



Implementation of IOT-Based Chili Plant Watering System Prototype with BLYNK Control

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Abstract: This research aims to design and implement a prototype of an Internet of Things (IoT)-based dual-mode irrigation system for chili plants, integrating automatic and manual control via the Blynk application. The background of this study is the need for efficient water management in chili farming, which is often constrained by traditional manual irrigation methods. The system is built using a NodeMCU ESP32 microcontroller connected to a capacitive soil moisture sensor, DHT11 sensor, and relay modules that control water and fertilizer pumps. The research method uses a prototyping model to design, build, and test the irrigation system. Real-time sensor data is transmitted to the Blynk dashboard, allowing farmers to monitor environmental conditions and control the pumps either automatically (based on threshold logic) or manually via smartphone. The calibration results show that the soil moisture sensor achieves 93.5% accuracy. Testing using the black-box method confirms that all system components function as expected, with responsive performance both in automatic and manual modes. The findings demonstrate that the dual-mode IoT-based irrigation system can maintain optimal soil moisture levels while providing flexibility for farmers to override the system based on real-world conditions. This hybrid solution offers a practical approach to modern agriculture, improving decision-making and efficiency in crop watering practices.

Keywords: IoT, chili plant irrigation, dual-mode system, Blynk application, ESP32 microcontroller.

1. INTRODUCING

The agricultural sector continues to play a strategic role in supporting food security and economic growth, with chili (*Capsicum annum L.*) being one of the key horticultural commodities in Indonesia due to its high demand for both household and industrial consumption. The success of chili farming, however, strongly depends on environmental conditions, particularly soil moisture. Chili plants require soil moisture levels between 60% and 70% to grow optimally, especially during the vegetative and flowering stages, and improper watering—either excessive or insufficient—can lead to reduced productivity, crop wilting, or even plant death.

In current agricultural practice, irrigation is still largely performed manually based on routine schedules and estimations, without relying on real-time environmental data. This approach is inefficient, labor-intensive, and can result in excessive water usage and inconsistent crop health. The integration of Internet of Things (IoT) technology into agriculture offers a promising solution by enabling real-time monitoring and control of environmental conditions. Through IoT, sensors and actuators can collect and





transmit data over the internet, allowing farmers to monitor soil and climate conditions and control irrigation systems remotely via microcontrollers such as NodeMCU ESP32.

Several studies have developed automatic irrigation systems using various hardware and software combinations. For instance, research using ESP8266 and soil moisture sensors provided automatic irrigation but lacked user intervention capabilities, while other systems using ESP32, DHT11, and moisture sensors operated purely automatically without manual control. Notification-based irrigation systems delivered information passively but did not allow real-time action. These limitations highlight a gap in existing research: most automated irrigation systems either rely fully on automatic operation or provide only passive notifications, neglecting the need for flexible manual control when sensor errors, sudden rainfall, or other unforeseen conditions occur. Moreover, there is limited research that combines real-time monitoring, dual-mode irrigation control, and user-friendly mobile application interfaces specifically for chili farming, leaving a critical need for an adaptive system that balances automation with human intervention.

To address these challenges, this research proposes the design and implementation of a dual-mode irrigation system that combines automatic and manual control using an IoT-based platform. The system uses NodeMCU ESP32, capacitive soil moisture sensors, DHT11 temperature and humidity sensors, relay modules, and a local LCD display. Automatic irrigation is triggered based on soil moisture thresholds, while a manual override is provided via the Blynk application, enabling farmers to control the system directly from a smartphone. The main objectives of this study are to develop a prototype capable of real-time environmental monitoring, implement both automatic and manual irrigation control, and evaluate the system's effectiveness in improving water-use efficiency and ensuring consistent crop growth. By integrating autonomous operation with direct human interaction, the system aims to fill the gap in current research and support more adaptive, efficient, and sustainable chili farming practices.

2. RESEARCH METHODOLOGY

This research utilizes the prototyping method as the development approach, which emphasizes iterative refinement through design, construction, testing, and evaluation. The goal is to build a functional prototype of a smart irrigation system for chili plants that integrates both automatic and manual control using Internet of Things (IoT) technology. The development begins with system requirements analysis and is followed by hardware and software design, integration, and functional validation.

The hardware architecture of the system uses the NodeMCU ESP32 microcontroller as the central control unit, chosen for its built-in Wi-Fi capabilities and compatibility with IoT-based communication. A capacitive soil moisture sensor is used to detect the moisture content of the soil, while a DHT11 sensor monitors ambient temperature and humidity. Two relay modules serve as the actuators to control the water and fertilizer pumps. The system also includes an LCD 16x2 display to present real-time sensor values directly at the physical site, providing local feedback alongside remote monitoring. The Blynk mobile application is integrated to allow users to remotely monitor sensor data and activate pumps via smartphone over an internet connection.



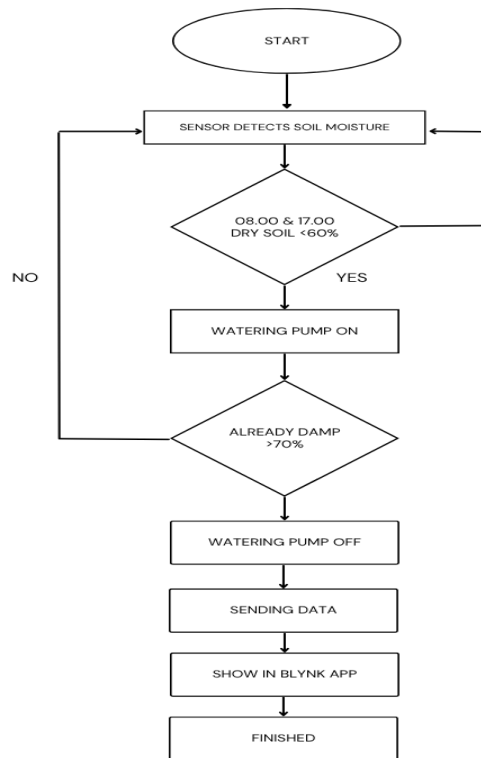


Figure 1. Control flow diagram of the irrigation system

The control logic is implemented in the Arduino IDE using the C++ programming language. The software reads data from sensors at regular intervals, processes the values, and displays them on both the LCD and the Blynk interface. In automatic mode, the irrigation pump is activated when the soil moisture reading falls below a predefined threshold (e.g., 30%) and stops when the value exceeds the upper threshold (e.g., 60%). In manual mode, users can activate the pump directly from the Blynk application through a virtual button or slider interface. This hybrid mechanism provides greater flexibility and addresses real-world limitations in fully automated systems [8].

System testing is carried out using black-box testing methods to ensure that all modules—sensing, display, communication, and actuation—perform as intended. A calibration procedure is conducted to validate the accuracy of the soil moisture sensor. Measurements from the capacitive sensor are compared with reference readings from a Three-Way Meter under five soil moisture conditions, ranging from dry to saturated. Based on the collected data, the system achieves an average accuracy of 93.5%, calculated using the formula:

$$\text{Average \%Error} = \left(\frac{\Sigma \%Error}{\text{Amount of Data}} \right) \quad (1)$$

$$\text{Accuracy (\%)} = (1 - \text{Average Error}) \times 100\% \quad (2)$$

The results confirm that the sensor is capable of providing reliable soil moisture measurements, ensuring that the system can operate effectively under real environmental conditions [9].

This methodology ensures that the developed system not only functions as expected in laboratory conditions but is also applicable in real-world agricultural scenarios. The use of off-the-shelf components

and cloud-based applications also supports scalability and potential future improvements, such as the addition of solar power, rain sensors, or long-term data logging.

3. RESULT AND DISCUSSIONS

This section outlines the outcomes of the system development and testing phases. It includes the hardware implementation, user interface setup via the Blynk application, system functionality tests using the black-box method, and accuracy validation of the soil moisture sensor. The discussion highlights the system's ability to meet design requirements and identifies areas for potential improvement.

3.1. System Implementation and Hardware Configuration

The prototype system was successfully developed using the NodeMCU ESP32 microcontroller as the central control unit. The system integrates a capacitive soil moisture sensor, DHT11 temperature and humidity sensor, LCD 16x2, two relay modules, and peristaltic pumps for water and fertilizer. The components were wired on a breadboard and connected to a 5V power supply via USB. The main goal of the implementation was to build a dual-mode irrigation system capable of both automatic and manual control through IoT.

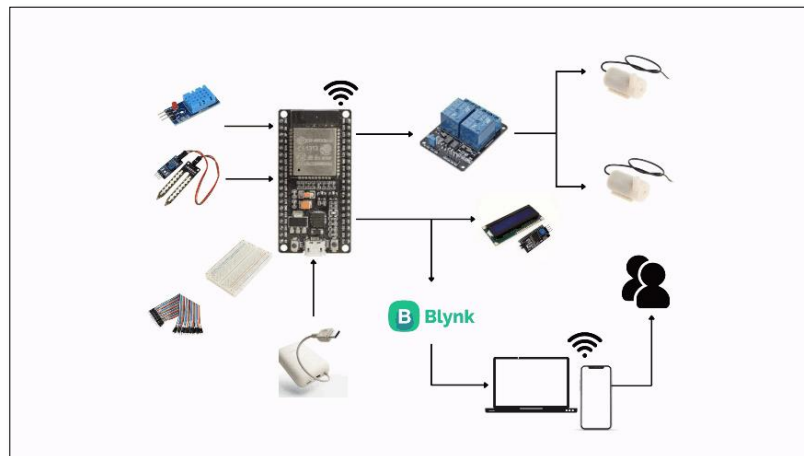


Figure 2. Complete circuit schematic of the system

Figure 2 illustrates the complete circuit schematic of the system, showing the interconnection between the ESP32, sensors, LCD, and relay modules. This diagram served as the main reference during the physical hardware assembly.

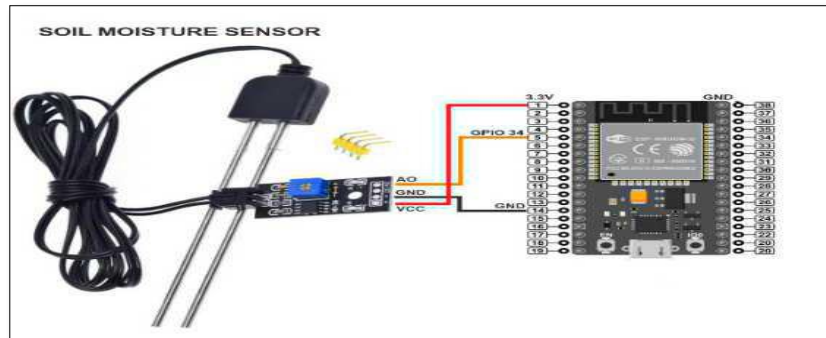


Figure 3. Soil moisture sensor circuit

Figure 3 shows the specific circuit wiring of the soil moisture sensor. The sensor's analog output is connected to the ESP32's ADC input. This sensor plays a key role in monitoring soil humidity and providing real-time input for automatic watering decisions.

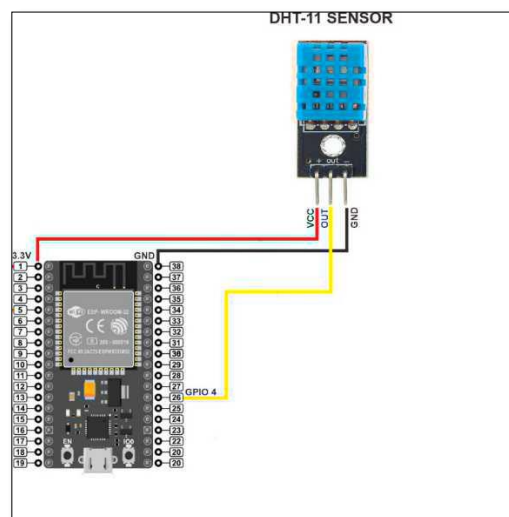


Figure 4. DHT11 temperature and humidity sensor circuit

Figure 4 displays the DHT11 sensor wiring. This sensor outputs digital readings of air temperature and humidity. It is connected to a digital pin on the ESP32 and is used to enrich the environmental data available to users through the Blynk interface.

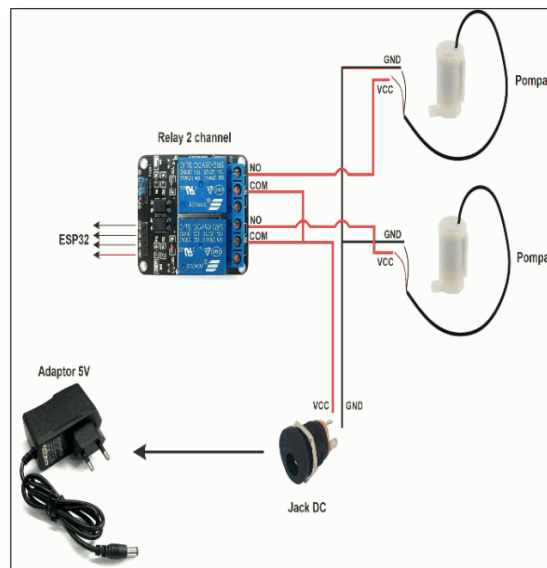


Figure 5. Water pump relay control circuit

Figure 5 shows the water pump circuit configuration. The pump is powered by a 12V supply and controlled using a relay module connected to the ESP32. This pump is responsible for delivering water to the chili plants automatically or manually, depending on the mode.

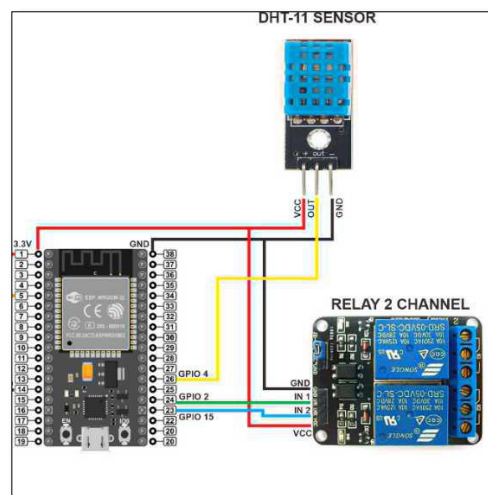


Figure 6. Relay wiring and pump connections

Figure 6 illustrates the overall relay wiring, which connects the ESP32's GPIO pins to the pump system. Each relay channel controls a separate pump (one for water, one for fertilizer), allowing both to be operated independently

3.2. User Interface through Blynk

The Blynk application serves as the mobile interface between the user and the system. It displays real-time sensor readings and provides controls for switching between manual and automatic modes. Users can monitor soil moisture, temperature, and air humidity, and activate or deactivate the pumps as needed.

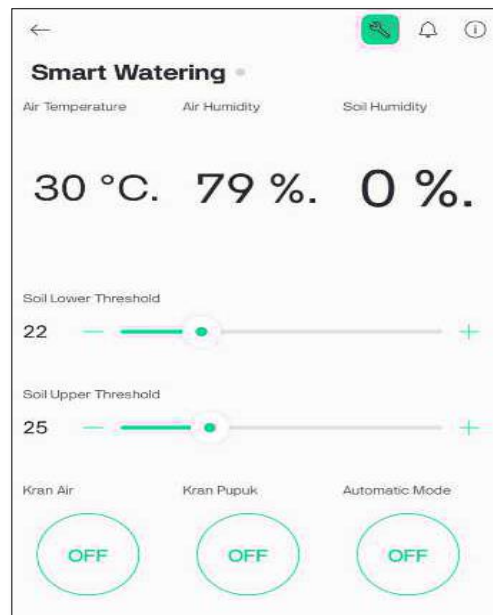


Figure 7. Blynk application interface for remote control and monitoring

Figure 7 presents the user interface layout in the Blynk application. The dashboard includes indicators for all sensor values, as well as buttons and sliders for user interaction.

3.3. Automatic and Manual Control Modes

The automatic mode activates the water pump when the soil moisture value drops below the user-defined threshold (e.g., 60%), and stops it once the value exceeds a second threshold (e.g., 70%). The logic is embedded within the ESP32 microcontroller. In contrast, the manual mode allows users to override the automation using the Blynk app, which provides virtual buttons for pump control regardless of sensor conditions. This dual-mode functionality offers flexibility in response to field conditions and sensor anomalies.

3.4. Functional Testing

The system was evaluated through a series of black-box functional tests to ensure that each hardware module and control logic worked as expected. Tests were performed on sensor response, LCD output, relay actuation, and overall data transmission to the mobile dashboard.

Table 1. Functional testing results of hardware components

No	Component Tested	Test Scenario	Expected Output	Valid/Invalid
1	NodeMCU ESP32	System is powered on	Indicator LED turns on and system becomes active	Valid
2	Soil Moisture Sensor	Sensor placed in both wet and dry soil	Menampilkan kelembaban dalam persentase pada LCD dan aplikasi Blynk	Valid



			Moisture percentage appears on LCD and Blynk application	
3	DHT11 Sensor	Sensor actively reads temperature and humidity	Temperature and humidity appear on LCD and Blynk (V2 and V3)	Valid
4	Water Pump Relay	Soil moisture < 60% (lower threshold)	Relay activates, water pump turns on automatically	Valid
5	Water Pump Relay	Soil moisture > 70% (upper threshold)	Relay deactivates, water pump turns off automatically	Valid
6	Fertilizer Pump Relay	Manual fertilizer button pressed in Blynk	Fertilizer pump turns on while button is active	Valid
7	LCD 16x2	System is active and all sensors are connected	Displays temperature, humidity, and soil moisture	Valid
8	WiFi & Blynk Connection	System connects to WiFi and Blynk platform	Data appears on Blynk dashboard; status shows "online"	Valid

Table 1 shows the functional test results for the main hardware components of the system. Each component was tested for expected behavior under controlled conditions. For example, the soil moisture sensor was verified to detect low moisture levels and trigger automatic pump activation, while the LCD display correctly showed updated temperature and humidity data. The test outcomes confirm that the integrated modules functioned reliably during repeated operation. The system's interaction with the Blynk Web Dashboard was also tested to verify that all sensor data and control commands were accurately transmitted between the microcontroller and the cloud platform. The tests focused on the responsiveness of the real-time monitoring features, the stability of the Wi-Fi connection, and the ability to manually control pumps via the web interface.

Table 2. Web dashboard testing results via Blynk platform

No	Component Tested	Test Scenario	Expected Output	Valid/Invalid
1	Display of temperature, air humidity, and soil moisture	Sensors are active and data is sent from ESP32	Dashboard displays temperature (°C), air humidity (%), and soil moisture (%) readings	Valid
2	Moisture threshold adjustment	Lower and upper threshold sliders are moved from dashboard UI	System reads the new thresholds and updates automatic control logic accordingly	Valid
3	Irrigation and fertilization control	Irrigation and fertilization switches are clicked from the browser	Water/fertilizer pump turns ON and OFF based on user commands	Valid





4	Real-time synchronization	Sensor data changes while system is online	Dashboard updates automatically without requiring manual refresh	Valid
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Table 2 presents the test results of the Blynk Web Dashboard. All sensor values (soil moisture, temperature, and humidity) were received without delay, and manual buttons on the dashboard responded effectively when tested. No communication errors were detected during testing. Furthermore, the mobile version of the Blynk application was tested using an Android smartphone to ensure compatibility and responsiveness. The manual controls (buttons and sliders) were evaluated for response time and stability, while real-time data updates were monitored across multiple testing sessions.

Table 3. Mobile application testing results via Blynk app

No	Component Tested	Test Scenario	Expected Output	Valid/Invalid
1	Temperature & humidity display	Data sent from DHT11 sensor	V2 and V3 display air temperature and humidity	Valid
2	Soil moisture display	Data sent from soil moisture sensor	V4 displays real-time soil moisture percentage	Valid
3	Manual irrigation button (V1)	Button is activated	Water pump relay turns ON while the button is active	Valid
4	Manual fertilization button (V5)	Button is activated	Fertilizer pump relay turns ON while the button is active	Valid
5	Lower threshold slider (V8)	Slider is moved to a new value	Lower threshold updated and printed in the serial monitor	Valid
6	Upper threshold slider (V9)	Slider is moved to a new value	Upper threshold updated and printed in the serial monitor	Valid
7	Auto-synchronization	System is newly connected	Data is synchronized and displayed in Blynk	Valid
8	System boot status	System is powered on	LCD displays "SMART WATERING by Cessi R"	Valid

Table 3 displays the results of Blynk smartphone application testing. The mobile dashboard performed well across all scenarios, with smooth transitions between automatic and manual modes,





real-time sensor data updates, and accurate command execution. The user interface proved reliable and intuitive.

Table 4 presents the results of the whole page testing conducted on the proposed irrigation system. The testing focused on verifying the functionality of both the hardware and software components to ensure that all system features operate as expected.

The first component tested was the **device functions**, which included all operational features of the hardware such as sensor readings, relay activation, and pump control. A total of 8 test cases were conducted for this component, and all 8 were validated successfully, indicating that the device functions work correctly. The second component involved the **Blynk web dashboard**, which serves as the interface for monitoring and controlling the system remotely via a web browser. Four test cases were executed to check dashboard responsiveness, data display accuracy, and control commands. All 4 test cases passed, confirming that the web dashboard functions properly. The third component tested was the **Blynk application functions on smartphones**, which allows users to monitor environmental parameters and control irrigation remotely through the mobile app. Eight test cases were performed, covering functionalities such as manual pump activation, sensor data visualization, and notification features. All 8 test cases were validated successfully, demonstrating the reliability of the mobile application interface. In total, **20 test cases** were conducted across all components, and all 20 test cases were validated, showing that the system performs as intended in both hardware and software aspects. This indicates that the proposed irrigation system is fully functional, with effective integration between device hardware, web dashboard, and smartphone application.

Table 4. Whole Page Testing

No	Tested Components	Test cases that are tested	Test case valid
1	Device Functions	8	8
2	Blynk Web Dashboard	4	4
3	Blynk Application Functions on Smartphones	8	8
Total		20	20

$$\begin{aligned} \text{Validation Percentage} &= \left(\frac{\text{Number of valid test cases}}{\text{Total test cases}} \right) \times 100\% \\ &= \left(\frac{20}{20} \right) \times 100\% \\ &= 100 \end{aligned}$$

3.5. Soil Moisture Sensor Calibration

In order to assess the accuracy of the capacitive soil moisture sensor, a calibration procedure was conducted. The readings from the sensor were compared with measurements taken from a reference device (Three-Way Meter) under multiple soil conditions. The tests spanned a range from dry to saturated soil. Table 4 shows the full calibration dataset. It includes raw sensor values, reference measurements, and calculated percentage error for each of the 14 testing points. The sensor achieved an average error of 6.49%, translating into an overall accuracy of 93.51%. This accuracy is considered acceptable for smart irrigation applications.

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Table 5 shows the calibration data for the soil moisture sensor used in the irrigation system and compares its readings with the reference measurements taken using a three-way meter. The table presents the measured soil moisture values from both the three-way meter and the sensor, along with the difference between them and the corresponding percentage error for each measurement. From the 14 calibration points, it can be observed that the sensor readings closely follow the reference values, with differences ranging from 0% to 16.67%. For example, in the first measurement, the three-way meter recorded 48% soil moisture, while the sensor measured 40%, resulting in an 8% difference and a 16.67% error. In some cases, such as the second and eleventh measurements, the sensor readings exactly matched the reference values, yielding 0% error. Overall, the sensor demonstrated good accuracy, with an **average percentage error of 6.49%** across all calibration points. This indicates that the soil moisture sensor provides reliable measurements suitable for automatic irrigation control, allowing the system to activate pumps appropriately based on soil moisture thresholds. The calibration results validate that the sensor can be effectively integrated into the IoT-based irrigation system for real-time monitoring and water management.

Table 5. Soil moisture sensor calibration data and accuracy comparison

No	Three Way Meter	Soil Moisture (%)	Three Way as Moisture (%)	Difference	Error(%)
1	4	48	40	8	16.67%
2	6	60	60	0	0.00%
3	5	53	50	3	5.66%
4	5	54	50	4	7.41%
5	6	63	60	3	4.76%
6	5	57	50	7	12.28%
7	5	56	50	6	10.71%
8	7	78	70	8	10.26%
9	6	65	60	5	7.69%
10	7	73	70	3	4.11%
11	7	70	70	0	0.00%
12	6	64	60	4	6.25%
13	6	63	60	3	4.76%
14	5	50	50	0	0.00%
Average %Error			(1)		0.0649

Calculating Accuracy using the equation formula (2)

$$\text{Accuracy} = (1 - \text{Average \% Error}) \times 100\%$$

$$= (1 - 0.0649) \times 100\% = 93.51\%$$

4. CONCLUSION

This study successfully designed and implemented a dual-mode smart irrigation system based on Internet of Things (IoT) technology using the NodeMCU ESP32 microcontroller. The system is capable of operating in both automatic and manual modes. In automatic mode, the water pump is activated when soil moisture falls below a predefined threshold and deactivated when it exceeds the upper limit. In manual mode, the user can control the irrigation and fertilization pumps via the Blynk mobile

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application. Real-time data from the soil moisture sensor and DHT11 sensor are displayed on both an LCD and the Blynk dashboard.

Functional testing using the black-box method confirmed that each module—including the sensors, relays, LCD, and mobile interface—operated as expected. The soil moisture sensor was also calibrated and achieved an average accuracy of 93.51%, which is sufficient for real-time irrigation management. The system interface, powered by Blynk, successfully displayed sensor data and responded accurately to manual control commands from both the web dashboard and mobile application.

The results show that this prototype meets the objectives of improving irrigation efficiency and providing flexible control to users. Compared to fully automated systems, this solution offers greater adaptability by allowing manual override through a user-friendly smartphone interface. However, the current system still has limitations, such as the absence of data logging, rain detection, and energy independence via solar power.

Future research and development can enhance this prototype by integrating a cloud-based database for historical data storage, adding environmental sensors such as a rain detector, and incorporating renewable power sources to support operation in remote agricultural areas.

5. REFERENCES

- [1] M. Y. E. Aditya and H. Wibawanto, "Sistem Pengamatan Suhu dan Kelembaban Pada Rumah Berbasis Mikrokontroler ATmega8," *Jurnal Teknik Elektro*, vol. 5, no. 1, pp. 15–17, 2013.
- [2] M. T. Akbar and A. Madisha, "Pemanfaatan Lahan Tidur Melalui Kebun Gizi dan Teknologi Irigasi Cerdas," *Jurnal Pusat Inovasi Masyarakat IPB*, vol. 1, no. 1, pp. 25–32, 2019.
- [3] E. Alfonsius, W. Kalengkongan, and S. C. W. Ngangi, "Sistem monitoring dan kontroling prototipe penyiram tanaman otomatis berbasis IoT (Internet of Things)," *Jurnal Teknoinfo*, vol. 18, no. 1, pp. 44–55, 2024.
- [4] M. Anisah, M. Siswandi, N. L. Noer, and N. L. Husni, "Penyiram Otomatis Berdasarkan Sensor Kelembaban Tanah," *Jurnal Teknik*, vol. 13, no. 2, pp. 137–142, 2019.
- [5] W. Aribowo, M. S. Udin, and A. C. Hermawan, "Rancang Bangun Drip Irrigation System Menggunakan Pompa Bertenaga Surya Dengan Kontrol Penyiraman Berbasis Node-Red," *Jurnal Teknik Elektro Universitas Negeri Surabaya*, vol. 12, no. 2, pp. 88–96, 2023.
- [6] A. N. Atmadja et al., "Realisasi Perangkat IoT untuk Sistem Monitoring Media Tanam Berbasis Smart Greenbox untuk Pertumbuhan Tanaman Cabai," *Telkom University Publications*, 2022.
- [7] R. E. Budiani, J. D. Irawan, and D. Rudhistiar, "Sistem Monitoring dan Penyiraman Otomatis pada Tanaman Cabai Berbasis Internet of Things (IoT)," *Jurnal Mahasiswa Teknik Informatika*, vol. 8, no. 2, pp. 1331–1332, 2024.
- [8] L. R. Darusman, "Pemanfaatan Fitur Bot Telegram Sebagai Pengendali Pada Sistem Penyiraman dan Pemupukan Bibit Kelapa Sawit," *Jurnal Ampere*, 2023.
- [9] N. Effendi, W. Ramadhani, F. Farida, and M. Dimas, "Perancangan Sistem Penyiraman Tanaman Otomatis Menggunakan Sensor Kelembaban Tanah Berbasis IoT," *J. Comp. Sci. and Inf. Tech. (CoSciTech)*, vol. 3, no. 2, pp. 91–98, 2022.
- [10] S. Greengard, *The Internet of Things*. Cambridge, MA: MIT Press, 2015.
- [11] Jepri, Hendrayudi, and Salamudin, "Rancang Bangun Sistem Keamanan Kendaraan Sepeda Motor Menggunakan Sidik Jari Berbasis Arduino Uno," *J. Inform. dan Komputer (JIK)*, vol. 13, no. 1, 2022.
- [12] N. Y. Kandowanko and M. Ahmad, "Pemberdayaan Masyarakat Desa Bihe melalui Diversifikasi Produk dan Teknologi Irigasi Evapotranspiratif," *Agrokreatif: J. Ilmiah Pengabdian kepada Masyarakat*, vol. 5, no. 1, pp. 61–68, 2024.
- [13] P. Lestari, Tasmii, and F. Antony, "Sistem Penyiraman Budidaya Tanaman Cabai Berdasarkan Pengukuran Suhu dan Kelembaban Tanah," *Universitas Indo Global Mandiri*, 2021.
- [14] Y. Mardiana and R. Iskandar, "Implementasi dan Analisis Arduino dalam Rancang Bangun Alat Penyiram Tanaman Otomatis Menggunakan Aplikasi Android," *Jurnal Pseudocode*, vol. 7, no. 2, pp. 151–152, 2020.
- [15] A. G. Pradana, "Rancang Bangun Game Edukasi 'AMUDRA' Alat Musik Daerah Berbasis Android," *Proc. Sem. Nasional Teknologi*, 2019.

