LED with the message "WARNING: PLEASE EVACUATE! NOW LOWERING RESERVOIR DAM."

Additionally, the program consequently checked the reservoir water level (*y*), crop field water level (*z*), and crop field moisture level (*m*).

The water pump for reservoir water to the crop field was turned off by default but turned on once m was less than or equal to 30%. Another water pump for the crop field to river water was turned off by default but turned on once *z* is greater than or equal to 70%.

The program then interpreted the *m*, *x*, *y*, and *z* values and sent the data to Blynk. Finally, the Blynk sent the interpreted *m*, *x*, *y*, and *z* data to a smartphone, concluding the system.

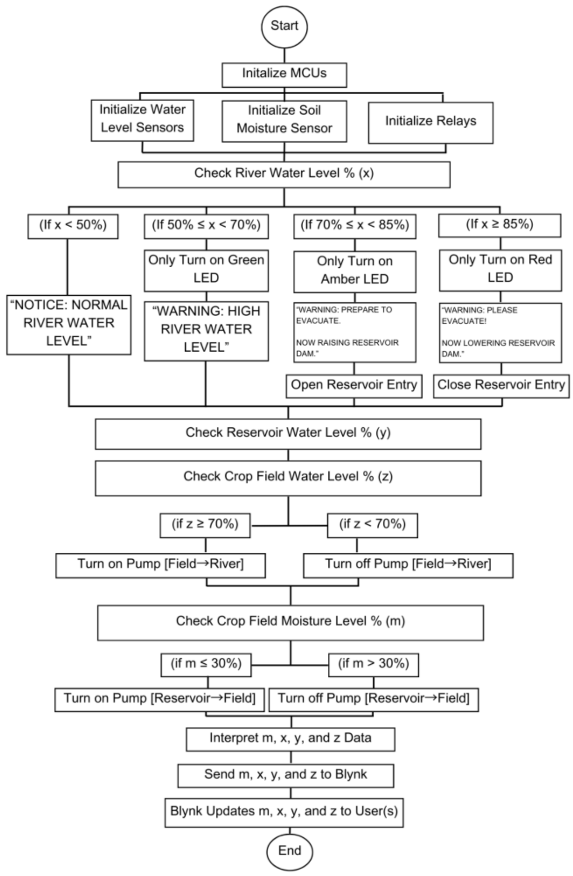

Figure 3: System Flow

2.3.3 Functionality Test

The functionality test for the integrated system involved a systematic checklist to ensure the proper operation of each component. The ESP32 microcontroller board was assessed for its ability to control the system, manage data communication over Wi-Fi and Bluetooth, and operate efficiently at the specified voltage. The stepper motor underwent testing to verify its precise control in opening and closing gates, ensuring accurate water flow regulation. The ultrasonic sensors were examined for their capability to detect water levels in the river, reservoir, and crop field. The LED indicators were checked individually, confirming the correct functionality of the green, amber, and red LEDs in response to varying river conditions. The soil moisture sensor was evaluated for its precision in measuring soil moisture levels. Lastly, the peristaltic water pump was tested to ensure it functioned as an automated response system, activating appropriately based on the soil moisture sensor readings to optimize irrigation.

2.3.4 Precision Tests for Water Levels and Soil Moisture

Multiple measurements were taken at designated points using appropriate equipment, such as sensors, to conduct precision tests for water level and soil moisture. For water

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level measurements, readings were recorded using ultrasonic sensors. Similarly, soil moisture sensors were used for soil moisture measurements, and readings were noted. This process was repeated for each measurement point, ensuring consistency in method and technique.

After completing ten trials for both water level and soil moisture measurements, the relative standard deviation (RSD) was calculated to assess precision and consistency. The RSD was calculated using the following formula:

$$\boldsymbol{RSD} = (\sigma \ / \ \mu) \times 100\%$$

Where:
σ = Standard Deviation
μ = Mean

2.3.5 Acceptability and Adaptability Test

The researchers determined the acceptability and adaptability by computing the weighted mean of evaluators' responses utilizing a provided questionnaire.

2.3.5.1 Respondents and Sampling Technique

The respondents were experts selected via purposive sampling. The experts were required to be: (a) degree holders of an engineering course (preferably electronics and communications engineering); (b) employed and practicing the profession for at least 3 years; and (c) residing in Region XII, Philippines.

2.3.5.2 Research Instrument

The questionnaire for the evaluation of the level of acceptability and adaptability consists of nine and eight appropriate questions, respectively. The prototype underwent pilot testing using the questionnaire to gather feedback regarding its performance.

Moreover, the internal validity of the feedback was assessed through computation of Cronbach's alpha, providing insight into the reliability and consistency of the prototype's performance and measurements.

2.4 Data Analysis

The data analysis for the study involved precision tests for water levels and soil moisture, using ultrasonic sensors and soil moisture sensor, respectively. Ultrasonic sensors ensured data collection for water level monitoring, which then underwent statistical analysis to determine the mean water level and standard deviation. After calculating the mean and standard deviation, the relative standard deviation was determined to assess precision and variability.

Similarly, soil moisture levels were assessed using a soil moisture sensor, with data analyzed to calculate mean moisture levels and standard deviation across different soil types and irrigation periods. Following this, the relative standard deviation was calculated to evaluate the consistency and variability of soil moisture levels. By conducting precision tests, the study aimed to evaluate the effectiveness and reliability of the system in managing water resources and optimizing crop cultivation practices.

Furthermore, the mean scores of evaluators' responses, which served as a central measure, were computed to evaluate the prototype's acceptability and adaptability levels. Additionally, standard deviation was calculated to gauge the extent of variability in evaluator judgments, providing insights into the consistency or diversity of opinions. The study's findings were illustrated and interpreted using a 5-point Likert Scale, as shown in Table 1.

Table 1: Interpretation for Level of Acceptability and Adaptability Test

Rating	Range	Descriptor	Interpretation (Level of Acceptability)
5	4.50 - 5.00	Strongly Agree	Very High Level
4	3.50 - 4.49	Agree	High Level
3	2.50 - 3.49	Neutral	Moderate Level
2	1.50 - 2.49	Disagree	Low Level
1	1.00 - 1.49	Strongly Disagree	Very Low Level

2.5 Ethical Consideration

The researchers conducted this study in complete accordance with established research protocols. Initially, a permission letter was sent to the principal seeking approval for the study's conduct. The researchers then drafted a consent letter for the evaluators, seeking their explicit approval and ensuring they were informed about the nature of their participation, which was voluntary, private, and confidential. Moreover, the evaluators were informed that the data gathered would be utilized solely for academic purposes and kept with the utmost confidentiality. Furthermore, the research was conducted with utmost integrity and was free from any form of plagiarism.

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III. RESULTS AND DISCUSSIONS

3.1 Design a smart water-irrigated management system with automated water level, monitoring notification, and irrigation control

A new irrigation and flood monitoring system has been created, combining IoT technology with Android apps, especially using Blynk servers. It connects seamlessly to an IoT cloud platform, allowing wireless communication. Data is sent efficiently to the cloud for remote access through web apps. The system automates water pumping and lets users monitor water levels remotely via Android phones. It also sends real-time disaster alerts via SMS, making it reliable. This system is an effective way to manage water in agriculture, reducing waste and environmental impact.

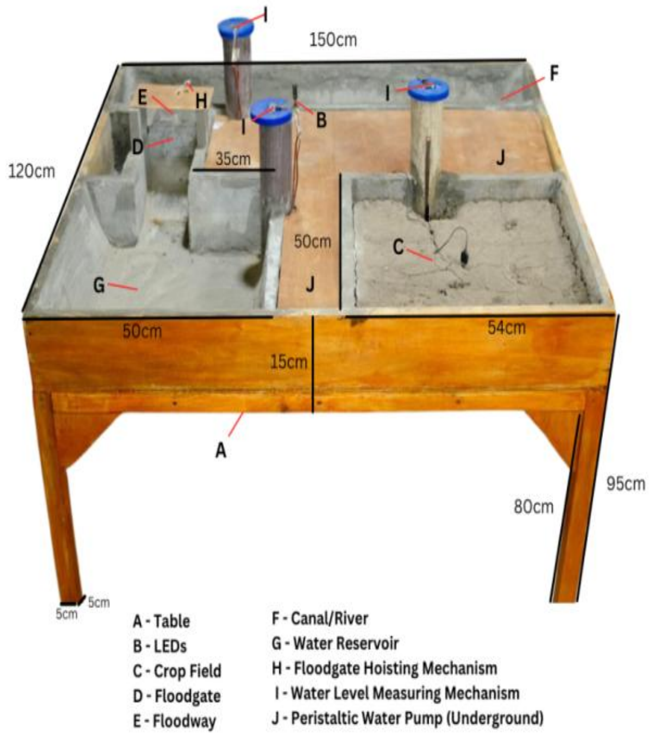

Figure 4: Prototype Design

3.2 Program Logic of the Prototype

The program logic for this system involved utilizing the Arduino to program the ESP32 MCU. The program monitors four variables: river water level (*x*), reservoir water level (*y*), crop field water level (*z*), and crop field moisture level (*m*). Each variable's functionality is independent, triggering specific actions based on predefined conditions. The system initializes by setting up the ESP32 and sensors. It then reads the analog value of *x* using an ultrasonic sensor to measure the river water level. A specific notification message gets sent to a smart device, and the floodgate raises or lowers while a corresponding LED lights up every time *x* shifts between predefined ranges. Additionally, the program checks *y*, *z*, and *m*. If *m* is 30% or lower, a water pump from the reservoir to the crop field is activated. Similarly, if *z* is 70% or higher, a water pump from the crop field to the river is activated. Finally, the program interprets the values of *m*, *x*, *y*, and *z*, sending the data to Blynk. It then forwards this interpreted data to a smartphone, completing the system's operation.

3.3 Functionality of the Prototype

Testing the functionality of the prototype involved comprehensive assessments across various scenarios. From stress tests to user experience evaluations, every aspect underwent scrutiny to ensure optimal performance. Feedback from users played a crucial role in refining the prototype, leading to enhancements in responsiveness, intuitiveness, and overall reliability.

Table 2: Functionality Test of the Prototype

No.	Components	Yes	No
1	28BYJ-48 Stepper Motor	/	
2	ESP32 DEVKIT DOIT V1	/	
3	Arduino Uno	/	
4	HC-SR04 Ultrasonic Sensors (3pcs)	/	
5	Power Supply	/	
6	Peristaltic Water Pumps (2pcs)	/	
7	Light-emitting Diodes or LEDs (3pcs)	/	
8	Soil Moisture Sensor	/	
9	Buck Converter	/	
10	ULN2003 Stepper Motor Driver	/	

Table 2 depicts the results of assessing the functionality of a prototype smart water-irrigated management system. The evaluation scrutinized the performance of crucial system components.

All components listed in the table were found to be operational, as evidenced by the absence of any "No" entries in the "Functional" column. This validates the functionality of individual components such as the 28BYJ-48 Stepper Motor, ULN2003 Stepper Motor Driver, ESP32 DEVKIT DOIT V1, Arduino Uno, HC-SR04 Ultrasonic Sensors (3pcs), Power Supply, Peristaltic Water Pump, Light-emitting diodes or LEDs, and soil moisture sensor. The successful functionality test indicates the prototype's readiness for further testing and deployment in practical farming settings.

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Table 2.1: Functionality of the LEDs, Stepper Motor, and River Ultrasonic Sensor

No.	NODE	Initial		Condition	Final	
		Indicator	OUTPUT		Indicator	OUTPUT
1	River Ultrasonic	Black	On	Turned On	Black	On
2	Green LED	Green	Off	$50\% \geq x < 70\%$	Green	On
3	Amber LED	Amber	Off	$70\% \geq x < 85\%$	Amber	On
4	Red LED	Red	Off	$x \geq 85\%$	Red	On
5	Stepper Motor	White	Off	$70\% \geq x < 85\%$	White	On (forward)
6	Stepper Motor	White	Off	$x \geq 85\%$	White	On (Reverse)

Table 2.2: Functionality of the Peristaltic Water Pumps, Reservoir Ultrasonic Sensor, and Crop Field Ultrasonic Sensor

No.	NODE	Initial		Condition	Final	
		Indicator	OUTPUT		Indicator	OUTPUT
1	Soil Moisture Sensor	Blue	On	Turned On	Blue	On
2	Reservoir Ultrasonic	Orange	On	Turned On	Orange	On
3	Crop Field Ultrasonic	Yellow	On	Turned On	Yellow	On
4	Water Pump 1	Gray	Off	$m \leq 30\%$	Gray	On
5	Water Pump 2	Violet	Off	$z \geq 70\%$	Violet	On

3.4 Precision Tests for Water Level and Soil Moisture

The precision tests for water level and soil moisture sensors leverage Blynk software for real-time precise measurement and analysis of water distribution and soil moisture content.

Table 3: Precision Tests Results for Water Levels and Soil Moisture

Trial	River Water Level Sensor (%)	Reservoir Water Level Sensor (%)	Crop Field Water Level Sensor (%)	Soil Moisture Sensor (%)
1	55	41	27	88
2	53	38	26	87
3	56	43	26	86
4	52	40	28	86
5	51	39	25	84
6	54	42	24	86
7	56	40	26	83
8	57	42	25	82
9	55	39	25	84
10	54	42	26	86
Mean	54.3	40.6	25.8	85.2
SD	1.79	1.56	1.08	1.78
% RSD	3.48	4.06	4.40	2.20

Note: The water level data are expressed in percentage to visualize the proportion of the max water level of the prototype to the max water level of an actual implementation of the project. The water levels for each sensor differ due to their location in the prototype.

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Table 3 presents data collected from the prototype's water level and soil moisture sensors. The data are based on ten trials conducted for a precision test of the components. The table also shows the values of the overall mean, standard deviation (SD), and percent relative standard deviation (%RSD) for each sensor.

The river water level sensor results have a mean value of 54.3, a standard deviation (SD) of 1.79, and a %RSD of 3.48. Correspondingly, reservoir and crop field water level sensors have mean values of 40.6 and 25.8, respectively, with standard deviations (SD) of 1.56 and 1.08 and %RSDs of 4.06 and 4.40. Lastly, the soil moisture sensor has a mean value of 85.2, a standard deviation (SD) of 1.78, and a %RSD of 2.20. The results from the river, reservoir, and crop field water level sensors, as well as the soil moisture sensor, indicate minimal variation in readings, suggesting minimal percent error in the prototype's sensors. The data prove that the components were consistent and reliable.

The performance of the sensors had significant implications for various applications, particularly in agriculture and water monitoring. These sensors can provide precise data for efficient water management strategies, optimizing irrigation schedules, and ensuring proper soil moisture levels for crop growth. This finding aligned with previous research by Priya and Chekuri (2017) and Dzulkarnain *et al.* (2019), which highlighted the potential of sensors for flood management in agricultural production.

3.5 Levels of Acceptability and Adaptability of the Prototype

The research rigorously tested and used Cronbach's alpha value to determine questionnaire reliability. This statistical metric is essential for assessing assessment tool internal consistency, which ensures reliability and validity. The research found remarkable Cronbach's alpha scores of 0.88 for acceptance and 0.94 for adaptability. Strong ratings indicate questionnaire reliability and consistency, indicating their correctness in capturing the targeted constructs. Cronbach's alpha verifies the evaluation tools' credibility and usefulness for assessing target population acceptance and adaptation.

Table 4.1 displays the data collected from the prototype’s evaluation in its acceptability test. The acceptability test assesses the prototype's adherence to predefined standards, covering usability, functionality, performance, reliability, and user satisfaction. The prototype received high ratings across various indicators, suggesting a positive reception among users.

Table 4.1: Acceptability Test of the Prototype

No.	Indicators	Mean	SD	Descriptor	Interpretation
1	Understanding the functionality of the prototype was easy.	4.00	0.63	Agree	High Level
2	I am satisfied with the performance of the prototype	4.40	0.49	Agree	High Level
3	I am likely to recommend this prototype to others.	4.40	0.49	Agree	High Level
4	The prototype was intuitive and easy to use.	4.40	0.49	Agree	High Level
5	The prototype design/layout is intricate and well-thought out.	3.80	0.40	Agree	High Level
6	The wire management of the prototype is satisfactory.	3.00	0.63	Neutral	Moderate Level
7	The features of the prototype are relevant to its purpose.	4.20	0.40	Agree	High Level
8	The different parts of the prototype are easy to navigate.	4.20	0.40	Agree	High Level
9	Overall, I am satisfied with the prototype.	4.20	0.40	Agree	High Level
	Overall Weighted Mean	4.07	-		High Level

The mean scores for each indicator range from 3.00 to 4.40, with an overall weighted mean of 4.07, indicating overall satisfaction with the prototype. Specifically, the evaluators found the prototype functionality comprehendible, were satisfied with its performance, and expressed likelihood to recommend it to others. Additionally, they perceived the prototype as intuitive and convenient, with relevant features and a well-thought-out design. The wire management of the prototype was also deemed satisfactory. These findings imply that the prototype was well-received by users and met their expectations in terms of functionality, usability, and design.

The acceptability of these findings was significant for various applications, particularly in agriculture and water monitoring. A high level of user acceptance suggested that the prototype was suitable for practical use. Farmers and agricultural professionals can rely on the prototype for accurate data collection and monitoring, facilitating informed decision-making processes related to

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water management and irrigation strategies, which aligned with the study conducted by Priya and Chekuri (2017). Furthermore, the positive feedback from users indicates that the prototype aligns with their needs and preferences.

Table 4.2: Adaptability Test of the Prototype

No.	Indicators	Mean	SD	Descriptor	Interpretation
1	The prototype can easily be adjusted to fit different user needs.	4.40	0.49	Agree	High Level
2	It is easy to add new features or functions to the prototype.	4.40	0.49	Agree	High Level
3	Users can change settings or how the prototype works without trouble.	4.20	0.40	Agree	High Level
4	The prototype can keep up with new trends or technology changes.	4.00	0.00	Agree	High Level
5	Users can make the prototype fit different places or conditions.	4.20	0.40	Agree	High Level
6	Putting together or taking apart the prototype is simple and doesn't need special tools.	4.20	0.40	Agree	High Level
7	The prototype's materials are strong and can handle different kinds of weather.	3.80	0.40	Agree	High Level
8	Storing, moving, and using the prototype in different places is easy.	3.80	0.40	Agree	High Level
	Overall Weighted Mean	4.13	-		High Level

Table 4.2 presents the data collected from the adaptability test conducted on the prototype. The evaluation test examined the prototype's flexibility, durability, and portability. Additionally, the adaptability was measured using variables such as the number of indicators, indicators, mean, standard deviation (SD), interpretation, and overall weighted mean. The results reveal an overall weighted mean value of 4.13 for the prototype's adaptability, denoting a high level of adaptability.

With a robust mean score, the prototype demonstrates remarkable flexibility in accommodating new features and systems, enriching the user experience. Notably, the lowest mean score, found in indicators 7 and 8, are both 3.80, underscoring the need for refinement in material selection and physical design to enhance the prototype's environmental adaptability.

The findings from the adaptability evaluation imply that the prototype was capable of being adapted for modifications to accommodate larger scales. This suggested that the prototype's design and components were flexible and can be adjusted or scaled up to meet the requirements of larger applications. The positive results from the adaptability test indicate that the prototype was versatile and can be implemented in various settings or environments with different scales of operation in areas with challenges in agriculture which aligned to the study of De Wrachien and Mamberetti (2015). This adaptability bodes well for the scalability and future development of the prototype, paving the way for broader deployment in real-world scenarios.

IV. CONCLUSION

The study developed and assessed a smart water-irrigated management system leveraging IoT technology. Through design and evaluation, the prototype demonstrated water level monitoring, irrigation control, and disaster preparedness notification capabilities. Functionality tests confirmed the operational readiness of key components, validating their potential for practical deployment in agricultural contexts. Precision testing further affirmed the reliability and consistency of sensors. Acceptability and adaptability assessments underscored the prototype's usability, performance, and flexibility, positioning it for scalable implementation.

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