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DESIGN AND IMPLEMENTATION OF AN IOT-BASED AWD IRRIGATION MONITORING PROTOTYPE FOR A RICE FIELD IN MINAHASA, INDONESIA

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ABSTRACT

Efficient water management is vital for sustainable rice cultivation, particularly in regions that still rely on conventional irrigation practices. This study presents an Internet of Things (IoT)-based irrigation monitoring prototype implementing the Alternate Wetting and Drying (AWD) method in a rice field plot in Minahasa, Indonesia. The experimental site covers 331.44 m², representing a typical smallholder rice field in the region. The system integrates an ESP32 microcontroller with an A02YYUW ultrasonic sensor for water-level measurement, a DHT20 sensor for temperature and humidity monitoring, and an FC-37 sensor for rainfall detection. Sensor data are processed locally, transmitted via Wi-Fi to the ThingSpeak cloud platform, and displayed on a 0.96-inch OLED module. Powered by a 6 V, 3.8 W solar panel and a rechargeable Li-ion battery, the system operates autonomously with low power consumption. Field testing demonstrated high measurement performance, achieving $R^2 = 0.9994$, MAE = 0.18 cm, RMSE = 0.24 cm, and an overall accuracy of 96.78%. The prototype effectively detected AWD thresholds and provided real-time alerts through ThingSpeak, offering a reliable and energy-efficient solution for precision irrigation.

I. INTRODUCTION

The management of water resources remains a fundamental component influencing the sustainability and productivity of agricultural practices, particularly in rice-growing areas. In Indonesia and many developing regions, conventional continuous-flooding irrigation practices still dominate, often resulting in inefficient water use, excessive energy consumption, and increased labor requirements. These challenges highlight the need for adaptive and data-driven irrigation strategies to ensure long-term productivity and environmental sustainability [1-3]. The Alternate Wetting and Drying (AWD) technique has been recognized as an effective and sustainable water-saving irrigation practice. The method alternates periods of flooding and drying in paddy fields to maintain optimal soil moisture for rice growth while reducing water consumption by up to 30 % without decreasing yields [4]. In addition, recent studies revealed that AWD could reduce greenhouse gas emissions from rice fields by up to 48 % compared to continuous flooding [5].

However, the adoption of the AWD technique among rural farming communities remains low, as it demands frequent manual monitoring of water levels, a task that is both time-consuming and susceptible to human error [6]. Recent progress in IoT technologies has created significant opportunities to automate irrigation management and real-time monitoring. IoT-based agricultural systems enable real-time data acquisition from distributed sensors, cloud-based storage, and automated control processes, supporting the emerging concept of precision agriculture [7-11]. The application of IoT for water management has grown rapidly in recent years, offering scalable solutions for smallholder farmers through low-cost sensor networks [12-14]. Recent studies have demonstrated the potential of IoT in irrigation management. For example, [15] designed an IoT-based system for rice cultivation under the AWD regime, achieving up to 36

% water savings. Similarly, [16] applied IoT to AWD irrigation in Vietnam's Mekong Delta and reported a 20 % reduction in water usage and 25 % reduction in energy consumption. According to [17] proposed a fuzzy-logic-based IoT control approach to optimize irrigation cycles. Other researchers have proposed various smart irrigation frameworks. In, [18] designed a wireless sensor network (WSN) to manage soil moisture and irrigation scheduling. According to [19] implemented a low-power WSN for field irrigation management, and [20] demonstrated a low-cost IoT irrigation platform adaptable to multiple crops. More recently [21], incorporated fuzzy logic into an IoT irrigation controller to enhance decision accuracy and energy efficiency. Complementary research also explores integration with renewable energy and edge computing [22],[23]. According to [24] reviewed IoT-enabled irrigation systems emphasizing sustainability and interoperability. Furthermore, in [25] introduced fuzzy control algorithms to enhance irrigation decision accuracy. In Indonesia, especially in the Minahasa region of North Sulawesi, irrigation is still largely managed manually, making it an ideal case for implementing and testing automated AWD-IoT systems. To fill this gap, this research aims to design, implement, and evaluate an IoT-based irrigation monitoring system integrating the AWD method for rice cultivation in Minahasa, Indonesia. The system utilizes an ESP32 microcontroller integrated with an A02YYUW ultrasonic sensor for water-level detection, a DHT20 sensor for temperature and humidity measurement, and an FC-37 rain sensor. Sensor data are processed and transmitted to the ThingSpeak cloud platform and displayed locally on a 0.96-inch OLED module. The device is powered autonomously using a 6 V, 3.8 W solar panel. Field testing was conducted directly in Minahasa rice fields to evaluate accuracy, reliability, and energy efficiency. The experimental results revealed a strong linear relationship between the sensor readings and the reference measurements, with a coefficient of determination (R^2) of 0.9994, a mean absolute error (MAE) of 0.18 cm, a root mean square error (RMSE) of 0.24 cm, and a mean absolute percentage error (MAPE) of 3.22%, corresponding to an overall measurement accuracy of 96.78%. The system also demonstrated the ability to accurately identify AWD irrigation phases and to generate real-time alerts via the ThingSpeak cloud platform when water levels reached critical thresholds, enabling timely and informed irrigation decisions.

II. THEORETICAL REFERENCE

In paddy agriculture, irrigation timing and depth control are the dominant levers for yield stability, water productivity, and input costs. Traditional continuous-flooding regimes rely on manual observation and canal scheduling, which often results in over-irrigation, high pumping energy, and inconsistent field conditions across plots. The Internet of Things (IoT) offers a programmable alternative: distributed, low-power sensors capture hydrologic and microclimatic states; edge devices filter and calibrate those signals; and cloud services persist time-series data, visualize trends, and trigger alerts or actuation.

II.1 ALTERNATE WETTING AND DRYING (AWD) IN RICE IRRIGATION

AWD is a controlled, intermittent irrigation strategy in which paddy fields are allowed to dry down to a pre-set threshold before being re-flooded. Practically, a perforated field water tube is installed; irrigation is withheld until the water table inside the tube drops to a target depth (commonly 10–15 cm below soil surface for “safe AWD”), then water is re-applied to a shallow ponded level [4]. By replacing continuous flooding with cyclical wet–dry phases, AWD preserves root-zone aeration while maintaining sufficient soil moisture for rice growth [16]. Multiple studies report that AWD can reduce irrigation water by ~16–30% versus continuous flooding without penalizing grain yield when thresholds are respected and crop stages (e.g., flowering) are protected from stress [4],[26]. Field deployments that pair AWD with sensor support (automated level detection, cloud alerts) further improve scheduling accuracy and operational consistency, helping smallholders convert theoretical savings into realized water productivity gains [15],[16],[27]. AWD offers a validated pathway to reduce irrigation inputs without yield penalties when safe thresholds and stage-specific safeguards are enforced. The main practical challenge—timely, accurate water-level observation—can be mitigated through low-cost sensing and cloud notifications. AWD offers a validated pathway to reduce irrigation inputs without yield penalties when safe thresholds and stage-specific safeguards are enforced. The main practical challenge—timely, accurate water-level observation—can be mitigated through low-cost sensing and cloud notifications, which strengthen rule compliance, reduce labor, and facilitate scale-out in smallholder rice systems [6],[8],[15].

II.2 IOT FOR PRECISION IRRIGATION: ARCHITECTURES AND TRENDS

II.2.1 Reference Architecture (sensor–edge–cloud)

Contemporary agricultural IoT follows a layered pattern: in-field sensing → edge processing on a low-power controller → backhaul to a cloud service for storage, analytics, visualization, and eventing [5],[22],[24]. The sensor layer measures hydrologic and microclimatic states (e.g., ponded water depth, rainfall, air temperature/relative humidity); the edge layer handles acquisition, filtering, calibration, compression, and duty-cycling; the cloud layer persists time-series data, renders dashboards, runs rules/analytics, and integrates notifications or downstream actuation [5],[8],[15]. This separation improves robustness and allows local autonomy when connectivity is intermittent.

II.2.2 Sensing modalities and design constraints

For paddy fields, non-contact ultrasonic ranging is favored for water-level observation due to turbidity tolerance and simple mechanics; accuracy depends on alignment, mounting geometry, surface agitation, and air-temperature-dependent sound speed, motivating co-measurement of thermo hygrometric context (e.g., DHT20) for compensation [5], [7],[15]. Rain sensors (contact or tipping) provide precipitation flags to disambiguate level changes driven by storms versus irrigation, stabilizing state classification near decision thresholds [15],[18]. Additional options—soil moisture probes, water-pressure transducers are useful in canals or subsurface monitoring but increase calibration and fouling risks. Recent reviews stress that sensor selection and placement dominate data fidelity in agricultural IoT deployments [5],[7],[24].

II.2.3 Communications: Wi-Fi, WSN, and LPWAN.

Connectivity choices trade range, throughput, and energy. Wi-Fi is practical where farmstead routers cover nearby plots; it offers high throughput but higher idle power and shorter range. Wireless Sensor Networks (WSN) using short-range radios form multi-hop meshes over distributed plots to extend coverage while balancing energy and reliability [18],[19]. For dispersed paddies and canal networks, LPWAN (e.g., LoRa/LoRaWAN) provides kilometer-scale links at ultra-low power with small payloads, well matched to periodic telemetry and event messages [13], [14]. Comparative studies highlight that LPWAN plus aggressive duty-cycling maximizes node lifetime, whereas Wi-Fi suits data-rich gateways or edge cameras near power [18],[13],[22].

II.2.4 Calibration, uncertainty, and QA/QC

IoT-based irrigation systems are typically evaluated by comparing sensor readings with ground-truth measurements using statistical metrics such as Mean Square Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and R² obtained from regression analysis [8],[15],[16]. Practical QA/QC includes two-point checks at installation, environmental drift checks (temperature/humidity effects), periodic spot-gauging, and flagging of physically impossible jumps (continuity constraints). Studies underline the need to publish calibration procedures and residual diagnostics for reproducibility [15],[16],[24].

Mean Absolute Error (MAE)

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|W_i - \widehat{W}_i\right| \tag{1}$$

Coefficient of Determination

$$R^2 = 1 - \frac{\sum(W_i - \widehat{W}_i)^2}{\sum(W_i - \overline{W})^2} \tag{2}$$

III. MATERIALS AND METHODS

This study designs and implements an IoT-based irrigation monitoring system integrating the Alternate Wetting and Drying (AWD) method for rice cultivation in Minahasa, Indonesia. The system employs an ESP32 microcontroller connected to an A02YYUW ultrasonic sensor for water-level detection, a DHT20 sensor for temperature and relative humidity, and an FC-37 rain sensor. Sensor data are processed and transmitted to the ThingSpeak cloud platform and displayed locally on a 0.96-inch OLED module. The device operates autonomously using a 6 V, 3.8 W solar panel together with a rechargeable Li-ion battery (3.7 V, 2000 mAh). The block diagram of the proposed system is presented in Figure 1.

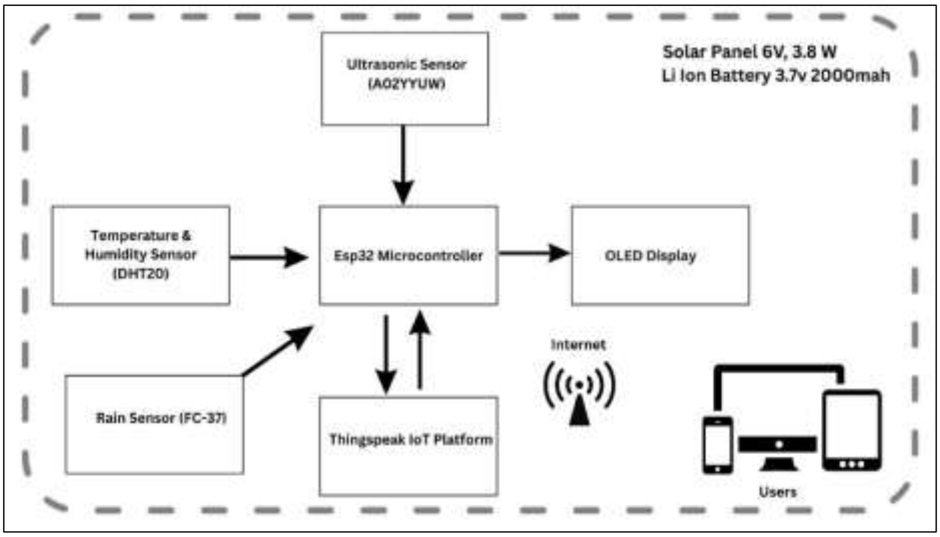

Figure 1: Proposed system architecture.
Source: Authors, (2025)

III.1 PROTOTYPE HARDWARE DESIGN

In Figure 2, the prototype comprises two parts: a monitoring box and a 120 cm long PVC tube. The tube includes a 20 cm perforated section with holes spaced 5 cm apart, allowing subsurface water to enter the tube so that the below-ground water level can be measured.

Figure 2: Prototype Hardware Design.
Source: Authors, (2025).

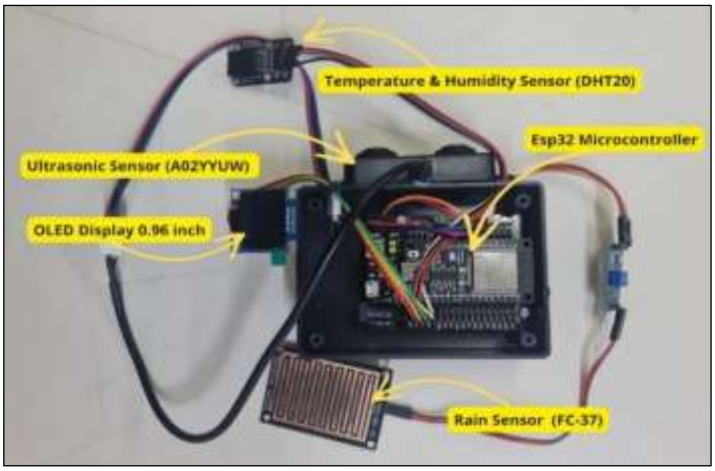

Figure 3: Monitoring Box.
Source: Authors, (2025).

Inside the monitoring box (Figure 3), the system is organized into input, processing, and output components. The inputs comprise an A02YYUW ultrasonic sensor, a DHT20 temperature–humidity sensor, and an FC-37 rain sensor. The processing unit is an ESP32 microcontroller that acquires, filters, and transmits the data. The output is a 0.96-inch OLED display presenting the measured water level, air temperature, relative humidity, and rain status in real time. The processing unit is based on an ESP32 system-on-chip selected for its integrated wireless connectivity, ample processing headroom, and low-power features suited to unattended field deployments. The device provides dual-core processing with hardware support for real-time tasks and includes on-chip Wi-Fi (2.4 GHz) and Bluetooth radios, enabling direct telemetry to the cloud without an external gateway.

Its rich peripheral set—UART (for the A02YYUW ultrasonic sensor), I²C (for the DHT20 and OLED), general-purpose digital I/O (for the FC-37 rain input), hardware timers, and watchdogs—simplifies sensor integration while maintaining deterministic sampling. The A02YYUW is an IP67-rated waterproof ultrasonic ranging module used for non-contact water-level measurement inside the AWD field tube. It operates over a nominal range of approximately 3–450 cm with a blind zone of about 3 cm, providing stable readings in humid, splash-prone paddy environments. The module communicates via a UART interface, enabling direct integration with the ESP32 microcontroller. The sensor emits an ultrasonic pulse and measures the round-trip time of the echo reflected from the water surface (time-of-flight). The instantaneous distance d from the transducer face to the water surface is converted to field water level using a fixed mechanical reference H_{ref} established at installation (the top rim of the AWD tube).
Thus, the instantaneous field water level is:

Water Level

$$W = H_{ref} - d \tag{3}$$

where W is the water level referenced to the soil surface (cm), H_{ref} is the transducer-to-rim offset (100 cm), and d is the measured distance from the transducer to the water surface (cm). In this project, a DHT20 digital sensor measures air temperature (°C) and relative humidity (%) to contextualize evapotranspiration and AWD dry-down dynamics. The device communicates over I²C, enabling a direct interface with the ESP32 alongside the OLED display. The third sensor is the FC-37 rain sensor, used to detect precipitation and to distinguish water-level changes caused by rainfall from those caused by irrigation. The module comprises a plated sensing pad and a comparator board that provides a digital rain flag ($R \in \{0,1\}$) to the ESP32. The pad is mounted on a short horizontal standoff at the top of the monitoring enclosure, projecting slightly beyond the case to intercept free-falling droplets while minimizing splash from the AWD tube. The cable ingress is sealed, and the pad is installed with a slight tilt (5–10°) to promote runoff and reduce water pooling. The system's local output is a 0.96-inch OLED display. The module interfaces with the ESP32 over an I²C serial bus, enabling real-time presentation of readings from the three sensors water level, air temperature, relative humidity, and rain status. The display also provides on-device AWD alerts, with the state encoded for quick interpretation: 0 = Normal, 1 = Low (re-irrigate), and 2 = High (excess ponding).

III.1 SOFTWARE SYSTEM

The software system of the irrigation monitoring prototype is designed to manage data acquisition, processing, transmission, and visualization through an integrated embedded–cloud framework based on the ESP32 microcontroller and the ThingSpeak cloud platform. ThingSpeak serves as the IoT data aggregation and analytics platform for this system. It supports both HTTP and MQTT communication protocols, enabling efficient and lightweight data transmission from the ESP32.

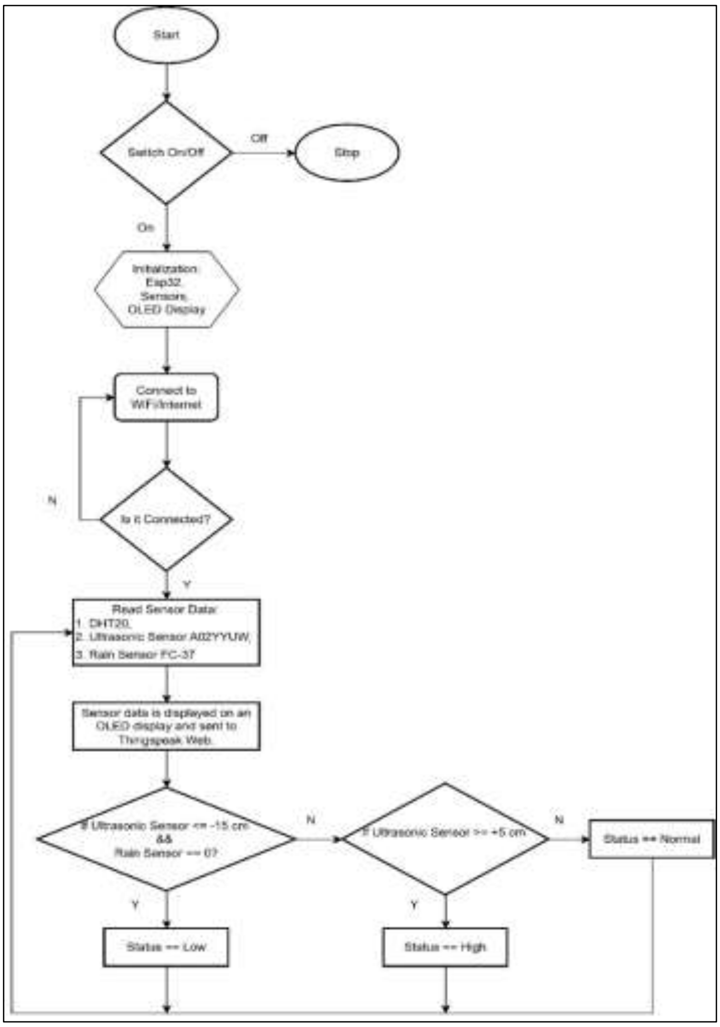

Figure 4: Flowchart of The Project.
Source: Authors, (2025).

Each measurement cycle, the system uploads sensor data including water level, air temperature, relative humidity, rain flag, AWD classification, battery voltage, and signal strength to the designated ThingSpeak channel. The platform provides real-time dashboards for visualization and supports event-based triggers that automatically send alerts via email or SMS when certain thresholds are reached (e.g., when the field becomes too dry or overly flooded). This integration allows continuous monitoring and real-time decision support for farmers implementing the AWD method. The software operation sequence is depicted in Figure 4, starting with an initialization stage where the ESP32 microcontroller configures all sensors. The microcontroller establishes UART communication with the A02YYUW ultrasonic sensor, I²C communication with both the DHT20 sensor and OLED display, and digital input with the FC-37 rain sensor. After initialization, the ESP32 attempts to connect to the Wi-Fi network.

If the connection succeeds, the system proceeds to the sensing stage; otherwise, it continues local measurements and retries the Wi-Fi connection periodically using a back-off delay to reduce power consumption. In the data acquisition stage, the ESP32 reads the outputs of all sensors sequentially. The ultrasonic sensor measures the distance between the sensor and the water surface (d), which is converted to the water level using the equation (1). The DHT20 provides air temperature and relative humidity, while the FC-37 rain sensor generates a digital flag ($R \in \{0,1\}$) indicating the presence or absence of rainfall. Each measurement is processed through a median filter (3–5 samples) to eliminate random noise and improve stability. During data processing, the system executes the AWD decision algorithm, which classifies irrigation conditions into three levels: High (2): $W \geq 5$ cm (excess water; drainage recommended), Normal

(0): water level within the AWD safe range, Low (1): $W \leq -15$ cm and $R = 0$ (soil drying; irrigation needed). After data processing, all readings including timestamp, water level, temperature, humidity, rainfall status, and alert status are transmitted to ThingSpeak via an HTTP POST request. If data transmission fails due to network instability, the system temporarily stores the measurements in local memory and retransmits them during the next communication cycle. The updated information is visualized on the ThingSpeak dashboard, and alerts are automatically generated when predefined thresholds are reached. After completing each cycle, the ESP32 enters deep-sleep mode to conserve energy. This continuous loop of sensing, processing, and transmission ensures reliable, low-power operation of the system under real field conditions.

IV. RESULTS AND DISCUSSIONS

The prototype system was installed in one of the rice field plots located in Minahasa, North Sulawesi, Indonesia, with a total area of approximately 331.44 m^2. In Figure 5, the AWD tube was placed at the center of the plot to ensure representative measurement of the field's average water level. The control unit houses the ESP32 microcontroller, the A02YYUW ultrasonic sensor, the DHT20 temperature–humidity sensor, the FC-37 rain sensor, and the 0.96-inch OLED display, all enclosed within a weatherproof box. This design allowed the system to withstand exposure to rain, and wind while maintaining stable performance.

Figure 5: Field Installation of the Prototype.
Source: Authors, (2025).

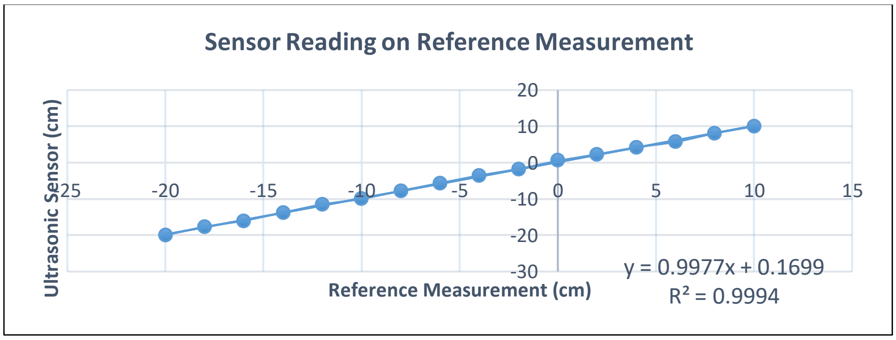

Figure 6: Correlation between Ultrasonic Sensor Reading and Reference Measurement.
Source: Authors, (2025).

The A02YYUW ultrasonic sensor was calibrated against manual reference measurements to verify accuracy in field conditions. During calibration, measurements were taken at several water levels within the AWD tube, ranging from −20 cm (below soil surface) to +10 cm (above ground level). The resulting correlation between sensor readings and reference measurements is shown in Figure 6, while statistical results are summarized in Table 1. The linear regression analysis between the sensor and reference readings yielded an R^2 value of 0.9994, indicating an almost perfect correlation. The low MAE (0.18 cm) and RMSE (0.24 cm) confirm that the sensor consistently produced accurate measurements under field conditions. The computed MAPE of 3.22% and overall accuracy of 96.78% are well within acceptable limits for agricultural monitoring applications. These results are comparable to previous works by [18],[20], who reported errors below 1% in controlled environments using similar low-cost ultrasonic sensors. The performance stability observed in varying weather conditions (direct sunlight, rainfall, and humidity) further demonstrates the robustness of the A02YYUW sensor when integrated with the ESP32 microcontroller. The stable signal quality was aided by the short sampling period and internal median filtering implemented in the firmware to eliminate spikes caused by surface ripples and wind interference.

Table 1: Field Testing Results.

Summary Metrics	**Test Results**
MAE	0.18
MSE	0.05
RMSE	0.24
R^2	0.9994
MAPE (%)	3.22
Percentage accuracy (%)	96.78

Source: Authors, (2025).

Following the International Rice Research Institute (IRRI) guidelines, the AWD practice used in this research involved interrupting irrigation after the flooding stage and reapplying it once the water level in the AWD tube dropped to about −15 cm below ground level. After re-irrigation, the ponded water was allowed to increase up to +5 cm above the soil surface, completing one alternation of wetting and drying [2],[28]. This cyclical management promotes intermittent aeration of the soil, reducing water consumption by up to 30% while maintaining grain yield and plant health. In this implementation, the AWD monitoring tube was installed vertically at the center of the plot to ensure representative measurement of the average ponding condition. The tube was perforated over a 20 cm section near its base to allow lateral water exchange between the surrounding soil and the inner tube column. The system operated autonomously throughout several AWD cycles. During each cycle, the water level fluctuated between −15 cm (dry threshold) and +5 cm (wet threshold), consistent with IRRI's recommended AWD regime. When the water level fell below −15 cm, the system automatically classified the state as *Low* and triggered a re-irrigation alert through the ThingSpeak platform. Once irrigation resumed and the level exceeded +5 cm, the state transitioned to *High*, prompting the user to stop irrigation. The automated detection and alert mechanism successfully guided irrigation scheduling during all observed cycles.

Figures 7 present the real-time monitoring data transmitted from the IoT-based AWD irrigation prototype to the ThingSpeak cloud platform. The system recorded and visualized five main parameters: water level, air temperature, relative humidity, rainfall status, and alert status, each represented in separate fields configured on the ThingSpeak dashboard. The water-level chart (Field 1) shows small fluctuations around 5.0 cm, corresponding to changes in the ponding depth measured inside the AWD tube. These variations represent the minor surface ripples and response sensitivity of the A02YYUW ultrasonic sensor. The threshold range for AWD operation was defined as ≤ -15 cm (dry limit) and $\geq +5$ cm (flood limit); the recorded data in this test remained near the flooded condition, consistent with the *High* AWD state. The temperature chart (Field 2) illustrates a gradual decline from 22.7 °C to 22.5 °C, reflecting the natural cooling trend during the nighttime monitoring period. Meanwhile, the humidity chart (Field 3) shows fluctuations between 96% and 97%, which align inversely with temperature changes, confirming the sensor's responsiveness and stability in humid paddy field conditions. The rain status chart (Field 4) provides a binary signal: *0* indicates no rainfall, and *1* denotes precipitation detected by the FC-37 rain sensor. A rain event was recorded shortly after 20:10, confirming the sensor's functionality and helping distinguish natural rainfall from irrigation-driven water level changes.

The alert status chart (Field 5) reflects automatic classification results generated by the ESP32 firmware. The system identifies three irrigation states based on AWD thresholds: Low (1) when the water level is ≤ -15 cm, indicating the field requires re-irrigation, Normal (0) when the water level is between −14 cm and +4 cm, representing stable soil moisture, High (2) when the water level is $\geq +5$ cm, signaling over-irrigation. Each detected state is uploaded to ThingSpeak via HTTP POST requests and visualized both numerically and through a color-coded alert indicator, as shown in Figure 7. A green indicator represents the *Normal* condition (safe AWD range), while a red indicator signals a *critical condition* requiring user attention. The system distinguishes between two red states: Low-water condition (≤ -15 cm): dry soil—irrigation required High-water condition ($\geq +5$ cm): excessive flooding—irrigation should be stopped. This visual alert system enhances the usability of the IoT platform by translating sensor data into intuitive, color-coded feedback that can be quickly interpreted by farmers in the field. The notification is automatically synchronized with the ESP32's internal AWD logic, ensuring that every color change corresponds precisely to a real-time event in the field.

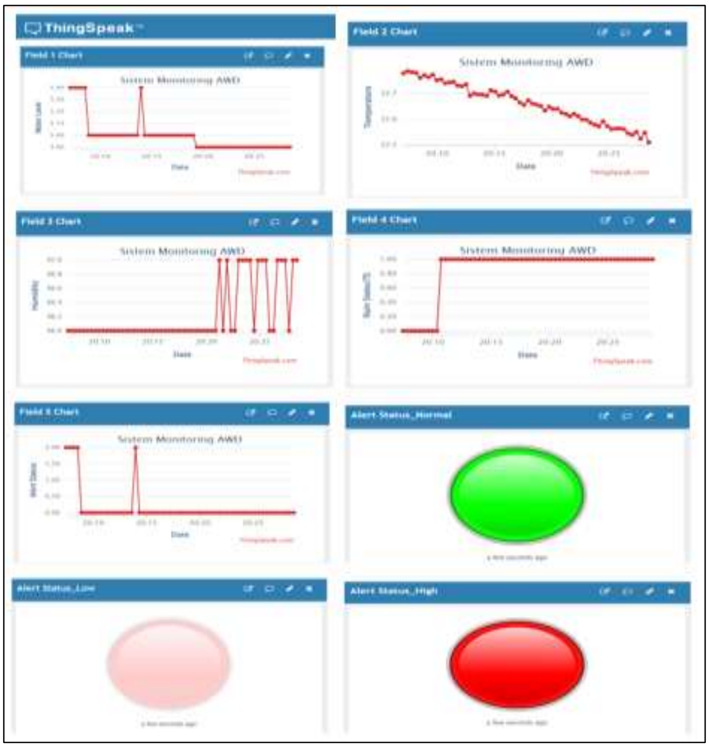

Figure 7: ThingSpeak Data Visualization.
Source: Authors, (2025).

A key advancement introduced by this study compared with previous IoT-based AWD implementations lies in the inclusion of additional environmental parameters, specifically air temperature, relative humidity, and rainfall detection. For example, [15] developed an automated irrigation system for AWD rice fields based solely on soil moisture and ultrasonic sensors, without integrating atmospheric or rainfall monitoring modules. Similarly, [16] implemented a LoRa-enabled AWD irrigation network that relied exclusively on water-level measurements from pressure transducers, with no sensing components for rainfall, temperature, or humidity. In contrast, the present prototype employs a multi-sensor architecture that combines: an A02YYUW ultrasonic sensor for non-contact water-level measurement, a DHT20 sensor for temperature and relative humidity monitoring, and an FC-37 rainfall sensor for direct precipitation detection. This configuration allows the system to differentiate between water-level changes caused by irrigation and those caused by rainfall, thereby preventing false alerts during natural rain events. Moreover, the inclusion of temperature and humidity sensing provides additional contextual data for evapotranspiration analysis, making irrigation recommendations more adaptive to real-time environmental conditions.

V. CONCLUSIONS

This study designed, developed, and field-tested an IoT-based irrigation monitoring prototype implementing the Alternate Wetting and Drying (AWD) method for rice cultivation in Minahasa, Indonesia. The system integrates an ESP32 microcontroller with an ultrasonic water-level sensor (A02YYUW), a DHT20 temperature–humidity sensor, and an FC-37 rainfall sensor. Field experiments conducted in a 331.44 m² rice plot demonstrated high accuracy, achieving $R^2 = 0.9994$, MAE = 0.18 cm, RMSE = 0.24 cm, and MAPE = 3.22% (accuracy 96.78%). The system effectively identified AWD thresholds (≤ -15 cm and $\geq +5$ cm) and provided real-time alerts and data visualization via the ThingSpeak cloud platform. Future work will focus on improving system scalability, integrating automated irrigation control, and applying AI-based prediction models to further optimize water use efficiency and crop yield performance.

VI. AUTHOR’S CONTRIBUTION

Conceptualization: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
Methodology: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
Investigation: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
Discussion of results: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
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Writing – Review and Editing: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
Resources: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
Supervision: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar
Approval of the final text: Ryan Laksmana Singgeta, Lianly Rompis and Ignatia Rosali Honandar

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