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DESIGN AND CONSTRUCTION OF CROP SUITABILITY PREDICTION SYSTEM USING FUZZY LOGIC CLASSIFIER METHOD

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Abstract. The potential of land in Indonesia which is quite large and has not been used optimally is one of the problems. this study focused on developing fuzzy logic models to predict plants that are suitable for planting on agricultural land to enable the land use more optimal. In conducting this study, there were two stages of implementation, namely hardware design, and software design which included system workflow design using the Fuzzy Logic Classifier method where three input variables were used, namely soil pH, soil temperature, and humidity. The findings of this study are in the form of predictions consisting of eight outputs, namely Unfavorable Land, Spinach, Cayenne Pepper, Beans, Long Beans, Cucumber, Eggplant, and Tomatoo. The prediction results generated were directly displayed on the LCD of the instrument that has been designed.

Keywords : fuzzy logic, agriculture land, prediction

1. INTRODUCTION

Agriculture has an important role in human life because it functions as a provider of food, feed for livestock, and bioenergy. Indonesia has considerable land potential and has not been used optimally. Most of the land is suboptimal, such as dry land, tidal swamps, and lowland swamps with low productivity due to various constraints, such as water shortage and/or excess, high soil acidity and salinity, as well as toxicity and nutrient deficiency [1]. Basically, farmers need prior expert knowledge to make decisions during land preparation, sowing, fertilizer management, irrigation management, integrated pest control, storage, etc. for higher crop production [2]. Land preparation is one of the most important factors that need to be done in starting a cultivation business. Good land preparation has a big effect on plant productivity. Many studies have shown that land preparation before cultivating can increase crop yields by up to 30% [3]. Therefore, optimal land use can be done, one of which is knowing information related to the land which is needed to increase agricultural productivity. Therefore, in order to minimize the possibility of crop failure, the community needs information about the condition of the land in order to estimate the plants that are suitable for planting. Information about the land might be analyzed based on data taken directly in the field using three measurement parameters, namely soil pH, temperature and soil moisture.

The nutrients contained in the soil directly affect the growth and development of plants in addition to the ability of plants to absorb nutrients from the soil. The ability of plants to carry out the process of absorbing nutrients is also influenced by the main factor, namely the level of acidity or soil pH. By knowing the pH level in the soil, farmers can determine what crops are suitable for planting or cultivating because each plant has different needs for different pH levels [4]. In addition, soil temperature and humidity are also elements that affect plant growth [5]. Soil temperature affects water absorption [6], the lower the temperature, the less water is absorbed by the roots, therefore a sudden drop in soil temperature can cause plants to wither. While soil moisture will determine the availability of water in the soil for plant growth, the factors that determine soil moisture are rainfall, soil type, and the rate of evapotranspiration [7]. Therefore, by using these three measurement parameters, it is hoped that it can help provide information to the public about predictions of plants that are suitable for planting.

A previous study [8] conducted in 2020 was a study that used the fuzzy classifier as a model to determine the sustainability of aquatic animals and plants by assessing the quality of pond water. The output of this study resulted in fairly good classification performance. In addition, another study [9] combined seasonal index forecasting algorithms and Fuzzy-MCDM development in a model to determine plants that are suitable for planting in Salatiga areas. Meanwhile, this study was using the Fuzzy Logic method in a model in the form of an instrument design to predict plants that are suitable to be planted on land to optimize agricultural land.

At this time fuzzy logic has been widely used in various studies. Fuzzy logic was used in rainfall modeling for South Western Nigeria [10]. A fuzzy expert system was developed to recognize changes in temperature, humidity and lighting within a plant area and determine the level of light intensity [11]. Fuzzy logic based structure for plant disease forecasting system, it has been shown that the proposed method can be implemented with minimum weather data such as temperature and humidity [12]. Using a weather model based on fuzzy logic, the proposed system is a hybrid system that is used to solve one problem, namely to produce the best irrigation advice for farmers [13]. Fuzzy logic is used to deal with imprecision, ambiguity and insufficient knowledge. Fuzzy logic allows expert systems to work optimally with uncertain or ambiguous data and knowledge [2].

2. METHODS

In this study, two stages of implementation were conducted, namely the hardware design stage and software design in the form of predictive system modeling using the fuzzy logic method. In addition, it will also explain how to use the tool.

2.1 Hardware Design

In designing the hardware, components to be used were selected and tool designs and circuit schematics were used. The components used were the soil pH sensor, YL-69 Humidity sensor, and DS18B20 Temperature sensor which later entered the Atmega 328 Microcontroller (Arduino Uno) input for processing. Then, to seen the output, the output will be displayed directly on the LCD. In this tool the power source used is a 2000 mAH Lipo Battery which will be connected to the UBEC 5A. Figure 2 below visualizes the design of the tool and the schematic of the circuit used.

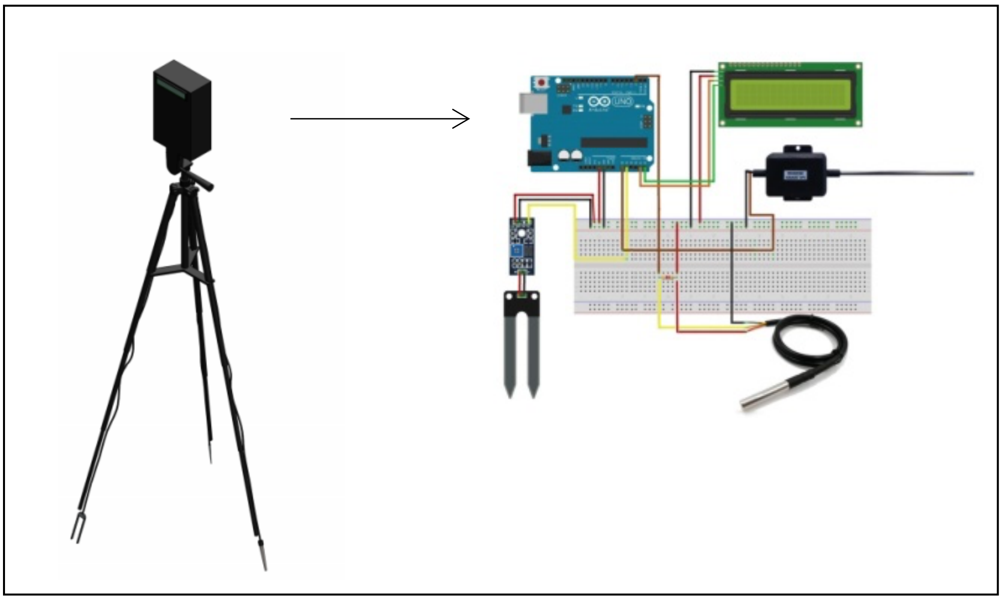

Figure 1. Tool Design and Hardware Circuit Schematic

2.2 Software Design

The design of the software that was made is very important in terms of the mathematical processing of the entire program. The core of this software design is the system workflow design using the Fuzzy Logic method.

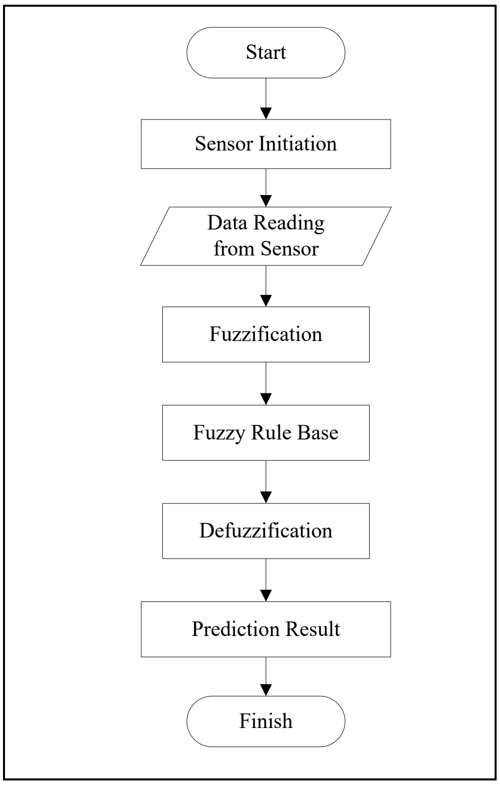

Figure 2. Software Flowchart

Prediction process using Fuzzy Logic [14]:

1. Fuzzification
   Fuzzification is a process of converting existing firm values into membership functions. In this study, 3 input variables were used, namely soil pH, soil temperature, and humidity using 8 outputs, namely Unfavorable Land, Spinach, Cayenne Pepper, Beans, Long Beans, Cucumber, Eggplant, and Tomatoo.
2. The basic rule (rule-based) on fuzzy logic control is a form of "if-then" relation rules as follows: if x is A then y is B where A and B are linguistic values defined in the range of variables X and Y, where the statement "x is A" is called the antecedent or premise, while the statement "y is B" is called the consequent or conclusion.
3. Reasoning (Inference Machine)
   The reasoning engine is a process of implication in reasoning the input value in order to determine the output value as a form of decision making. One reasoning model that is widely used is max-min reasoning. In this reasoning, the first process that is carried out is to perform the min operation of the fuzzification layer output signal which is continued with the max operation to find the output value which will then be defuzzified as an output form.
4. Defuzzification.
   The input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the domain of the fuzzy set. Thus, if given a fuzzy set within a certain range, it must be able to take a certain crisp value.

2.3 How to Use the Tool

The following is how to operate the tool:

1. Make sure the kit is properly installed and connected to the 2000 mAH Lipo battery which has been connected to the UBEC 5A.
2. If the tool is in good condition, plug the soil pH Sensor, DS18B20 Temperature Sensor, and YL-69 Soil Moisture Sensor into the land to be checked for crop suitability (the tool's support pole can be lengthened and shortened as needed).
3. For the soil pH sensor, try to wet the soil in the area where the sensor is placed first (the soil is moist), so that the soil pH sensor can produce accurate values or measurement results.
4. If all sensors have been properly plugged into the ground, then press the ON button to turn on the tool, then

after pressing the ON button the tool will immediately turn on, the LCD will display "Power ON".
5. After turning on, the tool will automatically work and will immediately display the Prediction results on the LCD.
6. To see the results of Prediction plants that are suitable for planting, it takes approximately 1-3 minutes.
7. The prediction results are strongly influenced by the value read by the sensor, so make sure that the sensor is in good condition.
8. To disable/turn off the appliance, press the OFF button, the appliance will turn off automatically.

3. RESULTS AND DISCUSSION

3.1 Results of Reading Data from the Tool

Testing of this tool was carried out in several locations of agricultural land in the city of Palembang, where this location included agricultural land in rice fields where there was silty soil (alluvial) and humus soils as well plantation areas where there was red-yellow soil (podzolicl). The results of the data from the test were as follows:

a. Muddy Soil (Alluvial))

Table 1. Results of Data Reading on Muddy Soil (Alluvial)

pH Sensor	Soil meter	Difference	Error (%)	Temp. Sensor (◦C)	Soil Meter	Differe-nce	Error (%)	Moisture Sensor (%)	Soil Meter
5,03	5,7	0,67	11,7	33	34	1	2,94	163	WET+
5,03	5,8	0,77	13,3	31	34	3	8,82	164	WET+
4,96	5,6	0,64	11,4	34	36	2	5,71	150	WET+
Error Average			12,1				5,82		

b. Humus Soil

Table 2. The Result of Data Reading on Humus Soil

pH Sensor	Soil meter	Difference	Error (%)	Temp. Sensor (◦C)	Soil Meter	Differe-nce	Error (%)	Moisture Sensor (%)	Soil Meter
5,4	5,2	0,2	3,85	34	33	1	3,03	84	WET+
5,7	6,0	0,3	5	33	33	0	0	77	WET+
5,7	6,0	0,3	5	33	33	0	0	80	WET+
Error Average			4,62				1,01		

c. Red-Yellow Soil (Podzolic)

Table 3. The Result of Data Reading on Red-Yellow Soil (Podzolic)

Ph Sensor	Soil meter	Difference	Error (%)	Temp. Sensor (◦C)	Soil Meter	Differe-nce	Error (%)	Moisture Sensor (%)	Soil Meter
4,61	5,4	0,79	14,62	25	29	4	13,8	40	DRY
4,63	5,7	1,07	18,77	29	30	1	3,33	56	DRY
7,39	6,0	1,39	23,17	25	29	4	13,8	72	DRY
Error Average			18,85				10,31		

The Formula of Error Cacluation:

$$\text{Error (\%)} = \frac{Difference}{Reading\ of\ Measurement\ Instrument} \text{ x } 100\% \quad (1)$$

$$\text{Error Average} = \Sigma \frac{Error}{Testing} \quad (2)$$

From the table above, the average error value of the three land tests on the pH sensor is 11.86% on the temperature sensor of 5.71%. meanwhile, the Humidity sensor obtained quite a good category value since on the soil meter 30-49% is DRY and ≥70% is WET+ [15]. The resulting value indicates that the level of accuracy of the sensors used is quite good. Data reading from this tool is used to predict plants that are suitable for planting on the land.

3.2 Prediction using Fuzzy Logic

a. Formation of a Fuzzy Set or Fuzzification

Table 4. Fuzzy Set

Fuzzy Variable	Fuzzy Set	Domain
Soil pH	Acid	[0, 5]
	Neutral	[4.5, 7.5]
	Base	[7, 14]]
Temperature (◦C)	Low	[0, 18]
	Normal	[15, 35]
	High	[32, 45]
Soil Humidity (%)	Low	[0, 40]
	Normal	[35, 90]
	High	[85, 130]

The membership function of the pH variable is represented in Figure 3 below:

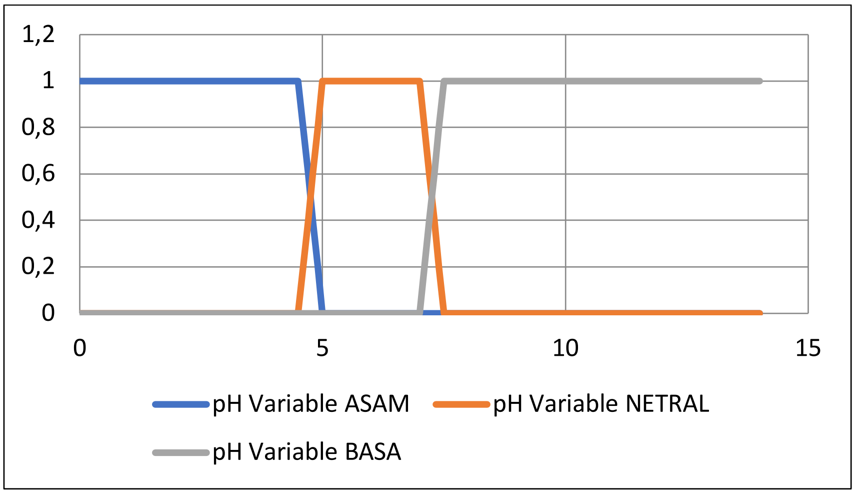

Figure 3. Membership function of pH Variable

$$\mu\text{Acid}(x) = \begin{cases} 1 & ; \ x \leq 5 \\ \frac{(5-x)}{(5-4,5)} & ; \ 4,5 \leq x \leq 5 \\ 0 & ; \ x \geq 18 \end{cases} \quad (3)$$

$$\mu\text{Neutral (x)} = \begin{cases} 0 & ; \ x \leq 4,5 \\ \frac{(x-4,5)}{(5-4,5)} & ; \ 4,5 \leq x \leq 5 \\ 1 & ; \ 5 \leq x \leq 7 \\ \frac{(7,5-x)}{(7,5-7)} & ; \ 7 \leq x \leq 7,5 \\ 0 & ; \ x \geq 7,5 \end{cases} \quad (4)$$

$$\mu\text{Base}(x) = \begin{cases} 0 & ; \ x \leq 7 \\ \frac{(x-7)}{(7,5-7)} & ; \ 7 \leq x \leq 7,5 \\ 1 & ; \ x \geq 7,5 \end{cases} \quad (5)$$

The membership function of the Temperature variable is represented in Figure 4 below:

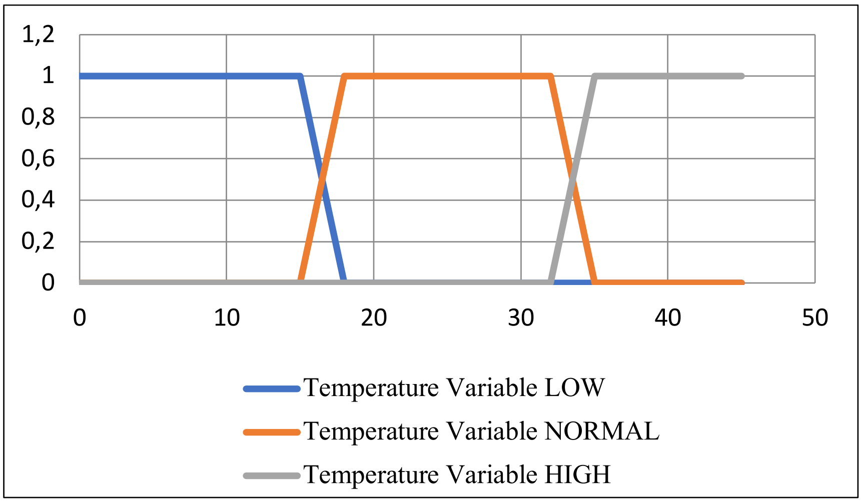

Figure 4. Membership function of Temperature Variable

$$\mu\text{Temperature Low }(x) = \begin{cases} 1 & ; \; x \leq 15 \\ \frac{(18-x)}{(18-15)} & ; \; 15 \leq x \leq 18 \\ 0 & ; \; x \geq 18 \end{cases} \tag{6}$$

$$\mu\text{Temperature Normal (x)} = \begin{cases} 0 & ; \; x \leq 15 \\ \frac{(x-15)}{(18-15)} & ; \; 15 \leq x \leq 18 \\ 1 & ; \; 18 \leq x \leq 32 \\ \frac{(35-x)}{(35-32)} & ; \; 32 \leq x \leq 35 \\ 0 & ; \; x \geq 35 \end{cases} \tag{7}$$

$$\mu\text{Temperature High }(x) = \begin{cases} 0 & ; \; x \leq 15 \\ \frac{(x-32)}{(35-32)} & ; \; 32 \leq x \leq 35 \\ 1 & ; \; x \geq 35 \end{cases} \tag{8}$$

The Membership function of the Moisture variable is represented in Figure 5 below:

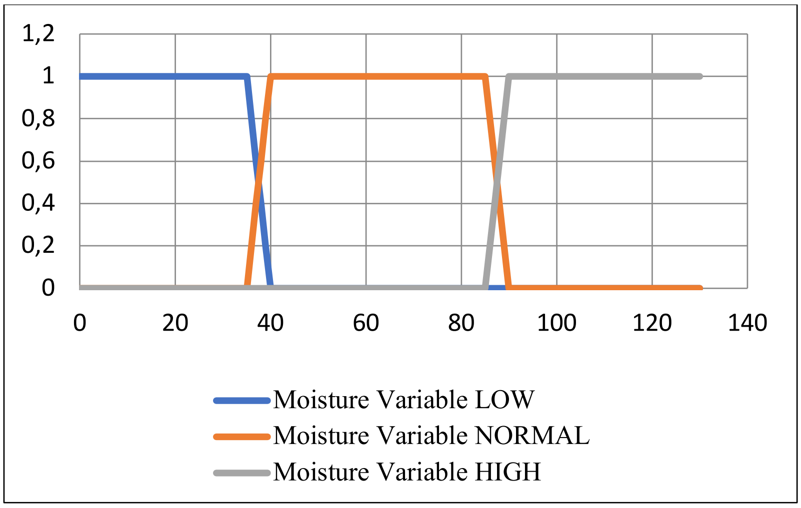

Figure 5. Membership function of Moisture Variable

$$\mu\text{Moisture Low }(x) = \begin{cases} 1 & ; x \leq 35 \\ \frac{(40-x)}{(40-35)} & ; 35 \leq x \leq 40 \\ 0 & ; x \geq 40 \end{cases} \tag{9}$$

$$\mu\text{Moisture Normal (x)} = \begin{cases} 0 & ; x \leq 35 \\ \frac{(x-35)}{(40-35)} & ; 35 \leq x \leq 40 \\ 1 & ; 40 \leq x \leq 85 \\ \frac{(90-x)}{(90-85)} & ; 85 \leq x \leq 90 \\ 0 & ; x \geq 90 \end{cases} \tag{10}$$

$$\mu\text{Moisture High }(x) = \begin{cases} 0 & ; x \leq 85 \\ \frac{(x-85)}{(90-85)} & ; 85 \leq x \leq 90 \\ 1 & ; x \geq 90 \end{cases} \tag{11}$$

b. Rule-Based

Fuzzy Rules were formed from three defined input variables, by analyzing the limit data of each fuzzy set on each variable. Then, 27 rules were formed according to the knowledge base that might be used in this system, with the arrangement of IF rules as follow: IF pH IS … AND Temperature IS … AND Moisture IS ... THEN Plant IS …. The results are presented in Table 5 as follows:

Table 5. Rule Based

pH	Temperature	Humudity	Plant
Acid	Low	Low	Less Good Land
Acid	Low	Normal	Less Good Land
Acid	Low	High	Less Good Land
Base	Low	Low	Less Good Land
Base	Low	Normal	Cucumber
Base	Low	High	Cucumber
Neutral	Low	Low	Less Good Land
Neutral	Low	Normal	Cucumber
Neutral	Low	High	Cucumber
Acid	Normal	Low	Less Good Land
Acid	Normal	Normal	Eggplant
Acid	Normal	High	Less Good Land
Base	Normal	Low	Spinach
Base	Normal	Normal	Spinach, Cayenne Pepper, bean, Cucumber
Base	Normal	High	Cucumber
Neutral	Normal	Low	Spinach
Neutral	Normal	Normal	Spinach, Cayenne Pepper, bean, Long Beans, Cucumber, Eggplant, Tomato
Neutral	Normal	High	Cucumber
Acid	High	Low	Less Good Land
Acid	High	Normal	Less Good Land
Acid	High	High	Less Good Land
Base	High	Low	Spinach
Base	High	Normal	Spinach
Base	High	High	Less Good Land
Neutral	High	Low	Spinach
Neutral	High	Normal	Spinach, Long Beans
Neutral	High	High	Less Good Land

c. Inference Machine

After the rules were made, the next step was to determine the membership value by using the Min implication function based on the fuzzy rules that had been made. Then next, the maximum value from the rule output was taken to obtain a fuzzy set solution, which produced an output.

3.3 Fuzzy Logic Prediction Results on the Tool

Fuzzy Logic that had been modeled was then programmed using Arduino IDE. Thus, the prediction results can be directly displayed on the LCD of the tool.

Figure 6. Results of Crop suitability Prediction

The following are the results of predictions using fuzzy logic carried out on two types of land, namely rice fields and plantations where there are three types of soil, namely alluvial, humus, and podzolic. The test carried out in this study were carried out periodically within three consecutive days at the same hour.

a. Rice Fields (Muddy Ground (Alluvial)), conducted on June 17-19, 2021 at 10.30 am (Indonesian Western Time)

Table 6. The Prediction Result on Muddy Soil (Alluvial)

Ph Sensor	Temperature Sensor	Moisture Sensor (%)	Prediction of Fuzzy Logic	Condition of Actual Data	Suitable/ Unsuitable
5,03	33	163	Cucumber	Rice/ Less Good Land	Unsuitable
5,03	31	164	Cucumber	Rice/ Less Good Land	Unsuitable
4,96	34	150	Less Good Land	Rice/ Less Good Land	Suitable

b. Rice Fields (Humus Soil), conducted on June 17-19, 2021 at 11.30 am (Indonesian Western Time)

Table 7. The Prediction Result of Humus Soil

Ph Sensor	Temperature Sensor	Moisture Sensor (%)	Prediction of Fuzzy Logic	Condition of Actual Data	Suitable/ Unsuitable
5,4	34	84	Spinach and Long Beans	Long Beans	Suitable
5,7	33	77	Spinach, Cayenne Pepper, bean, Long Beans, Cucumber, Eggplant, Tomato	Cayenne Pepper, Long Bean, Eggplant, Tomato	Suitable
5,7	33	80	Spinach, Cayenne Pepper, bean, Long Beans, Cucumber, Eggplant, Tomato	Cayenne Pepper, Long Bean, Eggplant, Tomato	Suitable

c. Plantation Land (Red-Yellow Land (Podzolic), conducted on June 1-3, 2021 at 11 am (Indonesian Western Time)

Table 8. The Prediction Result of Red-Yellow Soil (Podzolic)

Ph Sensor	Temperature Sensor	Moisture Sensor (%)	Prediction of Fuzzy Logic	Condition of Actual Data	Suitable/ Unsuitable
4,61	25	72	Eggplant	Eggplant	Suitable
4,63	29	56	Eggplant	Eggplant	Suitable
7,39	25	40	Spinach, Cayenne Pepper, Bean, Cucumber	Cayenne Pepper	Suitable

$$\text{Accuracy (\%)} = \frac{\textit{Number of Suitable Data}}{\textit{Total of All Data}} \text{ x } 100\%$$
$$= \frac{7}{9} \text{ x } 100\%$$
$$= 77{,}78\%$$

From the results of the calculation above, it can be seen that the accuracy of prediction of crop suitability using fuzzy logic has an accuracy of 77.78, Where the resulting value is quite good. In this study, the data read by the tool will greatly affect the prediction results, so the accuracy of the sensor must always be in good condition.

4. CONCLUSION

From the study that has been done, it can be concluded that fuzzy logic as a method used to predict crop suitability on agricultural land has a fairly good accuracy, which is above 75%. In this study, the output or predictions produced are strongly influenced by the input data from the tool. Thus, good accuracy is needed in the data generated by the sensors used in the tool.

The pH sensor has an error percentage of 11.86%, the DS18B20 sensor of 5.71%, and the YL-69 humidity sensor of a fairly good accurate value. From these results, it can be seen that the result of the percentage error on the pH sensor is quite large. Thus, in its implementation, correct measurements are required in order to produce accurate data.

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