

Design : Automatic Irrigation Tools on Chili Plants Using Microcontractor-Based Soil Moisture Sensor

Suparman^{1*}, Arief Ika Uktoro¹, Muhammad Rendi¹

¹Agricultural Engineering, Agricultural Technology, INSTIPER Yogyakarta

*Corresponding author: suparman.faiz.sf@gmail.com

Article History: Received: 14 January 26, Final Revision: 25 January 26, Accepted: 26 January 26, Online Publication: 30 January 26

ABSTRACT

The cultivation of chili plants (*Capsicum annum* L.) still faces problems in irrigation management that are not yet data-based, causing less efficient water use and risking reducing the productivity of chili harvests. This research aims to design an automatic watering system using soil moisture sensors and microcontrollers integrated with web dashboards and Google Sheets for real-time monitoring and control of soil moisture. The method used is engineering research which includes designing hardware and software, calibrating soil moisture measuring instruments and implementing tools in chili fields. The result of this research is to produce a soil moisture measuring tool in the form of a prototype that can be used for automatic irrigation of chili plants. The calibration results obtained an accuracy level of 99.73% and a tolerance of 0.27%, and the tool is able to water automatically when the soil moisture is dry, namely at soil moisture less than 60% RH. The tool can automatically save data to Google Sheets. This tool system is declared suitable for use as a precision irrigation solution in chili cultivation.

Keywords: Irrigation, microcontroller, automatic watering, sensors, chili plants.

INTRODUCTION

Chili peppers (*Capsicum annum* L.) are a horticultural commodity with high economic value, but their cultivation still faces challenges in water management. Watering that does not match soil moisture can cause abiotic stressors such as root rot if the moisture is above 80% and decreased yield if the soil moisture is below 60% (Sari, N. A., & Harahap, 2021). Therefore, accurate monitoring of soil moisture is essential for watering efficiency (Fitriani, D., & Wibowo, 2020). Internet of Things (IoT) technology allows the integration of sensors

and microcontrollers to monitor land conditions and set up automatic watering in real-time (Maulana, R., Hidayat, R., & Nuryadin, 2022). The implementation of a dashboard-based automatic watering system is expected to improve water efficiency, chili productivity, and support precision agriculture in the digital era (Putra, H. P., & Rachmat, 2023)

Soil moisture sensors are important in modern agriculture because they are able to read moisture content through soil resistance or

conductivity and allow for efficient automatic watering (Yulanda & Albako, 2025). The Soil Moisture V2.0 sensor provides accurate, durable, and suitable results for IoT (Sahrul, M., 2022). ESP32 serves as the main controller with WiFi connectivity and web server capabilities (Hidayat, M. A. J., & Amrullah, 2022). The Arduino IDE makes it easier to program sensor-based monitoring systems (Hakiki et al., 2020). Web dashboards and Google Sheets support real-time data monitoring and recording (Arifin et al., 2023).

MATERIALS AND METHODS

This research was carried out at the INSTIPER Yogyakarta campus and implemented in Rambah Hamlet, Muara Bungo, Jambi Province for 5 months, from January 2025 to May 2025. The method used is research in engineering design (Escudero-Mancebo et al., 2023) with the stages of problem identification, system design, tool calibration, and tool implementation in the field.

The tools used include a computer / laptop for the programming process. The main components of the hardware automatic irrigation equipment consist of an ESP32 microcontroller, soil moisture sensor, relay module, 16x2 I2C LCD, jumper cable, type-C cable, 14 × 8.5 × 3.8 cm component box, water pump and power supply with a capacity of 20,000 mAh and a Telkomsel WiFi 4G LTE modem as a power source and connection. On the software side, Arduino IDE version 1.8.19 is used, a web dashboard based on

This technology is effectively applied to chili cultivation (Gulo et al., 2025). The TAM model is used to evaluate user acceptance (Wahyu et al., 2020).

This study aims to design a prototype of an automatic watering system based on the ESP32 microcontroller which is equipped with a soil moisture sensor and a web dashboard integrated with Google Sheets as a data recording medium, calibrating soil moisture measuring tools and implementing tools in chili plantation fields.

Web Server ESP32, Google Sheets with Apps Script for data storage, and IBM SPSS Statistics for system acceptance test analysis. This research began by establishing the topic of developing an automatic watering system based on the ESP32 microcontroller. Problem identification is carried out by analyzing farmers' needs for watering efficiency which is often disrupted by delays and waste of water. Furthermore, system design was carried out including hardware and software design, including web dashboards and integration with Google Sheets. After assembly and programming, the tool is calibrated using a factory-made tool type RS485 to measure accuracy. Evaluations were carried out to ensure the system was running as expected, and if successful, the tool was implemented in the chili planting field, to test its effectiveness in maintaining soil moisture of 60% – 80% for two days.

RESULTS AND DISCUSSION

Automatic Irrigation Tool System Design

The design of this automatic irrigation system aims to regulate the process of watering plants efficiently and in a scheduled manner based on data from soil moisture sensors. This tool is designed to be able to water automatically and will stop when the soil moisture has reached the specified value, which is 60% - 80%. This is due to the good soil moisture value for the growth of chili plants (Sari, N. A., & Harahap, 2021). This tool is

also designed using a web dashboard to monitor soil moisture in real-time and can control watering manually/automatically and is designed with soil moisture data stored in Google Sheets so that it can be monitored and analyzed further. The schematic design of the hardware series is shown in the following figure 2.

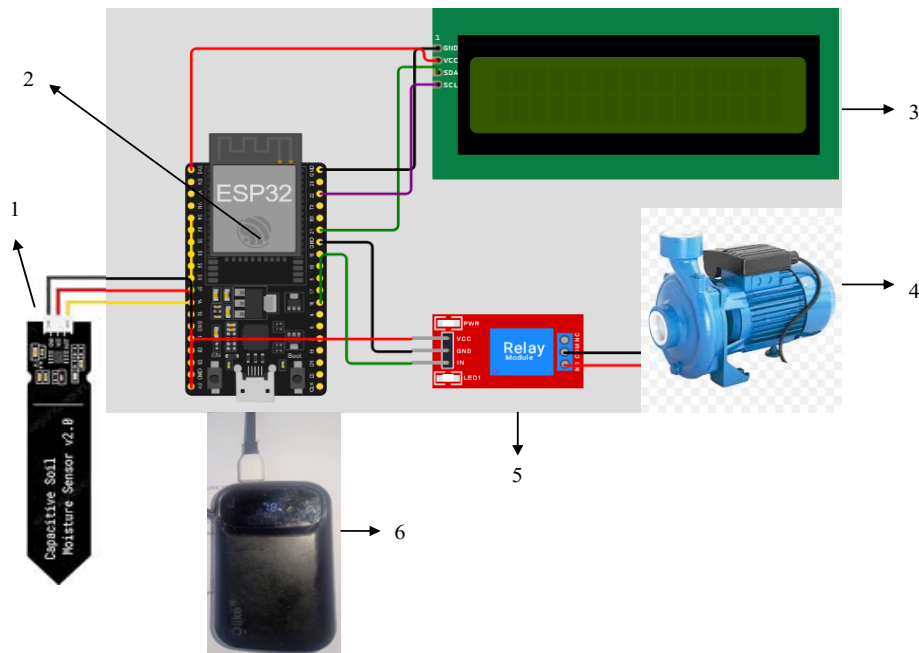


Figure 2. Schematic Design of Hardware Sets

In the analysis, figure 2 is the initial stage in hardware design. The components of the tool to be assembled are (1) Soil Moisture Sensor V2.0; (2) ESP32 Microcontroller; (3) 16x2 I2C LCD; (4) Water Pump; (5) Relay; (6) Power supply capacity of 20,000 mAh.

In software design, it uses C++, Java Script, HTML, and Apps Script programming languages. As for the design of this software, namely hardware programming, web dashboards, and google spreadsheets using Arduino IDE and Apps Script as additional software to google spreadsheets. The use of Arduino IDE software is a

step in designing a program that will be applied to a Web Dashboard-based automatic watering system, where the Arduino IDE serves as the main controller of the program for web-based automatic watering and saves the database into a google spreadsheet. The programming begins with the library, the WiFi connection and the main void consist of a void setup () void loop (), and other void functions. After the components are put into the box and the application software has been installed, the design of the tool is completed and produces a prototype of the tool as shown in figure 3.



Figure 3. Prototype automatic irrigation equipment size (14 x 8.2 x 3.8) cm

Table 1. Prototype Expression of Automatic Irrigation Equipment Design

No	Components	Technical Specifications
1	Tool Name	Horti smart irrigation
2	Mikrokontroler	ESP32 Devkit 1, support WiFi and Bluetooth, working voltage 3.3V.
3	Soil Moisture Sensor	Soil Moisture Sensor v2.0 – Analog, corrosion-resistant, accurate output for soil monitoring.
4	Display Screen	LCD 16x2 I2C Two-row display, I2C communication (save pin), As wifi status information display, IP address, soil moisture and soil condition.
5	Resources	5V DC adapter and Power Bank capacity 20,000 mAh as a powerer to ESP32 and LCD.
6	Communication Methods	WiFi (Web Server) – Sends and displays data through a web dashboard.
7	Actual Control	4 Channel Relay Module Controls the water pump based on soil conditions
8	Web Interface	Local Web Dashboard – Using HTML + JSON (data displayed & controlled via browser)
9	Historical Data Storage	Send data to Google Sheets Via HTTP POST-based webhooks for database storage
10	Black Plastic Box	As a protective container for design tool components. Height: 14 cm, Width: 11.5 cm Length: 18.5 cm, Material: Plastic atom

Design Tool Calibration

Tool calibration is to compare the reading results of the soil moisture sensor on the assembled tool compared to the reading results on the calibrated tool, which is factory-made with type RS485. The stages in sensor calibration are by inserting the two device sensors into one soil sample with dry soil conditions, until wet as many as 15 tests.

Table 2. Design Tool Calibration with RS485 Tool

No	Design Tools (%)	RS485 Tools (%)
1	14	13,8
2	24	24,9
3	32	33,1
4	45	43,8
5	54	54,1
6	61	61,2
7	68	68,8
8	72	73,4
9	75	78,1
10	78	77
11	78	78,1
12	82	83,7
13	90	89,2
14	98	97,1
15	100	97,5

Source: Primary Data 2025

Table 2 shows that the test equipment was carried out on dry soil conditions to wet soil

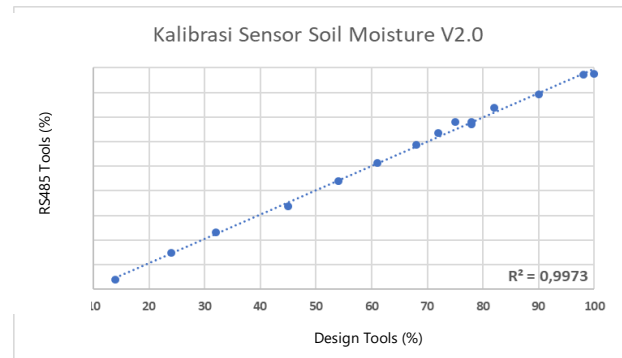


Figure 4. Comparison chart between assembled tools and manufacturer's tools

Figure 4 presents the calibration results of the prototype soil moisture sensor against a calibrated standard instrument. This process involves comparing the soil moisture readings from the developed sensor with the reference values of the standard tool, both in percent (%). The horizontal axis (x) on the graph shows the percentage of soil moisture from the prototype tool, while the vertical axis (y) represents the value of the calibrated instrument. The data points reflect measurements at various humidity conditions, and the dotted lines show the linear regression equations that are formed. The R2 coefficient of determination of 0.9973 confirms a very strong linear correlation. This shows that the assembled tool has a high accuracy rate of 99.73% and an error of 0.27%.

Implementation of Design Tools in the field



Figure 5. Installation of Design Tools on Chili Plants

Figure 5 shows the installation process of an automatic watering device designed on chili plants. The system is equipped with a water hose connection connected to the water pump as well as a water reservoir (bucket) as an irrigation source. Sensors inserted into the soil medium function to read the soil moisture level in real-time and transmit the data to the main control system. The irrigation hose is directed directly to the base of the plant for efficient water distribution. The installation of this system aims to automate the process of watering plants based on the actual conditions of soil moisture, in order to increase

water use efficiency and support the cultivation of chili plants with precision. Based on the results of the following tabulation, it shows that the designed tool has functioned optimally in detecting soil moisture conditions and activating or deactivating the pump automatically or manually as needed. During the test period from May 15 to 17, 2025, the system consistently recorded data in the form of

CONCLUSION

Based on the results of the study, a prototype of a microcontroller-based automatic watering tool consisting of hardware and software with the support of the ESP32 local web server has been successfully made. The system is able to automatically record soil moisture data to Google Sheets in a daily to yearly format. The calibration results of the tool showed an accuracy of 99.73% and an error of 0.27%. In the field test on chili plants, the tool works optimally by keeping the soil moisture above 60%, and automatically activates the pump when the soil condition is dry, which is below 60%.

recording time, soil moisture percentage, soil status (dry, moist, or wet), pump status (ON/OFF), and watering mode (automatic/manual). Through this data, it can be observed that the system is able to respond to the actual conditions of soil moisture accurately and perform the watering function if the soil moisture < 60% or the soil conditions are dry.

For further research development, several improvements can be made to improve system performance. The use of waterproof boxes is recommended so that the components are better protected from water. Humidity sensors can be upgraded by switching to a type of sensor that has better accuracy and is resistant to corrosion. The addition of a water level sensor (ultrasonic) is also important to monitor the volume of water in the reservoir. In addition, web dashboards can be developed using online servers to be accessed remotely. The system can also be tested on other horticultural crops such as lettuce, melon, strawberries, onions and others.

REFERENCES

- Arif Rachman, E. al. (2024). Metode Penelitian Kuantitatif, Kualitatif Dan R&D. In *CV Saba Jaya Publishr*.
- Arifin, Z., Puspita, S. G., Widya, D. P., Zuwarnando, D. P., & Prasetyawan, A. (2023). Pemantauan Daya Luar Panel Surya Secara Jarak Jauh Melalui Aplikasi Berbasis Website Monitoring Solar Panel Output via Website-Based Application. *Jurnal Riset Rekayasa Elektro*, 5(2), 93–102.
- Escudero-Mancebo, D., Fernández-Villalobos, N., Martín-Llorente, Ó., & Martínez-Monés, A. (2023). Research methods in engineering design: a synthesis of recent studies using a systematic literature review. In *Research in Engineering Design* (Vol. 34, Issue 2). Springer London. <https://doi.org/10.1007/s00163-022-00406>
- Fitriani, D., & Wibowo, A. (2020). Pengaruh Kelembaban Tanah Terhadap Pertumbuhan Tanaman Cabai. *Jurnal Ilmu Pertanian Tropika*, 5(1), 34–41.
- Gulo, A., Harefa, L., & Gea, F. J. (2025). Efektivitas Penggunaan Mulsa Plastik dalam Meningkatkan Produktivitas Tanaman Cabai (*Capsicum annuum* L .). *Jurnal Kajian Ilmu Pertanian Dan Perkebunan*, 2(1), 152–159.
- Hakiki, M. I., Darusalam, U., & Nathasia, N. D. (2020). Konfigurasi Arduino IDE Untuk Monitoring Pendeteksi Suhu dan Kelembapan Pada Ruang Data Center Menggunakan Sensor DHT11. *Jurnal Media Informatika Budidarma*, 4(1), 150–156.
- Hidayat, M. A. J., & Amrullah, A. Z. (2022).

- Hidroponik Berbasis Internet Of Things (IoT). *Jurnal Saintekom: Sains, Teknologi, Komputer Dan Manajemen*, 12(1), 23–32.
- Maulana, R., Hidayat, R., & Nuryadin, E. (2022). Rancang Bangun Sistem Monitoring Kelembaban Tanah Berbasis Internet of Things (IoT). *Jurnal Teknologi Dan Rekayasa*, 17(1), 23–30.
- Putra, H. P., & Rachmat, A. (2023). Pengembangan Sistem Pertanian Presisi Berbasis Mikrokontroler dan IoT. *Jurnal Inovasi Teknologi*, 5(3), 78–85.
- Sahrul, M., D. (2022). Alat Penyiraman Tanaman Otomatis Menggunakan Capacitive Soil Moisture Sensor V2.O Berbasis Arduino Uno. *Journal of Informatics and Electrical Engineering*, 4(1), 1–8.
- Sari, N. A., & Harahap, R. A. (2021). Manajemen Air pada Budidaya Tanaman Hortikultura di Lahan Terbuka. *Jurnal Ilmu Pertanian*, 10(1), 60–66.
- Wahyu, Y., Putra, S., & Hardiyanti, N. (2020). Penerapan Technology Acceptance Model (Tam) Pada E-Library Berbasis Web Abstraksi. *Information System Journal (INFOS)*, 3(2), 23–30.
- Yulanda, E. A., & Albako, S. (2025). Rancang Bangun Alat Penyiram dan Pemberi Nutrisi Tanaman Berbasis IOT dengan Sensor Kelembaban Tanah. *Jurnal Pendidikan Tambusai*, 9(1), 8242–8261.