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Implementation of Fuzzy Logic to regulate Water Quality in Maintaining the Aquascape Ecosystem

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Abstract
Aquascape is an artificial aquarium ecosystem that is increasingly popular, considering the high cost of creating and maintaining an aquascape. Several aspects need to be considered in maintaining an aquascape, namely maintaining water quality. To know the water quality, it is necessary to periodically check the aquascape manually and carry out maintenance, therefore knowledge is needed to regulate and maintain the water quality in the aquascape. This research aims to implement fuzzy logic as a water quality control system in aquascape maintenance. The research method includes collecting data from the literature as well as developing a fuzzy logic model to identify and control water quality such as pH and temperature. The output of the system developed is a water quality control device with the categories "Unbalanced", "Quite Balanced", "Balanced". This research method includes calculations by collecting data and using MATLAB software to develop a fuzzy logic system. The research results show that the application of fuzzy logic is able to regulate water quality effectively and minimize the risk of ecosystem damage in the aquascape. The research conclusion shows that the application of fuzzy logic to regulate water quality in aquascapes has great potential in maintaining the sustainability of aquascape ecosystems.

Keywords: *Aquascape, Fuzzy Logic, pH, Water Quality*

INTRODUCTION

Aquascape is a fake environment in an aquarium that is famous for its various kinds of plants, considering how difficult and expensive it is to create and maintain an aquascape itself. There are several basic points of view. One of the things that need to be considered in maintaining an aquascape is maintaining water quality (Fikri, Musthafa, & Pradhana, 2021). The most interesting thing about aquascape is that it creates a view below the surface of the water in the aquarium, so that it looks more beautiful and interesting to look at while improving the aesthetics of the room by considering the plant maintenance point of view (Udin, Istiadi, & Rofii, 2021).

Currently, aquascape attracts many enthusiasts so that the flow of aquascape is increasing every day. Aquascape also has the opportunity to become a source of income (Ruslianto, Ristian, Hasfani, & Sari, 2023). There are currently many types of aquascape, including Dutch fashion, iwagumi fashion, natural fashion, biotope fashion, German fashion, forest fashion, and others. Fashion for each individual or specialist has their own tendencies. Each type of aquascape can provide different beauty (Wijianto et al., 2022).

Every living animal certainly needs light for the survival of biota, including Aquascape. Aquascape is the skill of arranging water plants, wood, rocks, sand or other objects that have stylistic value in an aquarium (Rusimamto, Suprianto, & Buditjahjanto, 2022). The intelligence in making aquascapes can be made in various styles. The closeness of driftwood, pumice, rock and rocks can be arranged as desired, the composition styles vary: they can be made in a concave shape (high on both sides or moo in the middle), curved shape (moo in both sides or high in middle), triangular (high on one side, decreasing on the other), and rectangular (M. P. Sari, 2019). The most important asset that must be maintained in an aquascape is water, because water can affect the conditions or components of animal life such as fish and marine plants in the aquascape (Aztisyah, Yuniati, & Adi Setyoko, 2021).

The ds18b20 temperature sensor has a capacity so that the temperature in the aquascape aquarium can be controlled naturally. This device uses DS18B20 as water temperature input. DS18B20 as a control to control the PenCool fan engine to rotate according to the temperature being checked. It is believed that making this tool can help aquascape cultivators to maintain a stable water temperature (Thoha, Dwirastiaji, & Samsugi, 2021). This temperature sensor is placed at the bottom of the aquarium so that the sensor can still take temperature readings when the water is changed (Sandy, Endryansyah, Suprianto, & Rusimamto, 2022).

In caring for an aquascape there are several problems that often become obstacles. The extraordinary climate is not surprising and often changes rapidly. Warm Discussion: changes in water temperature in an aquascape during the day can reach 30°C, where the perfect water temperature for an aquascape is 22°C to 25°C (Brahmantika, 2019). Meanwhile, on average, aquatic plants require 20 to 27 degrees Celsius. An example is Lilaeopsis Brasiliensis or another name, Brazilian Micro Sword, which requires temperatures ranging from 15 to 26 degrees Celsius (Rachman & Santoso, 2022).

A pH sensor is a sensor that can identify the pH level of water. This sensor is very useful for alerting you about the pH level in water or for filtering water pH levels from water contamination (Imaduddin & Saprizal, 2023). The pH value of water is one of the things that is taken into account in maintaining an aquascape ecosystem, where the ideal pH value for maintaining an aquascape ecosystem ranges from 6-8 (Devi, Padmavathy, Aanand, & Aruljothi, 2017; Emerenciano, Martínez-Córdova, Martínez-Porchas, & Miranda-Baeza, 2017; Fikri et al., 2021). If the pH does not match the plant's needs, it means the plant will lose its ability to retain the healthy ingredients the plant needs. Each plant requires a different pH value, depending on the type of plant (Mufida et al., n.d.).

The most common way to maintain water quality is to drain and add water. Changing the water regularly will certainly take up time, energy and money. Therefore, many aquascape owners who are busy with other activities do not have time to monitor and control water quality (Fikri et al., 2021).

One of the markers that water is said to be clean and healthy is the PH level of the water, whether it is classified as an acidic, neutral or alkaline solution. The usual way to determine the PH level of a liquid is to use litmus paper. The litmus paper will be dipped into the test structure where the litmus paper will change color according to the PH level of the test structure (Pratama, Wibawa, & Suarjaya, 2022). The degree of acidity of water (pH) is an indicator used to state the level of corrosiveness or alkalinity of a solution. The degree of sharpness is characterized as the cologarithm of the movement of split hydrogen particles (H+) (Karangan, Sugeng, & Sulardi, 2019). PH is characterized as the relative sharpness or alkalinity of a substance. The pH scale includes values from (zero) to 14. A pH value of 7 is said to be neutral, below a pH value of 7 is said to be Acid while above a pH value of 7 is said to be Alkaline (V. F. Sari, Ekawita, & Yuliza, 2021).

Lotfi A. Zadeh was someone who first introduced fuzzy logic, namely in 1965. This fuzzy logic is one of the components that makes up soft computing. Fuzzy logic can be used as a way to map a form of real world problem from input to expected output (Rifanti, Pujiharsono, & Pradana, 2023). Fuzzy logic is a logic that has a value of vagueness or vagueness between true or false. In fuzzy logic theory, a value can be true or false simultaneously. However, the extent of existence and error of something depends on the weight of membership it has. Fuzzy logic has a degree of membership in the range 0 to 1 (Nasution, 2012).

The process in the Fuzzy system is that the input in the form of real data is changed by a fuzzifier (fuzzification stage) into a Fuzzy value in U which is then processed by a Fuzzy inference engine with

Fuzzy basic rules which are then reaffirmed with a defuzzifier (defuzification stage) to become a firm value (output) (Batubara, 2017). Several reasons why people use fuzzy logic to solve this case are because the concept of fuzzy logic is easier to understand, simple, flexible, has tolerance for inaccurate data, and is based on natural language (Maslim, Yudi Dwiandiyanta, & Susilo, 2018).

There are many kinds and types of fuzzy logic, including fuzzy which is classified as a Fuzzy Inference System type, namely Tsukamoto, Mamdani, and Sugeno fuzzy (Tundo, 2021). The Mamdani method is most often used in applications because of its simple structure, namely using the MIN-MAX or MAX-PRODUCT operation. To get the output, the following 4 stages are required. (1) Fuzzyfication, (2) Formation of a Fuzzy knowledge base (rules in the form of IF...THEN), (3) Application of the implication function using the MIN function and inter-rule composition using the MAX function (generating a new fuzzy set), (4) Defuzyfication using Centroid method (Nasir & Suprianto, 2017).

METHODS

The data collection method used is a literature review method by reviewing existing research journals related to water quality regulation for the aquascape ecosystem that will be produced. The data that will be taken includes pH levels and air Warme which will carry out a fuzzification calculation process and carry out analysis using a supporting application, namely Matlab. This research was carried out for approximately 3 (three) months at the IPB University Vocational School, Bogor City, West Java.

The Fuzzy Mamdani Method is a fuzzy method that can help make the best decisions in problems with uncertain linguistics (Puryono, 2014). The Fuzzy Mamdani method is a fuzzy inference system because the technique is a combination of each fuzzy rule (Yunan & Ali, 2020). The mamdani method is usually known as the max min method when it uses the MIN implication function. There are several stages in getting the output produced using the Mamdani method, namely using several stages of FIS or Fuzzy Inference System. Includes: Fuzzification, fuzzy logic operations, implication, compositing all output (aggregation), and defuzzification (testing) (Irwan, 2017). Fuzzy Mamdani has advantages. That is, a more intuitive approach, accepted by many stakeholders, applicable to the field of statistics, produces output that closely resembles real-world situations, is highly flexible and tolerant of existing data, and is more efficient (Muntahanah, Handayani, & Lidia, 2021). Therefore, the Mamdani fuzzy method was chosen as the method used to analyze the data obtained.

RESULTS AND DISCUSSION

In the first stage, namely carrying out fuzzification using several variables as input and output benchmarks to form a fuzzy set, the input and output variables in the table are as follows:

Table 1. Variable Input

No	Variabel	Units
1	pH	-
2	Temperature	°C

Table 2. Variable Output

No	Variabel	Description
1	Ecosystem Balance	In the aquascape ecosystem habitat, the pH and temperature values greatly influence abiotic life in maintaining the balance of the ecosystem. These two factors determine the balance of the ecosystem

The image below is a schematic display of the input and output in the Matlab application as a comparison in carrying out the next fuzzy calculation.

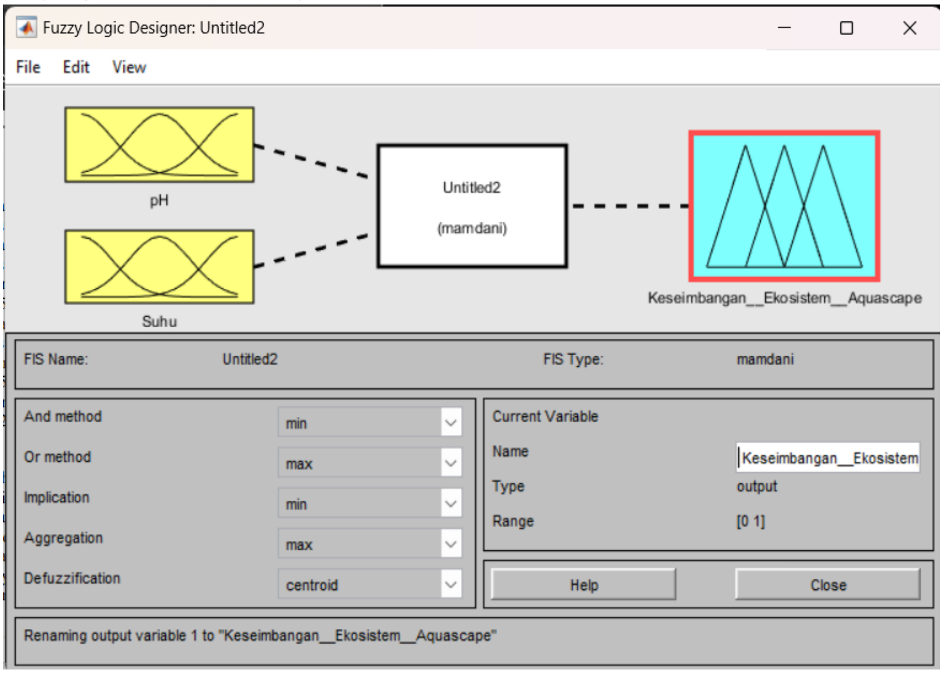

Figure 1. Input and Output Schematic in Matlab

For each input and output variable, a fuzzy set must be determined which has a value and range before determining the membership set, as follows:

Table 3. Set of pH Variables

Input Variables	**Fuzzy Sets**	**Range**	**Interval**
	Acid		0-6.8
pH	Normal	0-14	6-8
	Alkaline		7-14

Sumber: (Fachrezy Hamid & Harmadi, 2023; Syukur, Putrada, & Suwastika, 2019)

Table 4. Set of Warme variables

Input Variables	**Fuzzy Sets**	**Range**	**Interval**
	Cool		15°C -22°C
Suhu	Normal	15-30	22°C -25°C
	Warm		24°C -30°C

Sumber: (Fachrezy Hamid & Harmadi, 2023; Syukur et al., 2019; Triawan & Sardi, 2020)

The input variable pH has a fuzzy set of acidic, normal and basic. For acids, they are in the parameters [0 0 4 6.8], normal are [6 6.8 7.3 8], and bases are in the parameters [7 9 14 14].

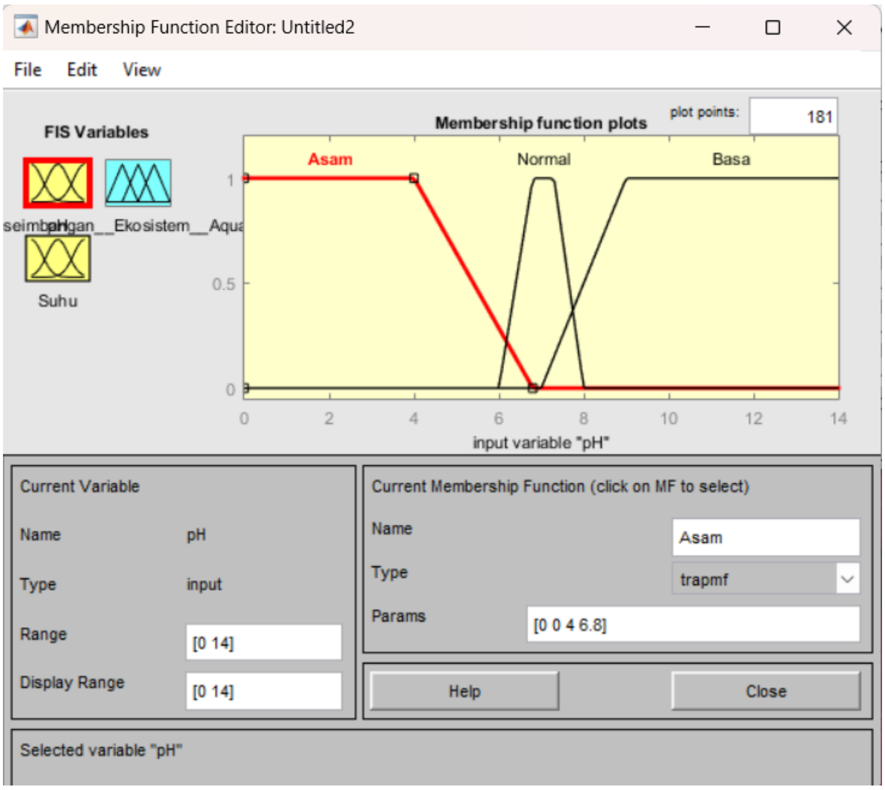

Figure 2. FIS Input Variable pH

Meanwhile, the Warme input variable has a fuzzy set of cold, normal and warm. For cold it is in the parameters [15 15 20 23], normal is [22 23 24 25], and warm it is in the parameters [24 26 30 30].

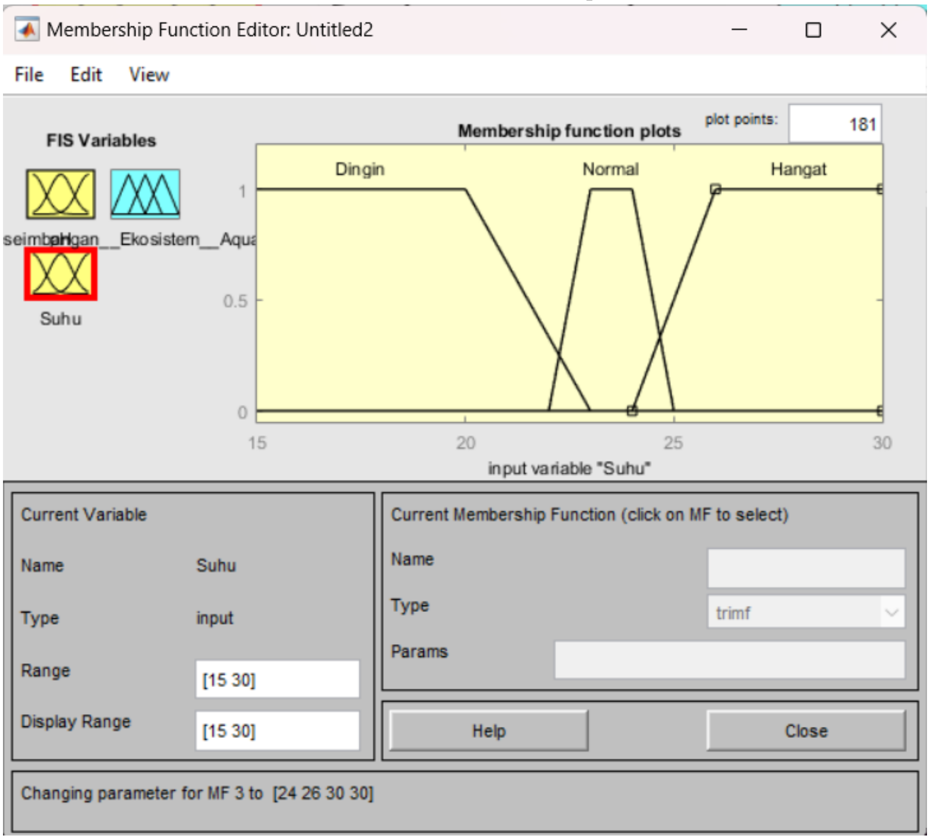

Figure 3. FIS Input Warm Variable

The variable used for output is the balance of the aquascape ecosystem with a fuzzy set consisting of unbalanced, quite balanced, and balanced which has a range of 0-10 and the respective intervals consist of 1-3 for unbalanced, 3-7 for quite balanced, and 7-10 for balance.

Table 5. Set of Ecosystem Balance Variables

Ouput Variables	**Fuzzy Sets**	**Range**	**Interval**
	Unbalanced		1-3
Aquascape Ecosystem Balance	Quite Balanced	0-10	3-7
	Balanced		7-10

For the balance output variable, the aquascape ecosystem has a fuzzy set of unbalanced, quite balanced, and balanced with the respective parameters being [0 1.5 3] for unbalanced, [3 5 7] for quite balanced, and [7 8.5 10] for balanced.

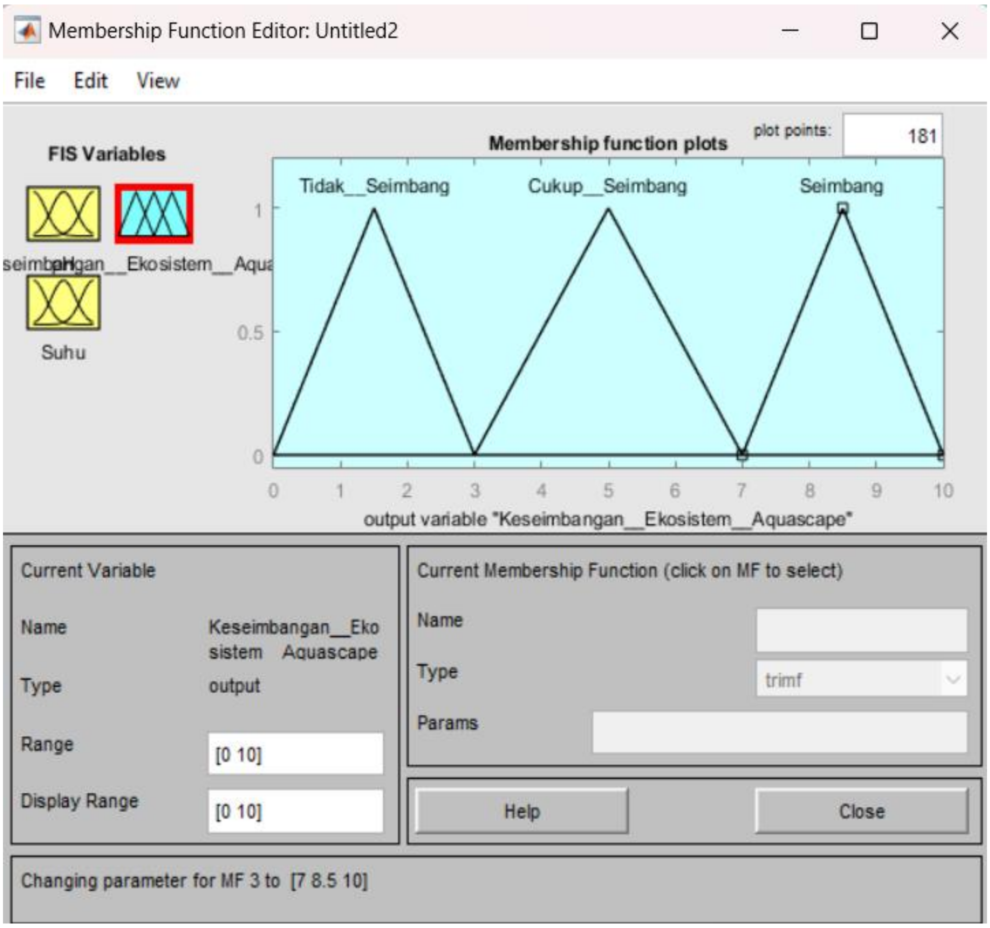

Figure 4. FIS Set of Ecosystem Balance Variable

In the next stage, determine the membership set that will be used to calculate the balance of the aquascape ecosystem based on the range of each fuzzy set by determining the membership degree value (μ_x). The following is the membership set function of the input variables that will be used in calculating the output value:

$$Fx(pH)\begin{cases} \mu Acid(x) = \begin{cases} 0 & : x < 0 \\ 1 & : 0 \leq x \leq 4 \\ \dfrac{6.8 - x}{6.8 - 4} & : 4 < x < 6.8 \\ 0 & : x \geq 6.8 \end{cases} \\ \mu Normal(x) = \begin{cases} 0 & : x \leq 6 \\ \dfrac{x-6}{6.8-6} & : 6 < x < 6.8 \\ 1 & : 6.8 \leq x \leq 7.3 \\ \dfrac{8-x}{8-7.3} & : 7.3 < x < 8 \\ 0 & : x \geq 8 \end{cases} \\ \mu Alkali(x) = \begin{cases} 0 & : x \leq 7 \\ \dfrac{x-7}{10-7} & : 7 < X < 10 \\ 1 & : 10 \leq X \leq 14 \\ 0 & : X > 14 \end{cases} \end{cases}$$

$$Fx(Temperatur)\begin{cases} \mu Cold(x) = \begin{cases} 0 & : x < 15°C \\ 1 & : 15°C \leq x \leq 20°C \\ \dfrac{23 - x}{23 - 20} & : 20°C < x < 23°C \\ 0 & : x \geq 23°C \end{cases} \\ \mu Normal(x) = \begin{cases} 0 & : x \leq 22°C \\ \dfrac{x-22}{23-22} & : 22°C < x < 23°C \\ 1 & : 23°C \leq x \leq 24°C \\ \dfrac{25-x}{25-24} & : 24°C < x < 25°C \\ 0 & : x \geq 25°C \end{cases} \\ \mu Warm(x) = \begin{cases} 0 & : x \leq 24°C \\ \dfrac{x-24}{27-24} & : 24°C < x < 26°C \\ 1 & : 26°C \leq x \leq 30°C \\ 0 & : x > 30°C \end{cases} \end{cases}$$

The next stage is the application of the rules used to carry out calculations according to the results of the fuzzy Mamdani method, where the fuzzy Mamdani method has min and max rules. The following are the rules used to determine the balance of an aquascape ecosystem:

1. IF pH is Acid AND Warme is Cold Then the Aquascape Ecosystem Balance is Unbalanced
2. IF pH is Acid AND Warme is Normal Then the Aquascape Ecosystem Balance is Unbalanced
3. IF pH is Acid AND Warme is Warm Then the Aquascape Ecosystem Balance is Unbalanced
4. IF pH is Normal AND Warme is Cold Then the Aquascape Ecosystem Balance is Quite Balanced
5. IF pH is Normal AND Warme is Normal Then the Aquascape Ecosystem Balance is Balanced
6. IF pH is Normal AND Warme is Warm Then the Aquascape Ecosystem Balance is Fairly Balanced
7. IF Alkaline pH AND Cold Warme Then the Aquascape Ecosystem Balance Is Unbalanced
8. IF pH is Alkaline AND Warme is Normal Then the Aquascape Ecosystem Balance is Unbalanced

9. IF Alkaline pH AND Warm Warme Then the Aquascape Ecosystem Balance Is Unbalanced

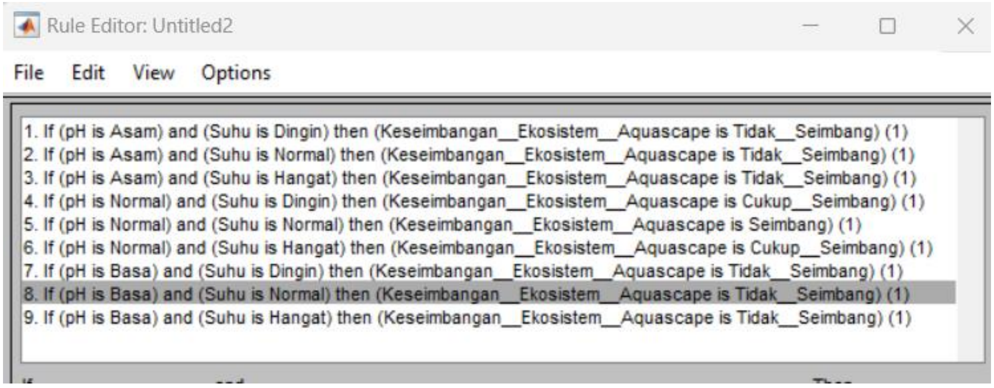

Figure 5. Fuzzification Process Rules

The next stage is to carry out calculations to analyze the output results between manual calculations using Matlab. In this case study, it is known that the pH of the aquascape is 4, and the Warme is 29°C. First we see that a pH of 4 is in the acidic range in the membership function that has been created, while a Warme of 29°C is in the warm range. The next step is to determine the membership degree value as follows:

$$\mu_x Acid = 4 = 1$$
$$\mu_x Warm = 29°\text{C} = 1$$

So from the calculation results it is found that the membership degree value of pH 4 is worth 1, and the membership degree value of temperature 29°C is worth 1. This is obtained because the pH value 4 is between 0≤x≤4 whose value is 1, and the temperature is 29°C is between 26°C≤x≤30°C which has a value of 1.

The next step is to determine the rules because pH 4 is Acid and a temperature of 29°C is Warm, so the rule used is the third rule, namely "IF pH Acid and Temperature Warm Then Aquascape Ecosystem Balance is Unbalanced" where the unbalanced range is between 1-3 then The formula for the rules is obtained as follows:

$$\alpha_3 = Min(\mu_x pH \cap \mu_x Temperatur)$$
$$\alpha_3 = Min(1 \cap 1)$$
$$\alpha_3 = 1$$

In this case study, using the AND operator, the rule value taken is the smallest value, and the rule value obtained is 1, this value will be used to determine x1 and x2 for the output variable at the defuzzification stage.

Next is the defuzzification stage or testing stage, at this stage the values x1 and x2 are needed which will be used to determine the membership set of the output variables as follows:

- Find the Value of x1
  - $1 = \frac{x1-a}{b-a}$
  - $1 = \frac{x1-1}{2-1}$
  - $1 = x1 - 1$
  - $x1 = 1 + 1$
  - $x1 = 2$
- Find the Value of x2
  - $1 = \frac{c-x2}{c-b}$
  - $1 = \frac{3-x2}{3-2}$
  - $1 = 3 - x2$
  - $x2 = 3 - 1$
  - $x2 = 2$

After obtaining the values of x1 and x2 which are 2, the range is 1-3, which means 2 is the peak point which divides it into 2 areas where the area area will be calculated as follows:

- find the area of region 1
  - $LD1 = \frac{a \times t}{2}$
  - $LD1 = \frac{(x1-a) \times t}{2}$
  - $LD1 = \frac{(2-1) \times 1}{2}$
  - $LD1 = \frac{1 \times 1}{2}$

- $LD1 = \frac{1}{2} = 0{,}5$

➢ find the area of region 2

- $LD2 = \frac{a \times t}{2}$
- $LD2 = \frac{(c - x2) \times t}{2}$
- $LD2 = \frac{(3-2) \times 1}{2}$
- $LD2 = \frac{1 \times 1}{2}$
- $LD2 = \frac{1}{2} = 0{,}5$

So the membership function is obtained as follows:

$$Fx(Aquascape\ Ecosystem\ Balance) \begin{cases} 0 & : \mathrm{x} < 1 \\ \dfrac{x-1}{2-1} & : 1 \le \mathrm{x} \le 2 \\ 1 & : x = 2 \\ \dfrac{3-x}{3-2} & : 2 \le \mathrm{x} \le 3 \\ 0 & : \mathrm{x} \ge 3 \end{cases}$$

After getting the membership function, the next step is to find the moment value which will be used as the final value to carry out defuzzification.

➢ Search Momen

- $m1 = \frac{x-1}{2-1} = x - 1$
- $m2 = 0.66$
- $m3 = \frac{3-x}{3-2} = 3 - x$

➢ Calculating Moment Value (M1)

- $M1 = \int_a^b f(x).x.dx$
- $M1 = \int_1^2 (x-1).x.dx$
- $M1 = \int_1^2 x^2 - x\ dx$
- $M1 = \int_1^2 \frac{2x^3 - 3x^2}{6}\ dx$
- $M1 = \frac{5}{6} = 0.8333333333333333$

➢ Calculating Moment Value (M2)

- $M2 = \int_a^b f(x).x.dx$
- $M2 = \int_2^2 1.x.dx$
- $M2 = \int_2^2 x\ dx$
- $M2 = \int_2^2 \frac{x^2}{2}\ dx$
- $M2 = 0$

➢ Calculating Moment Value (M3)

- $M3 = \int_a^b f(x).x.dx$
- $M3 = \int_2^3 (3-x).x.dx$
- $M3 = \int_2^2 (3x - x^2)\ dx$
- $M3 = \int_2^2 \frac{3x^2}{2} - \frac{x^3}{3}\ dx$
- $M3 = \frac{7}{6} = 1.166666666666667$

The value for each moment is obtained, where M1 has a value of 0.8333333333333333, M2 has a value of 0, and M3 has a value of 1.166666666666667. Next is the final stage, namely carrying out defuzzification by adding up the area area values divided by the number of moment values.

$$Z^* = \frac{\sum M}{\sum LD}$$

$$Z^* = \frac{M1 + M2 + M3}{LD1 + LD2}$$

$$Z^* = \frac{0.8333333333333333 + 0 + 1.166666666666667}{0{,}5 + 0{,}5}$$

$$Z^* = \frac{2}{1} = 2$$

The image below displays the output values from the defuzzification results using the Matlab application.

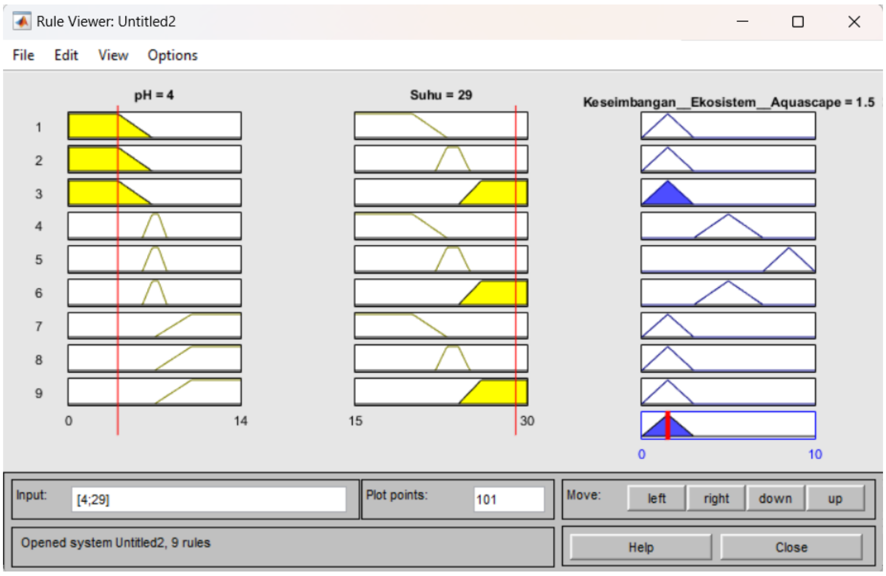

Figure 6. Defuzzification in matlab applications

Look at the results of the defuzzification calculation, you get a value of 2 with a margin of error of 0.5 from what should be 1.5 in calculations using Matlab where the value of 1.5 is the value for the balance of the aquascape ecosystem "Unbalanced".

CONCLUSION

Based on the description of the research results, this study presents a fuzzy logic system designed to assess the equilibrium state of an aquascape ecosystem. For each input and output variable, fuzzy sets are defined with corresponding ranges and membership functions. The system then employs rules based on the Mamdani fuzzy inference method to establish relationships between the inputs and the output. A case study is presented to illustrate the application of the system, the system successfully determines the ecosystem to be "unbalanced," which aligns with expectations for these conditions. However, a minor discrepancy exists between the calculated value and the anticipated value obtained using Matlab, this difference suggests potential for further refinement of the fuzzy sets or membership functions employed in the system. Overall, the fuzzy logic system demonstrates promise as a tool for evaluating the balance of aquascape ecosystems based on readily measurable parameters. Future refinements can enhance the system's accuracy and robustness.

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