

## MEASURING SOIL FERTILITY LEVELS AND SOIL ACIDITY FOR THE SUITABILITY OF PALM OIL PLANTING IN WEST PASAMAN WITH THE APPLICATION OF THE FUZZY INFERENCE SYSTEM

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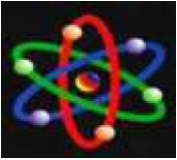
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**Abstract**

In the agricultural sector, land is a factor that plays a very important role in determining agricultural business. Each region has different levels of soil fertility, depending on the type of soil and geographic location of an area. So, soil fertility is one of the determining factors for the success of agricultural businesses. However, there are times when many agricultural businesses fail due to a lack of understanding of the level of soil fertility for certain types of plants. In related research, to determine the suitability of an agricultural area or type of agricultural plant, it can be done by assessing the suitability or suitability of an area for the plants that can grow or live in that area. Soil fertility analysis is assisted using the Matlab application. This system accepts input in the form of land data and regional data. Meanwhile, the output of this system is whether or not oil palm planting is suitable and agricultural land is suitable for oil palm planting. To help overcome this problem, a comparison of the results of the Matlab application was carried out with a manual search in calculating the level of soil fertility for plant types. From the results of this comparison, better accuracy was obtained. One method that can be applied to determine the level of soil fertility for this type of plant is fuzzy logic. The aim of research regarding the application of the fuzzy logic method to soil fertility is to determine the determination of soil fertility parameters using fuzzy logic in order to increase accuracy in selecting plant types. This research aims to create an expert system for detecting soil fertility levels to help people choose the right land according to soil samples from farmers when planting oil palm. It is hoped that the results of this research will provide understanding to farmers in determining the right type of soil to increase the feasibility of planting oil palm. With this system for detecting soil fertility levels, it is hoped that it can improve the economy and increase the number of oil palms

**Keywords:** Fuzzy logic, Matlab, Soil Fertility, Soil Acidity, Palm Oil

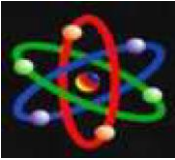


## INTRODUCTION

In the agricultural sector, land is a factor that plays a very important role in determining agricultural business. Each region has a different level of soil fertility and depends on the type of soil and geographic location of an area. Soil fertility is one of the determining factors for the success of agricultural businesses. However, there are times when many agricultural businesses fail or the results are not optimal due to a lack of understanding of the fertility level of their soil for the right type of crop and in accordance with the farmer's own soil samples. Farmers' lack of knowledge and understanding of the different levels of soil fertility for planting the right types of plants makes it difficult for farmers to determine the right types of plants for farmers to plant. To obtain all the necessary knowledge, of course, it takes quite a long time. Fuzzy Logic in the agricultural sector can help farmers make decisions regarding the feasibility of planting oil palm on farmers' agricultural land. Besides that, it can help the process of disseminating information and knowledge through applications that can be accessed at any time by farmers, Fuzzy logic is used in this research to be able to deal with a lot of data whose value contains uncertainty (uncertainty) data entered by farmers from every aspect of the land that has been tested in the laboratory (Ahmad,2017). Soil is a natural place for plants to grow. If it can be used correctly and supported by the size of Indonesia, it will be very beneficial for life. Soil greatly influences the plant growth process. There are many types and kinds of soil in Indonesia, one of which is peat soil. The area of peatlands is only 8% of the total

peatlands in the world which reached 400 million hectares as of February 2016. As much as 60% of peatlands are in Southeast Asia. In Indonesia, there are 11.5 million hectares of peat land. Meanwhile in Malaysia it is around 7 million hectares. Medium, there are many ways for farmers to grow plants. Salah One way is to choose the right land and soil by looking at its acidity. Not all plants are suitable for acidic soil. Land that has a high level of acidity will be difficult for plants to grow well, for example rice, while plants such as pineapple and rambutan really need this acid because each plant needs different nutrients to grow well. For this reason, farmers must be precise in cultivating the land so that it produces satisfactory results. The lack of knowledge and equipment in the community makes it difficult for people to know the level of soil acidity. To determine the acidity level of the soil, you cannot just look at the characteristics or shape of the soil, you must use a tool, namely a Soil Tester, which is plugged directly into the soil. The high cost of this tool means that people cannot afford to buy it. This research aims to determine the acidity of the soil in certain areas to predict the feasibility of planting oil palm. One of the most extensive plantations in Indonesia is oil palm plantations, one of which is West Sumatra, namely the West Pasaman Region. Specifically in the plantation sector, this district is a central area for palm oil plantations, the main producer of the raw material commodity for cooking oil. The total area of oil palm plantations is approximately 102,000 hectares, around 77,000 hectares including nucleus and plasma plantations, while the rest are smallholder plantations. Palm oil





plantations in this area have great potential to be developed because they have empty, unmanaged land. (Warman & Jihadi, 2019).

So it can be seen that most of the people make their living by farming, namely, one of the people is planting oil palm in a limited area, but the people do not pay much attention to soil fertility or soil acidity. So many harvest levels are unsatisfactory. At this time, it is necessary to pay attention to the level of fertility and acidity of the soil in each area where the majority of farming activities are carried out in order to obtain satisfactory harvest results. It is hoped that this attention to soil fertility will have a positive impact in the future, namely the better the quality of the fruit and harvest, so that the price of palm oil will be higher and improve the economy of the people in the area.

### RESEARCH METHODS

This research framework was carried out and implemented in a systematic manner as a guide for researchers in carrying out research so that the results achieved do not deviate from previously established objectives. This research framework is the steps that will be taken in order to solve the problem that will be discussed. The framework for conducting this research is as follows :

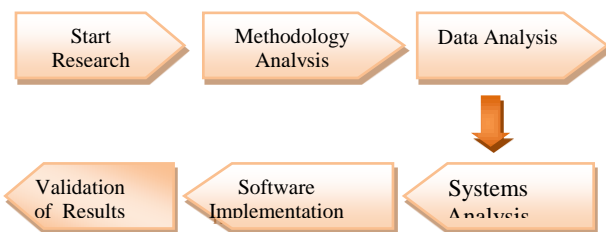


Figure 1. Research Framework

### RESULTS AND DISCUSSION

In processing the data, the data will be grouped into several groups based on the boundaries given from the soil analysis data in West Pasaman. In determining the level of soil fertility and soil acidity for planting oil palm in West Pasaman, there are several factors that need to be examined (Soil Physical and Chemical Properties Analysis). From some of the data that has been collected, analysis will be carried out so that the data will be grouped into fuzzy sets which can be processed using the Tsukamoto fuzzy system.

#### Data Processing and Fuzzy Analysis

This stage begins with determining the input variables that will be used to determine the amount of production as output. As in picture 2:

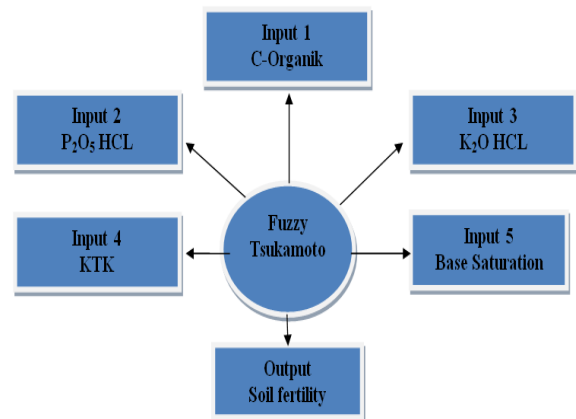
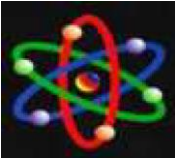


Figure 2. Fuzzy analysis of soil fertility

#### Fuzzyfication

There are several main variables for input and 1 output variable to determine soil fertility that will be used for oil palm suitability. C- Organic input 1, P2O5 HCL





input 2, K<sub>2</sub>O HCL input 3, KTK input 4, KTK input 5, As output, namely Soil Fertility. As seen in table 1:

Function	Variable	Universe of Conversations
Input	C- Organik	1 - 5
	P <sub>2</sub> O <sub>5</sub> HCL	0 - 50
	K <sub>2</sub> O HCL	0 - 70
	KTK	0 - 50
	Base Saturation	0 - 100
Output	pH H <sub>2</sub> O	0 - 10
	Soil fertility	0 - 200

Table 1. Universe of Talk

### 1. Analysis for C-Organic Variables

The C-Organic variable has values expressed in low, medium and high conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 1% to the highest value of 5% ppm and the Agriculture side provides a range of values set from the lowest value of 1% to the highest value of 5%. The fuzzy set for input 1 is show in table 2

Variable	Set Variables	Range
C- Organik	Low	1 - 2
	Medium	2 - 3
	Up	3 - 5

Table 2. Fuzzy Set for Input 1

The fuzzy membership diagram for request input can be seen in Figure 3

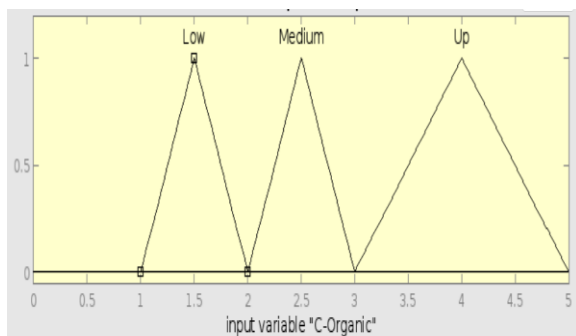


Figure 3. Membership Function Variabel C-Organic

From the fuzzy membership diagram it can be seen that the Low fuzzy set equation is:

$$\mu_{r(\text{Low})} = \begin{cases} 1 & ; 0 \leq a \leq 1 \\ \frac{2-a}{2-1} & \\ 0 & ; a \geq 2 \end{cases}$$

Set equation fuzzy

Medium:

$$\mu_{r(\text{Medium})} = \begin{cases} \frac{a-2}{3-2} & ; 1; 2 \leq a \leq 3 \\ \frac{3-a}{3-2} & ; 2 \leq a \leq 5 \\ 0 & ; a \leq 2 \text{ or } a \geq 5 \end{cases}$$

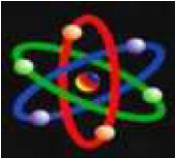
Set equation fuzzy Up :

$$\mu_{r(\text{Up})} = \begin{cases} 0 & ; a \leq 2 \\ \frac{5-a}{5-3} & \\ 1 & ; a 3 \leq a \leq 5 \end{cases}$$

### 2. Analysis for Variables P<sub>2</sub>O<sub>5</sub> HCL

The variable P<sub>2</sub>O<sub>5</sub> HCL has a value that is expressed in low, medium and high conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 4 ppm to the highest value of 20 ppm and the Agriculture side provides a range of values set from the lowest value of 1 ppm to the highest value of 15 ppm.





The fuzzy set for input 2 is shown in table 3.

Variabel	Set Variables	Range
P <sub>2</sub> O <sub>5</sub> HCL	Low	2 - 7
	Medium	7 - 10
	Up	10 - 15

Table 3. Fuzzy Set for Input 2

The fuzzy membership diagram for request input can be seen in Figure 4.

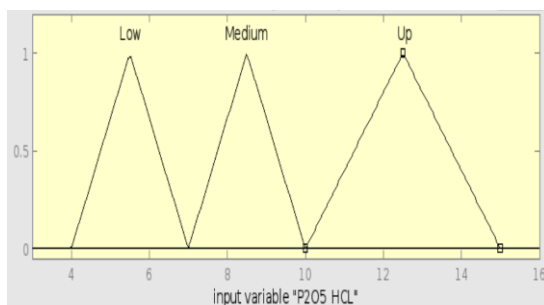


Figure 4. Membership Function Variabel P<sub>2</sub>O<sub>5</sub> HCL

From the fuzzy membership diagram, it can be seen that the Downward fuzzy set equation is:

$$\mu_r(\text{Low}) = \begin{cases} 1 & ; 2 \leq a \leq 6 \\ \frac{7-a}{7-2} & ; 6 < a < 7 \\ 0 & ; a \geq 7 \end{cases}$$

Set equation fuzzy Medium :

$$\mu_r(\text{Medium}) = \begin{cases} \frac{a-7}{10-7} & ; 7 \leq a \leq 8.5 \\ \frac{10-a}{10-7} & ; 8.5 < a < 10 \\ 0 & ; a \leq 7 \text{ or } a \geq 10 \end{cases}$$

Set equation fuzzy Up :

$$\mu_r(\text{Up}) = \begin{cases} 0 & ; a \leq 10 \\ \frac{15-a}{15-10} & ; 10 < a < 15 \\ 1 & ; a \geq 15 \end{cases}$$

### 3. Analysis for the K<sub>2</sub>O HCL Variable

The K<sub>2</sub>O HCL variable has values expressed in low, medium and high conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 10 ppm to the highest value of 60 ppm and the Agriculture side provides a range of values set from the lowest value of 10 ppm to the highest value of 60 ppm. The fuzzy set for input 3 is show in table 4.

Variabel	Set Variables	Range
K <sub>2</sub> O HCL	Low	1 – 20
	Medium	21 – 40
	Up	41 – 60

Table 4. Fuzzy Set for Input

The fuzzy membership diagram for request input can be seen in Figure 5

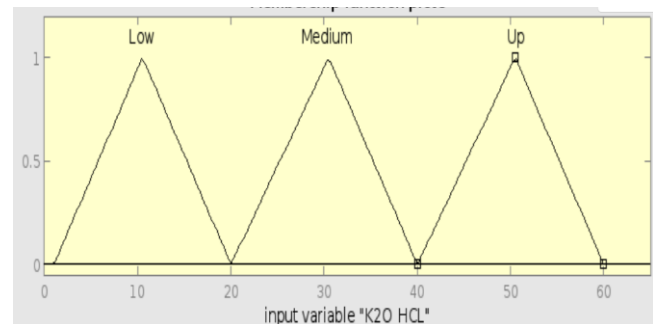
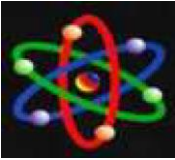


Figure 5. Membership Function Variabel K<sub>2</sub>O HCL

From the fuzzy membership diagram, it can be seen that the Downward fuzzy set equation is:

$$\mu_r(\text{Low}) = \begin{cases} 1 & ; 0 \leq a \leq 10 \\ \frac{20-a}{20-1} & ; 10 < a < 20 \\ 0 & ; a \geq 20 \end{cases}$$





Fuzzy set equations

Medium :

$$\mu_r(\text{Medium}) = \begin{cases} \frac{a-20}{40-20}; & 1; 20 \leq a \leq 40 \\ \frac{40-a}{40-20}; & 20 \leq a \leq 60 \\ 0; & a \leq 20 \text{ or } a \geq 40 \end{cases}$$

Set equation fuzzy Up :

$$\mu_r(\text{Up}) = \begin{cases} 0; & a \leq 40 \\ \frac{60-a}{60-40}; & 40 \leq a \leq 60 \\ 1; & a \geq 60 \end{cases}$$

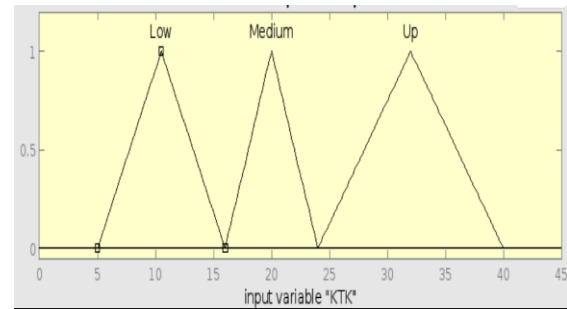
#### 4. Analysis for the KTK Variable

The KTK variable has values expressed in low, medium and high conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 5 (me/100g) to the highest value of 40 (me/100g) and the Agriculture side provides a range of values set from the lowest value of 5 (me/100g) to the highest value of 40 (me/100g). 100g). The fuzzy set for input 4 is shown in table 5.

Variabel	Set Variables	Range
KTK	Low	5 – 16
	Medium	17 – 24
	Up	25 – 40

**Table 5. Himpunan Fuzzy Untuk Input 4**

The fuzzy membership diagram for request input can be seen in Figure 6



**Figure 6 Membership Function Variabel KTK**

From the fuzzy membership diagram it can be seen that the Low fuzzy set equation is:

$$\mu_r(\text{Low}) = \begin{cases} 1; & 0 \leq a \leq 5 \\ \frac{16-a}{16-5}; & 5 \leq a \leq 16 \\ 0; & a \geq 16 \end{cases}$$

Fuzzy set equations

Medium :

$$\mu_r(\text{Medium}) = \begin{cases} \frac{a-16}{24-16}; & 1; 16 \leq a \leq 24 \\ \frac{24-a}{24-16}; & 24 \leq a \leq 40 \\ 0; & a \leq 16 \text{ or } a \geq 40 \end{cases}$$

Up fuzzy set equation:

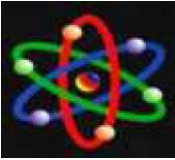
$$\mu_r(\text{Up}) = \begin{cases} 0; & a \leq 24 \\ \frac{40-a}{40-24}; & 24 \leq a \leq 40 \\ 1; & a \geq 40 \end{cases}$$

#### 5. Analysis for the Base Saturation Variable

The Base Saturation variable has values expressed in low, medium and high conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 10% to the highest value of 60% and the Agriculture side provides a range of values set from the lowest value of 10% to the highest







value of 60%. The fuzzy set for input 5 is shown in table 6

Variabel	Set Variables	Range
Base	Low	10 – 20
Saturation	Medium	20- 30
	Up	30 – 60

Table 6. Fuzzy Set for Input 5

The fuzzy membership diagram for request input can be seen in Figure 7.

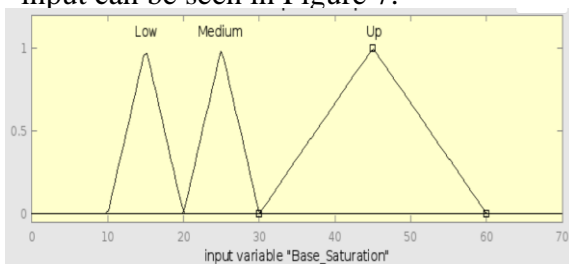


Figure 7. Membership Function Base Saturation Variable

From the fuzzy membership diagram, it can be seen that the Downward fuzzy set equation is:

$$\mu_r(\text{Low}) = \begin{cases} 1 & ; 0 \leq a \leq 10 \\ \frac{20 - a}{20 - 10} & \\ 0 & ; a \geq 20 \end{cases}$$

Fuzzy set equations

Medium :

$$\mu_r(\text{Medium}) = \begin{cases} \frac{a - 20}{30 - 20}; & 1; 20 \leq a \leq 30 \\ \frac{30 - a}{30 - 20}; & 20 \leq a \leq 60 \\ 0; & a \leq 20 \text{ or } a \geq 30 \end{cases}$$

Up fuzzy set equation:

$$\mu_r(\text{Up}) = \begin{cases} 0 & ; a \leq 30 \\ \frac{60 - a}{60 - 30}; & \\ 1 & ; a 30 \leq a \leq 60 \end{cases}$$

## 6. Analysis for the pH H<sub>2</sub>O Variable

The pH H<sub>2</sub>O variable has values expressed in low, medium and high

conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 4.5 to the highest value of 8.5 and Agriculture provides a range of values set from the lowest value of 4.5 to the highest value of 8.5.

The fuzzy set for input 6 is shown in table 7.

Variable	Set Variables	Range
pH H <sub>2</sub> O	Sour	4.5 – 5.5
	Medium	5.6 – 6.5
	Neutral	6.6 – 7.5
	Alkalis	7.6 – 8.5

Table 7. Fuzzy Sets for Input 6

The fuzzy membership diagram for request input can be seen in Figure 8.

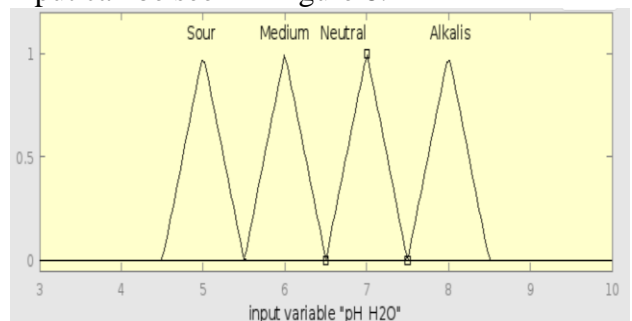


Figure 8. Membership Function Variabel pH H<sub>2</sub>O

From the fuzzy membership diagram it can be seen the equation of the Sour fuzzy set:

$$\mu_r(\text{Sour}) = \begin{cases} 1 & ; 0 \leq a \leq 4.5 \\ \frac{5.5 - a}{5.5 - 4.5}; & \\ 0 & ; a \geq 5.5 \end{cases}$$

Fuzzy set equations;

Medium :

$$\begin{cases} \frac{a - 5.5}{6.5 - 5.5}; & 1; 5.5 \leq a \leq 6.5 \\ \end{cases}$$





$$\mu_r(\text{Medium}) = \begin{cases} \frac{6.5 - a}{6.5 - 5.5} & 5.5 \leq a \leq 7.5 \\ 0 & a \leq 5.5 \text{ or } a \geq 6.5 \end{cases}$$

Neutral fuzzy set equation:

$$\mu_r(\text{Neutral}) = \begin{cases} 0 & a \leq 6.5 \\ \frac{7.5 - a}{7.5 - 6.5} & 6.5 < a < 7.5 \\ 1 & a \geq 7.5 \end{cases}$$

Alkalis fuzzy set equation:

$$\mu_r(\text{Alkalis}) = \begin{cases} 0 & a \leq 7.5 \\ \frac{8.5 - a}{8.5 - 7.5} & 7.5 < a < 8.5 \\ 1 & a \geq 8.5 \end{cases}$$

## 7. Analysis for Soil Fertility Variables

The Soil Fertility variable has values expressed in low, medium and high conditions. Where each condition has a predetermined value range from the agricultural side. The range of values set is from the lowest value of 10 to the highest value of 100 and Agriculture provides a range of values set from the lowest value of 10 to the highest value of 100. The fuzzy set for input 7 is shown in table 8.

Variable	Set Variables	Range
Soil fertility	Low	10 – 40
	Medium	40- 70
	High	70 - 100

Table 8. Fuzzy Sets for Output

Fuzzy membership diagram for Soil Fertility input can be seen in and picture 9.

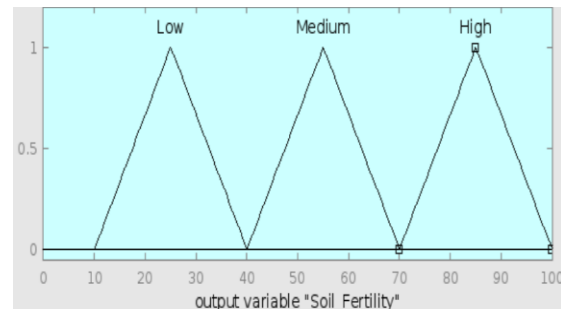


Figure 9. Membership Function Soil Fertility Variable

From the fuzzy membership diagram, it can be seen that the Downward fuzzy set equation is:

$$\mu_r(\text{Low}) = \begin{cases} 1 & 0 \leq a \leq 10 \\ \frac{40 - a}{40 - 10} & 10 < a < 40 \\ 0 & a \geq 40 \end{cases}$$

Fuzzy set equations

Medium :

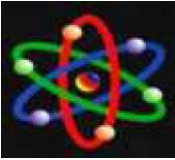
$$\mu_r(\text{Medium}) = \begin{cases} \frac{a - 40}{70 - 40} & 40 \leq a \leq 70 \\ \frac{70 - a}{70 - 40} & 70 < a < 100 \\ 0 & a \leq 40 \text{ atau } a \geq 100 \end{cases}$$

High fuzzy set equation:

$$\mu_r(\text{High}) = \begin{cases} 0 & a \leq 70 \\ \frac{100 - a}{100 - 70} & 70 < a < 100 \\ 1 & a \geq 100 \end{cases}$$







The fuzzyfication image using Matlab can be seen in Figure 10 below:

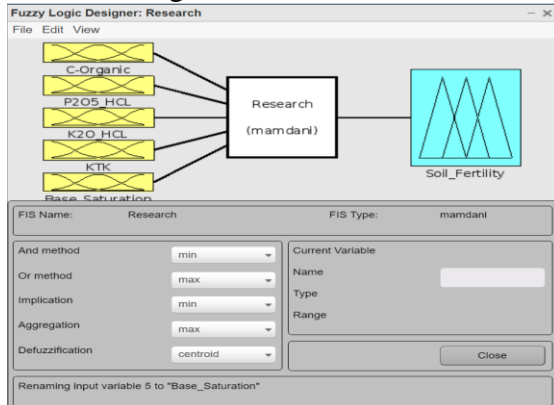


Figure 10. fuzzyfication with Matlab

## Fuzzy Mamdani Calculation Process

### a. Soil fertility

The amount that will be examined next is C-organic (%) as much as 0.81, total pH of H<sub>2</sub>O as much as 5.38, P<sub>2</sub>O<sub>5</sub> (ppm) as much as 2.32, KTK as much as 8.5, K<sub>2</sub>O (ppm) as much as 50, Base Saturation (%) as much as 50, then the soil fertility level will be found using the Fuzzy Mamdani calculation process. The calculation process will be explained below;

#### 1. Fuzzyfication

There are 3 fuzzy variables modeled:

- a. C- Organic consists of Low, Medium and Up

$$\mu_{\text{Low}}[1.74] = (2 - 1.74) / (2 - 1) = 0.26 / 1 = 0.26$$

$$\mu_{\text{Medium}}[1.74] = \text{Not in Range}$$

$$\mu_{\text{Up}}[1.74] = \text{Not in Range}$$

- b. P<sub>2</sub>O<sub>5</sub> HCL consists of Low, Medium and Up

$$\mu_{\text{Low}}[2.32] = (7 - 2.32) / (7 - 2)$$

$$= 4,62/5 = 0,9$$

$$\mu_{\text{Medium}}[2.32] = \text{Not in Range}$$

$$\mu_{\text{Up}}[2.32] = \text{Not in Range}$$

- c. K<sub>2</sub>O HCL consists of Low, Medium and Up

$$\mu_{\text{Low}}[50] = \text{Not in Range}$$

$$\mu_{\text{Medium}}[50] = \text{Not in Range}$$

$$\mu_{\text{Up}}[50] = (60 - 50) / (60 - 40) = 10/20 = 0.5$$

- d. KTK consists of Low, Medium and Up

$$\mu_{\text{Low}}[8.5] = (16 - 8.5) / (16 - 5)$$

$$= 7,5 / 11 = 0,68$$

$$\mu_{\text{Medium}}[8.5] = \text{Not in Range}$$

$$\mu_{\text{Up}}[8.5] = \text{Not in Range}$$

- d. Base Saturation consists of Lower, Medium and Increase

$$\mu_{\text{Down}}[50] = \text{Not in Range}$$

$$\mu_{\text{Medium}}[50] = \text{Not in Range}$$

$$\mu_{\text{Up}}[50] = (60 - 50) / (60 - 30) = 10 / 30 = 0,33$$

- f. The pH of H<sub>2</sub>O consists of Acid, Medium, Neutral, Alkaline

$$\mu_{\text{Sour}}[5.38] = (5.5 - 5.38) / (5.5 - 4.5) = 0.12 / 1 = 0,12$$

$$\mu_{\text{Medium}}[5.38] = \text{Not in Range}$$

$$\mu_{\text{Netral}}[5.38] = \text{Not in Range}$$

$$\mu_{\text{Alkalis}}[5.38] = \text{Not in Range}$$

#### 2. Rule

At this stage, the formation of fuzzy rules is formed from two input variables and one output variable, by analyzing data on the boundaries of each fuzzy set of input and output variables. So it is obtained that there are 9 fuzzy rules that are used, using the following rules:





No	C-Organik	Variable				Output Soil fertility
		P <sub>2</sub> O <sub>5</sub> HCL	Input K <sub>2</sub> O HCL	KTK	Basa	
1	Up	Up	Sedang	Medium	Up	Height
2	Up	Up	Low	Low	Up	Medium
3	Medium	Medium	Up	Up	Up	Height
4	Medium	Medium	Low	Low	Up	Medium
5	Up	Medium	Low	Low	Up	Medium
6	Low	Down	Up	Up	Up	Medium
7	Low	Down	Up	Up	Up	Low
8	Up	Up	Up	Up	Medium	Height
9	Up	Up	Low	Low	Medium	Medium
10	Medium	Medium	Up	Up	Medium	Medium
11	Low	Medium	Up	Up	Medium	Low
12	Up	Up	Up	Up	Down	Medium
13	Up	Up	Low	Low	Down	Low
14	Medium	Medium	Sedang	Medium	Down	Low
15	Up	Up	Low	Low	Up	Medium
16	Medium	Medium	Low	Low	Up	Medium
17	Medium	Down	Up	Up	Up	Low
18	Up	Up	Sedang	Medium	Medium	Medium
19	Medium	Medium	Low	Low	Medium	Medium
20	Low	Medium	Up	Up	Medium	Low
21	Up	Up	Up	Up	Down	Medium
22	Medium	Down	Low	Low	Down	Low
23	Up	Up	Up	Up	Up	Medium
24	Medium	Medium	Low	Low	Up	Low
25	Up	Up	Up	Up	Up	Medium
26	Medium	Up	Up	Up	Up	Low
27	Up	Up	Up	Up	Medium	Medium
28	Low	Down	Sedang	Medium	Medium	Low
29	Up	Down	Low	Low	Down	Low
30	Low	Down	Low	Low	Down	Low

Table 9. Rule Fuzzy

### 3. Inference Engine (Min Function)

[R1] = IF C-Organic Up And P2O5 Up And K2O Medium And KTK Up And Base Saturation Up THEN High Soil Fertility

$$\alpha-p_1 = \min(\text{Not in range; Not in range, Not in range, Not in range, 0.33}) = 0,33$$

[R2] = IF C-Organic Up And P2O5 Up And K2O Low And KTK Up And Base Saturation Up THEN Soil Fertility IS MEDIUM

$$\alpha-p_2 = \min(\text{Not in range; Not in range, Not in range, Not in range, 0.33}) = 0,33$$

[R3]= IF C-organic is medium and P2O5 is medium and K2O is high and KTK Up and base saturation Up THEN soil fertility is HIGH

$$\alpha-p_3 = \min(\text{Not in range; Not in range, 0.5, Not in range, 0.33}) = 0,33$$

[R4] = IF C-Organic Medium And P2O5

Medium And K2O Low And KTK Up

And Base Saturation Up THEN Soil

Fertility MEDIUM

$$\alpha-p_4 = \min(\text{Not in range; Not in range, Not in range, Not in range, 0.33}) = 0,33$$

[R5] = IF C-Organic Up And P2O5 Is Medium And K2O Is Decreased And KTK Is Increase And Base Saturation Is Increase THEN Soil Fertility IS MEDIUM

$$\alpha-p_5 = \min(\text{Not in range; Not in range, Not in range, Not in range, 0.33}) = 0,33$$

[R6] = IF C-Organic is low and P2O5 is down and K2O is up and KTK is up and base saturation is up THEN Soil fertility is MEDIUM

$$\alpha-p_6 = \min(0.26; 0.9, 0.5, \text{Not in range, 0.33}) = 0.26$$

[R7] = C-Organic IF is low and P2O5 is down and K2O is up and KTK is up and base saturation is up THEN soil fertility is low

$$\alpha-p_7 = \min(0.26; 0.9, 0.5, \text{Not in range, 0.33}) = 0.26$$

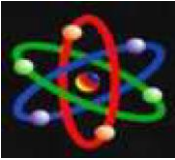
[R8] = IF C-Organic Up And P2O5 Low And K2O Up And KTK Up And Base Saturation Is Medium THEN Soil Fertility Is High

$$\alpha-p_8 = \min(\text{Not in range; 0.9, 0.5, Not in range, Not in range}) = 0.5$$

[R9] = IF C-Organic Up And P2O5 Up And K2O Low And KTK Up And Base Saturation Is Moderate THEN Soil Fertility IS MEDIUM

$$\alpha-p_9 = \min(\text{Not in range; Not in range, Not in range, Not in range, Not in range}) = 0$$





[R10] = IF C-Organic Medium And P2O5 Medium And K2O Increase And KTK Medium And Base Saturation Medium THEN Soil Fertility MODERATE

$$\alpha\text{-predicate1} = \min(\text{Not in range; Not in range, 0.5, Not in range, Not in range}) = 0.5$$

[R11] = IF C-Organic is Low and P2O5 is Medium and K2O is Increased and KTK is Increased and Base Saturation is Medium THEN Soil Fertility is LOW

$$\alpha\text{-p}_{11} = \min(0.26; \text{Not in range, 0.5, Not in range, Not in range}) = 0.26$$

[R12] = IF C-Organic Up And P2O5 Up And K2O Many And KTK Up And Base Saturation Low THEN Soil Fertility Is Moderate

$$\alpha\text{-p}_{12} = \min(\text{Not in range; Not in range, 0.5, Not in range, Not in range}) = 0.5$$

[R13] = IF C-Organic Up And P2O5 Up And K2O Low And KTK Up And Base Saturation Low THEN Soil Fertility LOW

$$\alpha\text{-p}_{13} = \min(\text{Not in range; Not in range, Not in range, Not in range, Not in range}) = 0$$

[R14] = IF C-Organic Medium And P2O5 Medium And K2O Medium And KTK Increase And Base Saturation Low THEN Soil Fertility LOW

$$\alpha\text{-p}_{14} = \min(\text{Not in range; Not in range, Not in range, Not in range, Not in range}) = 0$$

[R15] = IF C-Organic Up And P2O5 Up And K2O Low And KTK Is Moderate And Base Saturation Up THEN Soil Fertility IS MEDIUM

$$\alpha\text{-p}_{15} = \min(\text{Not in range; Not in range, Not in range, Not in range, 0.33}) = 0.33$$

[R16] = IF C-Organic Medium And P2O5 Medium And K2O A lot And KTK Up And Base Saturation Low THEN Soil Fertility MEDIUM

$$\alpha\text{-p}_{16} = \min(\text{Not in range; Not in range, 0.5, Not in range, Not in range}) = 0.5$$

[R17] = IF C-Organic Medium And P2O5 Low And K2O Up And KTK Medium And Base Saturation Up THEN Soil Fertility Is Low

$$\alpha\text{-p}_{18} = \min(\text{Not in range; Not in range, 0.5, Not in range, Not in range}) = 0.5$$

[R18] = IF C-Organic Up And P2O5 Up And K2O Medium And KTK Medium And Base Saturation Medium THEN Soil Fertility MODERATE

$$\alpha\text{-p}_{18} = \min(\text{Not in range; Not in range, 0.5, Not in range, Not in range}) = 0.5$$

[R19] = IF C-Organic Moderate And P2O5 Medium And K2O Down And KTK Medium And Base Saturation Medium THEN Soil Fertility Moderate

$$\alpha\text{-p}_{19} = \min(\text{Not in range; Not in range, Not in range, Not in range, Not in range}) = 0$$

[R20] = IF C-Organic is Low And P2O5 Is Medium And K2O Is Rising And KTK Is Medium And Base Saturation Is Medium THEN Soil Fertility Is LOW

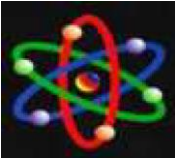
$$\alpha\text{-p}_{20} = \min(0.26; \text{Not in range, 0.5, Not in range, Not in range}) = 0.26$$

[R21] = IF C-Organic Up And P2O5 Up And K2O Up And KTK Is Moderate And Base Saturation Low THEN Soil Fertility IS MEDIUM

$$\alpha\text{-p}_{21} = \min(\text{Not in range; Not in range, 0.5, Not in range, Not in range}) = 0.5$$

[R22] = IF C-Organic Medium And P2O5 Down And K2O Down And KTK





Moderate And Alkaline Saturation  
Down THEN Low Soil Fertility  
 $\alpha_{p_{22}} = \min(\text{Not in range; } 0.9, \text{ Not in Range, Not in range, Not in range}) = 0.9$

[R23] = IF C-Organic Up And P2O5 Up And K2O Up And KTK Low And Base Saturation Up THEN Soil Fertility IS MEDIUM  
 $\alpha_{p_{23}} = \min(\text{Not in range; , Not in Range, } 0.5, 0.68, \text{ Not in range}) = 0.5$

[R24] = IF C-Organic Medium And P2O5 Medium And K2O Decreased And KTK Decreased And Base Saturation Increased THEN Soil Fertility LOW  
 $\alpha_{p_{24}} = \min(\text{Not in range; , Not in Range, Not in Range, } 0.68, 0.33) = 0.33$

[R25] = IF C-Organic Up And P2O5 Up And K2O Up And KTK Low And Base Saturation Up THEN Soil Fertility IS MEDIUM  
 $\alpha_{p_{25}} = \min(\text{Not in range; , Not in Range, } 0.5, 0.68, 0.33) = 0.33$

[R26] = IF C-Organic Medium And P2O5 Up And K2O Up And KTK Low And Base Saturation Up THEN Soil Fertility is LOW  
 $\alpha_{p_{26}} = \min(\text{Not in range, Not in Range, } 0.5, 0.68, 0.33) = 0.33$

[R27] = IF C-Organic Up And P2O5 Up And K2O Up And KTK Low And Base Saturation Is Moderate THEN Soil Fertility IS MEDIUM  
 $\alpha_{p_{28}} = \min(\text{Not in range; , Not in Range, } 0.5, 0.68, \text{ Not in Range}) = 0.35$

[R28] = IF C-Organic Low And P2O5 Low And K2O Medium And KTK Low And Base Saturation Medium THEN Soil Fertility LOW  
 $\alpha_{p_{28}} = \min(0.26, 0.9, 1.5, 0.68, \text{ Not in range}) = 0.26$

[R29] = IF C-Organic Up And P2O5 Low And K2O Low And KTK Low And Alkaline Saturation Low THEN Low Soil Fertility

$\alpha_{p_{29}} = \min(\text{Not in range, } 0.9, \text{ Not in range, } 0.68, \text{ Not in range}) = 0.68$

[R30] = IF C-Organic Low And P2O5 Down And K2O Down And KTK Down And Alkaline Saturation Down THEN Soil Fertility LOW

$\alpha_{p_{30}} = \text{mean}(0.26; , 0.9, \text{ Not in range, } 0.68, \text{ Not in range}) = 0.26$

### Defuzzifikasi

The final step in this process is defuzzification or also called the confirmation stage. The method used is the centroid method. The following converts fuzzy sets into real numbers:

[Rule 01]  $\mu$  Soil fertility High (x) = 0.33, then the value of x is;

$$\begin{aligned} \text{Soil Fertility (High)} &= 100 - a / 100 - 70 = 0.33 \\ &= (100 - (0.33 \times 30)) \\ &= 100 - 9.9 = 90.1 \end{aligned}$$

[Rule 02]  $\mu$  Medium Soil Fertility (x) = 0.33, then the value of x is;

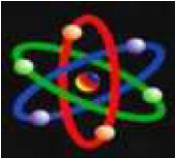
$$\begin{aligned} \text{Soil Fertility (Medium)} &= (a - 40) / 70 - 40 = 0.33 \\ &= (d - 40) / 30 = 0.33 \\ &= (0.33 \times 30) + 40 \\ &= 9.9 + 40 = 49.9 \end{aligned}$$

[Rule 03]  $\mu$  Soil fertility High (x) = 0.33, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (High)} &= 100 - a / 100 - 70 = 0.33 \\ &= (100 - (0.33 \times 30)) \\ &= 100 - 9.9 = 90.1 \end{aligned}$$

[Rule 04]  $\mu$  Soil Fertility Medium (x) = 0.33, then the value of x is;





$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,33 \\ &= (d - 40) / 30 = 0,33 \\ &= (0,33 \times 30) + 40 \\ &= 9.9 + 40 = 49.9\end{aligned}$$

[Rule 05]  $\mu$ Soil Fertility Medium (x) = 0.33, then the value of x is ;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,33 \\ &= (d - 40) / 30 = 0,33 \\ &= (0,33 \times 30) + 40 \\ &= 9.9 + 40 = 49.9\end{aligned}$$

[Rule 06]  $\mu$ Soil Fertility Medium (x) = 0.26, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,26 \\ &= (d - 40) / 30 = 0,26 \\ &= (0,26 \times 30) + 40 \\ &= 7.8 + 40 = 47.8\end{aligned}$$

[Rule 07]  $\mu$  Soil Fertility Low(x) = 0.26, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Low)} & \\ &= 40 - a / 40 - 10 = 0.26 \\ &= (40 - (0,26 \times 30)) \\ &= 40 - 7.8 = 32.2\end{aligned}$$

[Rule 08]  $\mu$  Soil Fertility High(x) = 0.5, then the value of x is ;

$$\begin{aligned}\text{Soil Fertility (High)} & \\ &= 100 - a / 100 - 70 = 0.5 \\ &= (100 - (0,5 \times 30)) \\ &= 100 - 15 = 85\end{aligned}$$

[Rule 09]  $\mu$ Soil Fertility Medium (x) = 0, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0 \\ &= (d - 40) / 30 = 0 \\ &= (0 \times 30) + 40 = 40\end{aligned}$$

[Rule 10]  $\mu$ Soil Fertility Medium (x) = 0.5, then the value of x is ;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,5\end{aligned}$$

$$\begin{aligned}&= (d - 40) / 30 = 0,5 \\ &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55\end{aligned}$$

[Rule 11]  $\mu$  Soil Fertility Low(x) = 0.26, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Low)} & \\ &= 40 - a / 40 - 10 = 0.26 \\ &= (40 - (0,26 \times 30)) \\ &= 40 - 7.8 = 32.2\end{aligned}$$

[Rule 12]  $\mu$ Soil Fertility Medium (x) = 0.5, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,5 \\ &= (d - 40) / 30 = 0,5 \\ &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55\end{aligned}$$

[Rule 13]  $\mu$ Soil Fertility Low(x) = 0,0, then the value of x is ;

$$\begin{aligned}\text{Soil Fertility (Low)} &= 40 - a / 40 - 10 = 0 \\ &= (40 - (0 \times 30)) = 40\end{aligned}$$

[Rule 14]  $\mu$ Soil Fertility Low (x) = 0,0, then the value of x is ;

$$\begin{aligned}\text{Soil Fertility (Low)} & \\ &= 40 - a / 40 - 10 = 0 \\ &= (40 - (0 \times 30)) = 40\end{aligned}$$

[Rule 15]  $\mu$ Soil Fertility Medium (x) = 0.33, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,33 \\ &= (d - 40) / 30 = 0,33 \\ &= (0,33 \times 30) + 40 \\ &= 9.9 + 40 = 49.9\end{aligned}$$

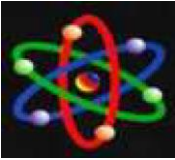
[Rule 16]  $\mu$ Soil Fertility Medium (x) = 0.5, then the value of x is;

$$\begin{aligned}\text{Soil Fertility (Medium)} & \\ &= (a - 40) / 70 - 40 = 0,5 \\ &= (d - 40) / 30 = 0,5 \\ &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55\end{aligned}$$

[Rule 17]  $\mu$ Soil Fertility Low (x) = 0.5, then the value of x is;

$$\text{Soil Fertility (Low)}$$





$$\begin{aligned} &= 40 - a / 40 - 10 = 0.5 \\ &= (40 - (0.5 \times 30)) \\ &= 40 - 15 = 25 \end{aligned}$$

[Rule 18]  $\mu$ Soil Fertility Medium (x) = 0.5, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (Medium)} \\ &= (a - 40) / 70 - 40 = 0,5 \\ &= (d - 40) / 30 = 0,5 \\ &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55 \end{aligned}$$

[Rule 19]  $\mu$ Soil Fertility Medium (x) = 0, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (Medium)} \\ &= (a - 40) / 70 - 40 = 0 \\ &= (d - 40) / 30 = 0 \\ &= (0 \times 30) + 40 = 40 \end{aligned}$$

[Rule 20]  $\mu$ Soil Fertility Low (x) = 0.26, then the value of x is;

$$\begin{aligned} \text{Soil Fertility (Low)} \\ &= 40 - a / 40 - 10 = 0.26 \\ &= (40 - (0.26 \times 30)) \\ &= 40 - 7.8 = 32.2 \end{aligned}$$

[Rule 21]  $\mu$ Soil Fertility Medium(x) = 0.5, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (Medium)} \\ &= (a - 40) / 70 - 40 = 0,5 \\ &= (d - 40) / 30 = 0,5 \\ &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55 \end{aligned}$$

[Rule 22]  $\mu$ Soil Fertility Low (x) = 0.9, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (Low)} \\ &= 40 - a / 40 - 10 = 0.9 \\ &= (40 - (0.9 \times 30)) \\ &= 40 - 27 = 13 \end{aligned}$$

[Rule 23]  $\mu$ Soil Fertility Medium (x) = 0.5, then the value of x is;

$$\begin{aligned} \text{Soil Fertility (Medium)} \\ &= (a - 40) / 70 - 40 = 0,5 \\ &= (d - 40) / 30 = 0,5 \end{aligned}$$

$$\begin{aligned} &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55 \end{aligned}$$

[Rule 24]  $\mu$ Soil Fertility Low (x) = 0.33, then the value of x is;

$$\begin{aligned} \text{Soil Fertility (Low)} \\ &= 40 - a / 40 - 10 = 0.33 \\ &= (40 - (0.33 \times 30)) \\ &= 40 - 9.9 = 30.1 \end{aligned}$$

[Rule 25]  $\mu$ Soil Fertility Medium(x) = 0.33, then the value of x is;

$$\begin{aligned} \text{Soil Fertility (Medium)} \\ &= (a - 40) / 70 - 40 = 0,33 \\ &= (a - 40) / 30 = 0,33 \\ &= (0,33 \times 30) + 40 \\ &= 9.9 + 40 = 49.9 \end{aligned}$$

[Rule 26]  $\mu$ Soil Fertility Low (x) = 0.33, then the value of x is;

$$\begin{aligned} \text{Soil Fertility (Low)} \\ &= 40 - a / 40 - 10 = 0.33 \\ &= (40 - (0.33 \times 30)) \\ &= 40 - 9.9 = 30.1 \end{aligned}$$

[Rule 27]  $\mu$ Soil Fertility Medium (x) = 0.5, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (Medium)} \\ &= (a - 40) / 70 - 40 = 0,5 \\ &= (a - 40) / 30 = 0,5 \\ &= (0,5 \times 30) + 40 \\ &= 15 + 40 = 55 \end{aligned}$$

[Rule 28]  $\mu$ Soil Fertility Low (x) = 0.26, then the value of x is;

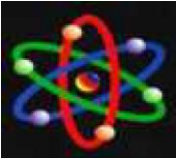
$$\begin{aligned} \text{Soil Fertility (Low)} \\ &= 40 - a / 40 - 10 = 0.26 \\ &= (40 - (0.26 \times 30)) \\ &= 40 - 7.8 = 32.2 \end{aligned}$$

[Rule 29]  $\mu$ Soil Fertility Low (x) = 0.68, then the value of x is ;

$$\begin{aligned} \text{Soil Fertility (Low)} \\ &= 40 - a / 40 - 10 = 0.68 \\ &= (40 - (0.68 \times 30)) \\ &= 40 - 20.4 = 19.6 \end{aligned}$$







[Rule 30]  $\mu_{\text{Soil Fertility Low}}(x) = 0.26$ , then the value of  $x$  is ;

$$\begin{aligned} \text{Soil Fertility (Low)} &= 40 - a / 40 - 10 = 0.26 \\ &= (40 - (0.26 \times 30)) \\ &= 40 - 7.8 = 32.2 \end{aligned}$$

So, by using the fuzzy weighted average method, the soil fertility level values obtained are:

$$\begin{aligned} Z1 &= (0,33 \times 90.1) + (0,33 \times 49.9) + (0,26 \times 90.1) \\ &+ (0,33 \times 49.9) + (0,33 \times 49.9) + (0,26 \times 47.8) + \\ &+ (0,26 \times 32.2) + (0,5 \times 85) + (0 \times 40) + (0,5 \times 55) + (0,26 \times 32.2) + \\ &+ (0,5 \times 55) + (0 \times 40) + (0 \times 40) + (0,33 \times 49.9) + (0,5 \times 55) + \\ &+ (0,5 \times 25) + (0,5 \times 55) + (0 \times 40) + (0,26 \times 32.2) + (0,5 \times 55) \\ &+ (0,9 \times 13) + (0,5 \times 55) + (0,33 \times 30.1) + (0,33 \times 49.9) + \\ &+ (0,33 \times 30.1) + (0,5 \times 55) + (0,26 \times 32.2) + (0,68 \times 19.6) + \\ &+ (0,26 \times 32.2) \end{aligned}$$

$$\begin{aligned} &0,33 + 0,33 + 0,33 + 0,33 + 0,33 + 0,26 + 0,26 + 0,5 + 0 \\ &+ 0,5 + 0,26 + 0,5 + 0 + 0 + 0,33 + 0,5 + 0,5 + 0,5 + 0 + \\ &0,26 + 0,5 + 0,9 + 0,5 + 0,33 + 0,33 + 0,33 + 0,5 + \\ &0,26 + 0,68 + 0,26 \end{aligned}$$

$$\begin{aligned} &= 29.73 + 16.45 + 29.73 + 16.45 + \\ &16.45 + 12.43 + 8.37 + 42.5 + 0 + 27.5 + \\ &8.37 + 27.5 + 0 + 0 + 16.47 + 27.5 + \\ &12.5 + 27.5 + 0 + 8.37 + 27.5 + 11.7 + \\ &27.5 + 9.9 + 16.47 + 9.9 + 27.5 + + 8.37 \\ &+ 13.3 + 7.37 \end{aligned}$$

10.61

$$= \frac{488,483}{10.61}$$

$$= 46.03$$

(Medium)

So the Soil Fertility Level is in the Medium range, namely in the range **40 - 70**, namely **Medium**.

The results can be seen in the image below.



Figure 11. Result Matlab

Soil fertility results analyzed from the Matlab application were obtained at 50, namely in the **medium** range (40 -70). Comparison with manual searches is not much different from the results in Matlab.

## CONCLUSION

In this research, calculations were carried out to determine soil fertility through several stages. These stages are: fuzzyfication which is used to determine the set variables and domain values, then the inference step for forming rules and min implication functions. The next step is defuzzification using the weighted average method.

From these steps, the results obtained were that the soil fertility level was in the range 40-70, namely the medium range.

Calculations were also carried out in the Matlab application to validate that the manual calculations carried out were correct, and the results obtained from the application were also at a moderate fertility level.

## BIBLIOGRAPHY





- [1] Ilmiah, T., & Tarigan, P. (2013). Air Conditioning Control System Using Fuzzy Logic Basfuzzy
- [2] ed on Atmega 8535 Microcontroller. Scientific Information and Technology (INTI).
- [3] Irawan, M. D., & Herviana, H. (2019). Implementation of Fuzzy Logic in Determining Majors for New Students of Air Putih State Vocational High School (Smk) 1. *Journal of Information Technology*, 2(2), 129. <https://doi.org/10.36294/jurti.v2i2.427>
- [4] Ketut, I, Suwintana. (2013) "Web-Based Fuzzy Mamdani Inference System". Vol. 3, no.
- [5] Larasati, I., Setiawan, B. D., & Data, M. (2018). Selection of Mamdani Fuzzy Inference System Rules Using the Particle Swarm Optimization Algorithm in an Automatic Watering System for Tomato Plants. *Journal of Information Technology and Computer Science Development (J-PTIHK) Brawijaya University*, 2(11), 5525–5534. <http://repository.ub.ac.id/161379/%0Ahttp://repository.ub.ac.id/161379/1/IndahLarasati.pdf>
- [6] Mufid, Ahmad. 2010. "Determining the Production Number of Brand "X" Television Using the Fuzzy Mamdani Method." Vol.5 No.2.
- [7] Ngurah, G., Nata, M., & Yudiastra, P. P. (2022). Fuzzy Inference System and Fuzzy Database as Database Intelligence for Stock Control. *Journal of Systems and Informatics (JSI)*, 16(2), 59–67.
- [8] Primartha, R., & Fathiyah, N. (2013). Fuzzy Expert System for Breast Cancer Diagnosis Using the Mamdani Method. *Generic Journal*, 8(1), 188–197.
- [9] Setiono, & Marwoto, S. (2010). Fuzzy Logic Modeling of Concrete Bridge Damage. *Civil Engineering Media*, 10, 28–35.
- [10] Sitio, S. L. M. (2018). Application of the Sugeno Fuzzy Inference System to Determine the Number of Drug Purchases (Case Study: Garuda Sentra Medika). *Pamulang University Journal of Informatics*, 3(2), 104. <https://doi.org/10.32493/informatika.v3i2.1522>
- [11] Supardi. (2012). Fuzzy Logic Implications for measuring community health status based on nutritional adequacy.
- [12] Vincentia, D., & Utami, Y. (2018). Application of the Fuzzy Inference System (FIS) Mamdani Method in Selecting Higher Education Majors. *Informatics Engineering Journal & Research Publications*, 2(2), 28–36.
- [13] Warman, I., & Jihadi, K. (2019). Web-based Palm Oil Plasma Results Progress Monitoring Service Application. *TechnoIf Journal*, 7(2), 105. <https://doi.org/10.21063/jtif.2019.v7.2.105-114>

