

Soil pH Monitoring System and Agricultural Land Watering Regulations Using the Fuzzy Method for Sidomulyo Village

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ABSTRACT

A community called Sidomulyo Village was located in Batam City's Sagulung District of Tembesi Village. There, farming was the main source of income for the majority of people, however, some also worked as farmers part-time. One of the sources of fresh veggies in Batam City was Sidomulyo. Some farmers claimed that the initial stage of farming, testing the pH of the soil, was challenging for them. This was due to the need for farmers to visit the Agriculture Service to borrow a soil pH testing instrument and the fact that some still utilized time- and energy-intensive conventional irrigation techniques. The goal of this research is to make it simpler for the community to grow crops by addressing their concerns and wants. To that end, an IOT (Internet of Things)-based soil pH monitoring system and an automatic land irrigation setting system utilizing the fuzzy technique were developed. The ESP32 will receive soil pH readings from the soil pH sensor and show them on the website or application. When it comes to automatic watering, the information that determines how long to water is dependent on temperature and humidity readings. With such a notion, it is now much easier for farmers to monitor the pH of the soil, which also makes it simpler for them to water and saves more time and energy.

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1. INTRODUCTION

The province of the Riau Islands has several towns and districts where each city has its own name. Batam City is one of the cities in this province that has the name of an industrial city where there are many large companies in it. Behind the stigma of industrial cities, there are still technologically backward settlements. As for settlements that still do fit crops to meet day-to-day needs. According to the

data from the Minister of Agriculture, there are a number of farms that are still cultivating in Batam City, one of which is in Kelurahan Tembesi.

In Tembesi Kelurahan there are some villages that are still doing crops. For example, the Sidomulyo Village. The people there have a lot of agricultural land to cover their daily lives. Many of the plants planted in their farms, for example, are singkong, sawi, pumpkin, corn, and others. In agriculture, according to the data we have, there are five aspects:

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food crops, plantations, forestry, farming and fishing. In the village of Sidomulyo itself, their agricultural fields are already included in the 5 aspects. However, on planting aspects still have deficiencies in knowledge of science and technology.

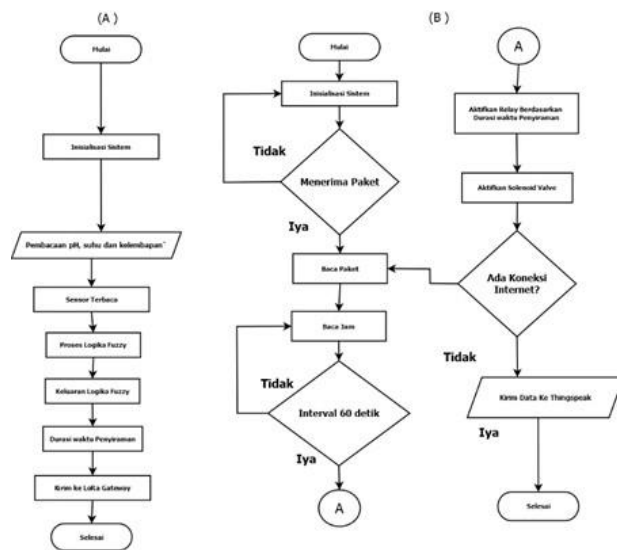
Before planting, the soil that will be used for planting should be tested first. People complain about the difficulty of obtaining tools for monitoring soil pH, where they have to take the tools from the Agricultural Service. Then, people also do the irrigation of the land by conventional methods, where such methods are very inefficient in terms of energy and time.

Therefore, it needs a monitoring system for the soil pH based on the Internet of Things (IOT), in order to make it easier for the public to check the pH of soil on the land to be used. Then, you need to set the automatic irrigation that will adjust the watering time. Then you use the fuzzy method to regulate the water needs used to irrigate plants, to match the rate required based on the temperature and humidity of the soil. With this, plant pH testing and automatic irrigation can be done easily.

This study is structured as follows: section II discusses the dataset used, proposed methods and proposed training and testing schemes. Section III displays the results of CNN accuracy and responses to forearm orientation. Section IV discusses the interpretation and comparison of results with other studies and limitations. Section V, conclusions, which rewrite the objectives, main findings and future works.

2. MATERIALS AND METHOD

A. Flow Chart System



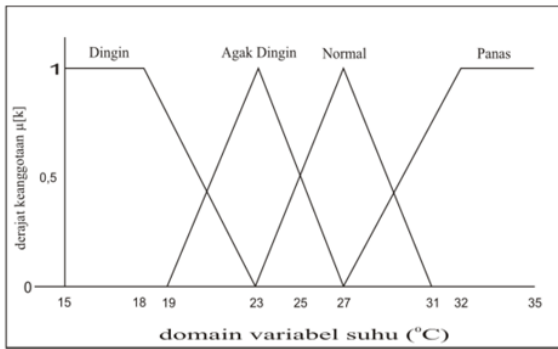
The system stage of the device is by pH reading by the pH sensor and temperature reading as well as humidity by the DHT-22 sensor, the unit of temperature will be converted into degrees Celsius ($^{\circ}\text{C}$). Then after reading the sensor will continue with the Fuzzy Logic Process with inputs of temperature and humidity. Once completed, the sender will send the data to the Gateway. In the system it will be set for irrigation within 60 seconds. If the time is already in the 60 seconds interval then the Relay will be activated according to the irrigating duration that has been processed by the Fuzzy logic on the sender. The irrigation duration is the regulator of the duration of the relay that becomes the contact of the solenoid valve. The results of soil pH readings, temperature, humidity and irrigation duration will be displayed on the website or application, so it can be monitored periodically without having to visit farmland.

B. Fuzzy Logic Design

The fuzzy logic system has four main structures: fuzzification, rule base, inference and defuzzification

1. Fuzzification

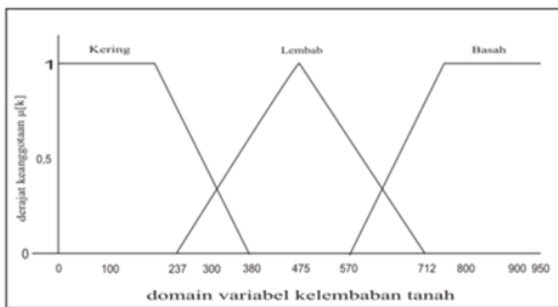
This plant watering system uses two inputs that will be diffuzzified into a fuzzy set. There are two membership functions in this system, namely the input membership of air temperature and soil humidity. It uses four linguistic values for temperature: cold, slightly cold, normal, and hot[1].



Where :

- Cold = 15°C – 23°C
- Slightly Cold = 19°C – 27°C
- Normal = 23°C – 31°C
- Hot = 27°C – 35°C

For the moisture membership function of the soil, three linguistic values are used: Dry, moist and Wet[1].



Where :

- Dry = 0 – 380
- Moist = 237 – 712
- Wet = 570 – 950

2. Rule Base (IF-THEN Rule)

After the formation of the fuzzy set, then the creation of the Fuzzy rule. (fuzzy rule). Rules are formed to specify the relationship between input and output. The operator used to connect between the two inputs is the AND operator, and the mapping between the input-output is IF-THEN[1]. Based on the input membership function that has been formed previously, 12 rules are formed which can be seen in table 1.[1].

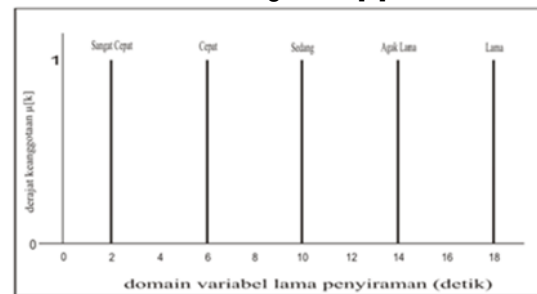
Suhu / kelembab	Dingin	Agak Dingin	Normal	Panas
Kering	Sedang	Sedang	Agk Lama	Lama
Lembab	Cepat	Cepat	Sedang	Agk Lama
Basah	Sgt Cepat	Sgt Cepat	Cepat	Cepat

3. Inference

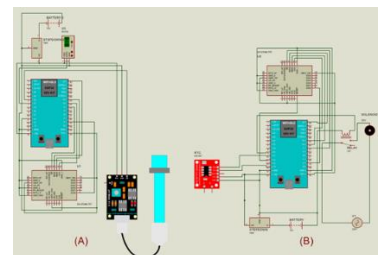
The next stage, the rules that have been made previously are used as a knowledge base for the process on the inference block. Inference is the process of evaluating the rule to produce the output of each rule. To get the output in the fuzzy domain used the implicit function application. The implication function used is the min implication (Using the AND operator)[1].

4. Defuzzification

Five linguistic values were selected to determine the conditions of the long period of irrigation represented in the form of singleton membership functions as seen in figure 17[1].

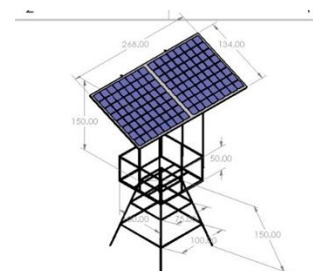


C. Electrical Design



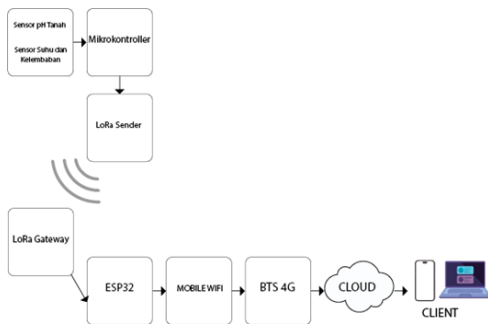
Here's an electrical design made using a proteus application. There are two electrical concepts namely, the electrical for the transmitter connected to the DHT-22 sensor and the soil pH sensor. Then the electric for the Gateway that is as the receiver that receives the data and will process the controls for irrigation. The receiver will also send the monitoring data to the website.

D. Mechanical Design



Here's a mechanical design made using the Solidworks application. So this is a drawing of a tower that will be used as a water torrent, a solar panel and also a panel box as its tool. The position consists of three main parts: the tower's foot, the towers' basket, and the solar panel's bottom.

E. IOT Blockdiagram

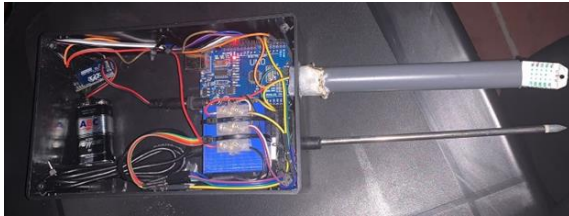


3. RESULTS

A. Product Result

1. Electrical Installation

The electrical installation is done by wiring all electrical components to the microcontroller used for transmitters and receivers.



The above transmitter uses an Arduino microcontroller, all components like the soil pH sensor, DHT22 and LORA are wired to the microcontrollers as inputs and outputs.



The PCB Receiver like figure above uses the

microcontroller ESP32, then solder other components such as the LORA, RTC Module, and relays to the ESP32 to receive input and send output.

2. Mechanical Manufacturing

After the mechanical design of the tower tower and the solar panels, it was extracted from the towers. Here are the results of the water tower manufacturing and solar panel embossing :



The material used for the water torrents and the solar panels is arc iron, then in the Welding. Then the bottom of it is used as a place for the control panel and the deep cycle battery as its power source.

B. Soil pH Measurement Test

After successfully creating a tool from an IOT-based soil pH monitoring system with Thingspeak, then proceeding with data retrieval from such a tool to obtain results from the reading of the soil's pH sensor and the value of the pH meter. The pH meter used is not a standard pH meter so it cannot be a reference for its accuracy level. Here are sample data from sensor pH soil and pH meter.

No	TIME	Sensor Ph Tanah	pH Meter
1	2024-06-20T23:15:22+07:00	8.18	6
2	2024-06-20T23:15:45+07:00	7.94	6
3	2024-06-20T23:16:14+07:00	7.87	6
4	2024-06-20T23:16:59+07:00	7.94	6
5	2024-06-20T23:17:15+07:00	8.04	6
6	2024-06-20T23:18:10+07:00	7.97	6
7	2024-06-20T23:18:40+07:00	7.8	6
8	2024-06-20T23:19:01+07:00	7.94	6
9	2024-06-20T23:19:24+07:00	7.9	6

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10	2024-06-20T23:19:52+07:00	7.87	6
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Table 1. Soil pH sensor result

C. Fuzzy Logic System Test

After successfully creating a fuzzy-based infusion configuration system, followed by data collection through the Thingspeak website, the data to be taken is the correspondence between the input variable and the output variable based on the Fuzzy method that has been created. From the comparison of the two outputs determine whether the same or there is a difference by giving the statement TRUE and FALSE, then perform a presentation calculation of the TRUE & FALSE which will be the material of the assessment of the success of the fuzzy system that has been created.

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T13:28:15+07:00	13	18	10	10	TRUE
2024-06-22T13:28:37+07:00	17	19	10	10	TRUE
2024-06-22T13:29:31+07:00	78	44	6	6	TRUE
2024-06-22T13:29:51+07:00	52	35	2	14	FALSE
2024-06-22T13:30:25+07:00	49	35	14	14	TRUE
2024-06-22T13:31:55+07:00	27	45	18	14	FALSE
2024-06-22T13:32:14+07:00	27	45	2	14	FALSE
2024-06-22T13:32:33+07:00	27	29	2	14	FALSE
2024-06-22T13:32:53+07:00	27	29	2	14	FALSE

Table 2. Result Fuzzy Logic

Here's the result of a classification created in google colab. By installing a fuzzy library on the program and giving the input variable that matches the system in Arduino as well as the corresponding output variable. Then calling the function from the fuzzie library to get the output from the Fuzzy classification using the python program.

```
[11] # Fungsi untuk menentukan durasi penyiraman berdasarkan input temperature dan humidity
def determine_watering_duration(temp, hum):
    watering_input['temperature'] = temp
    watering_input['humidity'] = hum
    watering.compute()
    return watering.output['watering_duration']

# Membaca data dari CSV dan menghitung durasi penyiraman
results = []
for index, row in data.iterrows():
    temp = row['temperature']
    hum = row['humidity']
    duration = determine_watering_duration(temp, hum)
    results.append(duration)
    print(f"Temperature: {temp}, Humidity: {hum} -> watering Duration: {duration:.2f} detik")

# Output
Temperature: 38.7, Humidity: 88.9 -> watering Duration: 6.00 detik
Temperature: 38.6, Humidity: 81.1 -> watering Duration: 6.00 detik
Temperature: 38.7, Humidity: 81.8 -> watering Duration: 6.00 detik
Temperature: 38.7, Humidity: 81.3 -> watering Duration: 6.00 detik
Temperature: 38.7, Humidity: 81.1 -> watering Duration: 6.00 detik
Temperature: 38.6, Humidity: 81.2 -> watering Duration: 6.00 detik
```

TESTING ALL RULES

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T13:28:15+07:00	13	18	10	10	TRUE
2024-06-22T13:28:37+07:00	17	19	10	10	TRUE
2024-06-22T13:35:16+07:00	27	15	10	10	TRUE

Table 3. Testing Rules 1

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T13:37:11+07:00	27	45	10	14	FALSE
2024-06-22T13:56:12+07:00	27	23	10	10	TRUE
2024-06-22T13:57:28+07:00	27	25	10	10	TRUE

Table 4. Testing Rules 2

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:15:59+07:00	1	28	14	14	TRUE
2024-06-22T14:16:24+07:00	1	19	14	10	FALSE
2024-06-22T14:16:48+07:00	1	28	14	14	TRUE

Table 5. Testing Rules 3

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:25:25+07:00	1	45	18	18	TRUE
2024-06-22T14:27:09+07:00	1	35	10	18	FALSE
2024-06-22T14:27:38+07:00	1	36	18	18	TRUE

Table 6. Testing Rules 4

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:52:05+07:00	48	19	2	6	FALSE
2024-06-22T15:08:51+07:00	48	23	6	6	TRUE
2024-06-22T15:09:11+07:00	48	21	6	6	TRUE

Table 7. Testing Rules 5

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:52:05+07:00	48	19	2	6	FALSE
2024-06-22T15:06:56+07:00	48	25	10	6	FALSE
2024-06-22T15:08:51+07:00	48	23	6	6	TRUE

Table 8. Testing Rules 6

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:14:06+07:00	55	28	10	10	TRUE
2024-06-22T14:14:24+07:00	55	28	10	10	TRUE
2024-06-22T15:23:22+07:00	48	27	10	10	TRUE

Table 9. Testing Rules 7

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T13:30:25+07:00	49	35	14	14	TRUE
2024-06-22T14:11:55+07:00	55	27	14	10	FALSE
2024-06-22T14:12:19+07:00	55	45	14	14	TRUE

Table 10. Testing Rules 8

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:51:46+07:00	74	19	2	2	TRUE
2024-06-22T16:21:58+07:00	80	17	2	2	TRUE
2024-06-22T16:22:18+07:00	80	17	2	2	TRUE

Table 11. Testing Rules 9

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:51:46+07:00	74	19	2	2	TRUE
2024-06-22T16:15:55+07:00	80	24	2	2	TRUE
2024-06-22T16:16:14+07:00	80	24	2	2	TRUE

Table 12. Testing Rules 10

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T14:15:21+07:00	91	28	6	6	TRUE
2024-06-22T15:59:55+07:00	80	30	6	6	TRUE
2024-06-22T16:00:16+07:00	80	27	6	6	TRUE

Table 13. Testing Rules 11

created_at	KELEMBABAN(%)	SUH(U(°C))	Durasi Penyiraman	Durasi Penyiraman	CHECK
2024-06-22T13:29:31+07:00	78	44	6	6	TRUE
2024-06-22T14:15:21+07:00	91	28	6	6	TRUE
2024-06-22T15:46:19+07:00	80	34	6	6	TRUE

Table 14. Testing Rules 12

D. Temperature Test

After the device was successfully constructed, a DHT22 sensor test was conducted to ensure the

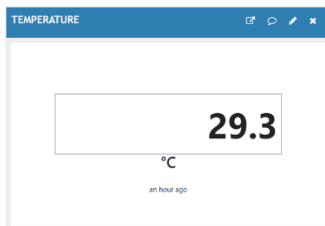
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accuracy of the sensor. The test was carried out by taking the data from the DHT 22 reading for the temperature of the soil at the same point as the thermometer.

NO	created_at	Sensor DHT22 (°C)	Termometer(°C)
1	2024-06-18T05:15:22+07:00	28.6	29
2	2024-06-18T05:18:56+07:00	28.5	29
3	2024-06-18T05:25:49+07:00	28.6	29
4	2024-06-18T05:26:17+07:00	28.5	29
5	2024-06-18T05:26:38+07:00	28.6	29

The image below shows the last reading of the DHT22 sensor for its temperature value. Where the data is transmitted by ESP32 connected to the WIFI network. If a network breakdown occurs then ESP32 cannot send its data to the website.



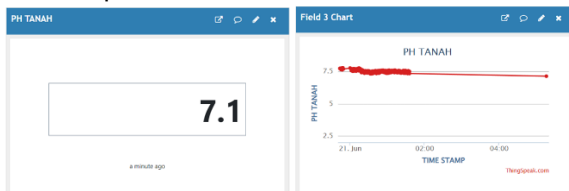
E. Plant Watering Test

After successfully creating a tool and performing tests for the fuzzy system, then proceed to testing the influence of the watering duration on the humidity. By observing changes in the moisture value after doing the irrigation based on the duration of watering emitted by the fuzzzy system. Where the initial value of humidity is the condition before irrigation.

NO	TIME	KELEMBABAN (%)	Termometer(°C)
1	2024-06-20T23:15:22+07:00	90	29
2	2024-06-20T23:15:45+07:00	90.8	29
3	2024-06-20T23:16:14+07:00	91.4	29
4	2024-06-20T23:16:59+07:00	91.8	29
5	2024-06-20T23:17:15+07:00	91.8	29

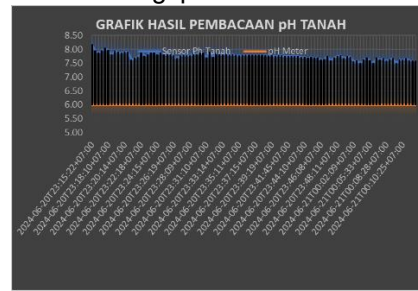
4. DISCUSSION

A. Soil pH Measurement



Here is the display result of the real-time ground pH read on the thingspeak website. The read value corresponds to the last value uploaded from ESP32 if no network interference is used. Because if there is

a network disruption then ESP32 will not send the data to Thingspeak.



From both the measurement data of the Earth pH sensor and the pH meter is made a graph from Microsoft Excel. From the graph can be seen the difference from the reading of the rising and descending pH sensor is unstable, with the lowest value is pH 7.11 and the highest pH value is 8.11. Whereas the reading from pH meter shows a stable figure where the value of the pH is read 6.

There are several factors that may affect the reading of soil pH sensors, including the state of the sensor that may require calibration to make the reading more accurate and stable. Environmental factors such as temperature and humidity of the soil can also influence the reading for soil PH sensors. Then the condition of the contents contained in soil such as minerals, water content, and organic compounds that may also affect the readings of soils pH sensing. Then, the quality of the selected sensor may also be a factor in the instability of soiling pH sensor reading such as the condition for probes and other components that may not work properly.

The readings of the pH meter used also allow for inaccurate readings even if the readings are stable. The values of the used pH meter can also not be used as a reference because the device used is not a standard tool for reading the pH value of the soil and the level of its accuracy is still uncertain.

B. Plant Watering Test

After testing fuzzy system and obtaining the data in table 7 above, proceed with the calculation of the results of the TRUE and FALSE conditions with the presentation of the two conditions. Where TRUE is the system's successful condition or the output of the system is correct according to the classification in the python program and FALLSE is the condition where the system output that has been created is inappropriate. By making Fuzzy classifications in the

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Python program as a reference, because it has a library and function for the fuzzy classification itself.

TRUE COUNT	FALSE COUNT	PRESENTASE TRUE (%)	PRESENTASE FALSE (%)
349	66	84.09	15.9

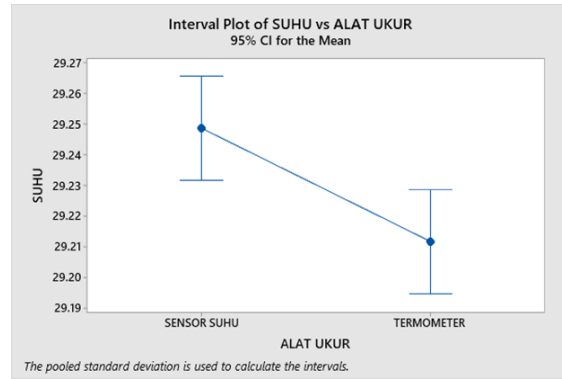
After successfully obtaining the data from the fuzzy system testing proceeded to the data processing. In the processing of data used Microsoft Excel application to determine the presentation of the TRUE and FALSE conditions. From table 8, we can see that the true and false conditions of the fuzzy system that have been created at obtained the presentation value of the true condition is 84,09% which is as many as 349 data and the presentation value of FALSE condition is 15.9% that is as much as 66 data out of a total of 415 data taken.

For TRUE condition with a presentation of 84,09% indicates that most of the observations in the system are working properly or are successful. However, there are still conditions that require system repairs where FALSE condition indicates a 15.9% presentation which means that the presentation of system failure is smaller than the success of the fuzzy system that has been created.

There are several factors that can be the cause of the FALSE condition that occurs. The first is the possibility that there are differences in the implementation of the fuzzy variables that are missing and slightly different so that there is a difference in the output of the Fuzzy system. Factors such as noise in input signals or power fluctuations can also affect Arduino's output. Then the bit limit on Arduinos can also influence fuzzy logic calculations, where Arduins have 8-bit memory, whereas the python used in google collab has a 64-bit processor. With power limitations in the middle of the plantation, it is forced to use arduino as an 8-bit microcontroller for power savings. level of its accuracy is still uncertain.

C. Temperature Test

The data sample was successfully taken from the DHT22 sensor for its temperature value, as well as the temperature value of the thermometer. To test the difference between the two data groups used the ANNOVA method to obtain the F-Value and the P-value.



The above table is a graphic plot of interval intervals between the DHT22 sensor and the thermometer. The graph shows the relationship between the Mean value of a DHT22-sensor and a Mean of a Thermometer, where the mean value of the Dht22 sensor is 29,2486 and the mean of a thermmeter is 29,2118.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
ALAT UKUR	1	0.3137	0.31366	9.05	0.003
Error	924	32.0185	0.03465		
Total	925	32.3321			

After doing the data testing with the ANNOVA Method using the minitab application, results are obtained as in the table above. The Mean Square value is obtained by dividing the sum of square by the Degree of freedom, whereas the F-Value value is derived by dividing the mean square of the measuring instrument by the means of the square error.

The F-Value value is used to test whether the difference between the group averages is significant. The larger the F-value value, the larger is the difference among the groups. While the P-values are used to indicate that the result is statistically significant.

The F-value indicates a value of 9,05, where the value shows a very small significant difference between the DHT22 sensor and the thermometer. With the value of the F-Value it has shown sufficient evidence to reject the hypothesis of zero. Whereas the P-Value indicates the value 0,003 where it is smaller than the significance level of the ANNOVA method of 0.05.

After successfully testing the data from two groups of data between the temperature values of the

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thermometer and the temperature of the DHT22 sensor, the result is there is a significant difference that is not too large. There are several factors that influence the difference between the DHT22 sensor and the thermometer. Among the factors is the different calibration of the device between the sensor DHT22, and the thermometer itself, which is produced by different manufacturers. Then the different levels of accuracy and precision between the sensors DHT 22 and thermometers, where for the sensor itself, the sensor has a tolerance value and based on the data sheet of the sensor, the tolerance level is $\pm 0.05^{\circ}\text{C}$. A change in ambient temperature can also affect the temperature readings of both sensors. And maybe the way the two different measuring instruments are used can also affect the difference in temperature values obtained.

D. Plant Watering Test

After the test is done, it takes the data of the humidity changes read by the DHT22 and sends it to the thingspeak website, which will then be observed and analyzed.

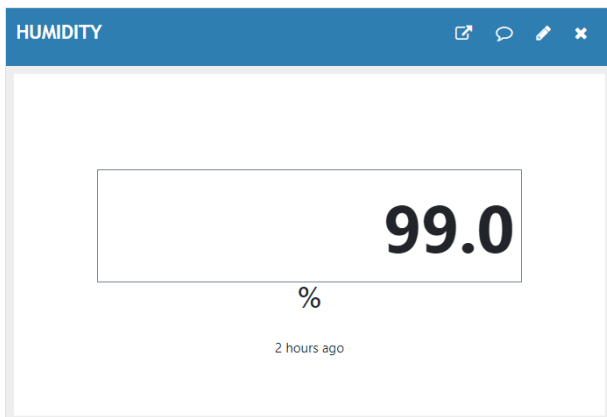
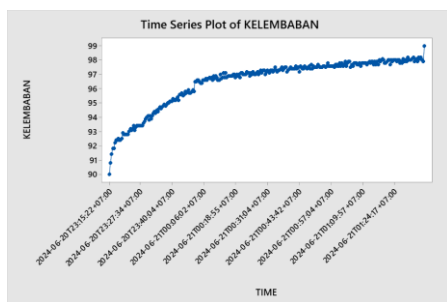


Figure above is a display of the real-time readings on thingspeak. The readings from DHT22 use percentage units for the readings of the humidity value, so it is also made a unit on thingspeak with percentages.



From the chart above we can see at 23:15:22 the humidity value before irrigation is 90%, then it is irrigated for 6 seconds according to the fuzzy output at that time. There was a development of a very significant change in humidity values. After observation, at the initial change there was an increase of 0.8% in its humidity value and continued to increase slowly. After about two hours of data collection, last time at 01:24:17, the humidity level reached 99%, which indicates that the soil is very humid or might be wet. With the initial value of 90% and for about 2 hours to 99% after 6 seconds of irrigation, there is an increase of $9\% \pm$ for changes in humidity values.

After observing and collecting data for two hours, there was a change in the humidity value from the initial 90% to 99%, a significant increase of $\pm 9\%$. Of course there are several factors that influenced the increase in the moisture, among them is the volume of water given large enough for the duration of the irrigation for 6 seconds, so there is a significant rise in the humidity. Another factor is that the soil used as a test object has a high water retention capacity, so it can absorb and retain the water given well where given a fairly significant and constant rise in humidity within about 2 hours.

However, as we know, to determine the amount of water required by the soil, using the duration as the irrigation output is assessed less accurately, because the unconstant flow of water becomes an obstacle to determining the water level given. Determining the volume of water is a reliable decision to determine how much water the plant needs.

5. CONCLUSION

From the discussions carried out on some tests of soil pH sensors and fuzzy systems, some conclusions can be drawn :

- A. Soil pH monitoring with LORA communication between Arduino and ESP32 has been successfully done. Where the data can be displayed on Thingspeak and show good results as it can display soil pH values in real time. The test results of the soil pH sensor showed unstable readings ranging from 7.11 to 8.11 due to a number of factors that influenced the selection of sensors that were less accurate and had not been calibrated on the soils pH sensor.
- B. The test results of the fuzzy system showed the true value of 84.09% and the FALSE value of

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15.9%. The temperature test also showed a significant difference of not too much with the ANOVA test result showing F-VALUE of 9.05, with the difference not too great so that the temperature readings of DHT22 as the input of the Fuzzy System can be reliable. And the test results from the irrigation show a steady increase of $\pm 9\%$ and lasts for 2 hours. With this the duration of the output of fuzzy can be trusted to keep the soil stable at the desired moisture.

- C. From some of the tests that have been done, data collection has been successfully carried out. Where the sensor reading data is recorded in the Thingspeak datalog, and the measuring tool reading is collected its data manually. By recording the sensor read data in the thingspeak data log, it indicates that the input and output readings are good.

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