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Application of Fuzzy Logic in Prediction to Determine the Value of Water Quality and Environment in Lettuce Hydroponics

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Abstract

The need for food such as vegetables and fruit will never stop. Meanwhile, as time goes by, agricultural land is decreasing. To meet food needs, people need to make efforts to utilize limited agricultural land by implementing hydroponic farming techniques. With hydroponic techniques, people can produce vegetables and fruit to meet their food needs. Hydroponic harvest results are influenced by several factors, such as water quality and the surrounding environment. In grouping the quality of harvest results can use the help of fuzzy logic. By using the input variables water pH and temperature, you can determine the quality of the harvest, especially the absorption of nutrients in plants. These two variables are important parameters in using fuzzy logic using manual calculations or application assistance. And of course, fuzzy logic offers a great approach to assessing the nutrient uptake that hydroponic plants receive, helping farmers make informed decisions to optimize plant health and productivity.

Keywords: hydroponic, fuzzy logic, water quality, temperature, nutrient absorption

INTRODUCTION

Farming using hydroponic techniques can overcome the problem of limited land. Hydroponics is a method of growing plants without using soil media, but by using nutritious mineral solutions or other materials containing nutrients such as coconut fiber, mineral fiber, sand, brick fragments, sawdust, and others as a substitute for soil media. (Ahmad, 2016). In its later development, hydroponics was defined as a way of cultivating farmers by not using soil media..

Hydroponic systems are evolving rapidly, ranging from simple to lighting-enhanced. In hydroponics, soil is replaced with a medium material to provide a foothold for the roots, and nutrients are provided in water that is directly applied to the plant roots. In this way, the amount and combination of nutrients are provided to the plants continuously so that plant growth is optimized. (Endang *et al.*, 2017).

Plants in their development and survival cycle are influenced by several factors such as physical support, water, nutrients, light and oxygen. Soil along with nutrients provide physical support for plants. However, over time, the nutrients in the soil are depleted so that plants no longer grow to their full potential. (Endang *et al.*, 2017).

According to Dr. Susilawati in her book, there are several main requirements for water to become a growing medium for hydroponic plants. First, the minerals in hydroponic water must be stable. Second, the pH value of the water must be maintained which greatly affects the ability of plant roots to absorb nutrients. Hydroponic plants require an optimal pH value in the range of 5.5 - 7.5. A pH value outside that range will greatly inhibit the ability of the roots to absorb nutrients in the solution. (Susilawati, dikutip dalam Reza *et al.*, 2024).

Apart from water, environmental factors such as temperature are important in hydroponic cultivation. Temperatures that are too high or low can affect the growth rate of hydroponic plants. Temperature can also affect the photosynthesis process and the absorption of nutrients or water in hydroponic plants. Any two of the above factors are important as the main support in the development and survival cycle of hydroponic plants. Therefore, hydroponic systems require strict maintenance and control. (Fitriani *et al*, 2023). This is useful for maintaining the quality of the hydroponic crops.

In carrying out the maintenance and control process in hydroponic cultivation, a method is needed to optimize and help farmers cultivate hydroponics, namely the use of fuzzy logic. Fuzzy logic is linguistically defined as fuzzy or vague. (Bayu & Agus, 2019). More specifically, fuzzy logic is logic that is fuzzy or contains elements of uncertainty. (Athia, 2009). Fuzzy logic is also an appropriate way to map an input space into an output space. (Yulia, 2018).

Unlike digital logic, which only has two values of 1 or 0. Fuzzy logic has membership degrees in the range of 0 to 1. Fuzzy logic is used to translate a quantity that is expressed using language, for example the speed of a vehicle that is expressed as slow, rather fast, fast, and very fast. And fuzzy logic shows the extent to which a value is true and the extent to which a value is false. (Bayu & Agus, 2019).

Fuzzy logic was first introduced by Prof. L.A. Zadeh (1965). In principle, fuzzy sets are an extension of crisp sets, namely sets that divide a group of individuals into two categories, namely members and non-members.(Yulia, 2018). Fuzzy sets are based on the idea of extending the range of a characteristic function such that the function will include real numbers on the interval 0 - 1. (R Mahdalena, 2019).

There are several things that need to be known in understanding fuzzy systems (Kusuma Dewi, cited in Indah, 2021), namely:

1. Fuzzy variables are variables to be discussed in a fuzzy system, for example age, temperature, etc.
2. A fuzzy set is a group that represents a certain condition or state in a fuzzy variable, for example: temperature variable which is divided into five fuzzy sets, namely: cold, cool, normal, warm, and hot..
3. The universe of speech is the entire value allowed to be operated on in a fuzzy variable. The universe of speech is a set of real numbers that always increases monotonically from left to right. The value of the universe of discussion can be positive or negative numbers. Under certain conditions, the value of the universe of discussion is not limited to its upper limit. An example of a universe of speech for a temperature variable [0 40].
4. The domain of a fuzzy set is the entire value that is allowed in the universe of speech and can be operated on in a fuzzy set. Like the universe of discussion, the domain is a set of real numbers that always increases from left to right and can be positive or negative numbers. Example of a fuzzy set domain: a) Cold = [0, 20], b) Cool = [15, 25], c) Normal = [20, 30], d) Warm = [25, 35], e) Hot = [30, 40].

In fuzzy logic there is a membership function. A membership function is a curve that shows the mapping of input data points into membership values that have an interval between 0 and 1. One way that can be used to get membership values is through a function approach. There are several functions that can be used; Linear Representation, Triangular Curve Representation, Trapezoidal Curve Representation, Shoulder-Shape Curve Representation, S-Curve Representation, and Bell-Shape Curve Representation. (Kusumadewi, quoted in Yulia, 2018).

In operating fuzzy sets, there are several operators in fuzzy logic to combine and modify fuzzy sets. The membership value as a result of the operation of two sets is often known by the name *fire strength* or α – predicate. There are three basic operators created by Zadeh, namely : AND Operator, OR Operator, and NOT Operator (Kusumadewi, quoted in Yulia, 2018).

The purpose of this study is to determine the use of fuzzy logic applications in predicting the quality of hydroponic lettuce with reference to water pH levels and temperature. The results of this study are expected to provide benefits, as follows:

1. Provides knowledge on how to predict the quality of hydroponic lettuce using fuzzy logic.
2. Provide information to related parties to help sustain the lettuce hydroponic cultivation process.

METHODS

The steps taken in this research are problem identification and literature study. At the problem identification stage, the problem discussed is how to apply fuzzy logic in predicting the quality of hydroponic lettuce. Next is the literature study. The author conducts a literature study to collect relevant references related to this paper.

In the process, the author uses the stages in the process of integrating fuzzy logic and lettuce hydroponics. According to M. Maftuh (2022), to make decisions made through several stages, namely the formation of fuzzy sets, application of implication functions, rule composition, defuzzification:

1. Fuzzy set formation

   Forming a fuzzy set or called fuzzification is a process carried out by transforming the input of a firm (crisp) set into a fuzzy set (N. Febriany, cited in M. Maftuh, 2022). Fuzzy sets have 2 attributes, namely numeric and linguistic. Numeric is a number-shaped value that shows the size of a variable such as: 20, 30, 40. While linguistics are grouped with languages that represent a state such as cold, normal, hot.

   After the set is formed, the next process is the process of finding the value of the set or called fuzzyfication. The following is an example of a linear image and fuzzyfication equation formula:

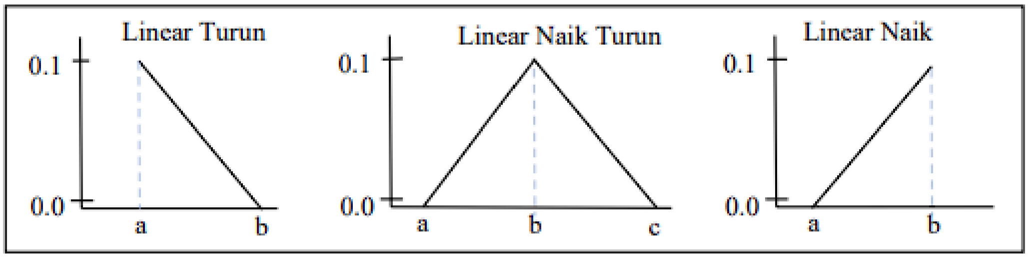

Figure 1 Linear Images of fuzzyfication

- Linear equation up and down

$$\mu_{(x)} = \begin{cases} 1;\ x \le a \\ \dfrac{(b - x)}{(b - a)};\ a \le x \le b \\ 0;\ x \ge b \end{cases}$$

- Linear equation up and down

$$\mu_{(x)} = \begin{cases} 0;\ x \le a \\ \dfrac{(x - a)}{(b - a)} = a \le x \le b \\ \dfrac{(c - x)}{(c - b)} = b \le x \le c \\ 0;\ x \ge c \end{cases}$$

- linear increasing equation

$$\mu_{(x)} = \begin{cases} 0;\ x \le a \\ \dfrac{(x-a)}{(b-a)};\ a \le x \le b \\ 1;\ x \ge b \end{cases}$$

a. Temperature input variable

The fuzzy sets for temperature variables are cold, normal, hot. Where the cold temperature has a range of 0-25OC, normal temperature has a range of 25-35OC, and hot temperature has a range of 35-50OC. The degree of membership of the fuzzy set for temperature is presented in the figure

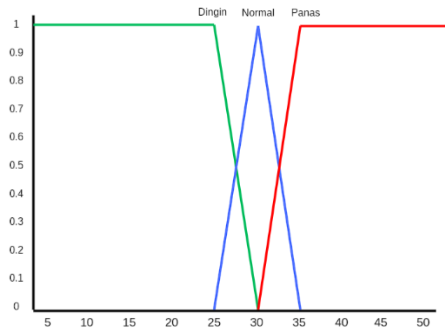

Figure 2 fuzzy set temperature variable

The membership degree in the image uses the formula:

$$\mu\ \text{Cold}(x) = \begin{cases} 1;\ x \le 25 \\ \dfrac{(30-x)}{(30-25)};\ 25 \le x \le 30 \\ 0;\ x \ge 30 \end{cases}$$

$$\mu\text{Normal}(x) = \begin{cases} 0;\ x \le 25 \\ \dfrac{(x-25)}{(30-25)};\ 25 \le x \le 30 \\ \dfrac{(35-x)}{(35-50)};\ 30 \le x \le 35 \\ 0;\ x \ge 35 \end{cases}$$

$$\mu\ \text{Hot}(x) = \begin{cases} 0;\ x \le 30 \\ \dfrac{(x-30)}{(35-30)};\ 30 \le x \le 35 \\ 1;\ x \ge 35 \end{cases}$$

The above calculation is part of the membership function for the fuzzy sets "cold", "normal", and "hot" in fuzzy logic. These membership functions are used to determine how "cold", "normal", or "hot" a variable x value is.

For the set "μ cold":

If $x \le 25$, then the degree of membership is 1. This means that if the temperature is less than or equal to 25, then the temperature is considered completely "cold".

- If $25 \le x \le 30$, then the membership degree is (30 - x)/(30 - 25). This means that if the temperature is between 25 and 30, the membership degree will decrease linearly with an increase in temperature.

- If x ≥ 30, then the membership degree is 0. This means that if the temperature is greater than or equal to 30, it is considered not "cold" at all.

For the set "µ normal":

- If x ≤ 25, then the membership degree is 0. This means that if the temperature is less than or equal to 25, the temperature is considered not "normal".
- If 25 ≤ x ≤ 30, then the membership degree is (x - 25)/(30 - 25). This means that if the temperature is between 25 and 30, the membership degree will rise linearly with an increase in temperature.
- If 30 ≤ x ≤ 35, then the membership degree is (35 - x)/(35 - 30). This means that if the temperature is between 30 and 35, the membership degree will decrease linearly with an increase in temperature.
- If x ≥ 35, then the membership degree is 0. This means that if the temperature is greater than or equal to 35, the temperature is considered not "normal".

For the set " µ heat":

- If x ≤ 30, then the degree of membership is 0. This means that if the temperature is less than or equal to 30, the temperature is considered not "hot".
- If 30 ≤ x ≤ 35, then the membership degree is (x - 30)/(35 - 30). This means that if the temperature is between 30 and 35, the membership degree will rise linearly with an increase in temperature.
- If x ≥ 35, then the degree of membership is 1. This means that if the temperature is greater than or equal to 35, the temperature is considered to be fully "hot".

b. Input variable ph water

Fuzzy sets for water pH variables are acidic, alkaline, neutral. Where the acid has a range of 1 - 6, the neutral has a value of 7, and the base has a range of values of 8 - 14. The degree of membership of the fuzzy set for temperature is presented in the figure

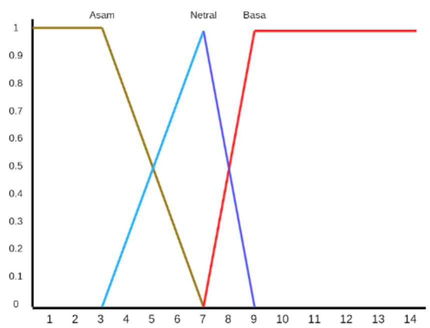

Figure 3 fuzzy set pH water variable

The membership degree in the image uses the formula :

$$\mu\text{Acid}(x) = \begin{cases} 1\ ;\ x \leq 3 \\ \frac{(7-x)}{(7-3)}\ ;\ 3 \leq x \leq 7 \\ 0\ ;\ x \geq 7 \end{cases}$$

$$\mu\text{Neutral}(x) = \begin{cases} 0\ ;\ x \leq 3 \\ \frac{(x-3)}{(7-3)}\ ;\ 3 \leq x \leq 7 \\ \frac{(9-x)}{(9-7)}\ ;\ 7 \leq x \leq 9 \\ 0\ ;\ x \geq 9 \end{cases}$$

$$\mu Base(x) = \begin{cases} 0 \; ; \; x \leq 7 \\ \frac{(x-7)}{(9-7)} \; ; \; 7 \leq x \leq 9 \\ 1 \; ; \; x \geq 9 \end{cases}$$

The above calculation is part of the membership function for the fuzzy sets "acid", "neutral", and "base" in fuzzy logic. This membership function is used to determine how "acidic", "neutral", or "basic" a variable x value is.

For the set "μ acid":

- If x ≤ 3, then the degree of membership is 1. This means that if the value of x is less than or equal to 3, the value of x is considered completely "acidic".
- If 3 ≤ x ≤ 7, then the membership degree is (7 - x)/(7 - 3). This means that if the value of x is between 3 and 7, the membership degree will decrease linearly with the increase of x value.
- If x ≥ 7, the degree of membership is 0. This means that if the value of x is greater than or equal to 7, the value of x is considered not "sour".

For the set " μ neutral":

- If x ≤ 3, then the degree of membership is 0. This means that if the value of x is less than or equal to 3, the value of x is considered not "neutral".
- If 3 ≤ x ≤ 7, the membership degree is (x - 3)/(7 - 3). This means that if the x value is between 3 and 7, the membership degree will increase linearly with the increase in x value.
- If 7 ≤ x ≤ 9, then the membership degree is (9 - x) / (9 - 7). This means that if the value of x is between 7 and 9, the membership degree will decrease linearly with the increase of x value.
- If x ≥ 9, the degree of membership is 0. This means that if the value of x is greater than or equal to 9, the value of x is not considered "neutral".

For the set " μ base":

- If x ≤ 7, then the degree of membership is 0. This means that if the value of x is less than or equal to 7, the value of x is considered not "alkaline".
- If 7 ≤ x ≤ 9, the degree of membership is (x - 7)/(9 - 7). This means that if the value of x is between 7 and 9, the degree of membership will increase linearly as the value of x increases.
- If x ≥ 9, the degree of membership is 1. This means that if the value of x is greater than or equal to 9, the value of x is considered to be completely "alkaline".

c. Nutrient absorption output variable

The fuzzy sets for the nutrient absorption output variable are less, normal, and high. Where in less has a range of values from 0 - 560, in normal has a range of values 560 - 850, and in high has a range of values 850 +. The degree of membership of the fuzzy set for temperature is presented in the figure

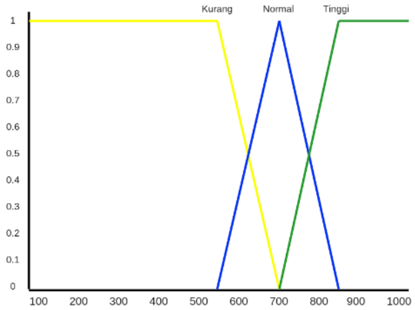

Figure 4 fuzzy set output variable

The membership degree in the image uses the formula :

$$\mu\ Less(x) = \begin{cases} 1 \,;\ x \le 560 \\ \frac{(700 - x)}{(700 - 560)} \,;\ 560 \le x \le 700 \\ 0 \,;\ x \ge 700 \end{cases}$$

$$\mu Normal(x) = \begin{cases} 0 \,;\ x \le 560 \\ \frac{(x-560)}{(700-560)} \,;\ 560 \le x \le 700 \\ \frac{(850 - x)}{(850- 700)} \,;\ 700 \le x \le 850 \\ 0 \,;\ x \ge 850 \end{cases}$$

$$\mu High(x) = \begin{cases} 0 \,;\ x \le 700 \\ \frac{(x - 700)}{(850- 700)} \,;\ 700 \le x \le 850 \\ 1 \,;\ x \ge 850 \end{cases}$$

The above calculation is part of the membership function for the fuzzy sets "less", "normal", and "high" in fuzzy logic. This membership function is used to determine how "less", "normal", or "high" a variable x value is.

For the set "μ less":

- If x ≤ 560, then the degree of membership is 1. This means that if the value of x is less than or equal to 560, the value of x is considered completely "less".
- If 560 ≤ x ≤ 700, then the membership degree is (700 - x)/(700 - 560). This means that if the value of x is between 560 and 700, the degree of membership will decrease linearly with an increase in the value of x.
- If x ≥ 700, the degree of membership is 0. This means that if the value of x is greater than or equal to 700, the value of x is not considered "less".

For the set " μ normal":

- If x ≤ 560, then the degree of membership is 0. This means that if the value of x is less than or equal to 560, the value of x is considered not "normal".
- If 560 ≤ x ≤ 700, then the membership degree is (x - 560)/(700 - 560). This means that if the x value is between 560 and 700, the membership degree will increase linearly with the increase in x value.
- If 700 ≤ x ≤ 850, the membership degree is (850 - x) / (850 - 700). This means that if the value of x is between 700 and 850, the degree of membership will decrease linearly with the increase of x value.
- If x ≥ 850, the membership degree is 0. This means that if the x value is greater than or equal to 850, the x value is considered not "normal".

For the set " μ high":

- If x ≤ 700, then the degree of membership is 0. This means that if the value of x is less than or equal to 700, the value of x is considered not "high".
- If 700 ≤ x ≤ 850, the membership degree is (x - 700)/(850 - 700). This means that if the value of x is between 700 and 850, the degree of membership will increase linearly with an increase in the value of x.
- If x ≥ 850, the membership degree is 1. This means that if the value of x is greater than or equal to 850, the value of x is considered to be completely "high".

2. Application of the implication function

An implication function is a logical structure that consists of a premise conclusion and a conclusion. The implication function is useful for knowing the relationship between the premises and the conclusion. The form of this implication function is the statement IF is

THEN is, with and are scalars, and A and are fuzzy sets (N. Febriany, cited in M. Maftuh, 2022).

Determination of Rules or inference from input and output variables on predictions to determine the value of water quality and temperature in fuzzy-based lettuce hydroponics using 6 input variables and three output variables, resulting in 9 rules, namely:

3. Rule composition

The aim is to determine inference from the collection and correlation between rules using the Max method, with another meaning, namely the procedure of combining the membership function of the implication function application rule (N. Febriany, cited in M. Maftuh, 2022).

4. Affirmation (defuzzyfication)

$$z^* = \frac{\int \mu_x(z).zdz}{\int \mu_x(z)dz}$$

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. So that if given a fuzzy set in a certain range, a certain firm (crisp) value must be taken as output (Haryanto et al, cited in M. Maftuh, 2022).

RESULTS AND DISCUSSION

Testing the value of the temperature value with a known case example of water pH 5 and temperature 24OC, what is the value of nutrient absorption (PPM) from these conditions:

1. The fuzzy membership degree value with a value of 5 for the pH value of water is obtained with the following formula.

$$\mu Asam(5) = \{ \frac{(7-5)}{(7-3)} = \frac{2}{4} = 0.5 \}$$

$$\mu Netral(5) = \{ \frac{(5-3)}{(7-3)} = \frac{2}{4} = 0.5 \}$$

$$\mu Basa(5) = \{ 0 ;\ 5 \leq 7 \}$$

For the set "µ acid":

The membership degree is calculated by the formula ((7 - 5))/((7 - 3)) = 2/4 = 0.5. This means that value 5 has a membership degree of 0.5 to the set "sour". This means that value 5 can be categorized as "slightly acidic".

For the set "µ neutral":

The degree of membership is calculated by the formula ((5 - 3))/((7 - 3)) = 2/4 = 0.5. This means that value 5 has a membership degree of 0.5 to the set "neutral". This means that value 5 can be categorized as "slightly neutral".

For the "base" set:

Since the value of x (5) does not fulfill the condition of the "base" set (5 ≤ 7), the degree of membership of the "base" set is 0. That is, the value of 5 is not categorized as "base".

2. The fuzzy membership degree value with a value of 24 OC for the temperature value is obtained with the following formula.

$$\mu Dingin(24) = \{ 1 ;\ x \leq 25 \}$$

$$\mu Normal(24) = \{ 0 ;\ x \leq 25 \}$$

$$\mu Panas(24) = \{ 0 ;\ x \leq 30 \}$$

For the set "µ cold":

Since 24 ≤ 25, the degree of membership of the "cold" set is 1. This means that the value 24 fully belongs to the "cold" set.

For the set "µ normal":

Since 24 ≤ 25, the degree of membership of the "normal" set is 0. This means that value 24 does not belong to the "normal" set.

For the set "μ hot":
Since 24 ≤ 30, the degree of membership of the "hot" set is 0. This means that the value 24 does not belong to the "hot" set.

3. The nutrient absorption output variable (PPM) consists of three sets: less, normal, and high. There is a domain of each set with a domain value of less than 0 - 560, in normal has a value range of 560 - 850, and in high has a value range of 850 +.
4. Apply fuzzy operators according to the rules that have been made.
[R1] IF PH IS ACIDIC AND TEMPERATURE IS COLD THEN PPM IS LESS
a_1 = max(μ acid[5] **AND** μ cold[24]) = max(0.5, 1) = 0.5
[R2] IF PH IS ACIDIC AND TEMPERATURE IS NORMAL THEN PPM IS LESS
a_2 = max(μ acid[5] **AND** μ normal[24]) = max(0.5, 0) = 0
[R3] IF PH IS ACIDIC AND TEMPERATURE IS HOT THEN PPM IS NORMAL
a_3 = max(μ acid[5] **AND** μ hot[24]) = max(0.5, 0) = 0
[R4] IF PH IS NEUTRAL AND TEMPERATURE IS COLD THEN PPM IS LESS
a_4 = max(μ neutral[5] **AND** μ cold[24]) = max(0.5, 1) = 0.5
[R5 IF PH IS NEUTRAL AND TEMPERATURE IS NORMAL THEN PPM IS NORMAL
a_5 = max(μ neutral[5] **AND** μ normal[24]) = max(0.5, 0) = 0
[R6] IF PH IS NEUTRAL AND TEMPERATURE IS HOT THEN PPM IS LESS
a_6 = max(μ neutral[5] **AND** μ hot[24]) = max(0.5, 0) = 0
[R7] IF PH IS ALKALINE AND TEMPERATURE IS COLD THEN PPM IS LESS
a_7 = max(μ alkaline[5] **AND** μ cold[24]) = max(0, 1) = 0
[R8] IF PH IS ALKALINE AND TEMPERATURE IS NORMAL THEN PPM IS LESS
a_8 = max(μ alkaline[5] **AND** μ normal[24]) = max(0, 0) = 0
[R9] IF PH IS ALKALINE AND TEMPERATURE IS HOT THEN PPM IS LESS
a_9 = max(μ alkaline[5] **AND** μ hot[24]) = max(0, 0) = 0
5. Applying the implication function in the output variable

- A1 = 0.5
  0.5 = $\frac{700-x}{700-560} = 70 = 700 - x = 630$

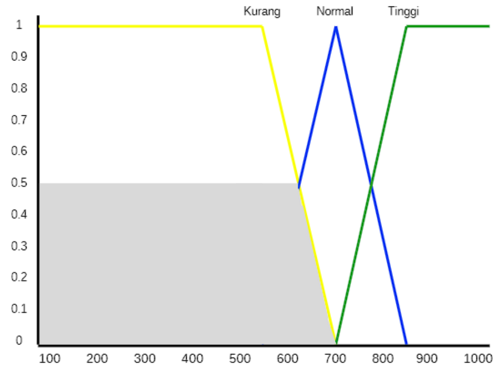

Figure 5 implication rule A1 in output variable

- A2 = 0
- A3 = 0
- A4 = 0.5
  0.5 = $\frac{700-x}{700-560} = 70 = 700 - x = 630$

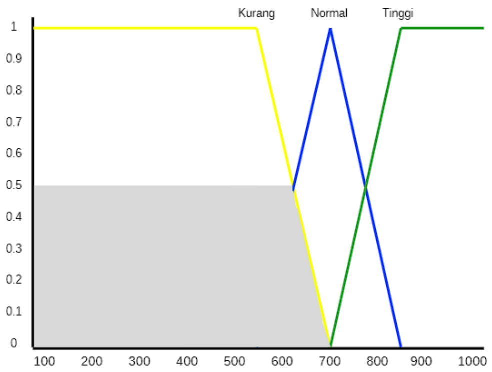

Figure 6 implication rule A4 in output variable

- A5 = 0
- A6 = 0
- A7 = 0
- A8 = 0
- A9 = 0

This calculation tries to solve for the value of x in the membership function with the given membership degree. In this case, A1 (degree of membership) is given as 0.5, and the membership function used is for the "less" set which has a range between 560 to 700. So, the result of the calculation is x = 630. This means that if the degree of membership of the "less" set in a variable is 0.5, then the variable has a value of 630.

A4 calculation:

The value of x in the membership function with the given membership degree. In this case, A4 (degree of membership) is also given as 0.5, and the membership function used is for the set "less" which has a range between 560 to 700. So, the result of the calculation is x = 630. This means that if the degree of membership of the "less" set in a variable is 0.5, then the variable has a value of 630

6. Composes all outputs

$$\mu SF[z] = \begin{cases} 0.5\,;\; 0 \le x \le 630 \\ \frac{700 - x}{700 - 560}\,;\; 630 \le x \le 700 \end{cases}$$

This calculation describes the membership function for a fuzzy set, in this case the "SF" set. This membership function appears to have two distinct parts to describe the change in degree of membership with a change in x value.

- The first part is for the range 0 ≤ x ≤ 630, where the degree of membership remains 0.5. This means that for x values between 0 and 630, the degree of membership of the "SF" set is 0.5, indicating a condition of being "half" a member of the set.
- The second part is for the range 630 ≤ x ≤ 700, where the membership degree is calculated as (700 - x)/(700 - 560). This means that for x values between 630 and 700, the degree of membership of the "SF" set changes linearly as the x value decreases from 700 to 560.

7. Defuzzyfication by calculating the moment and area of the result area

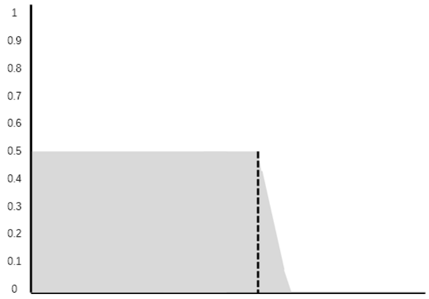

Figure 7 Defuzzyfication

- A1 = (630) x 0.5 = 315
- A2 = $\frac{(700 - 630)\, x\, 0.5}{2} = 17.5$

A1 is calculated as (630) x 0.5 = 315.

This means the value of A1 is 315, which indicates the value of x at which the degree of membership of the fuzzy set is 0.5.

A2 is calculated as ((700 - 630) x 0.5)/2 = 17.5.

First, we calculate 700 - 630 = 70.

Then, we multiply 70 by 0.5, the result is 35.

Finally, we divide 35 by 2, resulting in a value of 17.5.

This is likely a calculation to find the distance between the x value where the membership degree of the fuzzy set becomes 0.5 to the x value where the membership degree reaches 1 at maximum.

Simplifying the composition function:

μSF[z] = $\begin{cases} 0.5\,;\ 0 \le x \le 630 \\ \frac{700 - x}{700 - 560}\,;\ 630 \le x \le 700 \end{cases}$ → μSF[z] = $\begin{cases} 0.5\,;\ 0 \le x \le 630 \\ 5 - 0.007x\,;\ 630 \le x \le 700 \end{cases}$

This calculation is a transformation of the membership function of the fuzzy set "SF" from its initial form to a simpler or standardized form. The membership function is initially expressed in two parts, namely:

The first part, with a fixed membership degree of 0.5 for the range 0 ≤ x ≤ 630.

The second part, with a membership degree of (700 - x)/(700 - 560) for the range 630 ≤ x ≤ 700.

In this calculation, the second part of the membership function is reduced to a simpler form, namely 5 - 0.007x for the range 630 ≤ x ≤ 700.

Calculating the moment:

- M1 = $\int_0^{630} (0,5)x\, dx = 0.25x^2|_0^{630} = 99225$
- M2 = $\int_{630}^{700} (5 - 0.007x)x\, dx = \frac{47579}{3} = 15859$

The first moment (M1) is calculated as the integral from 0 to 630 of the fuzzy set membership function for that range, which is 0.5. The mathematical notation for this integral is ∫_0^630(0.5)x dx.

Calculating the integral gives a result of 0.25x^2 from 0 to 630.

Substitution of the value 630 into the formula gives the final result 0.25*630^2 = 99225.

The second moment (M2) is calculated as the integral from 630 to 700 of the fuzzy set membership function for that range, which is (5 - 0.007x)x. The mathematical notation for this integral is ∫_630^700 (5 - 0.007x)x dx.

Calculating the integral gives the result (47579/3), which can be simplified to 15859.

Calculating the centroid:

z* = $\frac{(m1 + m2)}{(a1 + a2)} = \frac{(99225 + 15859)}{(315 + 17.5)} = \frac{115084}{332.5} = 346.11$

This calculation seems to try to calculate the center of mass (centroid) of the membership function of the fuzzy set "SF" which has been transformed into a simpler form. This center of mass is often used in fuzzy logic to represent a "typical" or "representative" value of a fuzzy set.

In this calculation, the first moment value m1 is 99252 m2 is 15859 the area value a1 is 315 and the value a2 is 17.5. So, the centroid of the membership function of the fuzzy set "SF" is about 346.11. This is the value that represents the "middle" or "center" point of the fuzzy set.

8. Application-based testing using matlab to compare the prediction of nutrient absorption (PPM) of lettuce hydroponics with water temperature and pH variables.

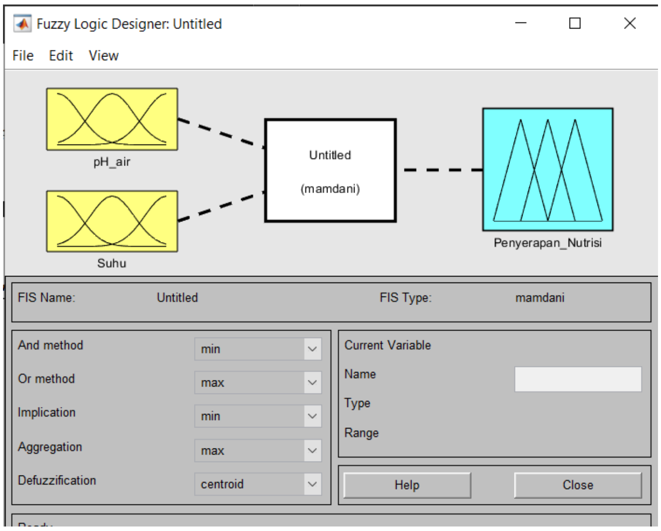

Figure 8 fuzzy logic in matlab

Fuzzy testing in matlab applications uses the mamdani method to determine the firm value of the calculation model. Compared to other methods, the Mamdani fuzzy method has a smaller error of 19.76% compared to the Tsukamoto method of 39.03% and Sugeno of 86.41%. The use of the mamdani fuzzy method is expected to get a smaller error rate (M. Irfan et al, cited in Sunanto et al, 2021). Fuzzy mamdani uses max and min calculations using 2 input variables, namely water temperature and pH and 1 output variable, namely nutrient absorption (PPM).

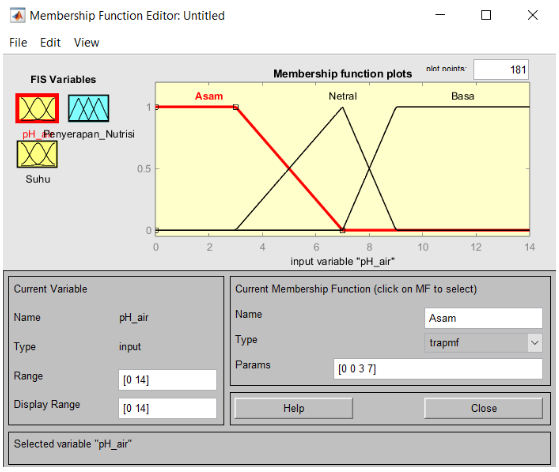

Figure 9 Membership function pH in matlab

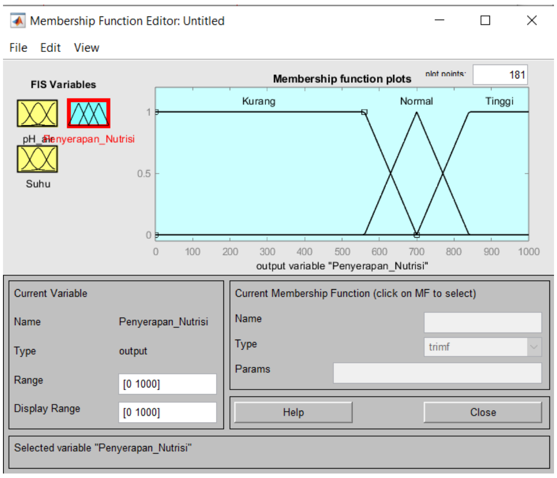

Figure 10 membership function output in matlab

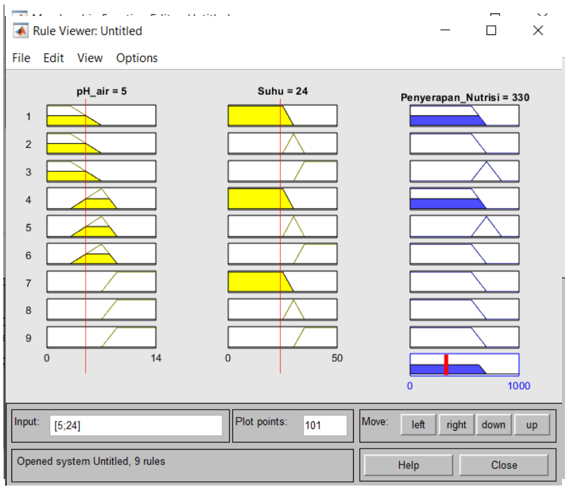

Figure 11 Rule viewer input and output

With the same input, namely 5 in the water pH input variable and 24 in the temperature input variable, the output obtained from the matlab application is 330 for nutrient absorption. This is slightly different from the results of the manual calculation.

With manual calculations and using the Matlab application produce two different outputs, in Matlab the result is 330 and in the manual calculation it is 346. However, using the fuzzy Mamdani method has an error value of 19.76%. So when you compare the two output values, you get an accurate result of 95.376%.

Explanation of calculation:

$$\frac{346 - 330}{346} \times 100\%$$

$$\frac{16}{346} \times 100\%$$

$$\{1 - |0.04624|\} \times 100\%$$

$$0.95376 \times 100\% = 95.376\%$$

CONCLUSION

Calculations using fuzzy on predictions determine the quality of water and the environment in lettuce hydroponics is done using two ways, namely manual calculations and calculations with the Matlab application. The value obtained is directly proportional to the rules that have been set, in this case if the pH of the water is acidic with a value of 5 and the temperature is cold with a value of 24, then the absorption of nutrients obtained is less than 560. The results obtained from manual work get 346.11, while the results obtained from working with the matlab application get 330 results. The results of the two methods are in accordance with previous research which explains that the use of fuzzy mamdani has a smaller error rate of 19.76% compared to other methods.

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