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Application of Fuzzy Logic to Detect TSS and DO Contamination in Aquaculture

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The quality of water in aquaculture systems plays a critical role in maintaining the health and productivity of aquatic organisms. Two key parameters affecting water quality are Dissolved Oxygen (DO) and Total Suspended Solids (TSS), both of which fluctuate and can negatively impact fish survival rates. This study aims to design and evaluate a fuzzy logic-based classification system using the Mamdani method to assess water quality conditions based on DO and TSS values. The research employed a qualitative approach supported by simulation using MATLAB software. The input variables were DO and TSS, while the output was the classification of water quality into two categories: good and poor. The fuzzy inference system was constructed using membership functions and rule-based logic. The results showed that the system was capable of generating accurate and adaptive outputs, with a sample input of DO 9.04 mg/L and TSS 235 mg/L producing an output value of 0.742, indicating good water quality. These findings demonstrate the effectiveness of the system in supporting water monitoring in aquaculture operations.

Keywords: TSS, fisheries cultivation, tangled.

INTRODUCTION

Aquaculture in Indonesia has experienced rapid development over the last decade in response to declining marine catches and increasing public demand for animal protein (Nugroho et al., 2024). These activities make a significant contribution to food security but also face serious challenges, particularly regarding water quality. Two parameters that are very influential are Total Suspended Solids (TSS) and Dissolved Oxygen (DO). High TSS levels can interfere with fish respiration, reduce light penetration, and worsen bottom water conditions, while low DO levels can cause physiological stress or even death in cultured organisms (Pratama et al., 2020). Research by Kurniawan et al. (2022) also confirmed that fluctuations in TSS and DO levels are closely correlated with reduced survival rates in aquaculture systems. Therefore, water quality management through regular monitoring of these parameters is very important to support the sustainability and productivity of aquaculture systems.

Apart from advances in aquaculture practices, technology also plays an important role in supporting water quality management. One technology that is being developed is the application of fuzzy logic, namely an artificial intelligence method that is capable of processing data and making decisions based on uncertain or ambiguous parameters. Fuzzy logic is widely used in water quality monitoring and control systems because of its ability to adjust decisions automatically and adaptively in response to changing environmental conditions in aquaculture ponds.

High levels of TSS (Total Suspended Solids) in water can reduce light penetration and inhibit photosynthesis in phytoplankton and aquatic plants (Rizka RF et al., 2020). DO (Dissolved Oxygen) is the amount of dissolved oxygen in water which is important for all aquatic organisms. TSS and DO levels in water are interrelated, because increasing TSS can cause a decrease in oxygen production. Therefore, automatic TSS and DO measuring devices are very important to simplify and shorten the time required for water quality assessment.

By using fuzzy logic, environmental parameters such as TSS and DO can be processed intelligently to detect existing values in aquaculture waters. This allows farmers to take preventative and corrective action more quickly, ensuring water quality is maintained and aquaculture productivity remains at optimal levels.

METHOD

Research Time and Location of Research Time

This research was conducted from April - May 2025, at the Vocational School of IPB University, located at Jalan Sarasa No. 45, Babakan Subdistrict, Cibeureum District, Sukabumi City.

Research Design

This research uses a qualitative approach using the literature review method. The aim of the research is to design and evaluate a water quality prediction system based on TSS (Total Suspended Solids) and DO (Dissolved Oxygen) parameters using the Mamdani fuzzy logic method. Through this approach, researchers conducted an in-depth review of scientific literature to understand the relationship between parameters and developed a fuzzy logic model that was able to determine water quality status (safe and dangerous) systematically.

Data Collection Techniques

Data collection was carried out through literature study and documentation. Researchers identified and collected various secondary data sources that describe the range of TSS and DO values commonly found in pond water or other aquatic environments. Apart from that, information was also collected regarding safe limits for TSS and DO concentrations in water, as well as methods for applying the Mamdani fuzzy logic approach in environmental-based classification or prediction systems.

Data Analysis Techniques

Data analysis was carried out qualitatively using descriptive methods supported by simulations using MATLAB software. The analysis begins with data reduction from various literature sources to organize the input and output variables of the fuzzy system. The input variables used are TSS and DO, while the output variable is water quality status which is categorized into two levels, namely safe and dangerous. Based on the data collected, researchers developed membership functions and inference rules in the form of if-then statements, which describe the relationship between the combination of TSS and DO levels and water quality status. The Mamdani fuzzy logic model was built and executed using the Fuzzy Logic Toolbox in MATLAB. Finally, the results are interpreted to assess the model's consistency with scientific findings.

RESULTS AND DISCUSSION

Input and Output Variables in Fuzzy Logic Systems

In this research, there are input and output variables used in the fuzzy logic system. Can be seen in Table 1.

Table 1. Fuzzy Input and Output

Function	Variable
Input Data	Dissolved Oxygen (DO)
	Total Suspended Solids (TSS)
Output Data	Water Quality

Fuzzy Set Planning

Fuzzy set design is a crucial initial stage in building a fuzzy logic system, because it determines how each input and output variable is modeled into a linguistic form that can be processed mathematically. Details are presented systematically in Table 2.

Table 2. Fuzzy Set

Variable	Fuzzy Collections	Parameter
Dissolved Oxygen (DO)	Low	[0 2 6]
	Currently	[4 6 8]
	High	[6 8 10]
Total Suspended Solids (TSS)	Low	[0 300 300]
	High	[300 400 400]

Rule Formulation - Fuzzy Rules

This stage includes the preparation of fuzzy inference rules that integrate DO and TSS inputs to produce output in the form of water quality status. The rule structure is designed logically based on the relationship between parameters, as formulated as follows.

1. **IF** (DO is Low) **AND** (TSS is High) **THEN** (Output is Bad).
2. **IF** (DO is Low) **AND** (TSS is Low) **THEN** (Output is Bad).
3. **IF** (DO is Medium) **AND** (TSS is Low) **THEN** (Output is Good).
4. **IF** (DO is Medium) **AND** (TSS is High) **THEN** (Output is Bad).
5. **IF** (DO is High) **AND** (TSS is Low) **THEN** (Output is Good).
6. **IF** (DO is High) **AND** (TSS is High) **THEN** (Output is Bad).

Based on the application of Mamdani fuzzy logic implemented using MATLAB in DO TSS data processing, the results obtained can be seen in the image below.

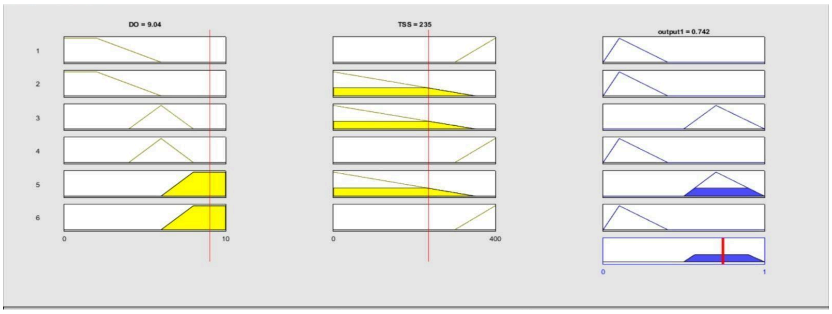

Figure 1. Display *Rule Viewer* fuzzy system with DO and TSS input

The image shows the Rule Viewer display of a fuzzy logic system with two inputs, namely DO of 9.04 and TSS of 235, and produces an output of 0.742. The graph shows the activation of several fuzzy rules (marked with yellow and blue areas) processed through inference and defuzzification. The final output is determined from the combined contributions of all the rules, with the crisp value indicated by the red line on the output graph.

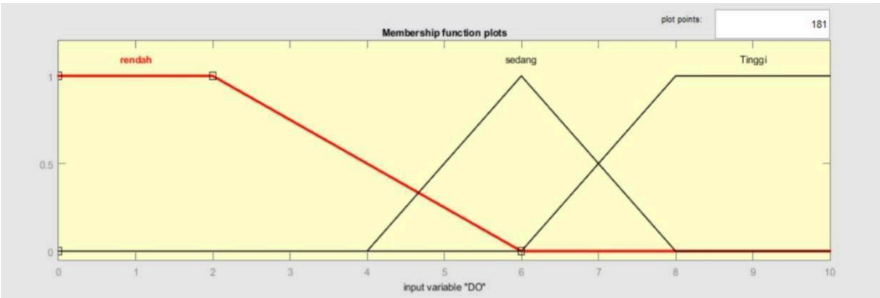

Figure 2. Membership function of the DO input variable

The image above is the Membership Function Editor display for the DO (Dissolved Oxygen) input variable in the fuzzy logic system. This variable has three membership sets, namely "low", "medium", and "high". The “low” membership function uses a trapezoidal shape (trapmf) with parameters [0 0 2 6] which indicate that the DO value is considered low if it is in the range 0 to around 2 mg/L, then decreases gradually to 6 mg/L. The "medium" function has the shape of a triangle with a peak at the middle value, while the "high" starts to increase around DO values >6 until it reaches a maximum value of 10. The range of DO values is limited between 0 and 10.

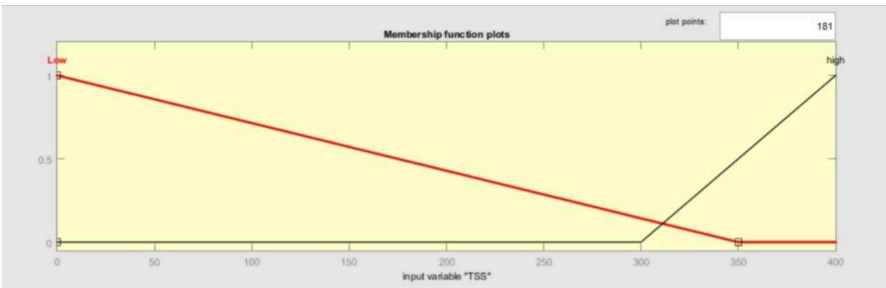

Figure 3. TSS input variable membership function

The image above is the Membership Function Editor display for the TSS (Total Suspended Solids) input variable in a fuzzy logic system. The TSS variable has a Low membership function which uses a triangular shape (trimf) with parameters [0 0 350]. This shows that the TSS value is low if it is in the range close to 0, and its membership decreases to 350 mg/L. Another membership function, namely height, begins to be active in the range of TSS values >300 mg/L and reaches full membership approaching 400 mg/L. The TSS input range is set from 0 to 400.

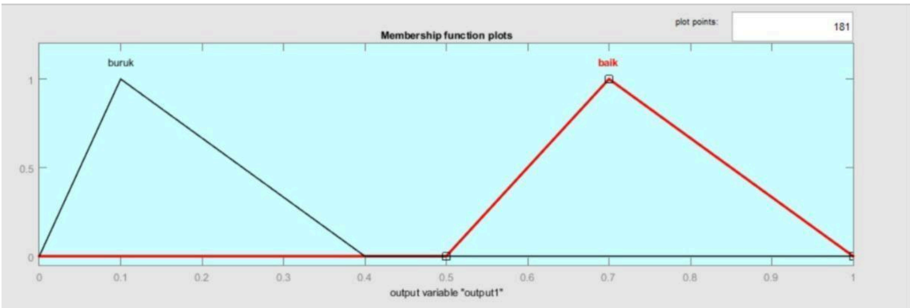

Figure 4. Water quality output variable membership function

The figure shows the output settings in a fuzzy system with two categories: "bad" and "good". Both use a triangle function (trimf) with a value range of 0–1. “Bad” actives are rated low, while “good” actives start at 0.5, peak at 0.7, and fall at 1.

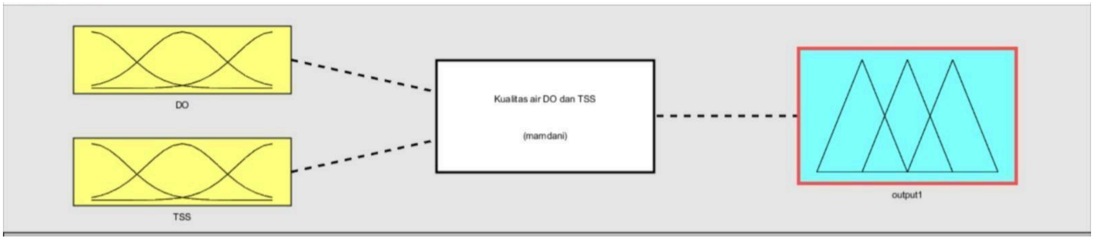

Figure 5. Results of defuzzification of the fuzzy system

The results of implementing the fuzzy logic system show that water quality is determined based on two main inputs, namely DO (Dissolved Oxygen) and TSS (Total Suspended Solids), using the Mamdani method. The DO variable has three membership categories (low, medium, high), while the TSS is divided into two categories (low and high). This system uses the min method for and and implication, max for or and aggregation, and centroid for the defuzzification process. In testing with a DO input of 9.037 and TSS of 234.5, the system produced a water quality output of 0.742. This value is included in the good category, which shows that even though the TSS is quite high, a high DO value is still able to maintain adequate water quality.

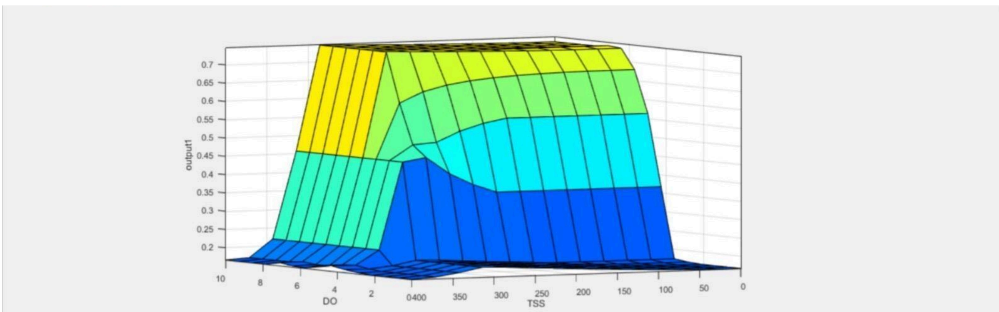

Figure 6. Display *surface viewer* relationship between DO and TSS on water quality

Based on the surface viewer image above, you can see the relationship between two water quality parameters, namely DO (Dissolved Oxygen) and TSS (Total Suspended Solid), on water quality output. The graph shows that water quality (output) tends to increase as the DO value increases and the TSS value decreases. In the part of the graph with high DO and low TSS, the graph surface is yellow to light green, which indicates that the water quality is at the best level. Conversely, in sections with low DO and high TSS, the graph surface is dark blue, indicating very poor water quality. The color transition from blue to yellow on the graph surface illustrates changes in water quality status from bad to good according to the combination of DO and TSS values.

TSS and DO have a close relationship in aquatic ecosystems. Increasing TSS levels can reduce the penetration of sunlight into the water, which inhibits the photosynthesis process by phytoplankton and aquatic plants. As a result, the production of dissolved oxygen (DO) decreases, because photosynthesis is one of the main sources of oxygen in waters. In addition, TSS particles in the form of organic material can trigger an increase in the activity of decomposing bacteria. This decomposition process also consumes oxygen, thereby further reducing DO levels in the water. Conversely, low TSS levels allow better light penetration and increase photosynthesis, which in turn increases DO levels. However, keep in mind that the relationship between TSS and DO is not always linear. Under certain conditions, increasing TSS can bring the nutrients needed by phytoplankton, thereby increasing growth and oxygen production. However, if TSS is too high, negative effects such as reduced light penetration and increased decomposition will be more dominant, so DO levels will decrease significantly.

The results shown in Figures 1 to Figure 6, the water quality assessment process begins with the formation of fuzzy sets for each input and output variable. The DO variable is categorized into three conditions, namely low, medium and high, while TSS is divided into two, namely low and high. The results of the fuzzification process are then processed through shaped fuzzy rules *if-then* designed based on ecological understanding of the impact of DO and TSS on aquatic organisms. The combination of these rules produces a final decision which is displayed in the form of a crisp value, as in the example of DO 9.04 and TSS 235 which produces an output of 0.742, included in the category *Good*. This research is in line with Rizka's findings *et al.* (2020), who explained that DO is an important indicator in maintaining the stability of aquatic ecosystems, and its fluctuations greatly influence the stress levels of cultivated organisms. Likewise, high levels of TSS can worsen water quality by reducing light penetration and increasing suspended particle loads, as emphasized by Pratmanto *et al.* (2029). Therefore, the combination of these two parameters is key in evaluating the quality of aquaculture waters. Fuzzy systems provide flexibility in considering threshold values and the relative influence between parameters simultaneously, which is difficult to do with a deterministic approach.

The use of the Mamdani method is proven to be able to capture nonlinear relationships between parameters effectively. This is also supported by Kurniadi's study *et al.* (2022) who show that the Mamdani fuzzy system can be used reliably in the context of environmental data-based classification predictions due to its flexibility in handling vague data (*vague*) and uncertain. In the context of this research, the system shows that water quality remains in good condition even though the TSS value is relatively high, as long as DO is within the optimal range. These results demonstrate the compatibility of fuzzy linguistic logic with complex and often poorly defined ecological realities. Next, Figure 6 shows *surface viewer* which shows the relationship between two input parameters (DO and TSS) on the water quality output value. This surface graph makes it clear that water quality generally improves as DO values increase and TSS values decrease. The areas on the graph in yellow and green indicate good water quality, which occurs when a combination of high DO and low TSS. Meanwhile, the dark blue color that dominates areas with low DO and high TSS indicates poor water quality conditions. The color gradient on the graph shows shifts in water quality status which reflects the sensitivity of the fuzzy model to changes in input parameters.

Overall, the results of implementing this fuzzy logic system show that the Mamdani approach is able to provide a realistic representation of water quality conditions in the aquaculture environment. The model built is able to respond to fluctuations in DO and TSS values and produce classification decisions that are adaptive and in accordance with human judgment logic. Thus, this system has the potential to become an applicable decision aid in water quality monitoring.

CONCLUSION

This study shows that the application of fuzzy logic Mamdani method is effective in classifying water quality based on Dissolved Oxygen (DO) and Total Suspended Solids (TSS) parameters in fisheries cultivation systems. The designed system is able to process ambiguous input data and produce linguistic output that is representative of real conditions in the field. The implementation results show that high DO values are able to offset the negative effects of high TSS values, so that water quality remains in the good category. Through the rule-based inference process and centroid defuzzification, this fuzzy model is proven to be able to respond to input variations with consistent and adaptive classification results. Thus, this system has the potential to be used as a decision-making tool for automatic and sustainable water quality monitoring in fisheries cultivation activities.

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