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The Use off Fuzzy Mamdani to Predict Tilapia Production Based on Freshwater Quality

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Abstract

The practice of raising fish in Indonesia is commonplace, occurring in a variety of settings, including ponds, rivers, and even the sea. However, the process of feeding fish requires consistent care and attention, and overfeeding can have detrimental effects on the water quality, which in turn affects the health of the fish. To address this challenge, a water quality monitoring system can be implemented. This research proposes a system based on Fuzzy Logic, which simplifies water quality control. The system utilizes sensors to measure temperature, pH, dissolved oxygen (DO), and ammonia levels. The data will be processed by Matlab software and displayed on a screen for easy monitoring. This allows fish farmers to make informed decisions about feeding and maintaining optimal water conditions for their fish.

Keywords: Fuzzy, Water quality, Tilapia, Survival Rate

INTRODUCTION

Fish farming is a common practice in Indonesia, whether in ponds, rivers, or even the sea. However, raising fish in ponds requires constant care. Farmers must feed their fish regularly and monitor their growth as well as the overall health of the pond environment. Research indicates that good water quality is essential for fish welfare, affecting their growth, development, and survival (Amri, 2021). Modern fish farming, also known as aquaculture, considers not only economic gain but also environmental impact and social acceptance. In order to be successful, farmers require a well-defined production strategy. This strategy should not only minimize costs and maximize profits but also manage environmental factors that may pose a risk to the fish. The choice of environmentally friendly technologies is crucial for long-term success. These technologies can not only bring economic benefits but also ensure the sustainability of fish farming practices. Fish growth is defined as the increase in weight or size of the fish. A multitude of factors influence this growth, both internal (biological) and external (environmental). Internal factors, such as genetics or disease, are challenging to control. External factors include the quality of the water and the fish's food supply. Clean water, free of chemicals and pollutants, is essential for healthy tilapia growth. The quality of water in fish ponds is influenced by a number of factors, including acidity, clarity, temperature, oxygen levels, and salinity (Rochyani, 2018). Monitoring these parameters can be time-consuming and complex (Sholihah W., 2022), which often results in delays in addressing water quality issues that can be detrimental to fish. Consequently, there is a necessity for the development of more straightforward and user-friendly technology for the efficient and accurate monitoring of water quality in aquaculture.

Fuzzy logic offers a problem-solving approach that translates inputs into desired outputs. Unlike traditional methods, it relies on linguistic terms and easily analyzed fuzzy algorithms, making it more intuitive (Kusumadewi, 2006 in Febriany, 2017). The method's flexibility, use of simple mathematics, and low power consumption render it an optimal choice for monitoring water quality in tilapia ponds, as evidenced by previous research (Ali Basrah Pulungan et al.). This research employs fuzzy logic to facilitate water quality control and enhance the well-being of tilapia. The system utilizes a TDS 10 sensor to measure turbidity and a separate pH sensor to monitor acidity. These sensors provide real-time data for the fuzzy logic system. Furthermore, a DC motor functions as a pump to regulate water levels when necessary. For remote control, the system is connected to WiFi. The system was tested in a 3 x 4-meter pond. The average error rate for the TDS 10 sensor was 3.05%, and the pH sensor achieved an average error of 2.25%. These results demonstrate the system's accuracy in monitoring water quality parameters.

METHODS

Location and Time of Research

This research was carried out from the 30th of April to the 14th of May 2024 at the Fisheries Tub, IPB Vocational School.

Figure 1. Research location

The objective of this study was to develop a system for tilapia production based on water quality. The system was designed to determine the specific growth rate of fish from water quality and to facilitate the control of water quality, thereby increasing the survival rate (SR) of fish being cultivated.

Data Collection Methods

Research employing fuzzy methods typically employs a variety of data collection techniques, including the use of secondary data, observation, and data modeling. Secondary data refers to the gathering of information that has already been collected by others. This may include fuzzified statistical data, categorized qualitative data using fuzzy scales, and research data that has been processed using fuzzy logic methods. Observation is a method of gathering data on real-world behaviors or events, employing fuzzy scales for assessment. Furthermore, the collection of secondary data entails the utilization of information that has been previously collected by others, including fuzzified statistical data, categorized qualitative data using fuzzy scales, and research data that has been processed with fuzzy logic methods.

Variable Fuzzy

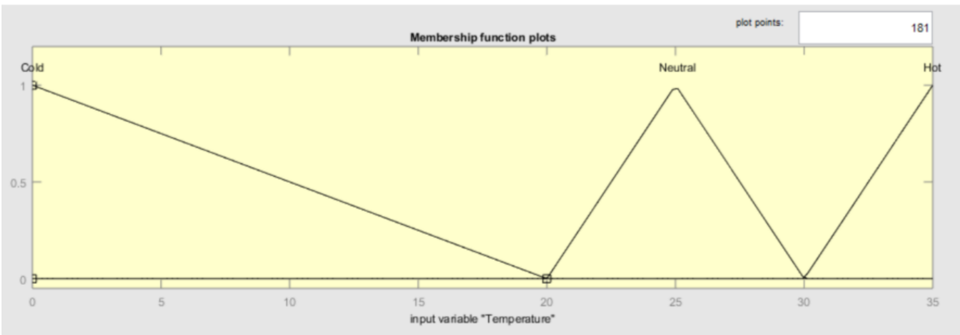

Figure 2. The set of temperature variables

Figure 2 illustrates that the temperature variable within the range of $0 \leq x \leq 20$ ℃ is categorized as cold, the temperature range of $20 \leq x \leq 30$ ℃ is categorized as neutral, and the temperature range of $30 \leq x \leq 35$ ℃ is categorized as hot.

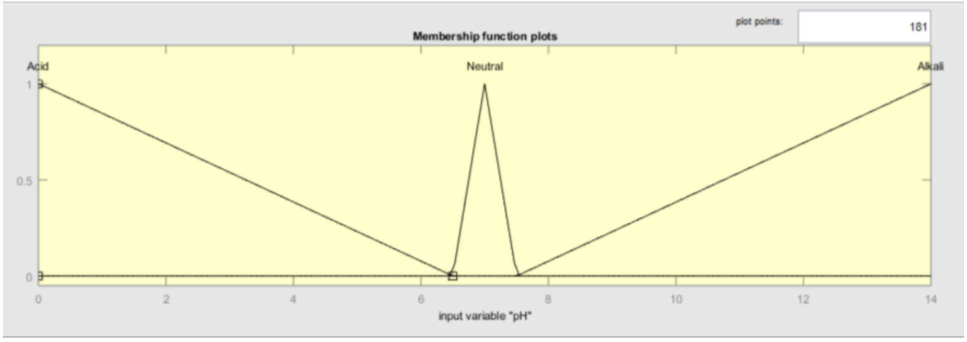

Figure 3. The set of pH variables

Figure 3 illustrates that the pH variable within the range 0 ≤ x ≤ 6.5 is categorized as acidic pH, the pH range 6.5 ≤ x ≤ 7.5 is categorized as neutral pH, and the pH range 7.5 ≤ x ≤ 14 is categorized as alkaline pH.

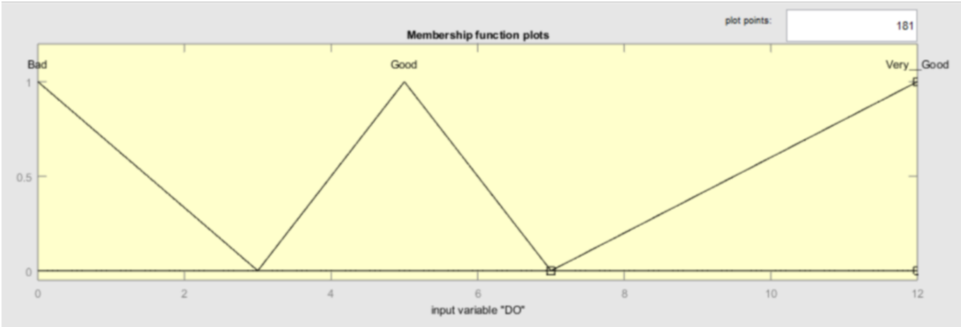

Figure 4. The set of DO (Dissolved Oxygen) variables

Figure 4 illustrates that the DO variable within the range of 0 ≤ x ≤ 3 mg/L is classified as a poor DO value, the DO range of 3 ≤ x ≤ 7 mg/L is categorized as a good DO value, and the DO range of 7 ≤ x ≤ 12 mg/L is categorized as an excellent DO value.

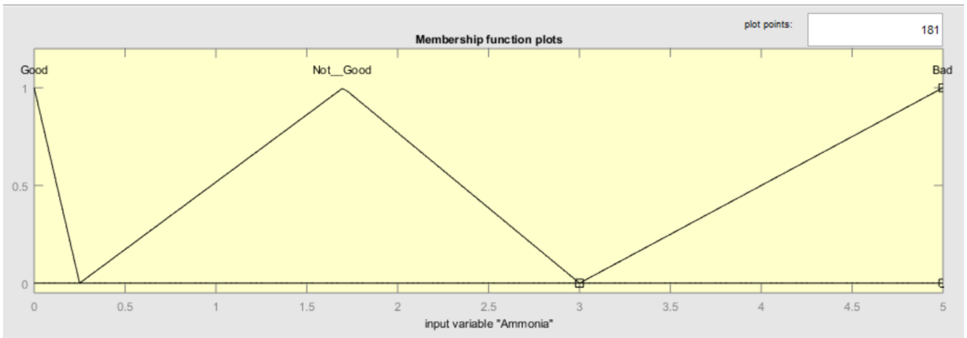

Figure 5. The set of Ammonia variables

Figure 5 illustrates that ammonia variables within the range of 0 ≤ x ≤ 0.25 ppm are classified as optimal ammonia values, ammonia ranges of 0.25 ≤ x ≤ 3 ppm are categorized as suboptimal ammonia values and ammonia ranges of 3 ≤ x ≤ 5 ppm are categorized as suboptimal ammonia values.

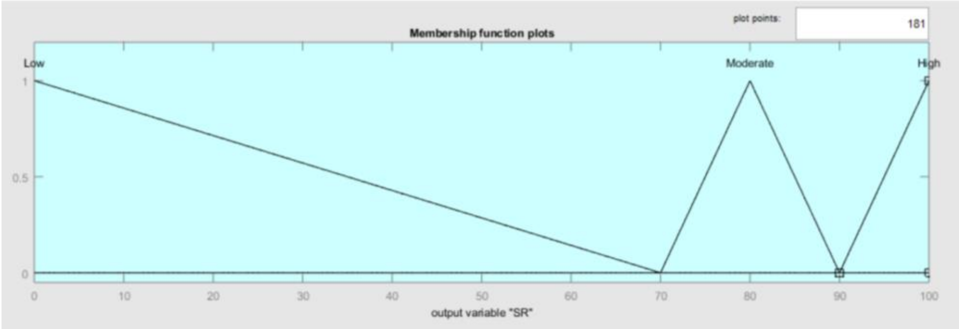

Figure 6. The set of SR (*Survival Rate*) variables

Figure 6 illustrates that variables classified as SR within the range of 0 ≤ x ≤ 70% are considered to have low SR values, while variables within the range of 70 ≤ x ≤ 90% are categorized as medium SR values, and variables within the range of 90 ≤ x ≤ 100% are classified as high SR values.

1. If (Temperature is Cold) and (pH is Acid) and (DO is Bad) and (Ammonia is Good) then (SR is Low) (1)
2. If (Temperature is Neutral) and (pH is Acid) and (DO is Bad) and (Ammonia is Good) then (SR is Moderate) (1)
3. If (Temperature is Hot) and (pH is Acid) and (DO is Bad) and (Ammonia is Good) then (SR is Low) (1)
4. If (Temperature is Cold) and (pH is Neutral) and (DO is Bad) and (Ammonia is Good) then (SR is Moderate) (1)
5. If (Temperature is Neutral) and (pH is Neutral) and (DO is Bad) and (Ammonia is Good) then (SR is High) (1)
6. If (Temperature is Hot) and (pH is Neutral) and (DO is Bad) and (Ammonia is Good) then (SR is Moderate) (1)
7. If (Temperature is Cold) and (pH is Alkali) and (DO is Bad) and (Ammonia is Good) then (SR is Low) (1)
8. If (Temperature is Neutral) and (pH is Alkali) and (DO is Bad) and (Ammonia is Good) then (SR is Moderate) (1)
9. If (Temperature is Hot) and (pH is Alkali) and (DO is Bad) and (Ammonia is Good) then (SR is Low) (1)
10. If (Temperature is Cold) and (pH is Acid) and (DO is Good) and (Ammonia is Good) then (SR is Moderate) (1)
11. If (Temperature is Neutral) and (pH is Acid) and (DO is Good) and (Ammonia is Good) then (SR is High) (1)
12. If (Temperature is Hot) and (pH is Acid) and (DO is Good) and (Ammonia is Good) then (SR is Moderate) (1)
13. If (Temperature is Cold) and (pH is Neutral) and (DO is Good) and (Ammonia is Good) then (SR is High) (1)
14. If (Temperature is Neutral) and (pH is Neutral) and (DO is Good) and (Ammonia is Good) then (SR is High) (1)
15. If (Temperature is Hot) and (pH is Neutral) and (DO is Good) and (Ammonia is Good) then (SR is High) (1)

Figure 7. Fuzzy Rules Numbers 1-15 in MATLAB

16. If (Temperature is Cold) and (pH is Alkali) and (DO is Good) and (Ammonia is Good) then (SR is Moderate) (1)
17. If (Temperature is Neutral) and (pH is Alkali) and (DO is Good) and (Ammonia is Good) then (SR is High) (1)
18. If (Temperature is Hot) and (pH is Alkali) and (DO is Good) and (Ammonia is Good) then (SR is Moderate) (1)
19. If (Temperature is Cold) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Good) then (SR is Moderate) (1)
20. If (Temperature is Neutral) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Good) then (SR is High) (1)
21. If (Temperature is Hot) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Good) then (SR is Moderate) (1)
22. If (Temperature is Cold) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Good) then (SR is High) (1)
23. If (Temperature is Neutral) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Good) then (SR is High) (1)
24. If (Temperature is Hot) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Good) then (SR is High) (1)
25. If (Temperature is Cold) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Good) then (SR is Moderate) (1)
26. If (Temperature is Neutral) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Good) then (SR is High) (1)
27. If (Temperature is Hot) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Good) then (SR is Moderate) (1)
28. If (Temperature is Cold) and (pH is Acid) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
29. If (Temperature is Neutral) and (pH is Acid) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
30. If (Temperature is Hot) and (pH is Acid) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)

Figure 8. Fuzzy Rules Numbers 16-30 in MATLAB

31. If (Temperature is Cold) and (pH is Neutral) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
32. If (Temperature is Neutral) and (pH is Neutral) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Moderate) (1)
33. If (Temperature is Hot) and (pH is Neutral) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
34. If (Temperature is Cold) and (pH is Alkali) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
35. If (Temperature is Neutral) and (pH is Alkali) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
36. If (Temperature is Hot) and (pH is Alkali) and (DO is Bad) and (Ammonia is Not__Good) then (SR is Low) (1)
37. If (Temperature is Cold) and (pH is Acid) and (DO is Good) and (Ammonia is Not__Good) then (SR is Low) (1)
38. If (Temperature is Neutral) and (pH is Acid) and (DO is Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
39. If (Temperature is Hot) and (pH is Acid) and (DO is Good) and (Ammonia is Not__Good) then (SR is Low) (1)
40. If (Temperature is Cold) and (pH is Neutral) and (DO is Good) and (Ammonia is Not__Good) then (SR is Low) (1)
41. If (Temperature is Neutral) and (pH is Neutral) and (DO is Good) and (Ammonia is Not__Good) then (SR is High) (1)
42. If (Temperature is Hot) and (pH is Neutral) and (DO is Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
43. If (Temperature is Cold) and (pH is Alkali) and (DO is Good) and (Ammonia is Not__Good) then (SR is Low) (1)
44. If (Temperature is Neutral) and (pH is Alkali) and (DO is Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
45. If (Temperature is Hot) and (pH is Alkali) and (DO is Good) and (Ammonia is Not__Good) then (SR is Low) (1)

Figure 9. Fuzzy Rules Numbers 31-45 in MATLAB

46. If (Temperature is Cold) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Low) (1)
47. If (Temperature is Neutral) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
48. If (Temperature is Hot) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Low) (1)
49. If (Temperature is Cold) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
50. If (Temperature is Neutral) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is High) (1)
51. If (Temperature is Hot) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
52. If (Temperature is Cold) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Low) (1)
53. If (Temperature is Neutral) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Moderate) (1)
54. If (Temperature is Hot) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Not__Good) then (SR is Low) (1)
55. If (Temperature is Cold) and (pH is Acid) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
56. If (Temperature is Neutral) and (pH is Acid) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
57. If (Temperature is Hot) and (pH is Acid) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
58. If (Temperature is Cold) and (pH is Neutral) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
59. If (Temperature is Neutral) and (pH is Neutral) and (DO is Bad) and (Ammonia is Bad) then (SR is Moderate) (1)
60. If (Temperature is Hot) and (pH is Neutral) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)

Figure 10. Fuzzy Rules Numbers 46-60 in MATLAB

61. If (Temperature is Cold) and (pH is Alkali) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
62. If (Temperature is Neutral) and (pH is Alkali) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
63. If (Temperature is Hot) and (pH is Alkali) and (DO is Bad) and (Ammonia is Bad) then (SR is Low) (1)
64. If (Temperature is Cold) and (pH is Acid) and (DO is Good) and (Ammonia is Bad) then (SR is Low) (1)
65. If (Temperature is Neutral) and (pH is Acid) and (DO is Good) and (Ammonia is Bad) then (SR is Moderate) (1)
66. If (Temperature is Hot) and (pH is Acid) and (DO is Good) and (Ammonia is Bad) then (SR is Low) (1)
67. If (Temperature is Cold) and (pH is Neutral) and (DO is Good) and (Ammonia is Bad) then (SR is Moderate) (1)
68. If (Temperature is Neutral) and (pH is Neutral) and (DO is Good) and (Ammonia is Bad) then (SR is High) (1)
69. If (Temperature is Hot) and (pH is Neutral) and (DO is Good) and (Ammonia is Bad) then (SR is Moderate) (1)
70. If (Temperature is Cold) and (pH is Alkali) and (DO is Good) and (Ammonia is Bad) then (SR is Low) (1)
71. If (Temperature is Neutral) and (pH is Alkali) and (DO is Good) and (Ammonia is Bad) then (SR is Moderate) (1)
72. If (Temperature is Hot) and (pH is Alkali) and (DO is Good) and (Ammonia is Bad) then (SR is Low) (1)
73. If (Temperature is Cold) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Low) (1)
74. If (Temperature is Neutral) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Moderate) (1)
75. If (Temperature is Hot) and (pH is Acid) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Low) (1)

Figure 11. Fuzzy Rules Numbers 61-75 in MATLAB

76. If (Temperature is Cold) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Moderate) (1)
77. If (Temperature is Neutral) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Bad) then (SR is High) (1)
78. If (Temperature is Hot) and (pH is Neutral) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Moderate) (1)
79. If (Temperature is Cold) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Low) (1)
80. If (Temperature is Neutral) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Moderate) (1)
81. If (Temperature is Hot) and (pH is Alkali) and (DO is Very__Good) and (Ammonia is Bad) then (SR is Low) (1)

Figure 12. Fuzzy Rules Numbers 76-81 in MATLAB

Figures 7, 8, 9, 10, 11, and 12 illustrate the outcomes of the devised rules, which will facilitate the prediction of the SR value of tilapia in the future should the value of the measured water quality parameters align with one of the existing categories. This value will also serve as the output reference for the tilapia production prediction tool based on water quality.

Methods of Data Analysis

The data analysis approach employed is qualitative, involving the identification of patterns, themes, and categories through coding and interpretation. This qualitative research is further enhanced by the integration of a fuzzy approach, which combines qualitative methods with fuzzy logic. The qualitative aspect of the research is designed to enable a profound comprehension of the problem, while the incorporation of fuzzy logic allows for the consideration of uncertainty and subjectivity within the data. The key components of fuzzy logic include fuzzification, a rule base, a fuzzy inference system, and defuzzification (Putra et al., 2021).

1. Determination of Variables and Fuzzy Factors
   In the context of the research, it is necessary to identify the relevant variables and determine their domain and level of uncertainty or fuzziness. This entails the application of fuzzy concepts to describe the variability and uncertainty inherent in the data.
2. Qualitative Data Collection
   Qualitative data is gathered through a variety of methods, including interviews, observations, and document analysis. This approach enables the researcher to comprehend the contextual and nuanced aspects of the problem under study.
3. Fuzzy Analysis
   Subsequently, the qualitative data is subjected to analysis in accordance with the tenets of fuzzy logic. This process entails the representation of uncertainty and subjectivity in the data through the use of fuzzy sets, fuzzy rules, and fuzzy operations, including fuzzy inference and defuzzification.

4. Interpretation

The results of a qualitative data analysis employing fuzzy techniques are interpreted in order to ascertain the implications and possible meanings. Conclusions are drawn based on this analysis, which provides a profound understanding of the problem under study.

RESULTS AND DISCUSSION

The objective of this study was to establish a correlation between the water quality values and the growth conditions of tilapia in the pond. Fish conditions were mapped based on each of the following parameters: temperature, pH, dissolved oxygen (DO) levels, ammonia, and survival rate (SR). Prior to the design of the complete system, it is necessary to test the hardware used in the automatic control system. The objective of hardware testing is to ascertain the performance and effectiveness of the system.

a. Testing the pH sensor

The 4502C pH sensor is tested with a pH meter measuring instrument to ascertain the accuracy of the sensor value data in comparison with the measuring instrument. This process allows for the evaluation of the pH sensor's performance in accordance with the actual data. The pH sensor is tested by measuring acidic, alkaline, and neutral parameters by taking a sample of aquarium water, which is then measured using an analog pH sensor. The output values of the analog pH sensor will be compared with those of the ATC digital pH meter, with an accuracy value of ±0.1 pH. Upon insertion of the analog pH sensor into the aquarium water sample, the microcontroller will process the data obtained from the analog pH sensor by converting the ADC (Analog to Digital Converting) value into a voltage value and pH value. This process is described in detail by Salim *et al.* (2023).

Table 1. Testing Results of Analog pH Sensor and Digital pH Sensor

No	**pH Sensor Reading**		**Temperature (ºC)**
	Analog pH Sensor	**Digital pH Sensor**	
1	6.74	6.7	27.25
2	6.74	6.7	27.25
3	6.77	6.8	27.25
4	6.77	6.8	27.25
5	6.77	6.8	27.25

The results of the test, as presented in Table 1, indicate that for all five measurements (1 to 5), the temperature is consistently recorded at 27.25°C. The pH readings for the analog sensor exhibit a slight variance between 6.74 and 6.77, whereas the digital sensor readings vary between 6.7 and 6.8. The data indicates that both types of sensors are providing readings of pH levels at the same temperature that are similar but not identical.

b. Temperature sensor test

The temperature of water can influence the appetite of fish. A temperature below 16 degrees Celsius has been observed to result in a reduction in fish appetite. Conversely, a temperature between 10 and 11 degrees Celsius has been identified as a potentially lethal temperature for fish. In the optimal temperature range, fish exhibit optimal metabolic rates, which facilitate growth and weight gain. Testing the DS18B20 sensor is simply a matter of measuring the temperature of the water in degrees Celsius. It is well established that the temperature of the water has a significant impact on the readings of the TDS and pH sensors. Therefore, it is of paramount importance to test the DS18B20 sensor. The DS18B20 sensor is a digital temperature sensor, and therefore the testing process is relatively straightforward (Salim *et al*. 2023).

Table 2. Test Results of DS18B20 Sensor with Analog Thermometer

No.	DS18B20 Sensor (ºC)	Analog Thermometer (ºC)
1	24.59	24
2	24.62	24
3	24.62	24
4	24.62	24
5	24.62	24

The results of the test, as presented in Table 2, demonstrate a discrepancy in the measurements of aquarium water samples, with a difference of 0.62 ºC. This is attributed to the inherent challenge of accurately determining the precise value on the analog thermometer, with only the number preceding the decimal point being considered. The outcomes of the examination of uncertain models on the results of temperature and humidity measurements are employed to ascertain the control conditions of the two variables (Siskandar *et al.* 2022).

c. DO sensor test

Oxygen is a vital component for all living organisms, including fish. It is not only necessary for respiration but also for growth. Consequently, it is of paramount importance to maintain the dissolved oxygen levels in water, as this is essential for the activity of these organisms. The DO sensor test described below is part of a research system. The user may adjust the set point by turning the potentiometer, thereby varying the value between 0 and 5.8 ppm. A comprehensive system testing procedure is employed to assess the efficacy of the dissolved oxygen control system. Upon testing the system in an aquarium with a set point of 3.5 ppm, the system took approximately one minute to reach the desired oxygen level (Riadhi *et al.*, 2017).

Table 3. Dissolved Oxygen Value Test Results

Oxygen DO meter (ppm)	Oksigen Alat (ppm)	Error sensor (ppm)	Output sensor (volt)	Output amplifier (ppm)
2.3	2.04	0.26	0.797	2.595
2.5	2.25	0.25	0.787	2.437
2.7	2.43	0.27	0.778	2.368
3	2.72	0.28	0.765	2.224
3.5	3.17	0.33	0.744	1.978
3.7	3.35	0.35	0.735	1.875
4	3.74	0.26	0.722	1.726

4.5	4.26	0.24	0.7	1.467
4.7	4.39	0.31	0.691	1.371
5	4.76	0.24	0.678	1.224
5.2	4.87	0.33	0.669	1.116
5.5	5.22	0.28	0.657	0.971
5.85	5.59	0.26	0.642	0.841

The results of measuring dissolved oxygen levels using the AZ-8403 DO sensor indicate a range of values between 2.3 and 5.8 ppm, with an average reading error of 0.28 ppm or 0.075%. Consequently, it is necessary to calibrate the test equipment against standard measuring instruments.

d. Ammonia sensor test

Ammonia is produced as a byproduct of an organism's excretion process and naturally occurs in ponds. However, if ammonia accumulates in large quantities, it becomes toxic to fish. The purpose of testing the MQ-135 ammonia sensor is to evaluate its performance within the intended system. The sensor's effectiveness will be judged based on its readings, which will be compared to those from an ammonia kit to determine the accuracy of the MQ-135 ammonia sensor used in this system (Kristiantya et al., 2022).

Table 4. Ammonia Sensor Test Results

Media	Mq-135 Sensor	Test Kit
Well Water	0,00 ppm	0
PDAM Water	0,00 ppm	0
Aquarium Water	0,01 ppm	0
Koi Pond Water	0,02 ppm	< 0,01
Tilapia Pond Water	0,02 ppm	< 0,01

The test results indicate a high satisfaction level with the ammonia sensor's accuracy in measuring ammonia levels in the pool, when compared to the performance of the ammonia kit. Although there are slight discrepancies between the sensor readings and the kit, they are closely aligned. While the ammonia kit does not offer the exact ammonia concentration in parts per million (ppm), its values can serve as a reference point in this assessment.

e. Fuzzy Method Test

The goal of testing the fuzzy method is to determine its effectiveness in calculating the program code by comparing it to the Fuzzy Inference System (FIS) in Matlab. Additionally, the computational results from the program code created in Matlab are compared (Kristiantya et al., 2022).

Table 5. System Execution Time Testing

Temperature	Ammonia	Arduino	FIS	Error percentage
25.50	0.02	0	0	0
26.50	0.01	0	0	0
24.50	0.08	17.5	14.4	17.7142857
20.00	0.01	30	30	0
25.00	0.08	12	12	0
30.00	0.1	60	60	0
31.00	0.08	21.4	16.8	21.495327
28.00	0.09	36	36	0
24.00	0.01	6	6	0
22.50	0.03	15	15	0

A summary of the tests conducted to evaluate the Fuzzy method used in this system is presented in Table 5. The process entails setting identical input values for temperature and ammonia on both the Arduino and Matlab platforms. Subsequently, fuzzy logic calculations are performed using the Arduino Integrated Development Environment (IDE) and Matlab in conjunction to determine the system's output, which controls the relay connected to the pump over an extended period. The comparison between the Fuzzy method calculations on Arduino and Matlab yielded an average error of 3.92.

The Fuzzy logic system is developed using MATLAB tools and serves as the foundation for predicting tilapia production based on water quality. Figure 13 depicts the Fuzzy logic design in MATLAB using the Mamdani method. It features four input variables (temperature, pH, dissolved oxygen, and ammonia) and one output variable (survival rate or SR).

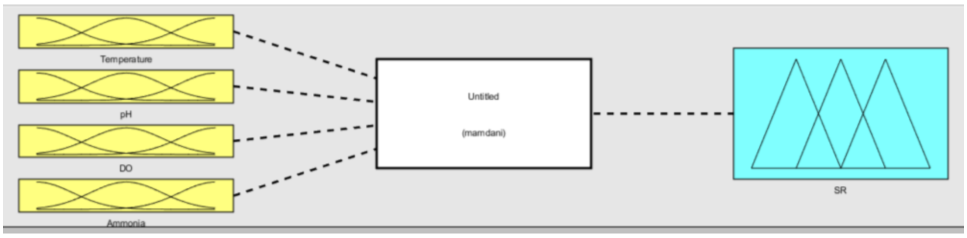

Figure 13. Mamdani Fuzzy Logic Design in MATLAB

Table 6. Input and Output Variables for Fuzzy Set

Function	Variable	Fuzzy Sets
Input	Temperature (℃)	Cold Neutral Hot

Function	Variable	Fuzzy Sets
	pH	Acid
		Neutral
		Alkali
	DO (mg/L)	Bad
		Good
		Very Good
	Ammonia (ppm)	Good
		Not Good
		Bad
Output	SR (%)	Low
		Moderate
		High

Table 6 outlines the input and output variables for a fuzzy set function. In this context, fuzzy sets are used to represent linguistic variables, allowing for a more nuanced representation of data than traditional binary sets. Table 6 presents the surface viewer results generated during testing, as illustrated in Figures 14 and 15.

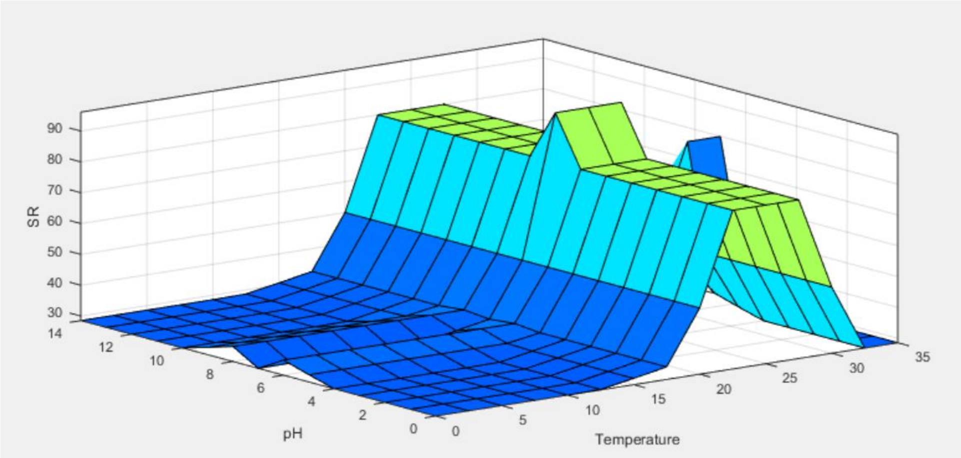

Figure 14. Surface Viewer for pH and Temperature in MATLAB

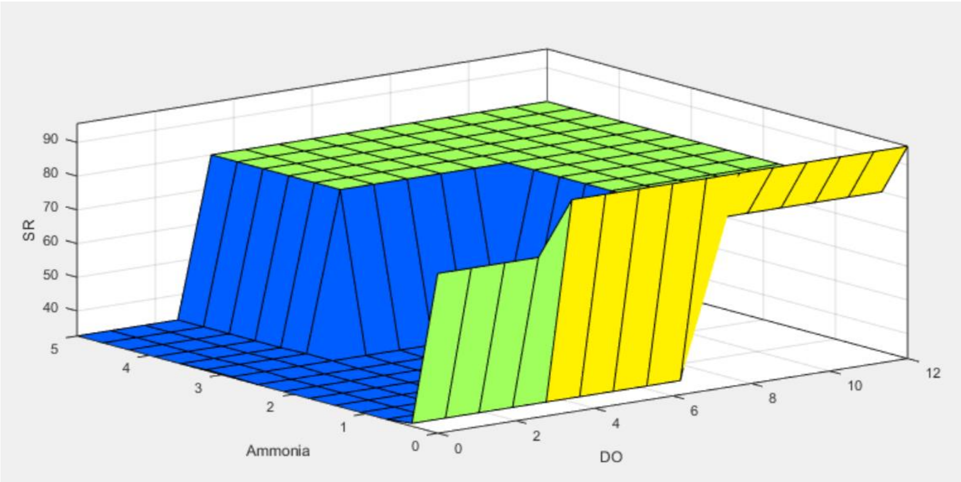

Figure 15. Surface Viewer for Ammonia and DO in MATLAB

As illustrated in Figures 14 and 15, the output of the fuzzy design defuzzification process, generated using the MATLAB tool, is presented herein. The value will then be employed as a reference for the output of the system to predict tilapia production based on water quality, as illustrated in Figures 14 and 15.

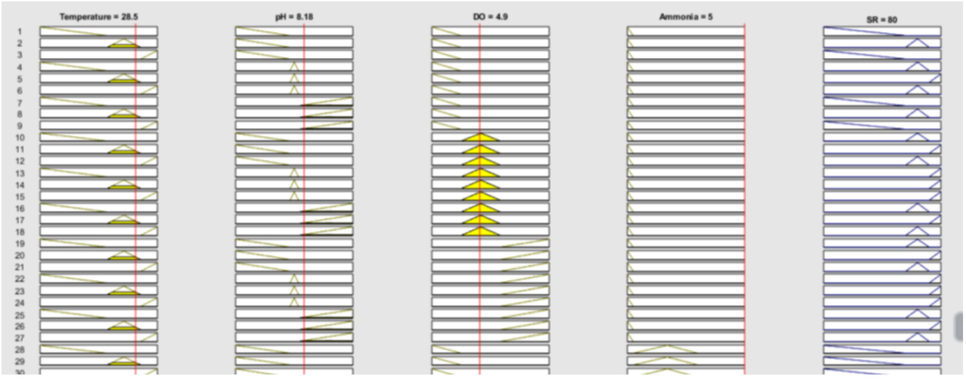

Figure 16. Rule Viewer in MATLAB

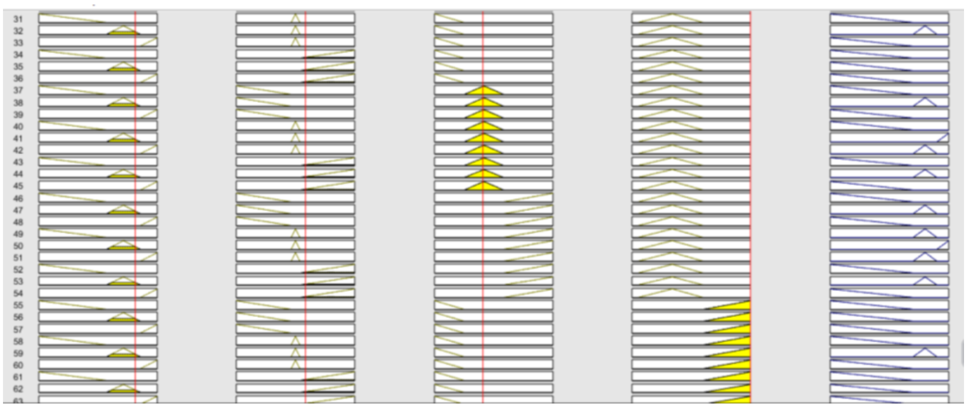

Figure 17. Rule Viewer in MATLAB

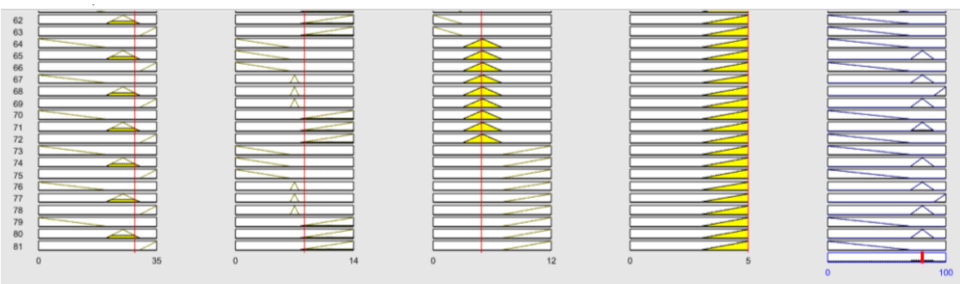

Figure 18. Rule Viewer in MATLAB

Figures 16, 17, and 18 illustrate the outcomes of the previously devised fuzzy rules. Once the fuzzy logic has been designed in MATLAB, the subsequent step is to implement it in order to predict the production of tilapia based on the quality of the water.

CONCLUSION

The application of fuzzy logic in determining the use to predict tilapia production yield based on water quality is expected to assist fish farmers who utilize this tool in identifying the specific growth rate of fish in relation to water quality. Furthermore, the application of fuzzy logic can facilitate the control of water quality, thereby enhancing the survival rate (SR) of fish being cultivated.

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