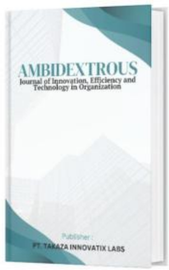
Ambidextrous: Journal of Innovation, Efficiency and Technology in Organizations
https://journal.takaza.id/index.php/ambidextrous
Vol. 5, no. 2, 2026 , pp. 379-387
E-ISSN: 3031-7002
E-mail:ambidex@takaza.id



Smart Drip Irrigation Monitoring and Control System for Melon Cultivation Based on ESP32 and Using Blynk Application

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Article History:
Received: 09-08-2026
Revised: 24-09-2026
Accepted: 24-09-2026

Keywords: Internet of Things; Smart Irrigation; ESP32; Blynk; Melon Cultivation.

Abstract : *This study aims to develop an intelligent drip irrigation monitoring and control system based on the Internet of Things (IoT) to automate watering and optimize soil moisture in melon cultivation, addressing the inefficiencies of conventional manual irrigation methods. The system was developed using the Research and Development (R&D) method with an IoT approach, consisting of a capacitive soil moisture sensor as input, an ESP32 microcontroller as the control center, and a water pump as an actuator, integrated with the Blynk application for remote monitoring and control. System evaluation was conducted through functional testing of hardware and software, assessing sensor reading accuracy, control response speed, and water use efficiency compared to manual irrigation methods. The results showed that the system was able to maintain soil moisture in the optimal range of 60-80% for melon plants with a sensor reading accuracy reaching 97.5%. Furthermore, the system successfully increased water efficiency by 45% compared to manual watering methods, and achieved an average response time of 2.5 seconds for sending data to the Blynk application. This study was limited to a single melon cultivation site with a short evaluation period; future research should expand to multiple crops and longer monitoring durations. The IoT-based monitoring system enables farmers to obtain soil moisture information and control irrigation more quickly and accurately, reducing manual intervention burdens and improving water use efficiency. Enhanced irrigation efficiency contributes to sustainable agricultural practices and supports the Islamic principle of khalifah fil ardh (stewardship of the earth) in responsible water resource management. This study integrates IoT technology with precision agriculture protocols in Indonesian melon cultivation, offering a novel approach to real-time soil moisture monitoring with Blynk-based remote control capabilities.*

How to Cite: Muhammad Dzikri Idham Surya, Soffa Zahara, Yanuarini Nur Sukmaningtyas. (2026). The title. Ambidextrous Journal of Innovation Efficiency and Technology in Organizations. 5(2). Pp 379-387 https://doi.org/10.61536/ambidextrous.v5i02.661

https://doi.org/10.61536/ambidextrous.v5i02.661

Introduction

Melon (Cucumis melo L.) is a superior horticultural commodity with high economic value, but its successful cultivation depends heavily on precise water management, especially in greenhouses (Nur Alif & Pertiwi, 2025; Aisyah et al., 2025). Conventional irrigation often causes problems with water shortages or excesses that inhibit plant growth, trigger root rot, and reduce crop productivity (Westari & Ilman, 2024). The development of Internet of Things (IoT) technology provides opportunities to support precision agriculture through automatic irrigation monitoring and control. The use of an ESP32 microcontroller integrated with the Blynk application has been proven to increase water use efficiency and facilitate remote monitoring (Walid et al., 2024; Pereira et al., 2023). Furthermore, advances in sensor technology enable IoT systems to understand soil environmental conditions in real time for precise irrigation needs (Ansari & Vidyarthi, 2025).

Several studies have examined the application of IoT in smart irrigation systems. Research by Nur Alif and Pertiwi (2025) developed a drip irrigation system using Takagi-Sugeno fuzzy logic based on ESP8266 that was able to maintain melon soil moisture within the optimal range. Meanwhile, Walid et al. (2024) and Pereira et al. (2023) showed that the integration of ESP32 and Blynk applications has the potential to increase the effectiveness of real-time irrigation monitoring and control. However, these studies still used a simple threshold-based control approach or used microcontrollers with limited connectivity, thus not being able to automate the entire process of adaptive drip irrigation monitoring and control for melons.

Based on these conditions, there is still a research gap because there is no system that integrates environmental condition monitoring, logic-based decision making, and actuator control in a single IoT-based workflow to support melon cultivation needs. Therefore, this study develops an intelligent drip irrigation monitoring and control system for melon cultivation based on ESP32 and the Blynk application. The novelty of this research lies in the application of the ESP32 framework that is fully integrated with Blynk to coordinate soil moisture and temperature sensor readings in a single integrated workflow, thus capable of producing precise irrigation control and real-time monitoring. Through this approach, the system is expected to be able to help melon cultivators manage water more efficiently, consistently, and easily.

Literature review

Internet of Things (IoT)

The Internet of Things (IoT) is a technological solution that connects physical devices to the internet for data exchange without manual intervention, enabling real-time land monitoring in a melon drip irrigation system (Musari et al., 2025). The IoT architecture in this system is implemented through three main layers: the Perception Layer that uses a capacitive soil moisture sensor to detect water content, the Network Layer that utilizes an ESP32 microcontroller to process and transmit data via Wi-Fi to the Blynk server, and the Application Layer in the form of the Blynk Application that provides an interactive dashboard for remote pump monitoring and control (Zakaria et al., 2026). The main advantage of implementing this architecture compared to conventional local automation lies in the ability of remote control and data logging to analyze historical soil moisture trends (Ella, 2026), as well as the push notification feature that provides automatic warnings to farmers in the event of a system failure to prevent melon plants from experiencing drought stress (Westari & Ilman, 2024).

Water Requirements and Environmental Parameters of Melon Plants

Water requirements and environmental conditions are crucial for the growth of melon (Cucumis melo L.), which has a root system that is sensitive to waterlogging but requires a consistent water supply, especially during the flowering and fruit-growing phases (Handayani & Irawati, 2022). The main parameter monitored in this system is soil moisture, with the ideal range for melon cultivation being 60% to 80% of field capacity (Thongleam et al., 2024). A decrease in humidity below 60% can cause water stress that inhibits fruit growth and reduces harvest quality,

https://doi.org/10.61536/ambidextrous.v5i02.661

while humidity above 80% risks triggering anoxia and root rot due to Fusarium spp. fungus attack (Thongleam et al., 2024). To maintain these optimal conditions, a drip irrigation system is implemented because it can deliver water in a measured manner directly to the root zone through emitters, thereby minimizing losses due to evaporation and surface runoff that commonly occur with manual watering (Handayani & Irawati, 2022; Muspiah et al., 2024). This method has been proven to significantly increase water use efficiency with a distribution efficiency level reaching >90% to 98.86%, making it an optimal solution to precisely meet the physiological needs of melon plants (Handayani & Irawati, 2022; Thongleam et al., 2024).

Soil Moisture, Temperature, and IoT Device Sensors

A capacitive soil moisture sensor is used as a vital transducer component to convert soil moisture content into an electrical signal, chosen because its working principle is based on changes in capacitance, making it more resistant to corrosion and having a longer service life than conventional resistive sensors (Bavitra et al., 2025). The analog voltage output from this sensor is read by the ADC pin on the ESP32 microcontroller, which acts as a central processing unit, then converted into a moisture percentage value (Ella, 2026). The ESP32 has the advantage of a dual-core processor that allows sensor readings and Wi-Fi data transmission in parallel without significant delay (Musari et al., 2025). When the moisture value is read below the minimum threshold, the ESP32 sends a LOW digital signal to a 1-channel relay module that functions as an electronic interface switch between the low-voltage control circuit and a 9V battery-powered mini DC pump (Mahendra & Ihsan, 2026). Activating this relay flows current to the pump to push water through the drip emitter, where the use of the relay is also crucial to protect the ESP32 GPIO pin from the inductive kickback generated by the DC pump coil when it is turned off (Mahendra & Ihsan, 2026).

IoT Based Monitoring and Control System

The IoT-based intelligent drip irrigation monitoring and control system operates on a closed-loop feedback principle, where the soil moisture sensor periodically reads the water content and sends the data to the Blynk application via the ESP32 for real-time visualization (Zakaria et al., 2026). On the automatic control side, the ESP32 runs threshold-based decision logic; if the humidity drops below the minimum limit (e.g., 60%), the pump is activated via a relay, and will be turned off again when the humidity reaches the maximum limit (e.g., 80%), ensuring that soil moisture remains within the optimal range without manual intervention (Bavitra et al., 2025). In addition to the automatic mode, the system provides a manual mode via the Blynk dashboard that allows farmers to remotely turn the pump on or off, which is very useful for intervention purposes such as fertigation (Saputri et al., 2025). As a layer of security and early warning, the system also features an automatic push notification feature to farmers' smartphones when critical humidity conditions or operational failures in the pump are detected (Mahendra & Ihsan, 2026).

CrewAI Framework

The application of the Internet of Things (IoT) in the Smart Farming concept has been proven to increase resource efficiency and crop productivity by providing real-time land data for precise decision-making, which in melon cultivation impacts root stability and water consumption efficiency (Binayao, 2024). Unlike conventional irrigation methods that rely on visual estimation and rigid schedules, which are prone to water stress or root rot, and require the inefficient physical presence of farmers (Tafrikhatin et al., 2024), an IoT-based precision irrigation system offers an objective solution. This system integrates capacitive soil moisture sensors to continuously read the actual condition of the growing medium and automatically activates the water pump only when a threshold is reached, ensuring optimal water intake without relying on the farmer's intuition or physical presence (Sobri & Agustini, 2026). Furthermore, the use of simple and affordable hardware—such as an ESP32, relays, mini DC

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pumps, and batteries—makes this smart farming approach highly feasible for widespread adoption by small- to medium-scale melon farmers (Theodora, 2024).

Blynk App

Blynk is an Internet of Things (IoT) platform that provides cloud services and mobile applications to facilitate real-time monitoring and control of microcontroller devices such as the ESP32 (Priyono, 2023). Blynk consists of a smartphone application, the Blynk Cloud Server, and the Blynk Library integrated into the firmware, enabling secure two-way communication via the TCP/IP protocol using Authentication Tokens and SSL/TLS encryption to prevent unauthorized access (Rakhmawati et al., 2024). In this study, data from the soil moisture sensor and DHT22 were processed by the ESP32 and sent to the Blynk dashboard for visualization, as well as for use in remote control of water pumps, data logging, and push notifications when soil moisture falls below a critical threshold (Melkhias & Akbar, 2023; Burhan et al., 2024). This platform offers easy interface configuration through ready-to-use widgets without the need for custom application development, as well as responsive communication performance with an average response time of 200–500 milliseconds and a disconnection rate below 2% (Rakhmawati et al., 2024; Burhan et al., 2024). Based on these advantages, Blynk is highly suitable for application in intelligent drip irrigation monitoring and control systems for melon cultivation because it can increase the efficiency of watering management and make it easier for farmers to monitor land conditions from anywhere (Priyono, 2023).

Research methods

This study uses the Research and Development (R&D) method to develop and evaluate an intelligent drip irrigation monitoring and control system for melon cultivation based on the Internet of Things (IoT) by utilizing the Blynk application. The R&D method was chosen because it includes a structured product development stage starting from needs identification, design, implementation, to system evaluation. The system was developed by utilizing the ESP32 microcontroller as a control center, a soil moisture capacitive sensor, a DHT11 air temperature and humidity sensor, and a BH1750 light intensity sensor as hardware components programmed through the Arduino IDE environment, and integrating the Blynk platform as a remote monitoring and control interface. The IoT approach is implemented with the ESP32 acting as a control center to read soil moisture, air temperature, air humidity, and light intensity data periodically, calculate the status of irrigation conditions based on thresholds determined according to the physiological needs of melon plants at each growth phase, and trigger the activation or deactivation of water pumps and solenoid valves automatically and send real-time notifications to the user's smartphone through the Blynk application. The research stages carried out include problem identification, literature studies, needs analysis, hardware and software design and implementation, and testing and evaluation of system functionality.

System Design

The system is designed using an Internet of Things (IoT) approach with an ESP32 microcontroller as a data processing center to automate the monitoring and control process of intelligent drip irrigation in melon cultivation. This approach allows several hardware and software components to work collaboratively in completing different tasks through a structured workflow. The ESP32 acts as the main microcontroller that regulates coordination, sensor data acquisition, and actuator control so that the irrigation monitoring and control process can run in real-time and be integrated with each other. The system design also utilizes a capacitive soil moisture sensor (Soil Moisture Sensor), a DHT11 temperature and air humidity sensor, and a BH1750 light intensity sensor to periodically read the environmental conditions of melon cultivation so that the resulting irrigation control decisions are more in line with the actual needs of the plants.

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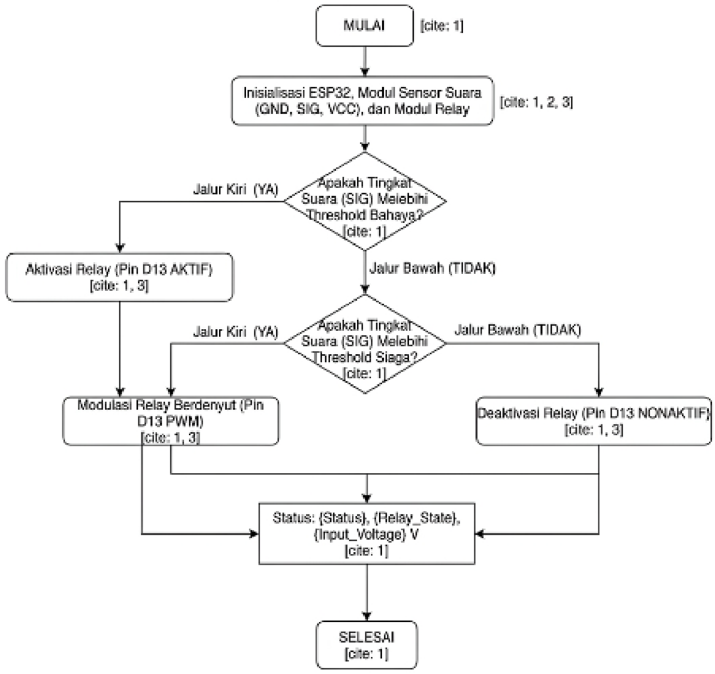

Picture1. System Architecture

The system architecture consists of three main subsystems: the Environmental Monitoring Subsystem, the Irrigation Control Subsystem, and the Blynk User Interface Subsystem. The process begins when sensors installed on the melon cultivation area read environmental parameters such as soil moisture, air temperature, humidity, and light intensity. This information is received by the Environmental Monitoring Subsystem via ESP32 to be processed and compared against predetermined threshold values according to the physiological needs of melon plants during their growth phase. The monitoring results are then forwarded to the Irrigation Control Subsystem to activate or deactivate the water pump and solenoid valve in the drip irrigation network based on pre-programmed control logic.

Furthermore, the Blynk User Interface Subsystem utilizes the Wi-Fi connection on the ESP32 to send real-time monitoring data to the Blynk application on the user's smartphone, and accepts manual control commands from the user when necessary. The Blynk interface displays sensor data visualizations in the form of graphs and gauges, provides pump control buttons, and sends push notifications when critical conditions occur such as soil moisture below the threshold or temperature anomalies that could potentially damage the plant. Collaboration between these subsystems produces interrelated outputs so that the process of monitoring and controlling drip irrigation in melon cultivation can be carried out automatically, more efficiently in water use, and still maintains the match between actual environmental conditions, irrigation control responses, and information conveyed to the user through the Blynk application.

Evaluation Method

The evaluation of the IoT-based intelligent drip irrigation monitoring and control system was conducted through functional testing of the hardware and software, as well as testing the effectiveness of notification delivery via the Blynk application. The system performance assessment focused on three main aspects: the accuracy of soil moisture sensor readings, the response speed of notification delivery (delay), and the success of delivering irrigation status information to users, as shown in Figure 2.

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Picture2. Smart Drip Irrigation System Functional Test Environment

Figure 2 displays the documentation of the system's functional testing environment. In the test, the ESP32 microcontroller module and environmental sensors were placed on top of a transparent container containing soil media to simulate soil moisture monitoring conditions in melon cultivation areas. A capacitive soil moisture sensor was embedded into the soil media, while a DHT11 temperature and air humidity sensor and a BH1750 light intensity sensor were positioned around the plant area to read environmental conditions in real time. The sensor readings by the system were displayed locally on an LCD screen showing real-time measurements of soil moisture, air temperature, and air humidity. Simultaneously, the data was processed by the ESP32 and sent remotely to the user's smartphone via a Wi-Fi network, which was indicated by the appearance of data updates on the Blynk application dashboard on the mobile device in the form of gauge displays and sensor reading graphs, as well as push notifications when soil moisture is below the threshold, which automatically activates the water pump.

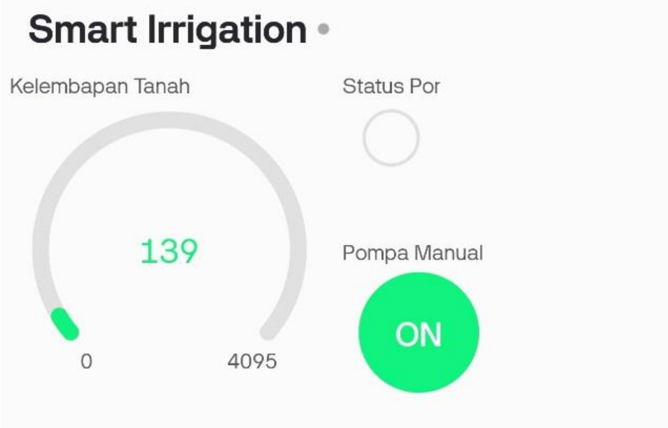
Sensor accuracy measurements were conducted by comparing the soil moisture values measured by the capacitive soil moisture sensor with the results of manual measurements using a physical soil moisture meter. The accuracy percentage and error percentage were calculated to determine the level of deviation in system readings. Next, the notification speed evaluation was conducted by measuring the time difference (delay) between changes in soil moisture conditions detected by the ESP32 microcontroller until the notification was received on the user's smartphone device via the Blynk application. The measurement results from several delivery trials were then analyzed using the average value (mean) to determine the level of consistency and reliability of the system in delivering monitoring information and early warnings to melon farmers. Data from the accuracy and response time evaluations were then presented in tables and graphs to facilitate the analysis process in the results and discussion sections.

Results and Discussion

System Evaluation Results

A system evaluation was conducted to determine the effectiveness of an IoT-based intelligent drip irrigation monitoring and control system in detecting soil moisture conditions and conveying information to melon farmers. The evaluation was conducted through direct functional testing of the hardware and software. Aspects evaluated included the accuracy of soil moisture sensor readings, notification response speed (delay), and successful classification of irrigation status. The evaluation results were used to measure the system's success in meeting real-time monitoring needs and to determine its effectiveness compared to conventional manual irrigation control methods.

https://doi.org/10.61536/ambidextrous.v5i02.661



Picture3. Monitoring and Control Evaluation Results on the Blynk Application

Based on the evaluation results visualized in Figure 3, the system successfully displays monitoring data automatically and in real-time through the Blynk application with the "Smart Irrigation" interface. The screenshot shows that the system is able to display accurate soil moisture readings (Soil Moisture) on a circular gauge with a value range of 0–4095, shows a pump status indicator (Status Por) which represents the active or inactive condition of the solenoid valve in the drip irrigation network, and provides a manual control button (Manual Pump) in the form of a green button labeled "ON" which allows farmers to take over control of the water pump remotely if needed. The system accurately sends push notifications when soil moisture conditions are below the programmed threshold according to the physiological needs of melon plants, so that the activation of the water pump and solenoid valve can be done automatically. These results indicate that the irrigation monitoring and control process, previously carried out manually through visual inspections in the field by farmers, can be effectively automated through the integration of capacitive soil moisture sensors, DHT11 sensors, BH1750 sensors, ESP32 microcontrollers, and the Blynk platform. Each component works in a structured manner, starting from detecting soil moisture conditions and environmental parameters, processing irrigation status logic, automatically controlling water pumps, to executing early warning notification delivery. These findings are in line with research stating that notifications via the Blynk application have a very fast and reliable response time, and which proves that the integration of ESP32 and capacitive soil moisture sensors is able to produce high reading accuracy. Thus, the application of the IoT system in this study can help melon farmers obtain information on land condition monitoring and irrigation control more quickly, accurately, and efficiently in water use without reducing the reliability of communication between devices in the field and the user's smartphone.

Conclusion

This research successfully developed a CrewAI-based content creator assistant system with a Multi-Agent System approach that is capable of generating content strategies, promotional captions, and visual recommendations in an integrated manner to support MSME digital promotion. The evaluation results on 17 MSMEs showed that the system was able to increase the efficiency of content creation by reducing the average time from 52.65 minutes to 6.71 minutes or by 87.26%, and obtained an ease of use score of 3.36 and user satisfaction of 3.28 on a four-point Likert scale. These results indicate that the system can help MSMEs produce promotional content more quickly, easily, and consistently. Further research can develop the system in the form of a web-based or mobile application, add integration with social media, and involve a larger number of respondents to obtain more comprehensive evaluation results.

Thank-you note

The author would like to thank the Informatics Study Program at Majapahit Islamic University for their support during this research. He also expresses his appreciation to his supervisor for his guidance and input during the research process, as well as to all melon farmers and related parties who participated in the testing and evaluation of this smart irrigation system.

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