Indonesian Journal of Engineering, Science and Technology
IJENSET
Volume 01 - Issue 02, December 2024
e-ISSN: xxxx-xxxx; p-ISSN: xxxx-xxxx
Journal Link: https://jurnal.umla.ac.id/index.php/ijenset/index

SMART AGRICULTURAL GOVERNANCE: METHODOLOGICALLY APPROACHED WEB-BASED AUTOMATIC MONITORING AND IRRIGATION USING SOIL MOISTURE AND ULTRASONIC SENSORS

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Article Information

Submitted	:	28th August 2024
Revised	:	11th December 2024
Accepted	:	15th December 2024
Paper page	:	79-89
DOI	:	10.38040/ijenset.v1i2.1029

ABSTRACT

Agricultural productivity in Lamongan, particularly in Kedungpring District, is critically challenged by manual land processing and recurring droughts that severely impact chili crop yields. The persistent lack of efficient monitoring and irrigation technologies exacerbates agricultural sustainability concerns. This study aims to develop an automated, IoT-based irrigation management system that optimizes water use efficiency for chili crops through advanced sensor technologies and fuzzy logic processing. Utilizing an ESP8266 microcontroller integrated with soil moisture and ultrasonic sensors, the research employs the Takagi-Sugeno fuzzy logic method to process real-time environmental data. The system dynamically monitors soil moisture levels and water resources, enabling precise irrigation control. Fuzzy calculations generated a solenoid valve operation time of 321 seconds, classified as moderate, demonstrating the methodology's potential for accurate irrigation management. The developed automated monitoring system successfully demonstrates the potential of IoT technologies in addressing agricultural challenges, providing real-time data visualization and intelligent irrigation decision-making. By integrating sensor technologies with fuzzy logic processing, the research offers a promising solution to improve water resource management and potentially enhance crop productivity in drought-prone agricultural regions.

Keywords— *Fuzzy Methode*, *Smart Agriculture, Soil Moisture, Takagi-Sugeno, Ultrasonic,*

I. INTRODUCTION

Agriculture plays a crucial role in sustaining human life and is the primary method for meeting food needs. In Indonesia, many people rely on agriculture as their main livelihood source. However, many land processing activities are still performed manually, often leading to suboptimal agricultural yields and decreased work efficiency (Heru Sandi & Fatma, 2023).

Lamongan Regency, located in East Java Province, covers an area of 181,280 hectares, with the majority of its land dedicated to agricultural activities. Most of its population depends on agriculture for their livelihood. This regency is a significant contributor to national food supplies and is recognized as the largest rice producer in East Java Province. Besides rice, chili peppers are also an important commodity in the region, with increasing demand to meet both local and national market needs. However, Lamongan is also vulnerable to drought, which can lead to crop failures and limited access to clean water. Over the past decade, approximately 12,000 hectares of land have been affected by drought (Sriwidi Astutik, 2017). Therefore, efficient irrigation systems and advanced soil moisture monitoring technologies are crucial for addressing these challenges, particularly in supporting the growth of chili peppers, which require precise water management (Aprillya & Chasanah, 2022)

Irrigation is an essential process for distributing water to agricultural lands through specific channels or infrastructure, aiming to ensure efficient water use and manage excess water not required by plants(Mahfud et al., 2022). Proper planning and implementation of irrigation systems are vital for sustainable agriculture, especially in drought-prone areas like Lamongan (Shodiq & Saputra, 2022).

Modern technological advances, including Internet of Things (IoT) technology, offer new solutions to challenges in the agricultural sector. By utilizing this technology, irrigation monitoring and management can be automated and carried out in real-time, thereby increasing efficiency and effectiveness in the use of water resources. One relevant technology is the use of Soil Moisture sensors and Ultrasonic sensors controlled by the ESP8266 microcontroller. The Soil Moisture sensor measures the hydration level of the soil, while the Ultrasonic sensor detects the distance and volume of water with high precision through sound waves, thus providing real-time data for automated and efficient irrigation management (Samsugi et al., 2020).

This research aims to develop an intelligent IoT-based irrigation system to address water resource limitations in agricultural areas. Utilizing soil moisture and ultrasonic sensors controlled by an ESP8266 microcontroller, the system employs the Takagi-Sugeno fuzzy method to process data adaptively in response to changes in soil moisture levels and water height. This approach enables more efficient, responsive, and sustainable irrigation management, assisting farmers in optimizing water usage, enhancing agricultural yields, and minimizing the risk of crop damage due to drought. This technological solution is expected to support agricultural productivity in regions with limited water resources (Heru Sandi & Fatma, 2023).

II. METHOD

Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is designed to measure the distance between the sensor and an object, with a range spanning from 2 to 450 cm. This sensor operates using two digital pins to transmit distance information. It functions by emitting ultrasonic pulses at approximately 40 kHz, and then detecting and calculating the time it takes for these pulses to return after reflecting off an object, as depicted in Figure 1. The HC-SR04 can generate up to 20 pulses per second and is capable of measuring distances up to 3 meters (Puspasari et al., 2019).

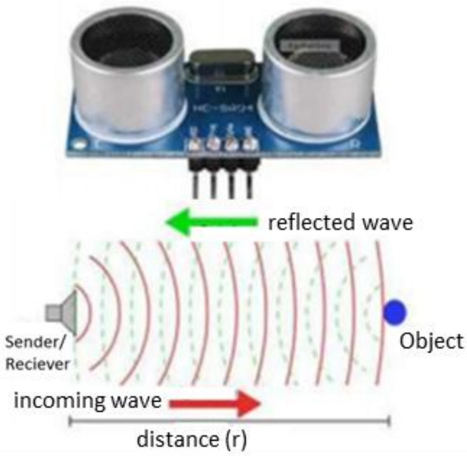


Figure 1. Ultrasonic Sensor

The ultrasonic sensor converts physical sound waves into electrical signals and vice versa. Its operating principle is based on the reflection of sound waves to determine the presence or distance of an object at a specific frequency. The term "ultrasonic" refers to sound waves with frequencies higher than 20,000 Hz, which are inaudible to the human ear (Arifin et al., 2022).

Soil Moisture Sensor

The Soil Moisture Sensor is designed to detect soil moisture levels. This straightforward sensor is particularly well-suited for monitoring urban gardens or water levels in potted plants. It consists of two probes that pass an electrical current through the soil. The soil's resistance is then measured to determine its moisture level. The presence of water in the soil decreases its electrical resistance, making it easier for electricity to flow (low resistance). Conversely, dry soil has high resistance and poorly conducts electricity. This sensor is highly effective for tracking moisture levels in plants or monitoring soil hydration. The YL-69 moisture sensor features the following specifications: Input Voltage: 3.3V or 5V, Output Voltage: 0–4.2V, Current: 35 mA, ADC Resolution: 1024 bits (0–1023 bits) (Ferdiansyach et al., 2013). The sensor's measurement range is illustrated in Figure 2.

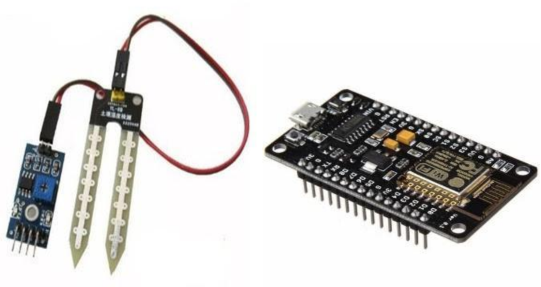


Figure 2. Soil Moisture Sensor and NodeMCU ESP8266

NodeMCU 8266

The NodeMCU ESP8266 is a development board featuring the ESP8266 chip, which integrates microcontroller functions with WiFi connectivity. This board includes several input/output pins, making it suitable for IoT applications involving monitoring and control. It can be programmed using the Arduino IDE, and its mini USB port facilitates easy programming. The NodeMCU ESP8266's combination of microcontroller capabilities and wireless connectivity offers significant flexibility for IoT project development (Nurul Hidayati Lusita Dewi, Mimin F. Rohmah, 2019). A visual representation of the NodeMCU ESP8266 is shown in Figure 2.

Website

A website is a collection of web pages designed for disseminating information, engaging in online commerce, and interacting with users. These pages are written in Hypertext Markup Language (HTML) and accessed via the Hypertext Transfer Protocol (HTTP). Websites can feature a range of content, including news, products, and services, and play a crucial role in the digital landscape. They serve as a key platform for information dissemination, online trading, and user interaction, thus facilitating access to and participation in the evolving digital world(Yunita Trimarsiah & Muhajir Arafat, 2017).

PHP

PHP, which stands for Hypertext Preprocessor, is a programming language specifically designed for web application development. The primary objective when developing a website is to ensure it is dynamic and interactive. "Dynamic" refers to the ability of the site to display content that changes based on certain conditions, such as showing different products to each visitor. "Interactive" means the website can respond to user actions, such as displaying search results. PHP functions as a server-side scripting language, meaning that PHP scripts are processed by the server before the results are sent to the user's browser. Consequently, a crucial prerequisite for PHP development is having a server. This processing capability enables the creation of more dynamic and responsive websites, enhancing user interaction (Kadarsih & Andrianto, 2022).

Logic of soil moisture

The fuzzy logic method integrates moisture values to determine the optimal duration of irrigation. Using fuzzy logic control, irrigation timing can be adjusted based on detected moisture levels, thereby enhancing the efficiency of irrigation management and adapting to varying environmental conditions.

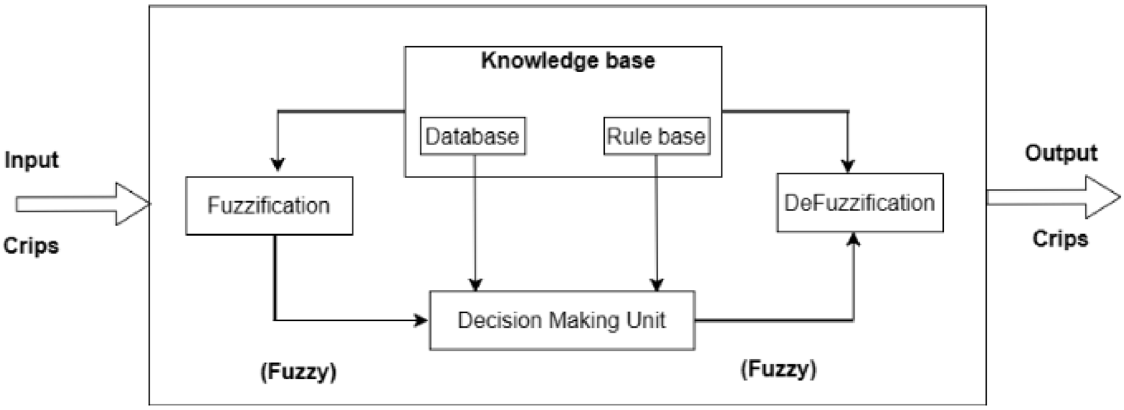


Figure 3. Inference fuzzy system

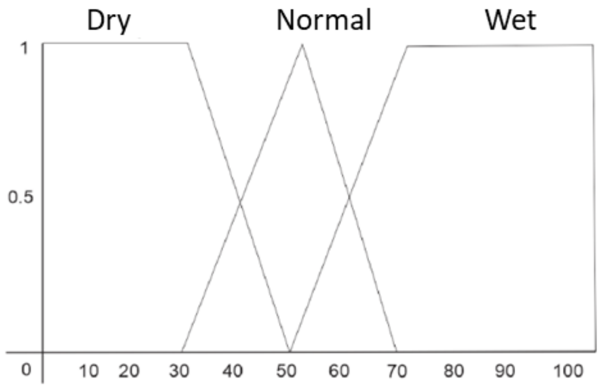


Figure 4. Functions to the water level members

Figure 4 illustrates a fuzzy membership function graph that categorizes soil moisture levels into three categories: Dry, Normal, and Wet, with a moisture scale ranging from 0 to 100. Moisture levels below 20 are considered dry, above 80 are considered wet, and around 50 is deemed normal. The graph depicts linear transitions between categories, reflecting the fuzzy logic approach that allows for adaptive assessment of soil conditions. Fuzzy logic is employed to determine irrigation needs by evaluating soil moisture, enabling the irrigation system to make more responsive decisions to changes in soil conditions (Sanca, 2018).

Fuzzy method

Fuzzy logic is an integral component of soft computing concepts used to map real-world problems from input to desired output. Previous studies have demonstrated that fuzzy logic is an effective method for decision support systems across various fields. The Sugeno fuzzy model is a highly effective tool for

developing fuzzy systems that deliver accurate and understandable results. It has numerous applications in areas such as control, forecasting, and classification, making it a valuable tool for technical and analytical applications. The model's strengths lie in its ability to provide precise solutions with clear and reliable interpretations (Sitio, 2018).

The fuzzy inference system shown in Figure 3 consists of five main components:

1. Fuzzification is used to convert an assertive value into a fuzzy value or linguistic degree.
2. The rulebase, defines a number of fuzzy if-then rules.
3. database, describes the fuzzy set membership function used in fuzzy rules
4. Decision making units are used to perform inference operations on rules
5. Defuzzification is used to convert the result of fuzzy inference into a definite value again.

The membership function is represented by a membership degree, which ranges from 0 to 1. This function describes a curve that maps input data points to their respective membership values. Various curve patterns are used to define membership functions, including trapezoidal, bell-shaped, triangular, Gaussian, and sigmoidal functions [8]. In this study, trapezoidal and triangular membership functions are employed. A depiction of these membership functions is shown in Figure 5.

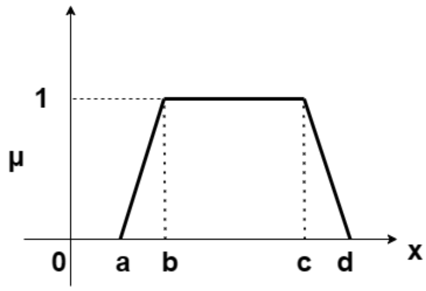


Figure 3. Trapezoidal Function

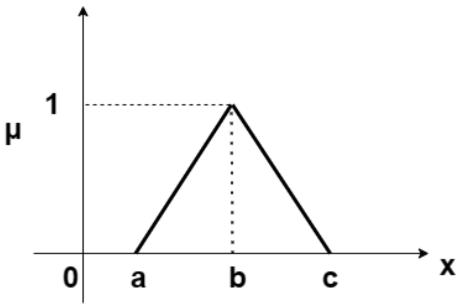


Figure 4. Triangle function

The trapezoidal membership function uses four parameters as shown in Figure 6 is \({a, b, c, d}\) as described by Equation (2), while the triangular membership function uses three parameters \({a, b, c}\) as outlined in Equation (3). Each value \(x\) is determined based on the membership function value \(\mu\) for each parameter.

IF x is A and ..... and y is B then z=f(x,y)

$$\mu(x,a,b,c,d) = \begin{cases} 0 & ,x \le a \\ \frac{x-a}{b-a} & ,a \le x \le b \\ 1 & ,b \le x \le c \\ \frac{d-x}{d-c} & ,c \le x \le d \\ 0 & ,d \le c \end{cases} \quad (1)$$

$$\mu(x,a,b,c) = \begin{cases} 0 & ,x \le a \\ \frac{x-a}{b-a} & ,a \le x \le b \\ \frac{c-x}{c-b} & ,b \le x \le c \\ 0 & ,c \le 0 \end{cases} \quad (2)$$

See Figure 9 and Figure 10, in equation (1), \(A \) and \(B \) represent fuzzy sets as premises, while \(z = f(x, y) \) is a crisp function as the consequent. Typically, \(z = f(x, y) \) is a polynomial in the input variables \(x \) and \(y \), but it can also describe other outputs from the fuzzy function according to the fuzzy rule premises. If \(f(x, y) \) is a first-order polynomial, the fuzzy inference system is referred to as a first-order Sugeno fuzzy model. If \(f \) is a constant, the system is known as a zero-order Sugeno fuzzy model. This model employs membership functions with a degree of 1 at the crisp value and a degree of 0 at other crisp values. Each fuzzy rule in a Sugeno model produces a crisp output, and the overall output is derived using a weighted average, as described by Equation (4) (Samsugi, S., Mardiyansyah, Z., & Nurkholis, A.,2020).

$$Z^* = \frac{\sum_{i=1}^{n} w_i z_i}{\sum_{i=1}^{n} w_i}$$

In this study, the Takagi-Sugeno fuzzy logic flowchart for automatic drip irrigation is illustrated in Figure 3. The process of using Takagi-Sugeno fuzzy logic is as follows:

1. **Input Data Reading**: The first step involves reading data from soil moisture and temperature sensors, which is initially in crisp form.
2. **Fuzzification**: The second step converts the crisp data into fuzzy values. This stage processes two inputs based on membership functions, as shown in Figure 4. Soil moisture membership functions are categorized into three linguistic values: Dry, Moist, and Wet. Temperature membership functions are categorized into Cold, Normal, and Hot.
3. **Inference**: The third step involves fuzzy inference to draw conclusions based on the rule base. This process uses AND operations with MIN implication and MAX aggregation. The fuzzy rules are presented in Table 1, which shows a total of 9 fuzzy rules based on the rule base.

   a) R1: If water level is low and soil moisture is dry, then irrigation duration is long.
   b) R2 : If water level is low and soil moisture is moist, then irrigation duration is moderate.
   c) R3 : If water level is low and soil moisture is wet, then irrigation duration is short.
   d) R4 : If water level is medium and soil moisture is dry, then irrigation duration is long.
   e) R5 : If water level is medium and soil moisture is moist, then irrigation duration is moderate.
   f) R6 : If water level is medium and soil moisture is wet, then irrigation duration is short.
   g) R7 : If water level is high and soil moisture is dry, then irrigation duration is long.

h) R8 : If water level is high and soil moisture is moist, then irrigation duration is moderate.
i) R9 : If water level is high and soil moisture is wet, then irrigation duration is short.

The fourth step involves defuzzification , which converts the fuzzy values back into crisp values. This process uses Equation (4). During this step, membership functions for the linguistic terms—Long, Moderate, and Short—are utilized as illustrated in Figure 5.

1. Final Step : Determine the irrigation duration output based on the results of the fuzzy calculations, see figure 7.

Soil	*Water*		
	Low	*Medium*	*High*
Dry	*Slow*	*Slow*	*Slow*
Damp	*Medium*	*Medium*	*Medium*
Wet	*Fast*	*Fast*	*Fast*

Figure 5. Fuzzy Rule

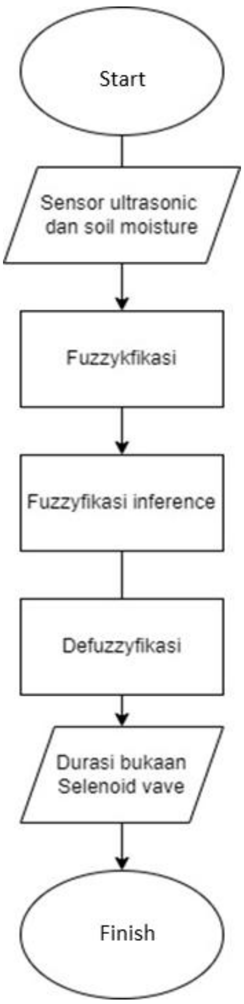


Figure 6. Flowchart system

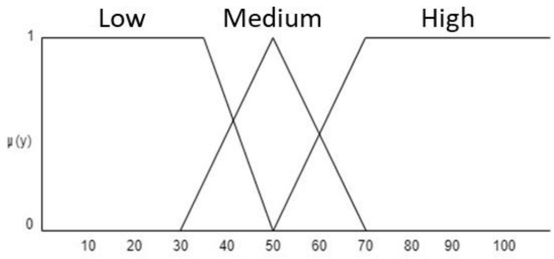


Figure 7. Functions to soil moisture members

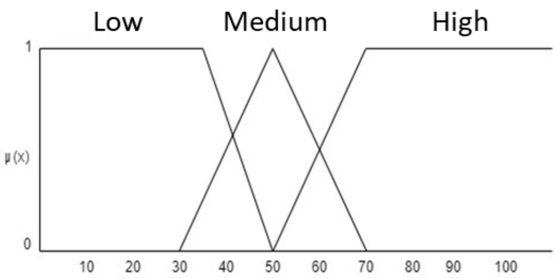
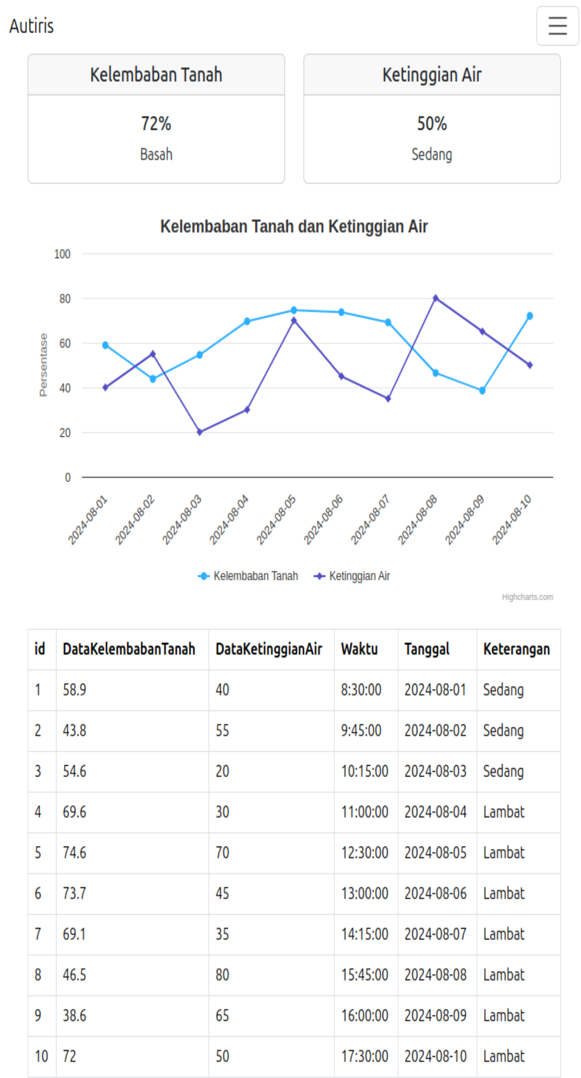


Figure 8. Functions to the water level members



id	DataKelembabanTanah	DataKetinggianAir	Waktu	Tanggal	Keterangan
1	58.9	40	8:30:00	2024-08-01	Sedang
2	43.8	55	9:45:00	2024-08-02	Sedang
3	54.6	20	10:15:00	2024-08-03	Sedang
4	69.6	30	11:00:00	2024-08-04	Lambat
5	74.6	70	12:30:00	2024-08-05	Lambat
6	73.7	45	13:00:00	2024-08-06	Lambat
7	69.1	35	14:15:00	2024-08-07	Lambat
8	46.5	80	15:45:00	2024-08-08	Lambat
9	38.6	65	16:00:00	2024-08-09	Lambat
10	72	50	17:30:00	2024-08-10	Lambat

Figure 11. Website Autiris

Figure 11 shows the Auritis website display. The website displays several data including soil moisture, water level time and description. All data is displayed in real time and previous reading results.

III. DISCUSSION AND RESULTS

The data obtained from the Autiris (Automatic Irrigation and Monitoring System) website displays information collected from soil moisture sensors and water level sensors. The website features both graphical and tabular representations of the data, allowing users to visualize and analyze soil moisture levels and water heights effectively. This integration provides a comprehensive view of the irrigation system's performance, facilitating real-time monitoring and management of water resources.

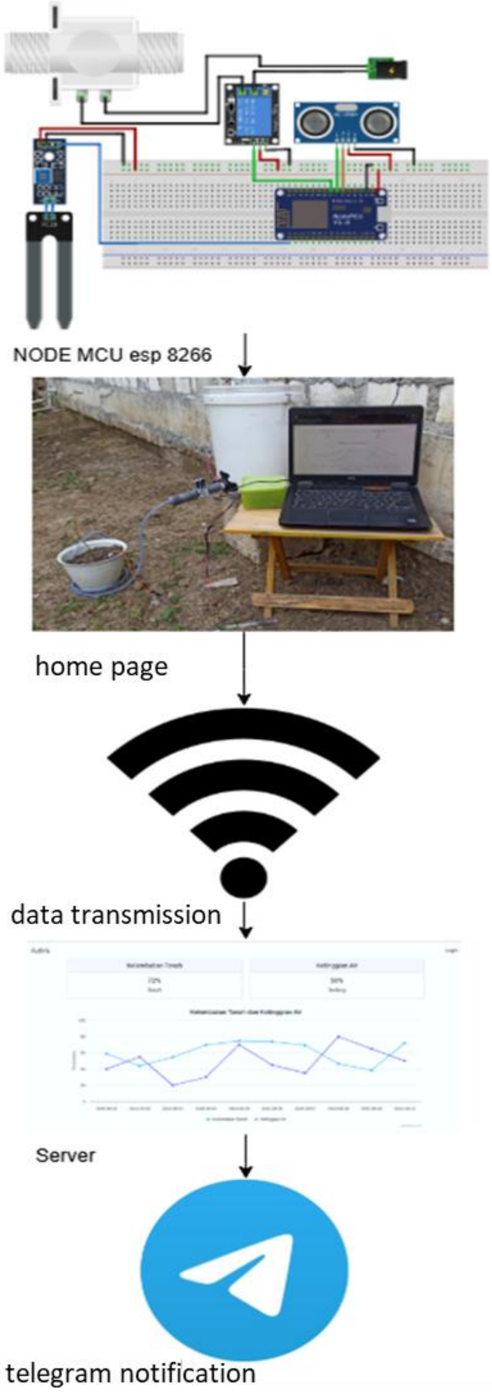


Figure 9. Design Sensor

The automatic irrigation system is designed with an integrated setup that includes ultrasonic and soil moisture sensors, all connected to an ESP8266 microcontroller. The ultrasonic sensors are tasked with measuring water levels, while the soil moisture sensors assess the hydration level of the soil. The ESP8266 microcontroller processes this information and transmits it to a centralized server. This server then updates a dedicated website, providing real-time graphical and tabular data displays. When soil moisture levels indicate that the soil is dry, the system automatically sends notifications via Telegram, ensuring prompt alerts for necessary irrigation actions. This approach improves water management efficiency by facilitating real-time monitoring and automated alerts. A brief overview of this system can be seen in Figure 11.

For this study, data were collected in the morning and evening over a span of 5 days. The data were gathered from soil moisture and water level sensors deployed in a chili field. The collected sensor data are summarized in Table 1.

Table 1. Data sensor collected

No.	Soil Humudity (%)	Water High level (%)	Time	Date
1	58	89	8:30:00	2024-07-01
2	43	85	9:45:00	2024-07-02
3	54	80	10:15:00	2024-07-03
4	69	71	11:00:00	2024-07-04
5	74	62	12:30:00	2024-07-05
6	73	51	13:00:00	2024-07-06
7	69	50	14:15:00	2024-07-07
8	46	45	15:45:00	2024-07-08
9	38	38	16:00:00	2024-07-09
10	72	33	17:30:00	2024-07-10

Table 1 presents the measurements of soil moisture and water level obtained from the sensors. This data will serve as input for the fuzzy control system. The process begins with fuzzification, which involves converting numerical values into linguistic terms (e.g., dry, moist, wet). For example, a soil moisture value of 58% will have a specific degree of membership in the fuzzy set "moist." These fuzzy values are then used to activate the predefined fuzzy rules. For instance, if the measured soil moisture is "moist" and the water level is "normal," the system will decide to irrigate with a "moderate" duration.

After obtaining the fuzzified values for soil moisture, water level, and irrigation duration, the next step is to compute the irrigation duration. The following outlines the steps in the Takagi-Sugeno fuzzy calculation process:

Determine the fuzzification value of the soil moisture for each dry, moist and wet member function using the soil moisture fuzzification equation.

$$\mu dry(58) = 0;$$
$$\mu moist(58) = \frac{70-58}{70-50} = 0{,}5;$$
$$\mu wet(58) = \frac{58-50}{68-50} = 0{,}5;$$

1. Determine the fuzzification value of from the Water level for each low, medium and high membership function using the equation and fuzzification of the Water level.

$\mu_{low(89)} = 0$
$\mu_{medium(89)} = 0$
$\mu_{high(89)} = 1$

Remarks: for the fuzzy value of all membership functions if added up, it must be worth 1

Calculate inference on each rule

R1 = if the water level **is low and** the soil moisture **is dry** then the irrigation duration **is long**

$$\alpha predicate_1 = \mu_{low\,(x)} \cap \mu_{dry(y)}$$
$$= \min(\mu_{low}(89);\ \mu_{dry}(58))$$
$$= \min(0\,;0)$$
$$= 0$$

$Value\ Z_1 = 480$

R2 = if the water level **is low and** the soil moisture **is moist** then the irrigation duration **is moderate**

$$\alpha predicate_2 = \mu_{low\,(x)} \cap \mu_{moist(y)}$$
$$= \min(\mu_{low}(89);\ \mu_{moist}(58))$$
$$= \min(0\,;0{,}5)$$
$$= 0$$

$Value\ Z_2 = 240$

R3 = if the water level **is low and** the soil moisture **is wet**, then the duration of **cepa irrigationt**

$$\alpha predicate_3 = \mu_{low\,(x)} \cap \mu_{wet(y)}$$
$$= \min(\mu_{low}(89);\ \mu_{wet}(58))$$
$$= \min(0\,;0{,}5)$$
$$= 0$$

$Value\ Z_3 = 240$

R4 = if the water level **is medium and** the soil moisture **is dry** then the duration of **irrigation is long**

$$\alpha predicate_4 = \mu_{medium\,(x)} \cap \mu_{dry(y)}$$
$$= \min(\mu_{medium}(89);\ \mu_{dry}(58))$$
$$= \min(0\,;0)$$
$$= 0$$

$Value\ Z_4 = 480$

R5 = if the water level **is moderate and** the soil moisture **is moist** then the irrigation duration **is moderate**

$$\alpha predicate_5 = \mu_{medium\,(x)} \cap \mu_{moist(y)}$$
$$= \min(\mu_{medium}(89);\ \mu_{moist}(58))$$
$$= \min(0\,;0{,}5)$$
$$= 0$$

$Value\ Z_5 = 240$

R6 = if the water level **is medium and** the soil moisture **is wet** then the duration of irrigation **is fast**

$$\alpha predicate_6 = \mu_{medium(x)} \cap \mu_{wet(y)}$$
$$= \min(\mu_{medium}(89);\ \mu_{wet}(58))$$
$$= \min(0\,;0{,}5)$$
$$= 0$$

$Value\ Z_6 = 240$

R7 = if the water level **is high and** the soil moisture **is dry** then the **irrigation duration is long**

$$\alpha predicate_7 = \mu_{high\,(x)} \cap \mu_{dry(y)}$$
$$= \min(\mu_{high}(89);\ \mu_{dry}(58))$$

$$= \min(1\,; 0)$$
$$= 0$$

$$Value\ Z_7 = 480$$

R8 = if the water level **is high and** the soil moisture **is moist** then the irrigation duration **is moderate**

Tabel 2. Calculation Results on the fuzzy method

No.	Soil Humudity (%)	Water High Level (%)	Time	Date	Description
1	58	89	07:30:00	2024-07-01	Medium
2	43	85	16:45:00	2024-07-01	Fast
3	54	80	07:30:00	2024-07-02	Medium
4	69	71	16:45:00	2024-08-02	Medium
5	74	62	07:30:00	2024-08-03	Fast
6	73	51	16:45:00	2024-08-03	Fast
7	69	50	07:30:00	2024-08-04	Medium
8	46	45	16:45:00	2024-08-04	Slow
9	38	38	07:30:00	2024-08-05	Medium
10	72	33	16:45:00	2024-08-15	Fast

$$\alpha predicate_8 = \mu_{high(x)} \cap \mu_{moist(y)}$$
$$= \min(\mu_{high}(89);\ \mu_{moist}(58))$$
$$= \min(1\,; 0{,}5)$$
$$= 0{,}5$$

$$Value\ Z_8 = \frac{Z - 240}{480 - 240}$$
$$0{,}5 = \frac{Z - 240}{240}$$
$$Z_8 = 120$$

R9 = if the Water level **is high and** the soil moisture **is wet** then the duration of **irrigation is fast**

$$\alpha predicate_9 = \mu_{high\,(x)} \cap \mu_{wet(y)}$$
$$= \min(\mu_{high}(89);\ \mu_{wet}(58))$$
$$= \min(1\,; 0{,}5)$$
$$= 0{,}5$$

$$Value\ Z_9 = \frac{480 - Z}{480 - 240}$$
$$0{,}5 = \frac{480 - Z}{240}$$
$$Z_9 = 360$$

2. Defuzzyfikasi

$$Z^* = \frac{\sum_{i=1}^{n} w_i z_i}{\sum_{i=1}^{n} w_i}$$

$$Z^* = \frac{(0x480)+(0x240)+(0x240)+(0x480)+(0x240)+(0x240)+(0x480)+(0{,}5x120)+(0{,}5x360)}{(0+0+0+0+0+0+0+0{,}5+0{,}5)}$$

$$Z^* = \frac{60 + 180}{1}$$

$$Z^* = 240$$

Do this step for the 2nd to 10th data

The following are the results of calculations using the Takagi-Sugeno fuzzy method, as shown in Table 3. Table 3 indicates that fuzzy logic can be effectively applied for automatic irrigation, with an average irrigation duration of 321 seconds. Based on this average value, the fuzzy classification for the first data set is "moderate." Do this step for the 2nd to 10th data

The results of table 2 get In a smart irrigation system using the Takagi-Sugeno fuzzy method, soil moisture categorization is performed through three main groups: “Moderate,” “Fast,” and “Slow,” which represent the system’s systematic response to the farmland hydration conditions. The “Moderate” category reflects the optimal condition where the system effectively maintains soil moisture at ideal levels while efficiently managing water use. The “Fast” category signifies urgent irrigation needs, characterized by low soil moisture levels, while the “Slow” category represents a water conservation strategy that still takes into account the physiological needs of the crop. This approach allows the system to make adaptive and contextual irrigation decisions, dynamically responding to variations in field conditions. The fuzzy-based decision-making mechanism optimizes the allocation of water resources, supporting the principles of efficient water use within the framework of precision agriculture.

IV. CONCLUSION

Based on the results obtained from the research on smart agriculture management—specifically, the development of a website-based monitoring and automatic irrigation system utilizing soil moisture and ultrasonic sensors with a fuzzy logic approach:

The monitoring and irrigation system has been successfully developed and implemented. The tools and system effectively process data in real-time and display it on a simple website, showcasing real-time values for water level, soil moisture, status information, and graphs.

The trial results show that the developed automatic monitoring and irrigation system accurately measures soil moisture and water levels while providing real-time data. Empirical tests demonstrated the system's robust performance in managing soil moisture, categorizing responses into three distinct groups: "Moderate" (70%), "Fast" (20%), and "Slow" (10%). The Takagi-Sugeno fuzzy logic method enabled precise irrigation decision-making, with the "Moderate" category achieving an optimal irrigation duration of 321 seconds. This approach ensures efficient water usage while maintaining ideal soil moisture levels. This study highlights the significant potential of an IoT-based irrigation system, which integrates ultrasonic and soil moisture sensors with fuzzy logic data processing, in improving water use efficiency in agriculture..

BIBLIOGRAPHY

Aprillya, M. R., & Chasanah, U. (2022). Sistem Pendukung Keputusan Identifikasi Daerah Rawan Kekeringan dengan Metode Fuzzy Analytical Hierarchy Process (Studi Kasus: Kabupaten Lamongan). *Jurnal CoSciTech (Computer Science and Information Technology)*, *3*(2), 159–167. https://doi.org/10.37859/coscitech.v3i2.3983

Arifin, T. N., Febriyani Pratiwi, G., & Janrafsasih, A. (2022). Sensor Ultrasonik Sebagai Sensor Jarak. *Jurnal Tera*, *2*(2), 55–62. http://jurnal.undira.ac.id/index.php/jurnaltera/

Ferdiansyach, M. I., Astutik, R. P., & S.S., P. P. (2013). Rancang Bangun Sistem Monitoring dan Penyiram Tanaman Otomatis Menggunakan Wemos D1 Berbasis Web. *Seminar Nasional Fortei7-4 Forum Pendidikan Tinggi Teknik Elektro Indonesia Regional VII*, 29–34.

Heru Sandi, G., & Fatma, Y. (2023). Pemanfaatan Teknologi Internet of Things (Iot) Pada Bidang Pertanian. *JATI (Jurnal Mahasiswa Teknik Informatika)*, *7*(1), 1–5. https://doi.org/10.36040/jati.v7i1.5892

Kadarsih, K., & Andrianto, S. (2022). Membangun Website SMA PGRI Gunung Raya Ranau Menggunakan PHP dan MYSQL. *JTIM: Jurnal Teknik Informatika Mahakarya*, *03*(2), 37–44.

Mahfud, F., Ardiansyah, H., & Aprillya, M. R. (2022). *SISTEM MONITORING KELEMBABAN TANAH DENGAN SENSOR*. 117–124.

Nurul Hidayati Lusita Dewi, Mimin F. Rohmah, S. Z. M. (2019). Prototype Smart Home Dengan Modul Nodemcu Esp8266 Berbasis Internet of Things (Iot). *Teknologi Informasi*, 3–3.

Puspasari, F.-, Fahrurrozi, I.-, Satya, T. P., Setyawan, G.-, Al Fauzan, M. R., & Admoko, E. M. D. (2019). Sensor Ultrasonik HCSR04 Berbasis Arduino Due Untuk Sistem Monitoring Ketinggian. *Jurnal Fisika Dan Aplikasinya*, *15*(2), 36. https://doi.org/10.12962/j24604682.v15i2.4393

Samsugi, S., Mardiyansyah, Z., & Nurkholis, A. (2020). Sistem Pengontrol Irigasi Otomatis Menggunakan Mikrokontroler Arduino Uno. *Jurnal Teknologi Dan Sistem Tertanam*, *1*(1), 17. https://doi.org/10.33365/jtst.v1i1.719

Sanca, P. A. (2018). Perancangan mesin penyiraman taman menggunakan Fuzzy Logic. *Indonesian Journal of Engineering and Technology (INAJET)*, *1*(1), 28–34. https://journal.unesa.ac.id/index.php/inajet/article/view/5387

Shodiq, M., & Saputra, B. D. (2022). Grey Forecasting Model Untuk Peramalan Harga Ikan Budidaya. *JURIKOM (Jurnal Riset Komputer)*, *9*(6), 1770. https://doi.org/10.30865/jurikom.v9i6.5120

Sitio, S. L. (2018). Penerapan Fuzzy Inference Sistem Sugeno untuk Penentuan Jumlah

Pembelian Obat. *Jurnal Infor Universitas Pamulang*, *3*(2), 104.

Sriwidi Astutik, A. (2017). Perkembangan Sektor Pertanian Tanaman Pangan Di Kabupatenlamongan Pada Masa Pemerintahan Bupati H. Masfuktahun 2000-2010. *Avatara*, *5*(1), 1559–1568.

Yunita Trimarsiah, & Muhajir Arafat. (2017). Analisis Dan Perancangan Website Sebagai Sarana Informasi Pada Lembaga Bahasa Kewirausahaan Dan Komputer Akmi Baturaja. *Jurnal Ilmiah MATRIK*, *19 No 1*, 1–10.