Research Article

Agriculture Application to Predict Soil Fertility with the Application of Fuzzy Tsukamoto

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Abstract.
Indonesia is as an agricultural country, having majority of the population working in agriculture. Indonesia is an agricultural country that has extensive agricultural land and diverse and abundant natural resources. Based on Sakernas BPS 2021 data, Indonesian farmers numbered 38.77 million people. In the agricultural sector, land is a factor that plays a very important role in determining agricultural businesses. Where 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. Many farmers do not understand soil fertility in determining the right type of plant. This research aims to help people determine soil fertility parameters such as (C-Organic, P_2O_5 HCL, K_2O HCL, KTK, Base Saturation, PH H_2O), which will be processed using a WEB-based application using the Tsukamoto fuzzy method to predict fertility. Soil for selecting plant types and choosing the right land. From the land data obtained at the agricultural center, it is processed manually using the fuzzy method and applied to a system. Therefore, the results of this research will provide soil fertility status from data processed with C-organic (0.81%), pH H_2O (5.38), P_2O_5 (2.32 ppm), KTK (8.5), K_2O (50 ppm), Base Saturation (50%), we got a soil fertility status of 46.03, which is in the medium range. Meanwhile, in the system that has been built, the results obtained were 45.54, which is also in the same range, namely medium. From the results obtained, there was not much difference observed in the manual search and the system obtained results, it is estimated that they obtained 97% similarity. With this soil fertility detection system, it can increase the accuracy of soil fertility and make it easier to predict soil fertility. It is hoped that this system can have implications for the agricultural sector.

Keywords: agriculture, soil fertility, Fuzzy Tsukomoto, Web

1. Introduction

Indonesia has a majority of its population's livelihood in agriculture, so land is a natural container for plant growth [1]. One of the determining factors for the success of an agricultural business is soil fertility. Soil fertility factors greatly determine success in agricultural and plantation cultivation, if agricultural land has a high level of fertility then cultivation success will be achieved [2]. Improper land processing according to the characteristics of the plant type can result in plants that are not optimal [3]. Land resources in each region (region) vary or vary [4]. These variations depend on human

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physical and environmental factors, therefore humans must be able to know information to determine land use, along with information about land that is very necessary in land use. To be able to utilize land resources sustainably, it is necessary to have complete data and information regarding the physical properties of the soil, soil fertility content, texture and soil pH [5].Soil consists of several nutrients that are important for effective plant growth. Nitrogen, phosphorus and potassium are micronutrients that are very important for plant growth [6]. There are several methods and soil tests that have been developed to test the composition of these nutrients in the soil. Interpreting the results obtained from these tests is a difficult task for farmers [7]. Land suitability is the level of suitability of land for a particular use. Even though plants appear to be able to grow in one area, each type of plant has different characteristics. Land suitability is determined from land evaluation. Land evaluation can be carried out using several methods, namely Fuzzy Tsukamoto and land survey methods for collecting data directly from the field [8]. This research aims to evaluate soil fertility for the suitability of oil palm plantations. To obtain quality palm oil, supporting factors are needed, one of which is soil fertility [9].

This research builds an application by applying fuzzy Tsukamoto to help farmers make decisions regarding the feasibility of planting oil palm on farmers' agricultural land and determine the status of soil fertility. In research [10], researchers built a system for detecting nutrient levels in soil using the fuzzy method with the nutrient parameters N (Nitrogen), P (Phosphorus), K (Potassium). The results obtained manually and the system have an error value of 1.62%. According to [11], fuzzy logic is set theory, the mathematical concepts underlying fuzzy reasoning are quite easy to understand. Apart from that, fuzzy logic is believed to be very flexible and tolerant of existing data [12]. The Fuzzy method is a generalization of classical logic which only has two membership values between 0 and 1 [13] or states that everything is binary, which means there are only two possibilities, namely "yes or no", "right or wrong", "good or bad" and soon other [14].

The fuzzy method was also used in research [15] to determine the level of soil fertility for coffee plant types. This method can detect the level of moisture and acidity of the soil. Researchers took samples every 100 meters from the zero point of agricultural land. As at point 0, if the Ateng coffee plant loses its shoots plant it, then the results will be very good, and so on It is hoped that this fuzzy method for soil fertility will have a good impact in the future, namely better quality of fruit and harvest so that the price of palm oil will be better. higher and improve the economy of the people in the area.

2. Methodology

In research on measuring soil fertility levels and soil acidity for the suitability of oil palm planting, the data will be processed using the fuzzy Tsukamoto method. Fuzzy Logic is applied to measure soil fertility and acidity levels for the feasibility of planting oil palm. Several steps were taken, such as determining the research input and output to form a fuzzy set and carrying out fuzzyfication, determining the rules to be used, and applying fuzzy to the final search with a formula or defuzzyfication.

There are several inputs (C-Organic, P2O5 HCL, K2O HCL, KTK, base saturation, soil pH, and soil type) and outputs (soil fertility and acidity level or soil pH). After getting the results, the results will be validated and tested and the results will even be compared with the system being built. So that the accuracy of manual and system searches is better and not much different. The framework for conducting this research is as follows :

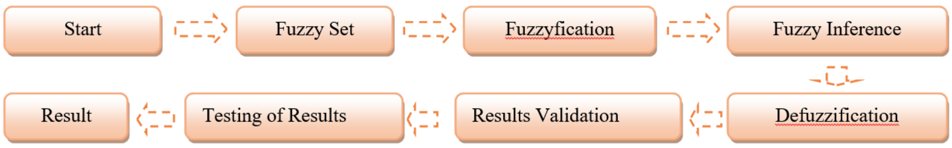

Figure 1: Research Framework.

Explanation of the research framework based on Figure 1 :

Start Research

In starting this research, the first step was to identify the problem so that this research could be directed based on the problem to be discussed, so that problem formulation and problem boundaries were needed to achieve the right scope.

Fuzzy Set

Fuzzy sets are models mathematics from vague qualitative or quantitative data, often generated through natural language. Fuzzy sets allow one to work in uncertain and ambiguous situations and solve problems that are not expected or problems with incomplete information [16]. In this research, several fuzzy sets (input and output) were selected such as C-Organic, P2O5, K2O, KTK, Base Saturation, Soil Fertility.

Fuzzyfication

This stage is the process of changing an input from a crisp form to a fuzzy (linguistic variable) which is usually presented in the form of fuzzy sets with their respective member functions. For example, this research takes input, one of which is C-Organic, one of the parameters for measuring soil fertility, which has 3 memberships, namely low, medium and up.

The fuzzy inference method used in this research is the Tsukamoto method. Several stages are required, namely the formation of rules, one of which is.

Defuzzification

The process of mapping fuzzy control actions to non-fuzzy (crips)

Result Validation, Testing and Result

This stage carries out an analysis process using fuzzy calculations manually by inputting values for each soil fertility parameter using existing formulas and based on interviews with agricultural offices. As well as testing the data and systems that have been built. With the aim of whether the results obtained can be used by agricultural parties and obtain valid results. So activities are also carried out to compare manual results with the system so that the results can be the same and not much different.

3. Result and Discussion

In processing the data, determine the level of soil fertility and soil acidity for there are several factors that need to be studied (Analysis of the Physical and Chemical Properties of Soil). In this research, an analysis of the properties of the nutrient elements in the soil is carried out which have parameters such as C-Organic, P2O5, K2O, KTK, Base Saturation, Soil Fertility. From these parameters a fuzzy set is formed which is processed using the Tsukamoto fuzzy system, where there are several stages. The stages are as follows ;

3.1. Fuzzyfication

This research has input and output to determine soil fertility that will be used for the suitability of oil palm. The first input variable is C-organic, the second input is HCL P2O5, the third input is HCL K2O, input to rmpst KTK, base saturation kelims input, and as output Soil Fertility and Acid Content. As seen in table 1:

3.1.1. Variabel of soil fertility

The following is a description of the soil fertility variable ;

TABLE 1: Soil Fertility Parameters.

Function	Variable	Linguistic Values
Input	C- Organik	1 - 5
	P_2O_5 HCL	0 - 50
	K_2O HCL	0 - 70
	KTK	0 - 50
	Base Saturation	0 - 100
	pH H_2O	0 - 10
Output	Soil fertility	0 - 200

3.1.2. Variables of C-Organic

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 shown in table 2.

TABLE 2: Fuzzy Set C-Organic.

Set Variables	Range
Low	1 - 2
Medium	2 - 3
Up	3 - 5

3.1.3. Variables of P2O5 HCL

The variable P2O5 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.

TABLE 3: Fuzzy Set P_2O_5 HCL.

Set Variables	Range
Low	2 - 7
Medium	7 - 10
Up	10 - 15

3.1.4. Variable of K2O HCL

The K2O 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 1 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.

Table 4: Fuzzy Set K2O HCL.

Set Variables	Range
Low	1 – 20
Medium	21 – 40
Up	41 – 60

3.1.5. Variable of KTK

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). The fuzzy set for input 4 is shown in table 5.

Table 5: Fuzzy Set KTK.

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

3.1.6. Variable of Base Saturation

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.

Table 6: Fuzzy Set for Base Saturation.

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

3.1.7. Variable of pH H2O

The pH H2O 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.

Table 7: Fuzzy Sets pH H_2O.

Set Variables	Range
Sour	4.5 – 5.5
Medium	5.6 – 6.5
Neutral	6.6 – 7.5
Alkalis	7.6 – 8.5

3.1.8. Variables of Soil Fertility

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. HThe fuzzy set for input 7 is shown in table 8.

Table 8: Fuzzy Sets Soil Fertility.

Set Variables	Range
Low	10 – 40
Medium	40 – 70
High	70 – 100

3.2. Fuzzy Knowledge Base (rules)

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 30 fuzzy rules that are used.

3.3. Inferensi

The amount that will be examined next is C-organic (%) as much as 0.81, total pH of H2O as much as 5.38, P2O5 (ppm) as much as 2.32, KTK as much as 8.5, K2O (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 ;

Fuzzification of 6 modeled fuzzy variables:

C- Organic consists of Low, Medium and Up µLow [1.74] = (2- 1.74) / (2– 1) = 0.26/ 1 = 0.26

µMedium [1.74] = Not in Range µ

Up [1.74] = Not in Range

b. P_2O_5 HCL consists of Low, Medium and Up µLow [2.32] = (7-2.32) / (7–2) = 4,62/5 = 0,9 µMedium [2.32] = Not in Range µ Up [2.32] = Not in Range

K_2O HCL consists of Low, Medium and Up µLow [50] = Not in Range µMedium [50] = Not in Range µUp [50] = (60-50) / (60–40) = 10/20 = 0.5

d. KTK consists of Low, Medium and Up µLow [8.5] = (16-8.5) / (16–5) = 7,5 /11= 0,68 µ Medium [8.5] = Not in Range µ Up [8.5] = Not in Range

Base Saturation consists of Lower, Medium and Increase µLow[50] = Not in Range µMedium [50] = Not in Range µ Up [50] = (60 – 50) / (60 – 30) = 10 /30 = 0,33

f. The pH of H2O consists of Acid, Medium, Neutral, Alkaline µSour [5.38] = (5.5–5.38) /(5.5 – 4.5) = 0.12 /1 = 0,12 µ Medium [5.38] =Not in Range µ Netral [5.38] = Not in Range µ Alkalis [5.38] = Not in Range

Machine Inference (Function Min) of 30 fuzzy rules that are used :

[R1] = IF C-Organic Increases and P2O5 Increases and K2O is Moderate and CEC Increases and Base Saturation Increases THEN Soil Fertility is High

α-predicate1 = µUp ∩ µ Up ∩ µMedium ∩ µUp ∩ µUp

= min (µUp, µ Up, µMedium, µUp, µUp)

= min (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

α-predicate2 = μUp ∩ μ Up ∩ μDown ∩ μUp ∩ μUp

= min (μUp, μ Up, μDown, μUp, μUp)

= min (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

α-predicate3 = μMedium ∩ μMedium ∩ μA lot ∩ μUp ∩ μUp

= min (μMedium, μ Medium, μA lot, μUp, μUp)

= min (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

α-predicate4 = μMedium ∩ μMedium ∩ μLow ∩ μUp ∩ μUp

= min (μMedium, μ Medium, μLow, μUp, μUp)

= min (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

α-predicate5 = μIncrease ∩ μMedium ∩ μDecrease ∩ μIncrease ∩ μIncrease

= min (μUp, μ Medium, μDown, μUp, μUp)

= min (Not in range, Not in range, 1.5, 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

α-predicate6 = μLow ∩ μLow ∩ μUp ∩ μUp ∩ μUp

= min (μLow, μLow, μUp, μUp, μUp)

= min (0.26, 0.9, 0.5, 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

α-predicate7 = μLow ∩ μLow ∩ μUp ∩ μUp ∩ μUp

= min (μLow, μLow, μUp, μUp, μUp)

= min (0.26; 0.9, 0.5, 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

α-predicate8 = μIncrease ∩ μDecrease ∩ μIncrease ∩ μIncrease ∩ μMedium

= min (μUp, μDown, μUp, μUp, μMedium)

= min (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

α-predicate$_9$ = μUp ∩ μUp ∩ μLow ∩ μUp ∩ μMedium

= min (μUp, μUp, μLow, μUp, μMedium)

= min (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 Up And KTK Medium And Base Saturation Medium THEN Soil Fertility MODERATE

α-predicate$_{10}$ = μMedium ∩ μMedium ∩ μUp ∩ μMedium ∩ μMedium

= min (μMedium, μMedium, μUp, μMedium, μMedium)

= min (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 Up and KTK is Up and Base Saturation is Medium THEN Soil Fertility is LOW

α-predicate$_{11}$ = μLow ∩ μMedium ∩ μUp ∩ μUp ∩ μMedium

= min (μLow, μMedium, μUp, μUp, μMedium)

= min (0.26 ; Not in range, 0.5, Not in range, Not in range)

= 0.26

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

α-predicate$_{12}$ = μUp ∩ μUp ∩ μ Many ∩ μUp ∩ μDown

= min (μUp, μUp, μLot, μUp, μDown)

= min (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

α-predicate$_{13}$ = μUp ∩ μUp ∩ μ Down ∩ μUp ∩ μDown

= min (μUp, μUp, μ Down, μUp, μDown)

= min (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

α-predicate$_{14}$ = μ Medium ∩ μ Medium ∩ μ Medium ∩ μUp ∩ μLow

= min (μ Medium, μ Medium, μ Medium, μUp, μLow)

= min (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

α-predicate1 = μ Up ∩ μ Up ∩ μLow ∩ μMedium ∩ μUp

= min (μUp, μUp, μLow, μMedium, μUp)

= min (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

α-predicate$_{16}$ = μMedium ∩ μ Medium ∩ μUp ∩ μUp ∩ μLow

= min (μMedium, μMedium, μUp , μUp, μLow)

= min (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

α-predicate$_{17}$ = μMedium ∩ μLow ∩ μUp ∩ μMedium ∩ μUp

= min (μMedium, μLow, μUp, μMedium, μUp)

= min (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 MEDIUM

α-predicate$_{18}$ = μ Up ∩ μ Up ∩ μUp ∩ μMedium ∩ μMedium

= min (μ Up, μ Up, μUp, μMedium, μMedium)

= min (Not in range; Not in range, 0.5 , Not in range, Not in range)

= 0.5

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

α-predicate$_{19}$ = μ Medium ∩ μ Medium ∩ μLow ∩ μMedium ∩ μMedium

= min (μ Medium, μ Medium, μLow, μMedium, μMedium)

= min (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

α-predicate$_{20}$ = μ Low ∩ μ Medium ∩ μUp ∩ μMedium ∩ μMedium

= min (μLow, μ Medium, μUp, μMedium, μMedium)

= min (0.26; 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

α-predicate$_{21}$ = μ Up ∩ μ Up ∩ μUp∩ μMedium ∩ μLow

= min (μ Up, μ Up, μUp, μMedium, μLow)

= min (Not in range; Not in range, 0.5, Not in range, Not in range)= 0.5

[R22] = IF C-Organic Medium And P2O5 Low And K2O Low And KTK Medium And Alkaline Saturation Down THEN Low Soil Fertility

α-predicate$_{22}$ = μ Medium ∩ μLow ∩ μLow ∩ μMedium ∩ μLow

= min (μ Medium, μLow, μLow, μMedium, μ Low)

= min (Not in range; 0.9, 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

α-predicate$_{23}$ = μ Up ∩ μ Up ∩ μ Up ∩ μLow ∩ μUp

= min (μ Up, μ Up, μ Up, μLow, μUp)

= min (Not in range;, Not in Range, 0.5, 0.68, Not in range)

= 0.5

[R24] = IF C-Organic Medium And P2O5 Medium And K2O Decreased And KTK Low And Base Saturation Up THEN Soil Fertility LOW

α-predicate$_{24}$ = μ Medium ∩ μ Medium ∩ μLow ∩ μLow ∩ μUp

= min (μ Medium, μ Medium, Low, μLow, μUp)

= min (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

α-predicate$_{25}$ = μ Up ∩ μ Up ∩ μUp ∩ μLow ∩ μUp

= min (μ Up, μ Up, Up, μLow, μUp)

= min (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

α-predicate$_{26}$= μ Medium ∩ μ Up ∩ μUp ∩ μLow ∩ μUp

= min (μ Medium, μ Up, Up, μLow, μ Up)

= min (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

α-predicate$_{27}$= μ Up ∩ μ Up ∩ μUp ∩ μLow ∩ μMedium

= min (μ Up, μ Up, Up, μLow, μ Medium)

= min (Not in range;, Not in Range, 0.5, 0.68, 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

α-predicate$_{28}$ = μ Low ∩ μ Low ∩ μMedium ∩ μLow ∩ μMedium

= min (μ Low, μ Low, Medium, μDecreased, μMedium)

= min (0.26, 0.9 , 1.5 , 0.68, 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

α-predicate$_{29}$= μ Up ∩ μLow ∩ μLow ∩ μLow ∩ μLow

= min (μ Up, μ Low, μ Low, μ Low, μ Low)

= min (Not in range, 0.9 , Not in range, 0.68, Not in range)

= 0.68

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

α-predicate$_{30}$= μ Low ∩ μLow ∩ μLow ∩ μLow ∩ μLow

= min(μ Low, μ Low, μLow, μLow, μLow)

= min (0.26, 0.9, Not in range, 0.68, Not in range)

= 0.26

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

Z1 = $\sum$ (α-predikat$_n$*Z$_n$)

$\sum$ α-predikat$_n$

= 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

10.61

= 488,483

10.61

= 46.03 (Medium)

The Soil Fertility Level is in the Medium range, namely in the range **40 -- 70** (**Medium)**.

So the predicted soil fertility obtained is 46 with Medium status. The prediction results using the fuzzy Tsukamoto method showed that the soil fertility level was in the range of 40 - 70, which is in the medium range. After that, testing was carried out with an application that had been built to predict soil fertility which included several stages. One of them is identifying needs, preparing a Web-based system design and implementing the system in the agricultural department. After that, the application that has been created is tested to validate the suitability of the design and validate the accuracy of the soil fertility prediction results. From these results, the level of accuracy of manual soil fertility prediction with the application that was built is not much different, still in the same range.

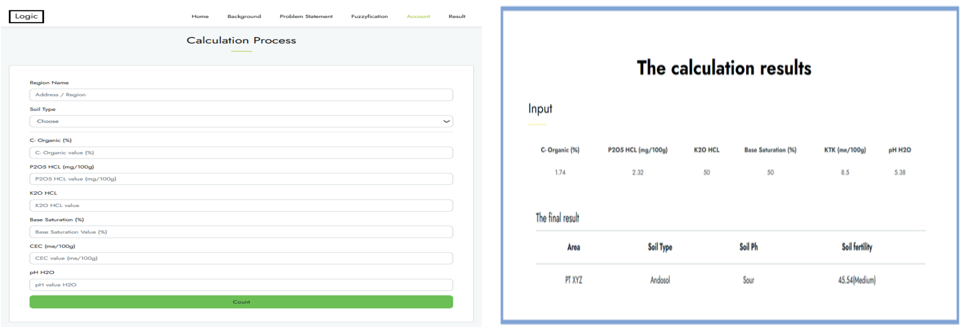

Figure 2: (a) Application determines soil fertility ; (b) Results of the fuzzy system.

In Figure 2 is an application that has been tested using manual search results. The data tested were the same data, namely C-organic is 1.74, total pH of H2O is 5.38, P2O5 is 2.32, KTK is 8.5, K2O is 50, Base Saturation is 50. The results obtained from this application were 45.54 which where the soil fertility status is in the Medium range. This proves the accuracy of the application that was built to determine soil fertility results according to the manual results obtained using the fuzzy Tsukamoto method. These results have also been adjusted by the agricultural department, so that the results obtained are said to be valid or appropriate. So this application can be used by agricultural parties or communities who need to determine the status of soil fertility in order to improve the economy and smooth farming activities.

4. Conclusion

The conclusions of this research are as follows :

1. This research can help farmers/agricultural sector find out the status of soil fertility with an application that is built to make it easier to carry out activities in the agricultural sector.
2. In this research, farmers can find out the parameters used to determine soil fertility such as (pH H2O, P2O5, KTK, K2O and Base Saturation). So farmers can improve agriculture by paying attention to known parameters.
3. With this application, farmers can maintain and increase soil fertility so that they get quality crops effectively and are able to get better results. So that it can improve the economy in the agricultural sector
4. This research has been tested and validated with manual results carried out using the fuzzy Tsukamoto method and the results of the applications built. These two methods have results that are not much different and researchers have also reviewed the agricultural service data obtained until the results obtained are valid.

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