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Autogation: An Alternate Wetting and Drying-Based Automatic Irrigation and Paddy Water Level Control System through Internet of Things

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ABSTRACT

This study aims to create an automated watering system that can adapt with network-based irrigation monitoring and a safe alternate wetting and drying or AWD. A secure AWD irrigation method is one in which the rice paddy is alternately subsided and immersed with a critical level of 100mm below the ground and a maximum irrigation level of 150 mm above the ground. The designed methodology automates irrigation by considering the needed water level in the field and its present level. It determines and controls the watering schedule based on the data collected by the sensors and then acts on it. It regulates the irrigation delivery gate to close or open the counterweight-designed water gate valve following the smart timetable that it has established. This approach conserved around 20% of the water used in a two-hectare area with four weirs compared to the traditional irrigation method in three weeks.

INTRODUCTION

The rapid growth of the population worldwide results in a constant increase in demand for food; thus, faster and advanced technology improvement concerning food production is necessary. Irrigation provides and delivers enough water to rice fields for sustenance essential for the crops. The Philippines is known to be a part of the top 10 leading rice producers in the world. It comes with the duty of providing enough water for our farmers and agricultural workers, even though substandard irrigation systems still plague the Philippines (Labiano, 2012).

In irrigation, the supply of water must be continually increased. This necessity prompted the launch of several other studies aimed at developing and comprehending technologies for monitoring and measuring irrigation water (Doraiswamy et al., 2004). Monitoring soil or crop water condition helps determine the amount and volume of water to rinse. It allows for the avoidance of water leakage and crop water stress and enables equal delivery of the maximum water needs and the lowest critical level of soil water (Coates, Delwiche, & Brown, 2005).

This research tried to merge several studies to obtain the best and most cost-effective. They will calculate the amount of field effort required for vegetation crops and the various types of soil. An "open-source" Microcontroller was discussed in the study of Bitella, Rossi, Bochicchio, Perniola, & Amato (2014). This Microcontroller was programmed in an accessible Integrated Development Environment (IDE) to outline a cost-effective "open hardware" platform. The designed platform will be used to measure parameters including soil water content at different levels and the temperature of the soil and air.

Meanwhile, Chung, Caya, & Chen (2013) discussed the "open hardware" platform. This platform was designed with sensors that are being observed with Zigbee wireless network. The measurements of critical parameters in a

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greenhouse plantation or vegetative plants are the subject of this. Temperature, brightness, and relative humidity were among the many parameters investigated and tested in this study. These parameters were measured using SHT1x, M25P10, and TSL2550 and were merged by a microcontroller JN5121 with a Zigbee sensor node.

Yumang, Paglinawan, Perez, Fidelino, & Santos (2017), in contrast to earlier studies on the use of sensor technology, evaluated soil infiltration rate in shortening irrigation duration as a technique in irrigation control. Although the use of electricity in high-end and low-end irrigational systems promotes efficiency for maximum plant growth, the usage of a large power need for an electric pump is unfeasible for the ordinary farmer. Because the anticipated time of irrigation is reduced, the power consumption in the irrigation system is reduced.

Aside from this, various studies have been undertaken to optimize the water delivery from individuals involved in rice crop irrigation. Another study by Zawawi, Mustapha, & Puasa (2010) used multiple algorithms to determine the water needs for one season of paddy plantation. A more precise and detailed irrigation scheduling was also produced by calculating many parameters. Crop water requirements, the season, weather, water losses in the agricultural fields, and flooding are just a few of these parameters.

Salazar conducted a study concerned with lowering the amount of water used in a rice field using a soil moisture sensor that automates the irrigation method and is not dependent on schedule (Yumang, Paglinawan, Perez, Fidelino, & Santos, 2017). Gutierrez, Villa-Medina, Nieto-Garibay, & Porta-Gandara (2014) employed two sensors to collect data on the two parameters under consideration, soil moisture content and soil temperature, and automatically activate the irrigation process when the threshold value was reached. The study also used wireless data transfer, which sends the data collected from the sensors directly to the controller, analyzing the situation and deciding whether to switch on or off the automatic irrigation system.

Meanwhile, in their irrigation approach, Veeramanikandasamy, Sambath, Rajendran, & Sangeetha (2014) utilized an air temperature sensor, an air humidity sensor, a soil moisture sensor, and an infrared transceiver. When the required soil parameters are reached concerning the stage of growth of the rice crop, the irrigation process begins. The growing stage of the crops is monitored using an infrared transceiver. A GSM module is fitted for complete control automation, allowing the farmer to operate the irrigation operation automatically and wirelessly efficiently.

Lastly, Liu, Ismail, Wang, & Lin (2021) developed a smart irrigation control system through the internet, using probiotic and rice intensification (SPRI) techniques. Their study employed sensors that measure illumination, air temperature and humidity, water level, soil moisture, soil temperature, and soil electrical conductivity considered parameters in controlling the irrigation. A mobile phone app was developed for the farmers and irrigation specialists to monitor the field parameters and inform them of the SPRI cultivation (planting, drainage, probiotics and fertilizer adding notifications, etc.).

Table 1 provides and summarizes the survey of different electronic irrigation control methods. The various methods previously used are discussed in the study of Difallah, Benahmed, Draoui, & Bounaama (2017).

In contrast to earlier research, this study does not include essential parameters in rice cropping, such as soil temperature, moisture, and so on. Because rice is a semi-aquatic plant, the water level in the paddy is the primary concern for this measurement. This research is a revision of the irrigation principle known as “alternate wetting and drying” or AWD. The AWD principle procedure has been published in works by Bouman, Lampayan, & Tuong (2007), Chou et al. (2016), Manzano, Mizoguchi, Mitsuishi, & Ito (2011), and Zawawi, Mustapha, & Puasa (2010). This idea refers to drying below saturation and plunging or swamping a particular rice field region. The AWD threshold was known based on measurements e.g. soil water potential, or SWP, in the rooting zoon and field water level, or FWL.

On the other hand, the AWD threshold can be divided into two categories: FWL, or safe AWD, and SWP or severe and mild AWD (Bouman, Lampayan, & Tuong, 2007). The FWL in safe AWD cannot be less than 150mm. According to Richards & Sander (2014), Seckler (1996), and van der Hoek et al. (2001), the AWD method is generally used in lowland paddy since it has been proven to reduce harmful gas emissions and water consumption in farmland while maintaining rice quality and quantity.

Techniques and benefits of adopting the AWD principle were emphasized in the cultivation of rice crops. The researchers in IRRI established the 15 cm threshold limit after a series of tests and studies on the different ecosystems of rice crops. There is the maintenance of the crop yield in rice cultivation (Lampayan, Rejesus, Singleton, & Bouman, 2015). It has been reported that countries such as Bangladesh and the Philippines have adopted the principle and recorded a 15% in yield increase over the traditional irrigation method. It is due to the more active and healthy roots of rice until its maturity. AWD, in theory, is also a solution to zinc deficiency due to oxidation of the rhizosphere soil.

The study's general objective is to develop a low-cost paddy water level and irrigation control system using the safe AWD method of water distribution using the Internet of Things (IoT) medium. As a result, we can provide the exact volume of water required for the rice field while eliminating wastage and spills that most irrigational infrastructures are now experiencing. Specifically, the study aims to: (1) develop an automated delivery gate that will limit the discharge of water following safe AWD; (2) construct a device using an ultrasonic transducer that will accurately measure the water level in the paddy, therefore limiting the water input by the specific water requirement; and (3) develop a webpage as a monitoring system that constantly displays the water level, the expected time of irrigation, the delivery gate status (open or closed), the non-standard and standard status of plant's growth and the stage of its growth.

Table 1. Survey of Different Irrigation Control Methods (Difallah, Benahmed, Draoui, & Bounaama, 2017; Gutierrez, Villa-Medina, Nieto-Garibay, & Porta-Gandara, 2014; Jaichandran, Rajaprakash, Karthik, & Somasundaram, 2017; Liu, Ismail, Wang, & Lin, 2021; Veeramanikandasamy, Sambath, Rajendran, & Sangeetha, 2014; Yumang, Paglinawan, Perez, Fidelino, & Santos, 2017)

Authors	**Irrigation Method Problem to be Automated**	**Solution/Implementation**		
		Sensors Used	**Hardware Platform**	**Software/ Programming Languages**
Yumang, Paglinawan, Perez, Fidelino, & Santos (2017)	Soil infiltration rate	Ultrasonic sensor Moisture sensor Temperature sensor	Gizduino (Arduino)	-
Salazar (Yumang, Paglinawan, Perez, Fidelino, & Santos, 2017)	Soil Moisture	Moisture sensor	-	-
Gutierrez, Villa-Medina, Nieto-Garibay, & Porta-Gandara (2014)	Drip Hole Spacing	Moisture sensor Temperature sensor	Zigbee, GPRS module, PIC24FJ64GB004	C# SQL Server 2005
Veeramanikandasamy, Sambath, Rajendran, & Sangeetha (2014)	Drip Irrigation	Moisture sensor Temperature sensor Humidity sensor	GSM SIM900, Zigbee, IR LED and TSOP1738 IR Receiver, PIC18F4550, LPC2148	MPLAB compiler, and KEIL µVISION4 Compiler
Jaichandran, Rajaprakash, Karthik, & Somasundaram, (2017)	Irrigation through well water resource	Moisture sensor Floating sensor	LPC 2148 GSM module	C, KEIL µVISION Compiler, XCTU
Liu, Ismail, Wang, & Lin (2021)	Paddy field irrigation	Air temperature and relative humidity sensor Illumination sensor Moisture sensor Electrical conductivity sensor Soil temperature sensor Water level sensor	Datalogger NB-IoT module	Xcode 10 (Swift) Firebase JSON

MATERIALS AND METHODS

The study's goal denotes that when the light indicator produces a red light, the water level on the farm is already on its critical level or below 150 mm submergence depth. These data will show up on the computer monitors and smartphones, thus, giving the users full access to the data gathered. When the water is being distributed to the farmland, the flow rate data will also be displayed in the monitor. Moreover, the estimated shutting downtime of the irrigation gate will be shown. The HC-SR04 ultrasonic sensor will be linked to an Arduino Nano to detect the water level in one rice field's paddy fields. All of the information gathered will be saved in a database for future use.

As shown in Fig. 1, the produced prototype platform consists of numerous elements structured in several parts: the gate that acts as the correction system, the source and the sensor used for data collection, and the project website, which displays the parameters being monitored.

The hardware will be constructed and altered to achieve the objectives to maximum dependability and accuracy possible. The following modules are integrated to build the hardware that will be used in this project: sensors for flow rate and water level, as well as a smartphone, computer, and the Arduino YUN. In terms of power, it contains the following: Solar Panel, Buck Converter, Voltage Sensor, LCD Display, Battery, Wi-Fi Module, and Arduino Nano are all included.

The water level sensor will be the system's input, and the condition of the gate will be the rice crop. The Arduino Mega will serve as the system's brain, processing data and containing and developing the implementation and computation of commands. The system's output will allow users to connect by displaying their smartphones and laptops.

Sensors

The ultrasonic transducer is a sensing device that can measure by converting energy into an ultrasonic vibration. This sensing device is a commercially available level and flows proximity. As displayed in Fig. 2, these ultrasonic devices are imparted in a cylindrical hollow tube with a length of 600 mm and diameter of 150 mm. This will be plunged 200 mm underneath the ground for water level measurement. For this procedure to be implemented, a cylindrical tube in the sensor's chassis was installed. Because the cylindrical tube has holes, the ground surface water will be reflected in the tube's interior. Thus, letting the measurement possible through radiation frequency.

The paddy water level system's chassis design is shown in Fig. 3. This fig. shows that the system contains an ultrasonic device that accentuates the prearrangement of the components inside the chassis. The device has Xbee that implements Zigbee protocol to propagate data in the given system and the ESP 8266 Wi-Fi Module.

The Microcontroller

The project made use of a microcontroller called Arduino Mega. This is an open-source board from the Arduino family. Furthermore, it can be connected to a computer via a USB cable. It is used in this project because all Arduino boards are designed to be simple to program and expand for various uses. The objectives of this project are mentioned in the next section.

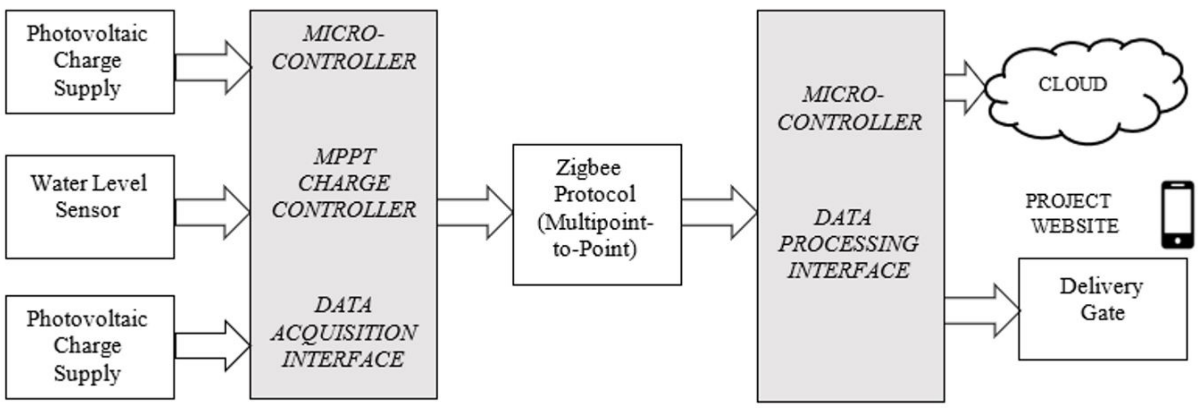

Fig. 1. Block Diagram of the Proposed System

Fig. 2. Actual Paddy Water Level Sensor

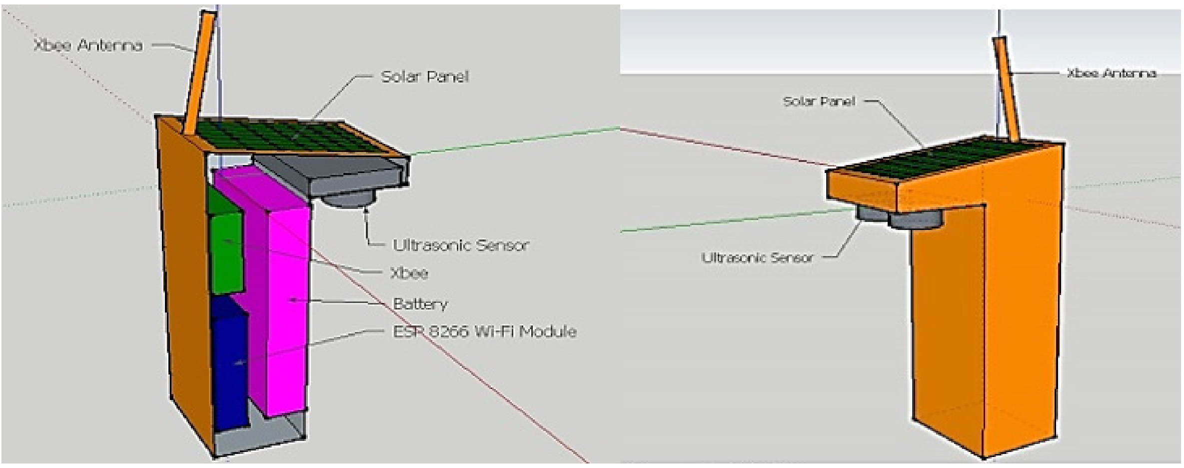

Fig. 3. Paddy Water Level Sensor Chassis Design

Wireless Transmission using Zigbee Protocol Multipoint to Point

The Arduino Mega will gather sensors' readings for command evaluation. It helps communicate data from other sensors, assuming that there will be two or more paddy sensors. Meanwhile, the Zigbee protocol will be employed by the system for wireless data evaluation and transmission. The server will be linked to this database. The MySQL database will be used to store all data gathered in real-time and will be shown on the website. Timing and data collection are configurable and subject to alteration as needed. These data are only available to the National Irrigation Administration of the Philippines, farmers who would use the irrigation, and concerned stakeholders and parties.

Delivery Gate Arduino Controller

In the Arduino circuit, the automation of the delivery gate is dependent on the software. The facts that have been determined and gathered will serve as the foundation for its conduct.

When the Arduino Mega receives the data, it will determine whether to open the gate based on the various endpoints' information. This will allow enough water to be supplied to the rice field. Two conditions will be considered: the rice field's water level is crucial, and there is enough water for the rice crops. The gate's response will be determined by the criteria stated. The Arduino Mega will measure the water level in a specific area of the rice field. If the rice field need water, it will open and close when adequate water is delivered.

The Graphic Display

The primary goal of this project is to provide an easy-to-use monitoring system on the measurement devices of the persons involved, namely farmers and irrigation associations. Data sending devices that use the Zigbee Protocol for wireless transmission were installed in the system to monitor the platform. All collected data is reliably and consistently displayed on the system's online webpage for convenient monitoring. The system's website server is named after the proponents.

Delivery Gate

A Stepper motor is used to operate the delivery gate, as shown in the design in Fig. 4 and Fig. 5, with two chains connecting the counterweight and the moving flap. Adapting and constructing a counterweight designed gate lessens the torque requirement of the machine, allowing the use of a NEMA 23 stepper motor – which has a torque holding capacity of 30 kg-cm for its control.

Fig. 6 shows the system's automatic steel delivery gate. This is used to secure the system from high water pressure caused by the irrigation canal. However, due to its enormous weight and the nature of steel, the gate is utilized as a counter-weight-designed type. The gate's chassis weighs roughly 20 kg, the gate door 5.7 kg, and the adjustable counterweight starts at 5.4 kg. Without human intervention or understanding, this can limit water discharge to only the required irrigation water of rice crops by utilizing the project's correction system, which functions in "OPENING" and "CLOSING" in specified levels of paddy water.

In Fig. 7, the counterweight of the gate is shown. The motor implemented is a NEMA 23 stepper motor with a pulse/rev setting of 25600 and a voltage-current requirement of 24V-1.5A and a Driver DM542A. Since a 24V battery supplies it, this functions as a balance to lower the voltage demand of the gate. The gate weighs 5.4 kg and can hold two extra circular metal pieces, weighing 2.5 kg each. This design consideration is due to the pressure in which the gate is positioned rises.

There is a box inside the delivery gate for the delivery gate's data receiver and motor driver circuit box. Inside the box is the connection for the receiving device or the "end-point" Xbee of the Zigbee protocol connected to an Arduino Mega – which has a 12V and 1.5A power and current requirement – where the program of the system is being implemented. The box also provides housing for the motor driver and relay driver of the delivery gate.

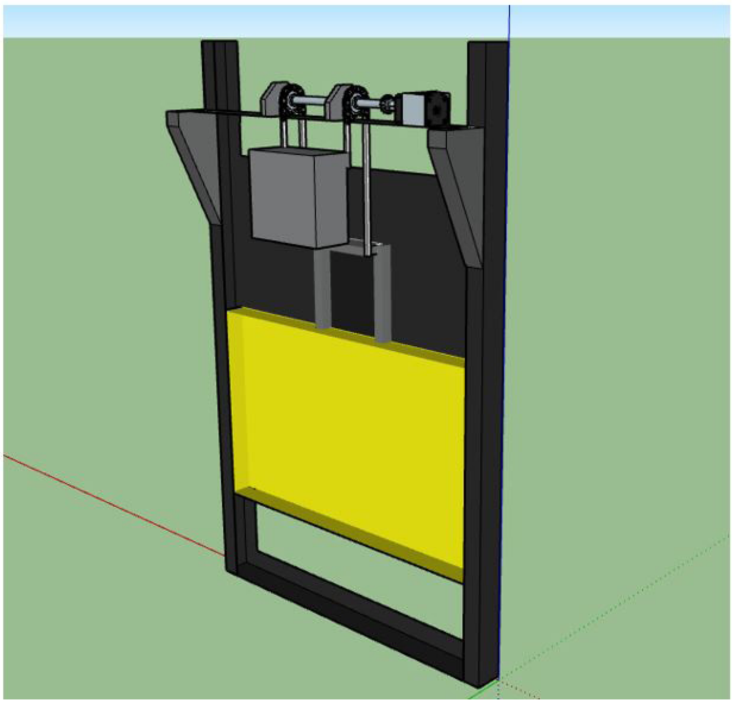

Fig. 4. Automated Gate Design

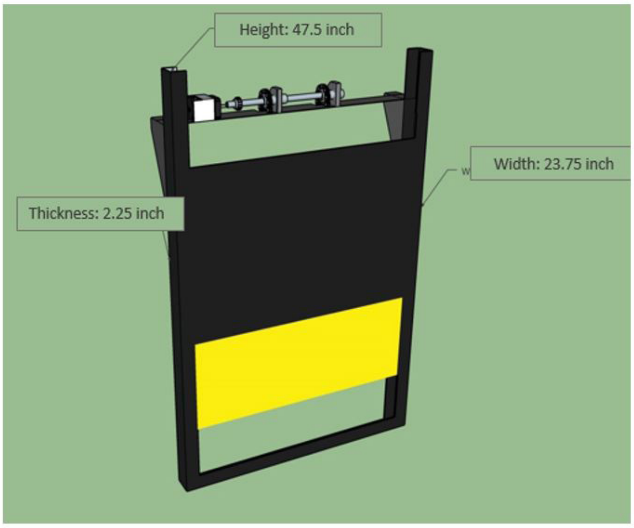

Fig. 5. Automated Gate Design Specifications

Fig. 6. Actual Automated Delivery Gate

Fig. 7. Counterweight design

Fig. 8. MPPT charge controller and battery cabinet

Table 2. Rice Cycle and its Specific Water Requirement (Zawawi, Mustapha, & Puasa, 2010)

Days After Planting	Stage	Depth of Submergence	Depth of Saturation	Requirement
15	Vegetative	100 mm	100 mm	Very Critical
30		50 mm		
49	Active	150 mm		Critical
60	Maximum			
70	Initiation			
80	Reduction	100 mm		Very Critical
100	Forming of Spikelets	0		
115	Ripening		No limit	Not Required
130	Harvest			

MPPT Solar Charge Controller

Fig. 8 is the house of the MPPT and the battery connections from the solar panel. Two 12-V/26mAh battery in parallel connection was used to supply the required 24-V of the stepper motor NEMA 23. The gate and the Arduino will have an Arduino-based Power Point Tracking Controller (MPPT) as the source power; this will be connected to a Solar Panel. This algorithm-based controller heightens the output between the battery bank and solar panel, thus charging faster than a standard panel. The MPPT Solar Charge Controller's function is to transfer the maximum power from the solar panel to the battery and to track the entire powerpoint of the solar panel (Batarseh & Za'ter, 2018; Gratela et al., 2019; Madrigal et al., 2019; Merin et al., 2018; Tolentino, Cruz, Garcia, & Chung, 2015; Tolentino, Cruz, & Chung, 2018).

Data Management

The proposed system monitors the crop water requirement, as shown in Table 2. Engr. Eusebio S. Villamanto of the National Irrigation Administration (NIA) of the Philippines is acknowledged for this gathered data. Because this system employed the AWD approach, the project's critical component is the precise assessment of peak water requirements of plants at each stage of development. The study also follows the research of Zawawi, Mustapha, & Puasa (2010), in addition to the NIA, for more precise measurements and a more detailed explanation of the rice crop growth cycle.

To summarize the system's irrigation level threshold, the saturation depth is 100 mm below the earth, and the irrigation level submergence depth is 150 mm above ground. Fig. 9 shows the submergence and saturation depths, as well as the average evapotranspiration of 5 mm/day during a typical day in the country, percolation in regular clay soil for rice crops of 2 mm/day, and a rooting depth of 300 mm on an ordinary rice crop.

The system follows the safe AWD principle and uses it as a guide for maximum irrigation water usage. With this, the scheduling for irrigation follows an algorithm and prototype logic about the rice cycle's specific water requirement. The logic guides of the system are shown in Table 3.

Table 3 contains the system's test cases and prototype logic I/O, which are as follows:

1st Case: the water in the overland canal is enough. Additionally, the water level (WL) in fields 1 (F1) and 2 (F2) is beneath the saturation (sat) depth.

2nd Case: the water in the overland canal is enough. Additionally, the WL in F1 is beneath the sat depth. Meanwhile, F2 is at a safe level.

3rd Case: the water in the overland canal is enough. Additionally, the WL in F1 is beneath sat depth. Meanwhile, F2 is above submergence (sub) depth.

4th Case: the water in the overland canal is enough. Additionally, the WL in F1 is safe. Meanwhile, the water level in F2 is beneath the sat depth.

5th Case: the water in the overland canal is enough. Additionally, the WL in F1 and F2 is at a safe level.

6th Case: the water in the overland canal is enough. Additionally, the WL in F1 is safe. Meanwhile, F2 is above the sub depth.

7th Case: the water in the overland canal is enough. Additionally, the WL in F1 is above the sub depth and below the sat depth.

8th Case: the water in the overland canal is enough. Additionally, the WL in F1 is above the sub depth. Meanwhile, F2 is at a safe level.

9th Case: the water in the overland canal is enough. Additionally, the WL in F1 and F2 is above the sub depth.

Table 3. System's experimental cases and logic input and output (I/O)

Case	Field Sensor (FS) State	Sensor State						State of the Delivery Gate Motor	Direction Valve State	
		F1			F2				Clockwise	Counterclockwise
		sub	nor	sat	sub	nor	sat			
1		0	0	1	0	0	1		1	0
2		0	0	1	0	1	0	1	1	0
3		0	0	1	1	0	0		1	0
4		0	1	0	0	0	1		1	0
5	1	0	1	0	0	1	0	0	0	0
6		0	1	0	1	0	0		0	1
7		1	0	0	0	0	1		1	0
8		1	0	0	0	1	0	1	0	1
9		1	0	0	1	0	0		0	1

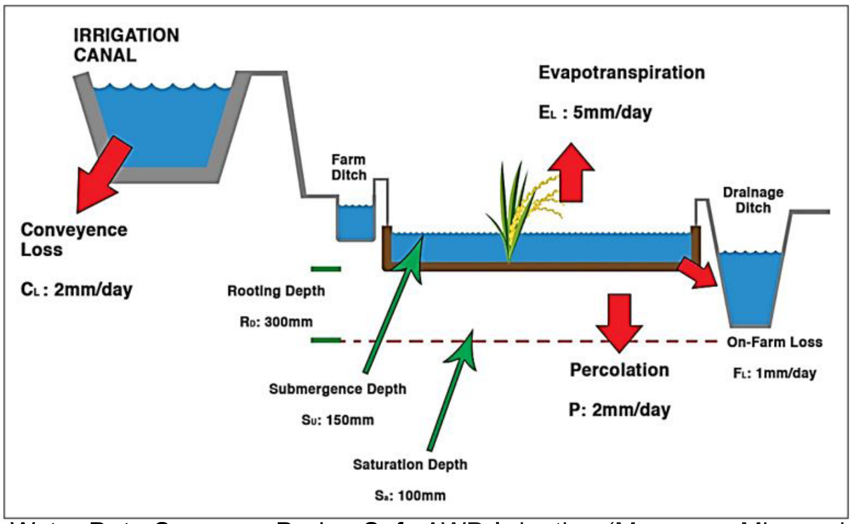

Fig. 9. Irrigation Water Data Summary During Safe AWD Irrigation (Manzano, Mizoguchi, Mitsuishi, & Ito (2011)

RESULTS AND DISCUSSION

Each system's component and design were rigorously tested in this research. The testing portion changes according to its purpose on that piece of the system. It was tested several times to ensure that the system's operation was correct before installing it in the deployment region. The deployment site for a more precise functioning test was chosen as Cantilipe, Apalit, Pampanga. The proponent used a variety of ways to collect the following information.

Fig. 10 shows the placing of the different features of the system. "1" refers to the placing of the photovoltaic charging and battery source. "2" refers to the placing of the delivery gate and its automation circuits. "3 and "4" show the weir placing of the ultrasonic sensors in cylindrical tubes.

Performance of Delivery Gate

The response time of a corrective device in a control system is significant, and the time needed for the gate to "open" and "close" is used to quantify the error in the system. Table 4 displays the results of measuring the delivery gate's response time, or the time it takes to react after receiving the system program's command. It was found that the system has a response time of few seconds. This is because of the enormous area of foliage involved. Furthermore, this length of time is minimal in comparison to the amount of water discharged.

Fig. 10. Project Implementation Location

Table 4. Delivery Gate's Response Time

Trial	Condition	Response Time (s)	Gate movement (cm)
1	GATE OPENS	3.0	49
2	GATE CLOSES	4.0	
3	GATE OPENS	3.0	
4	GATE CLOSES	2.0	
5	GATE OPENS	3.0	
6	GATE CLOSES	2.0	
7	GATE OPENS	4.0	
8	GATE CLOSES	2.0	
9	GATE OPENS	2.0	
10	GATE CLOSES	2.0	
	Mean:	**2.7**	

Table 5. Paddy Water Level Sensor Precision Test (Calibration)

Trial	True Value (cm)	Experimental Value of Height (cm)		Gate movement (cm)		% Error	
		1st Sensor	2nd Sensor	1st Sensor	2nd Sensor	1st Sensor	2nd Sensor
1	13	13	13	12	12	0	0
2	64	64	64				
3	802	802	802				
4	63	63	63				
5	485	485	485				
6	555	555	555				
7	845	845	845				
8	849	849	849				
9	850	850	850				
10	76	76	76				
					% Error	**0**	**0**

Value	Date	
78	February 23, 2018 11:40 AM	Delete
77	February 23, 2018 11:36 AM	Delete
77	February 23, 2018 11:36 AM	Delete
78	February 23, 2018 11:35 AM	Delete
78	February 23, 2018 11:33 AM	Delete
78	February 23, 2018 11:33 AM	Delete
78	February 23, 2018 11:32 AM	Delete
76	February 23, 2018 11:31 AM	Delete
78	February 23, 2018 11:31 AM	Delete
77	February 23, 2018 11:31 AM	Delete
74	February 23, 2018 11:30 AM	Delete
73	February 23, 2018 11:29 AM	Delete
74	February 23, 2018 11:29 AM	Delete

Fig. 11. Level values collected from the ultrasonic sensor setup

Sensor Precision and Accuracy Performance

For an efficient measuring duty, the sensor's accuracy and precision in the paddy water level system are highly valued. The table shows that the system's sensor devices have nearly slight inaccuracy compared to other water level determining devices. As shown in Table 5, the results of this test indicate that the system functions well in terms of giving accurate water level displays and irrigation schedule recommendations. Sensors 1 and 2 refer to the sensors installed in the field's first and second choice weirs.

Performance of Website User-Interface Display

The values obtained from the Ultrasonic transducer sensor setup are presented in Fig. 11. Meanwhile, Fig. 12 depicts the information shown on the project's online monitoring webpage. The project's internet website displays real-time data measurements from the actual paddy field it is set on. It executes the measurement description at least every 2 minutes to ensure that the system is continuously monitored. The sensor's results were supplied to the database and internet consistently. The values are constant, although the time it takes to upload data depends on the Internet connection. No time lag was ensured when there is a solid and consistent connection. It indicates the dependability of this project component in terms of showing real-time measurements for monitoring purposes.

Summary of Findings

The proposed system was tested in Cantalipe, Apalit, Pampanga, on a two-hectare farm with four weirs. It incorporates paddy water level sensors that use an ultrasonic transducer to calculate distances per task. Furthermore, rather than burying devices straight under the soil, which can be readily destroyed, a cylindrical polyvinyl chloride is buried in the soil to reflect the water content measured by the preceding device. Also, due to its minimal power requirements and stability in wireless transmission, the Zigbee protocol circuit was used.

Fig. 13 shows the meaning of the graph motion and the comparable water level in the paddy. Since the graph shown on the website contains a summary of all data acquired within the research time-lapse, the system's efficiency can be found by analyzing its data. The data recorded in the database of the system is the measurements in the ultrasonic transducer. Since it is a one-way device, there is no division on whether the water is below or above the ground. The equivalence of these measurements is as follows:

400 mm = ground level
250 mm = 150 mm above the ground
500 mm = 100 mm below the ground.

Based on the system's graph, which contains measurements taken within one month, the water level never exceeded the maximum required irrigation water for rice crops, 150 mm above ground, or fell below 250 mm in sensor measurements. It also never got above 500 mm, which is 100 mm below the earth and is the fundamental level of irrigation water in rice harvests. The graph in the system includes the measurements gathered within one month. As shown in the diagram, the water level never surpassed the given maximum irrigation water required for rice crops. In sensor measurement, it also means that there is consistency in the system where the system operates by "OPENING" and "CLOSING" the delivery gate at the time it is required to do so.

Table 6 reveal the database findings and their summary and corresponding paddy measurements for the dates January 27-29, 2018 respectively; it demonstrates the continual gathering of data in the database and modifications in the system in reaction to the acquired data.

The sensors reliably display location-specific and real-time water level values. Simultaneously, it provides a consistent electrical power charge. It can also cause the irrigation valve to open and close when a certain level of soil water is achieved. It shows the efficiency of the system's performance. It achieves its goal of assisting those in charge of allocating the precise amount of water required for irrigation.

When the proposed controlled system is compared to the conventional irrigation method, the proposed controlled system significantly improves water use efficiency while retaining the same crop yield quality and quantity. The proposed method is ideal for efficiently utilizing irrigation water from the Angat Dam. This is evident that implementing a decision assistance system is preferable. Traditionally, the mentioned closed-loop system uses an affordable sensor device for watering. The recommended field water requirement, on the other hand, is not considered in this manner. Furthermore, because the timetable is predefined, it does not adapt to either the weather or the water source.

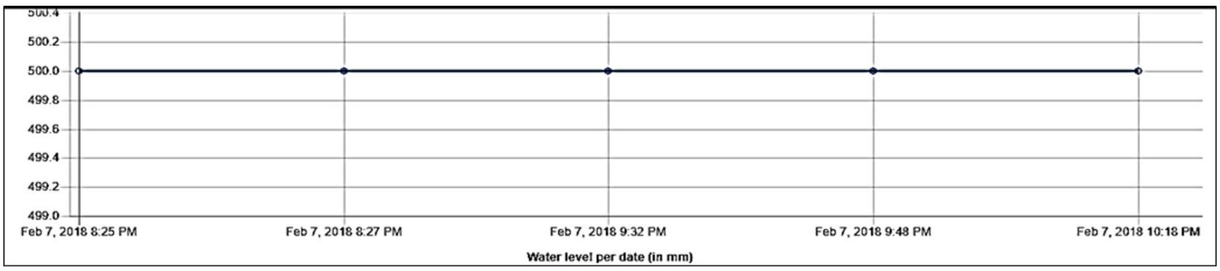

Fig. 12. Real-time water level measurements (in mm) at a particular date

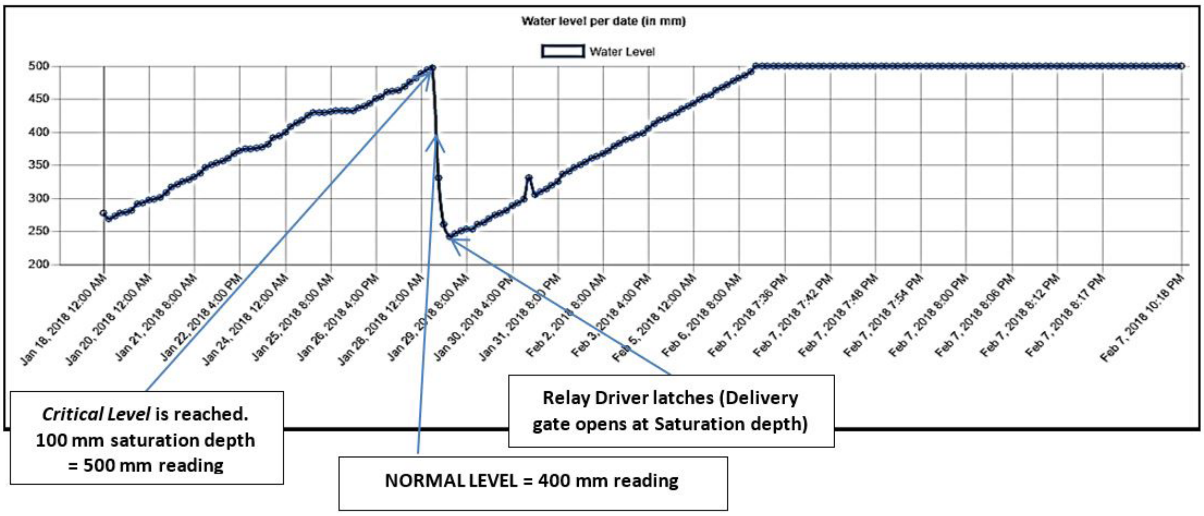

Fig. 13. Irrigation Monitoring Website Graph Parts and Meanings

Table 6. Summary of Database Records and Its Equivalent in Real-Paddy Measurements

Day After Planting	Time	Level from Sensor	Level Equipment (mm)		Gate Status
			Above Ground	Below Ground	
1/27/2018	12:00AM	460	-	60	No movement
1/27/2018	4:00AM	462	-	62	No movement
1/27/2018	8:00AM	464	-	64	No movement
1/27/2018	12:00PM	469	-	69	No movement
1/27/2018	4:00PM	476	-	76	No movement
1/27/2018	8:00PM	482	-	82	No movement
1/28/2018	12:00AM	489	-	89	No movement
1/28/2018	4:00AM	495	-	95	No movement
1/28/2018	8:00AM	497	-	97	1 (Counter Clockwise)
1/28/2018	12:00PM	331	69	-	No movement
1/28/2018	4:00PM	260	140	-	No movement
1/28/2018	8:00PM	242	158	-	1 (Clockwise)
1/29/2018	12:00AM	246	154	-	No movement

Irrigation groups and farmers alike had little difficulty installing the system. The data from the sensors was continuously provided. Moreover, the feedback correction, which included the delivery gate's "OPENING" and "CLOSING," operated adequately. Through IoT, the data was appropriately recorded in the team's database. Furthermore, the irrigation status and details were shown correctly on the website that was designed and produced.

On December 12, 2017, the group began growing crops in the deployment location. After 36 days of seeding, the system installation began. It is entirely operational two days later, January 18. Fig. 14 (a) depicts the farmed area's regular irrigation using the conventional method. As seen on the data gathering sheets, after the automated irrigation system was fulfilled, the resulting schedule is shown in Fig. 14(b).

Every Thursday, water is discharged from the systematized irrigation for traditional irrigation. There is an irrigation separation time that spans 11 days. It is nearly double of the time in ordinary farming. A 7:11 irrigation pattern to conventional agriculture and farming using the suggested system was exhibited if the irrigation is done consistently.

It accumulates 75 m^3 less or approximately 20% less utilizing the standard watering method, with just 1 week and 3 weeks of testing throughout 3 weeks of prototype evaluation. Using the proposed system, data collected during this period shows roughly 300m^3 of water outflow from irrigation and 374.99976 m^3 of water output from traditional irrigation methods.

Lastly, Table 7 summarizes the overall findings.

	Sun	Mon	Tue	Wed	Thurs	Fri	Sat
1:00-3:00							
1:00-3:00							
1:00-3:00							

(a)

	Sun	Mon	Tue	Wed	Thurs	Fri	Sat
1:00-5:00	Jan 14	Jan 15	Jan 16	Jan 17	Jan 18	Jan 19	Jan 20
1:00-5:00	Jan 21	Jan 22	Jan 23	Jan 24	Jan 25	Jan 26	Jan 27
1:00-5:00	Jan 28	Jan 29	Jan 30	Jan31			

(b)

Fig. 14. Resulting Schedule for (a) Normal Irrigation and (b) Automated Irrigation

Table 7. Summary of Findings

Problem to be Solved	Outcome
Development of an automated delivery gate for water discharge	The delivery gate successfully opened and closed when it was instructed by the paddy water level system. Its average response time (opening and closing) is 2.7 seconds.
Construction of the paddy water level system	The sensors were well-calibrated based on real measurements. Although two different water level systems are placed far apart from each other, the water level readings are the same. Both their average response time is 12 seconds.
Monitoring of the water level and the status of the delivery gate	An online website of the project was created that displays real-time data measurements from the actual paddy field it is set on. It runs the measurement description at least every 2 minutes to ensure continuous monitoring of the system.
Development of an automated irrigation system based on safe AWD	The developed system could economize about 20% of water consumption within three weeks in a two-hectare area with four weirs analogized to the traditional irrigation method

CONCLUSION AND SUGGESTION

An automated irrigation and water level control system based on the AWD concept was successfully designed to ensure optimized apportionment of water supply. Most of the current irrigation infrastructure difficulties have been resolved. They could give the exact amount of water required for the rice crop while minimizing waste and spills. After the design and execution of the system, the conditions are met. The proponents created an automated discharge control system for irrigation water to the paddy without compromising the maximum water requirement.

Moreover, a webpage was developed to serve as an online monitoring system that displays the water level, the expected time of irrigation, the delivery gate status (open or closed), the non-standard and standard status of plant's growth and the stage of its growth.

Future work comprises generating a "mini gate" with its control system for all weirs in the paddy field. In addition, since a small farm area is covered in this study, the primary strategy for a large farm will be to decide which site to be irrigated at a specific time.

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