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Using Fuzzy Logic-Based Mamdani to Predict Catfish Larval Rearing

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Catfish (*Clarias sp.)* larvae are highly sensitive to environmental changes, particularly in water quality parameters such as temperature, pH, and dissolved oxygen (DO), which significantly affect their survival rate (SR). This study aims to design a real-time prediction system for catfish larval survival using Mamdani fuzzy logic to support more accurate and adaptive water quality management. The research was conducted from April to May 2025 at the Hatchery, IPB Vocational School. The methodology involves constructing a Mamdani fuzzy inference system in MATLAB based on secondary data (SNI 6484:3:2014 and previous studies) and field observations. Three main input parameters temperature, pH, and DO. Were categorized into fuzzy sets using triangular membership functions. A total of 84 fuzzy rules were developed to infer SR, which was also divided into three categories: low, moderate, and high. Simulation results using the Rule Viewer and Surface Viewer showed that DO had the strongest influence on SR followed by temperature, while pH had a relatively minor effect. Under low DO conditions (<3 mg/L), SR predictions were consistently low regardless of other variables. The system successfully mimics human decision-making in dynamic environments and offers actionable insight for real-time larval rearing management. In conclusion, the Mamdani fuzzy logic system proves effective in predicting catfish larval SR and can be a valuable tool for optimizing aquaculture practices, especially in the early life stages.

Keywords: Catfish Larval, Fuzzy Mamdani, MATLAB, Water Quality, Simulation.

INTRODUCTION

Catfish (*Clarias sp*.) is one of the most popular and widely cultivated freshwater fisheries commodities in Indonesia (Gustiano & Sri Haryani, 2021). Apart from its high economic value and good nutritional content, catfish is also known for its fast growth and resistance to varied environments. However, one of the main challenges in catfish farming is success in its early life phase, the larval phase. This phase is the most critical stage with a high mortality rate due to the sensitivity of larvae to environmental changes, especially water quality (Khoir et al., 2023).

Environmental parameters such as temperature, pH, dissolved oxygen (DO), and total dissolved solids (TDS) greatly affect larval survival. In small-scale aquaculture practices, the management of these parameters is often manual and intuitive, potentially resulting in delays in handling water quality problems and reducing larval survival rate (SR). Therefore, a more systematic and precise technological approach is needed to support the successful rearing of catfish larvae.

One promising approach is the use of Mamdani fuzzy logic. Fuzzy logic is able to handle uncertain data and mimic the way humans think in making decisions based on linguistic variables such as “low”, “medium”, and “high”. This approach is considered very suitable for complex systems such as aquaculture environments that are dynamic and non-linear. As demonstrated by (Bautista et al., 2022) a fuzzy logic-based water quality monitoring system was able to improve the efficiency of aquaculture environment management by utilizing temperature, pH, DO, and TDS parameters to classify water conditions into categories: excellent, good, poor, and toxic. The system enables automatic responses such as activating aerators or circulation pumps when water quality declines.

Modern aquaculture not only targets economic benefits, but also considers environmental and social aspects. For this reason, the production strategies implemented must consider efficiency, sustainability, and ease of implementation in the field. Environmentally friendly technologies such as fuzzy logic-based monitoring systems not only answer the challenges of efficiency and accuracy, but are also adaptive to the needs of farmers in the field.

External factors such as water and feed quality are important elements that can still be controlled to promote fish growth and survival, especially in the larval phase. Clean water, free from chemicals and pollutants, is vital for early larval development. As explained by (Rochyani 2018), parameters such as pH, temperature, clarity and dissolved oxygen greatly affect the performance of fish, including catfish. However, manual monitoring of all these parameters is often cumbersome, time-consuming and inefficient (Sholihah et al., 2022). Therefore, a technology-based system that is more practical, easy to understand, and capable of providing a quick evaluation of pond water conditions is needed.

Fuzzy logic offers a solution by translating various environmental parameter inputs into a condition assessment using a linguistic approach. Unlike conventional methods that are rigid, fuzzy logic, especially the Mamdani model, relies on rules based on experience or empirical data to conclude decisions. This approach is considered more intuitive and appropriate in the fisheries sector (Laboni et al., 2024).

METHODS

Location and Time of Research

This research was carried out from April to May 2025 at the Hatchery, IPB Vocational School. The purpose of this research is to design a real-time Mamdani fuzzy logic-based catfish larvae rearing prediction system. This system is expected to assist farmers in maintaining optimal environmental quality for catfish larvae, thereby supporting increased survival rates and seed production efficiency.

Data Collection Methods

This study used a fuzzy logic approach and data were collected through two main methods. First, a fuzzy model was created and the optimal parameter ranges were found with secondary data from scientific journals, past research reports, and water quality standards for catfish farming. Secondly, direct observations were made on the actual conditions of the catfish larvae rearing ponds validating the ranges of important parameters such as wells.

Some recent findings on the use of fuzzy logic in catfish farming systems are discussed in this study. (Alim et al., 2021) created a fuzzy logic-based decision support system to optimize water quality management when rearing catfish larvae. (Akhter et al., 2021)used fuzzy logic to predict the survival rate of catfish fry based on environmental parameters. (Akhter et al., 2021) used artificial intelligence and fuzzy logic to control the water recirculation system in intensive catfish farming. To reduce the mortality rate in the critical phase of catfish larval rearing,

This study uses a Mamdani fuzzy logic system approach to predict the survival rate (SR) of catfish larvae based on water quality parameters. The main input variables used consisted of temperature, pH, and dissolved oxygen (DO) levels, which have a significant influence on larval life in the early phase. Each of these variables is divided into several linguistic categories using a triangular membership function, the water quality parameters in catfish larvae ponds refer to SNI 6484:3:2014 as follows.

Table 1. Water quality requirements for Catfish Larval Rearing in the Indonesia.

Water Quality Parameters	Optimal larval survival	Description	Refrences
Dissolved Oxygen (mg/L)	>3	Optimal for survival rate	SNI 6484:3:2014
pH	6,5 – 8,5	Optimal for osmotic balance	SNI 6484:3:2014
Temperature (°C)	27-30	Optimal for survival rate	SNI 6484:3:2014

Variable Fuzzy

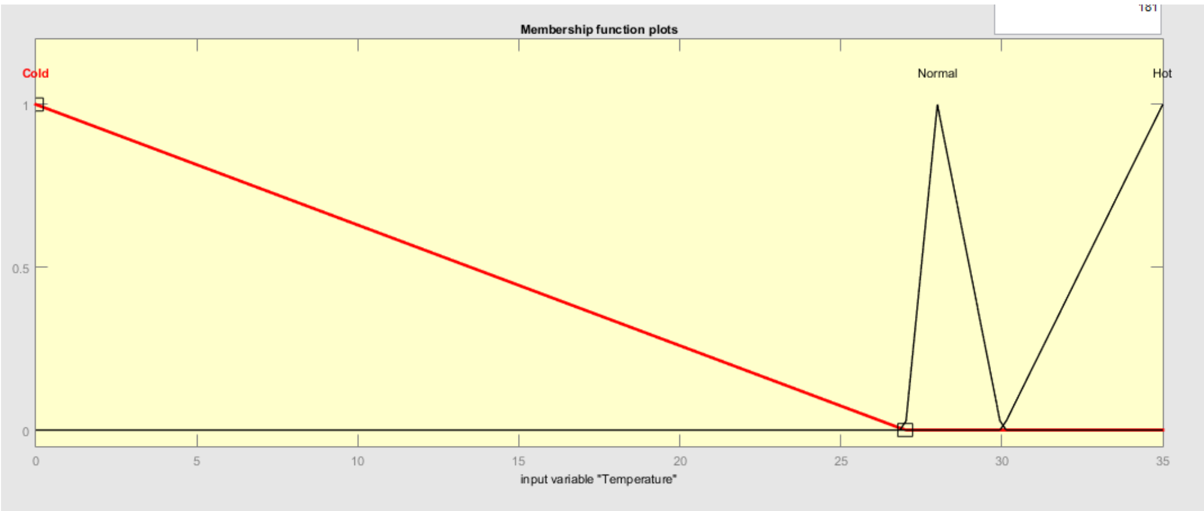


Figure 1. The set temperature variables in MATLAB

Temperatures between 0 to 27°C are classified as cold, while temperatures in the range of 27 to 30°C are categorized as normal, and temperatures of 30 to 35°C are classified as hot.

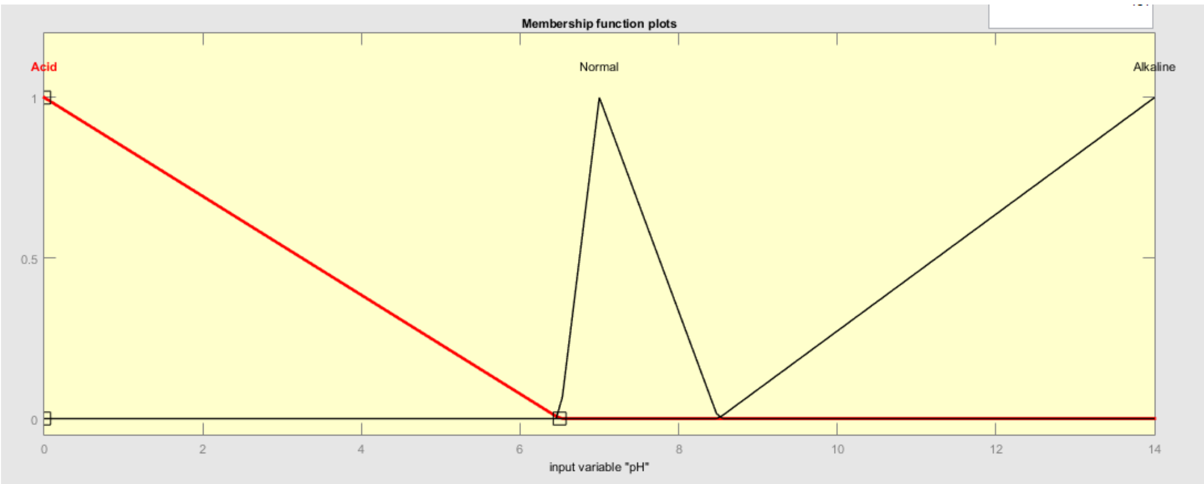


Figure 2. The set pH variables in MATLAB

The pH variable is also divided into three categories, namely pH between 0 and 6.5 which is considered as acidic, pH between 6.5 and 7.5 is categorized as normal, and pH between 7.5 and 14 is categorized as alkaline.

Figure 3. The set DO variables in MATLAB

For dissolved oxygen (DO) parameters, a value range of 0 to 3 mg/L is considered to have low oxygen quality, DO between 3 to 7 mg/L is classified as medium, and DO in the range of 7 to 12 mg/L is categorized as high.

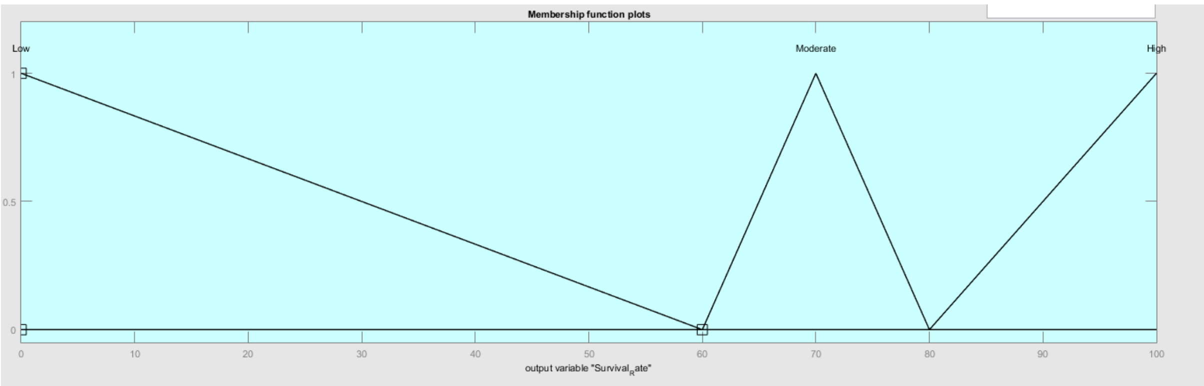
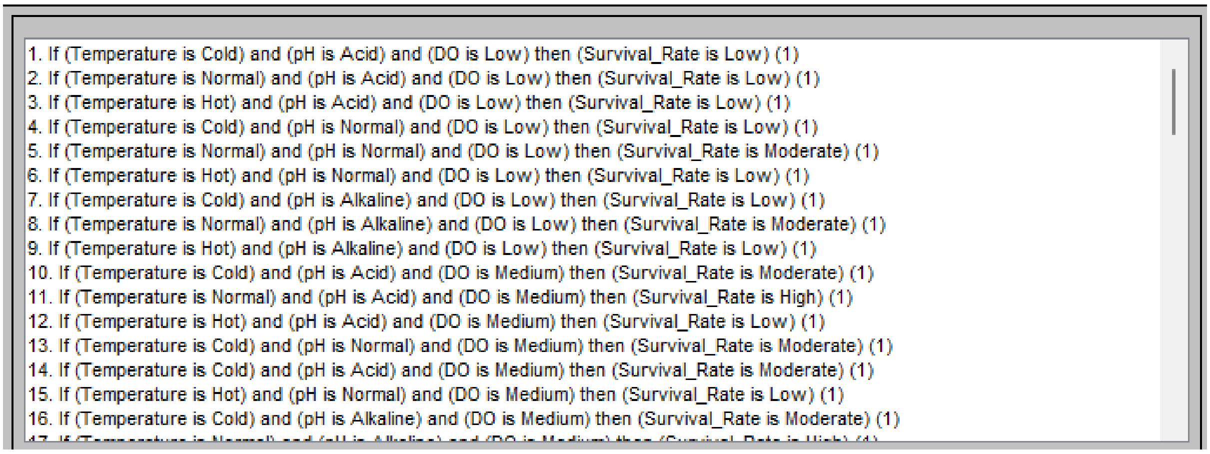


Figure 4 The set SR (Survival Rate) variables in MATLAB

The output variable used in this system is the survival rate (SR) which is also divided into three categories, namely SR between 0 to 70% is categorized as low, SR between 70 to 90% as moderate, and SR between 90 to 100% is included in the high category.



1. If (Temperature is Cold) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
2. If (Temperature is Normal) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
3. If (Temperature is Hot) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
4. If (Temperature is Cold) and (pH is Normal) and (DO is Low) then (Survival_Rate is Low) (1)
5. If (Temperature is Normal) and (pH is Normal) and (DO is Low) then (Survival_Rate is Moderate) (1)
6. If (Temperature is Hot) and (pH is Normal) and (DO is Low) then (Survival_Rate is Low) (1)
7. If (Temperature is Cold) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
8. If (Temperature is Normal) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Moderate) (1)
9. If (Temperature is Hot) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
10. If (Temperature is Cold) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Moderate) (1)
11. If (Temperature is Normal) and (pH is Acid) and (DO is Medium) then (Survival_Rate is High) (1)
12. If (Temperature is Hot) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Low) (1)
13. If (Temperature is Cold) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Moderate) (1)
14. If (Temperature is Cold) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Moderate) (1)
15. If (Temperature is Hot) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Low) (1)
16. If (Temperature is Cold) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Moderate) (1)

Figure 5 Fuzzy Rules Numbers 1-16 in MATLAB

16. If (Temperature is Cold) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Moderate) (1)
17. If (Temperature is Normal) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is High) (1)
18. If (Temperature is Hot) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Moderate) (1)
19. If (Temperature is Cold) and (pH is Acid) and (DO is High) then (Survival_Rate is Moderate) (1)
20. If (Temperature is Normal) and (pH is Acid) and (DO is High) then (Survival_Rate is Moderate) (1)
21. If (Temperature is Hot) and (pH is Acid) and (DO is High) then (Survival_Rate is Moderate) (1)
22. If (Temperature is Cold) and (pH is Normal) and (DO is High) then (Survival_Rate is Moderate) (1)
23. If (Temperature is Normal) and (pH is Normal) and (DO is High) then (Survival_Rate is High) (1)
24. If (Temperature is Hot) and (pH is Normal) and (DO is High) then (Survival_Rate is Low) (1)
25. If (Temperature is Cold) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Moderate) (1)
26. If (Temperature is Normal) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Moderate) (1)
27. If (Temperature is Cold) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Low) (1)
28. If (Temperature is Cold) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
29. If (Temperature is Normal) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
30. If (Temperature is Hot) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
31. If (Temperature is Cold) and (pH is Normal) and (DO is Low) then (Survival_Rate is Low) (1)
32. If (Temperature is Normal) and (pH is Normal) and (DO is Low) then (Survival_Rate is Moderate) (1)
33. If (Temperature is Hot) and (pH is Normal) and (DO is Low) then (Survival_Rate is Low) (1)
34. If (Temperature is Cold) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)

Figure 6 Fuzzy Rules Numbers 16-34 in MATLAB

34. If (Temperature is Cold) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
35. If (Temperature is Normal) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
36. If (Temperature is Hot) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
37. If (Temperature is Cold) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Low) (1)
38. If (Temperature is Normal) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Moderate) (1)
39. If (Temperature is Hot) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Low) (1)
40. If (Temperature is Cold) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Low) (1)
41. If (Temperature is Normal) and (pH is Normal) and (DO is Medium) then (Survival_Rate is High) (1)
42. If (Temperature is Hot) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Low) (1)
43. If (Temperature is Cold) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Low) (1)
44. If (Temperature is Normal) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Moderate) (1)
45. If (Temperature is Hot) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Low) (1)
46. If (Temperature is Cold) and (pH is Acid) and (DO is High) then (Survival_Rate is Low) (1)
47. If (Temperature is Normal) and (pH is Acid) and (DO is High) then (Survival_Rate is Moderate) (1)
48. If (Temperature is Hot) and (pH is Acid) and (DO is High) then (Survival_Rate is Low) (1)
49. If (Temperature is Cold) and (pH is Normal) and (DO is High) then (Survival_Rate is Moderate) (1)
50. If (Temperature is Normal) and (pH is Normal) and (DO is High) then (Survival_Rate is High) (1)
51. If (Temperature is Hot) and (pH is Normal) and (DO is High) then (Survival_Rate is Moderate) (1)
52. If (Temperature is Cold) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Low) (1)

Figure 7 Fuzzy Rules Numbers 34-52 in MATLAB

52. If (Temperature is Cold) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Low) (1)
53. If (Temperature is Normal) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Moderate) (1)
54. If (Temperature is Hot) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Low) (1)
55. If (Temperature is Cold) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
56. If (Temperature is Normal) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
57. If (Temperature is Hot) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)
58. If (Temperature is Cold) and (pH is Normal) and (DO is Low) then (Survival_Rate is Low) (1)
59. If (Temperature is Normal) and (pH is Normal) and (DO is Low) then (Survival_Rate is Moderate) (1)
60. If (Temperature is Hot) and (pH is Normal) and (DO is Low) then (Survival_Rate is Low) (1)
61. If (Temperature is Cold) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
62. If (Temperature is Normal) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
63. If (Temperature is Hot) and (pH is Alkaline) and (DO is Low) then (Survival_Rate is Low) (1)
64. If (Temperature is Cold) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Low) (1)
65. If (Temperature is Normal) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Moderate) (1)
66. If (Temperature is Hot) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Low) (1)
67. If (Temperature is Cold) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Moderate) (1)
68. If (Temperature is Normal) and (pH is Normal) and (DO is Medium) then (Survival_Rate is High) (1)
69. If (Temperature is Hot) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Moderate) (1)
70. If (Temperature is Cold) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Low) (1)

Figure 8 Fuzzy Rules Numbers 52-70 in MATLAB

66. If (Temperature is Hot) and (pH is Acid) and (DO is Medium) then (Survival_Rate is Low) (1)
67. If (Temperature is Cold) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Moderate) (1)
68. If (Temperature is Normal) and (pH is Normal) and (DO is Medium) then (Survival_Rate is High) (1)
69. If (Temperature is Hot) and (pH is Normal) and (DO is Medium) then (Survival_Rate is Moderate) (1)
70. If (Temperature is Cold) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Low) (1)
71. If (Temperature is Normal) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Moderate) (1)
72. If (Temperature is Hot) and (pH is Alkaline) and (DO is Medium) then (Survival_Rate is Low) (1)
73. If (Temperature is Cold) and (pH is Acid) and (DO is High) then (Survival_Rate is Low) (1)
74. If (Temperature is Normal) and (pH is Acid) and (DO is High) then (Survival_Rate is Moderate) (1)
75. If (Temperature is Hot) and (pH is Acid) and (DO is High) then (Survival_Rate is Low) (1)
76. If (Temperature is Cold) and (pH is Normal) and (DO is High) then (Survival_Rate is Moderate) (1)
77. If (Temperature is Normal) and (pH is Normal) and (DO is High) then (Survival_Rate is High) (1)
78. If (Temperature is Hot) and (pH is Normal) and (DO is High) then (Survival_Rate is Moderate) (1)
79. If (Temperature is Cold) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Low) (1)
80. If (Temperature is Normal) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Moderate) (1)
81. If (Temperature is Hot) and (pH is Alkaline) and (DO is High) then (Survival_Rate is Low) (1)
82. If (Temperature is Normal) and (pH is Normal) and (DO is Medium) then (Survival_Rate is High) (1)
83. If (Temperature is Normal) and (pH is Normal) and (DO is Low) then (Survival_Rate is Moderate) (1)
84. If (Temperature is Cold) and (pH is Acid) and (DO is Low) then (Survival_Rate is Low) (1)

Figure 9 Fuzzy Rules Numbers 70-84

All data is converted into linguistic forms (such as “high”, “low”, or “normal”) to suit the fuzzy system. This process is known as fuzzification, which converts numerical values into linguistic representations based on membership functions. After the fuzzification process, fuzzy rules are created as many as 84 combinations based on possible relationships between parameters. These rules serve as a knowledge base to determine the SR level based on water quality conditions. These rules are simulate using the MATLAB Fuzzy Logic Toolbox interface to facilitate the inference process and visualization of results. The fuzzy inference system uses the Mamdani method, which is the most commonly used approach for linguistic rule-based systems. The inference process is performed using the min-max method, while defuzzification is performed using the centroid method to produce a numerical SR output value.

Figures 5, 6, 7, 8 and 9 show the results of the fuzzy rules that have been designed to facilitate the process of predicting the survival rate (SR) of catfish larvae in the future. This prediction can be done if the measured air quality parameter values such as temperature, pH, and dissolved oxygen fall into one of the predetermined linguistic categories. The results of this prediction can also be used as an output reference for decision support systems in catfish larvae rearing management, especially in an effort to improve the efficiency of cultivation based on real-time water quality conditions.

Data analysis was qualitative, involving the identification of patterns, themes and categories through fuzzy logic-based interpretation. This approach enabled a deeper understanding of the relationship between environmental parameters and the predicted SR of catfish larvae. Fuzzy logic was used to bridge the uncertainty and subjectivity in the environmental data, thus supporting an intelligent systems-based decision-making process. This approach is relevant to field conditions, where decisions are often made based on intuition rather than definitive quantitative data.

RESULTS AND DISCUSSION

Water quality parameters such as temperature, pH, and dissolved oxygen (DO) have a major influence on the growth and survival of catfish larvae so that it is necessary to regularly observe and monitor the water quality conditions of fish ponds in order to maintain water quality in ponds maintained at parameter conditions in accordance with predetermined standards to avoid death in fish larvae (Farmadi & Kartini, 2021). Fluctuations in water quality parameters such as temperature, pH, and dissolved oxygen (DO) can directly affect the physiology and endurance of catfish larvae so that when the condition of these water quality parameters is unstable it can be the main cause of high mortality rates in catfish larvae.

Dissolved oxygen (DO) is needed by fish so that fish metabolism runs well, so when DO levels are insufficient or not optimal, it can cause a decrease in larval survival which can lead to death (Riadhi et al., 2017). While a pH that is not optimal can interfere with the osmotic balance of the larvae. Low pH can cause clumping of mucus in the gills, high pH can cause a lack of appetite in fish so that it can cause death (Saputra et al., 2018). In addition, temperature has a significant effect on larval survival. Suboptimal temperatures can have a negative impact on larval development, such as inhibiting growth rates, increasing the number of larvae, and increasing the number of larvae that die (Adi et al., 2024).

Determination of input variables to be used are dissolved oxygen (DO), pH, and temperature. The input that has been set further determines the output for the percentage of survival.

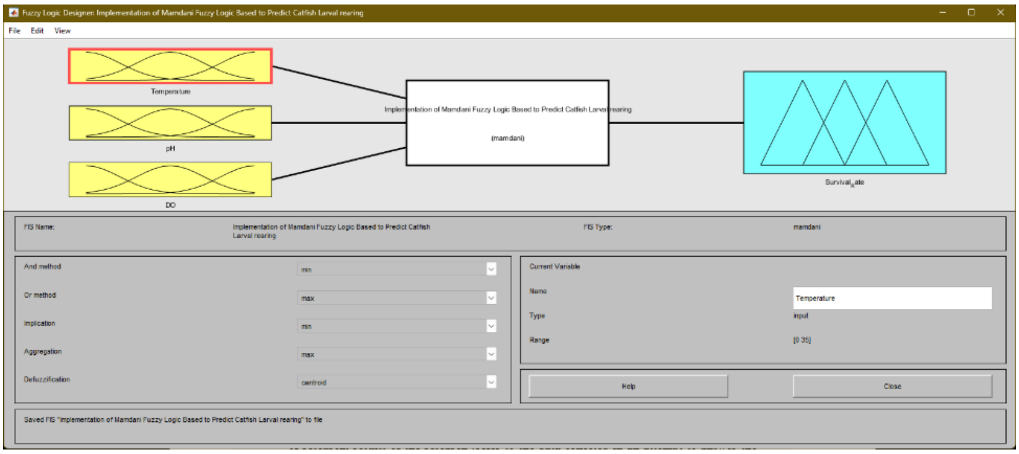


Figure. 10 Fuzzy Logic Designer

Simulation of a fuzzy logic mamdani-based prediction system is useful for monitoring water quality conditions in catfish larvae rearing ponds. The mamdani fuzzy logic approach was chosen because of its ability to handle uncertainty in sensor data and provide adaptive decisions.

Table 2. Input and Output in Fuzzy

Fuction	Variable	Fuzzy Sets	Range	Parameter
		Cold	<28	[0 0 27]
	Temperature (C)	Normal	28 – 30	[27 28 30]
		Hot	>30	[30 35 35]
		Acid	<6.5	[0 0 6.5]
Input	pH	Normal	6.5 – 8.5	[6.5 7 8.5]
		Alkaline	8.5 - 14	[8.5 14 14]
		Low	<3	[0 0 3]
	DO (mg/L)	Medium	3 – 7	[3 5 7]
		High	7 – 12	[7 12 12]
		Low	<60 %	[0 0 60]
Output	Survival Rate	Moderate	60 – 80%	[60 70 80]
		High	>80 %	[80 100 100]

This Mamdani fuzzy logic-based catfish larvae survival prediction system uses three main input parameters, namely temperature, pH, and dissolved oxygen (DO), each of which is classified into several fuzzy sets. Based on the visualization results of Rule Viewer and Surface Viewer, it can be seen that DO is the most influential factor on larval SR. When the DO value is low (<3 mg/L), the system predicts the SR level to be in the low category, even if the temperature and pH are in the normal range.

Temperature is the second priority factor after DO, where the optimal range (28-30°C) can increase SR when DO is sufficient (Yusuf et al., 2025). Meanwhile, pH has a more stable and less significant effect than DO and temperature. With this fuzzy approach, the system is able to flexibly capture the dynamics of environmental parameters, mimic the human judgment process, and provide more adaptive and realistic predictions of larval SR. These results reinforce the importance of managing oxygen levels and temperature as top priorities in catfish larval rearing to achieve optimal survival rates. Based on the selection of the rule editor, the result with inputs 17.5, 7, and 6 is 36. As shown below:

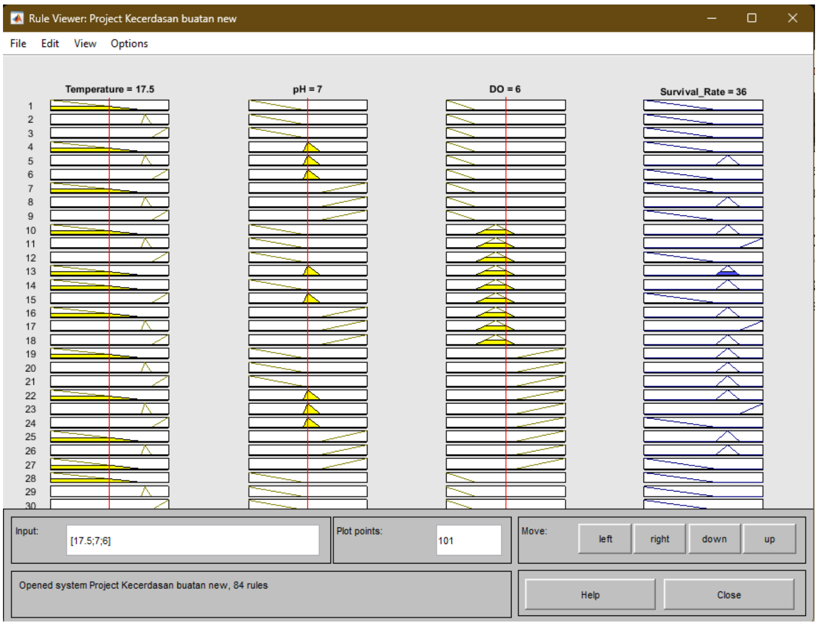


Figure 11. Rule Viewer

Rule Viewer of a Mamdani fuzzy logic system designed to predict the Survival Rate (SR) of catfish larvae based on three main water quality parameters: temperature, pH, and dissolved oxygen

(DO). The system works by reading each relevant rule based on the input, then combining the effects of all the rules to produce one output in the form of SR value. The yellow color and triangle in the rule viewer indicate the part of the rule that is active/responsive to the input.

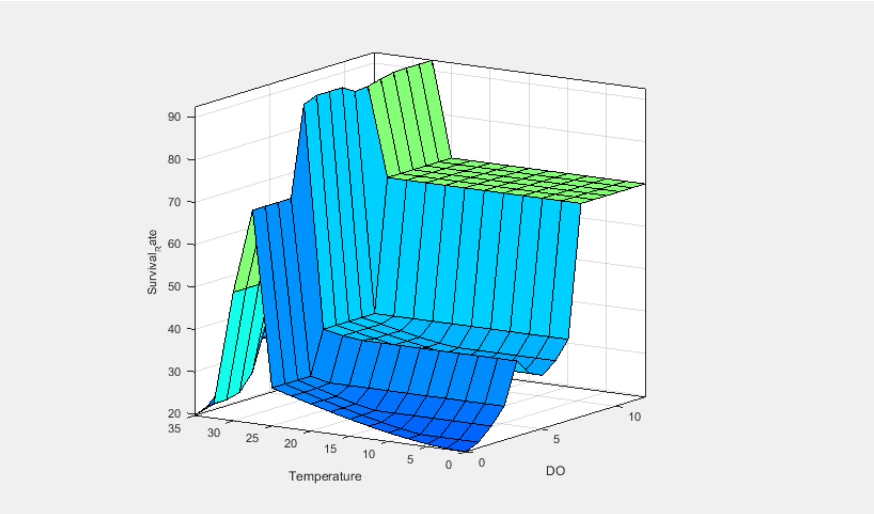


Figure 12. Surface Viewer Temperature and DO

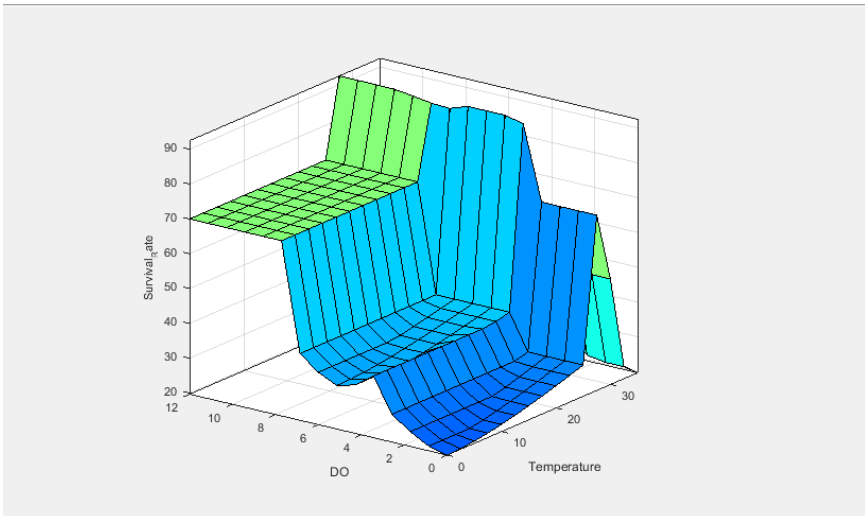


Figure 13. Surface Viewer Temperature and pH

It is clear that under low DO conditions (0-3 mg/L), the SR of catfish larvae tends to be very low, even if the temperature is close to ideal as shown in Figure (12) and (13). This means that even if the temperature is well maintained, the lack of dissolved oxygen remains the main cause of the low larval survival rate. DO (Dissolved Oxygen) is the most crucial parameter in the rearing of catfish larvae. Low oxygen levels directly cause the survival rate to fall to very low levels. Temperature is the second priority factor. Once DO is sufficient, the optimal temperature will largely determine the increase in SR, as can be seen from the contours of the surface plot which starts to rise significantly at the ideal temperature range. pH has a more moderate influence than DO and temperature, but is still important in maintaining the stability of the larval environment.

CONCLUSION

The application of the Mamdani fuzzy logic-based system has proven effective in supporting the management of catfish larval rearing. The system is capable of processing uncertain and fluctuating water quality parameters. By categorizing these parameters into fuzzy sets such as cold, neutral, and hot for temperature, or low to high for dissolved oxygen the system enables more flexible and realistic predictions of larval survival rates. This demonstrates its adaptability and strong potential for enhancing real-time decision-making in aquaculture environments. However, its reliance on static rule bases and the omission of other critical parameters such as ammonia and turbidity present notable limitations. Therefore, further development is recommended, including the incorporation of additional environmental variables, real-time sensor integration, and the use of adaptive or AI-assisted rule generation to improve system accuracy and responsiveness. Practically, farmers can adopt this system using affordable sensors connected to mobile applications or microcontroller-based automation to monitor and maintain optimal pond conditions. This study highlights the practical value of fuzzy logic systems in reducing larval mortality, improving hatchery performance, and advancing sustainable innovation in catfish aquaculture.

REFERENCES

Adi, R. M. S., Michelli, L. M., Alkori, H., & Ramadhan, R. G. (2024). The Applications of Mamdani Fuzzy in Water Selection of Pangas Catfish Ponds. *Journal of Informatics Information System Software Engineering and Applications (INISTA)*, *6*(2), 108–115. https://doi.org/10.20895/inista.v6i2.1030

Akhter, F., Siddiquei, H. R., Alahi, E. E., Mukhopadhyay, S. C., Alahi, M. E. E. ;, & Mukhopadhyay, S. C. (2021). *computers Recent Advancement of the Sensors for Monitoring the Water Quality Parameters in Smart Fisheries Farming Recent Advancement of the Sensors for Monitoring the Water Quality Parameters in Smart Fisheries*. https://doi.org/10.3390/computers

Alim, S. A., Sumaila, M., & Ritkangnga, I. Y. (2021). Design of a Fuzzy Logic Controller for Optimal African Catfish Water Production. *MEKATRONIKA*, *3*(2), 42–48. https://doi.org/10.15282/mekatronika.v3i2.7352

Analiah Fahlevy Yusuf, Zidan Febrian, Muhammad Fathurrahman, Rajwa Daffa Adyatama Yuristiawan, Steven Jona Duari Huta Balian, Dwi Yulinar Chairunisa, & Agung Prayudha Hidayat. (2025). Fuzzy Inference System to Improve Catfish Care in Bioflok Pools Based on Temperature and Water Quality. *Journal of Applied Science, Technology & Humanities*, *2*(1), 1–12. https://doi.org/10.62535/c6c50w10

Arifuddin, A., Wahyudin, W., Prabawanto, S., Yasin, M., & Elizanti, D. (2022). The Effectiveness of Augmented Reality-Assisted Scientific Approach to Improve Mathematical Creative Thinking Ability of Elementary School Students. *Al Ibtida: Jurnal Pendidikan Guru MI*, *9*(2), 444-455. http://dx.doi.org/10.24235/al.ibtida.snj.v9i2.11647

Bautista, M. G. A. C., Palconit, M. G. B., Rosales, M. A., Concepcion, R. S., Bandala, A. A., Dadios, E. P., & Duarte, B. (2022). Fuzzy Logic-Based Adaptive Aquaculture Water Monitoring System Based on Instantaneous Limnological Parameters. *Journal of Advanced Computational Intelligence and Intelligent Informatics*, *26*(6), 937–943. https://doi.org/10.20965/JACIII.2022.P0937

Choiri, A. F. (2024). IoT-Based Water Quality Monitoring System for Fish Ponds Using Fuzzy Inference Method. In *Jurnal Teknologi Informasi Dan Terapan (J-TIT* (Vol. 11, Issue 2). https://doi.org/10/25047/jtit.v11i2.5794

Cholilulloh, M., & Syauqy, D. (2018). Implementasi Metode Fuzzy Pada Kualitas Air Kolam Bibit Lele Berdasarkan Suhu dan Kekeruhan (Vol. 2, Issue 5). http://j-ptiik.ub.ac.id

Derli Aidil, Ilham Zulfahmi, Muliar.2016.Pengaruh suhu terhadap derajat penetasan telur dan perkembangan larva ikan lele sangkuariang(Clariasgariepinusvar.sangkuriang).JESBIO Vol. V No. 1.

Farmadi, A., & Kartini, D. (2021). Iplementasi Fuzzy Pada Monitoring dan Kontrol Kualitas Air Tangki Pembibitan ikan Menggunakan LabView. In Jurnal Komputasi (Vol. 9, Issue 2).

Gustiano, R., & Sri Haryani, G. (2021). Economically Important Freshwater Fish Native to Indonesia: Diversity, Ecology, and History (Vol. 48, Issue 10).

H.D, N. K., & Mahardani, J. (2024). Perancangan Dan Integrasi Iot Pada Sistem Kendali Air Kolam Dengan Metode Fuzzy Berdasarkan Ph Dan Turbidity Berbasis Mikrokontroler. *EPSILON: Journal of Electrical Engineering and Information Technology*, *22*(1), 17–32. https://doi.org/10.55893/epsilon.v22i1.114

Khoir Afdan, R., Khairuddin, F., Fazil Mawla Lubis, M., & Rahmadhani Hasibuan, F. (2023). Pengaruh Kualitas Air Terhadap Produksi Ikan Lele Dumbo (Clarias gariepinus). *Pubmedia Jurnal Biologi*, *1*, 1–8. https://doi.org/10.47134/biology.v1i1.193

Kurniawan, R., Hasibuan, M. S., & Prayuda, I. (2022). Automatic Fish Sorter With Microcontroller Based Sugeno Fuzzy Logic. *INFOKUM, August, Data Mining, Image Processing, and Artificial Intelligence*, *10*(3), 85–92. Retrieved from http://infor.seaninstitute.org/index.php/infokum/article/view/583

Laboni, T. A., Khatun, H., Khatun, M. S., Rahman, M. A., Islam, M. A., Ratry, Y. A., Uddin, M. M., Hossain, M. S., & Hossain, M. Y. (2024). Reproductive performance of Channa striata in wetland ecosystems: a fuzzy logic approach to water quality and eco-climatic factors for long-term sustainable management and aquaculture advancement. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-024-35701-9

Maghriza, R. Y. (2020). Publication Periode Development of a Water Quality Control System for Catfish Cultivation Using the Fuzzy Logic Method with IoT-Based Monitoring.

Mendoza, C. D. P., Caguimbal, R. G. R., Mandocdoc, J. B., & Sarmiento, J. S. (2023). Developing Fuzzy Rules for Small Scale Rearing of Black Soldier Fly Eggs. 2023 International Conference on Disruptive Technologies, ICDT 2023, 708–713. https://doi.org/10.1109/ICDT57929.2023.10151393

Muhammad Aqshol Dafa Ramadhan, Deyastra, M. R., Fadlurohman, F., Syahidah, R., Naufal Apriansyah, M. R., Ryanta Mulya, D., Octavia, N., Angeline, E., Mukti Dermawan, M. D., Wibisono, B., Naktavia, B., Ramadhan, M. S., Maharani, E., Rizky, Y., Keyvin Sitio, Y. I., Arista Dewi, F., Zulfia, G., Ryanda, P., Damayanti Nur, R., & Fiqri Nurfadillah. (2024). The Use off Fuzzy Mamdani to Predict Tilapia Production Based on Freshwater Quality. *Journal of Applied Science, Technology & Humanities*, *1*(5), 521–533. https://doi.org/10.62535/3jfbnh51

Muhammad Fajarudin, Handika Saputra Harahap, Irmansyah, Muhamad Al Habsy, Fardiana Yunita, Inna Novianty, Nanda Octavia, & Ivan De Nerol. (2024). Implementation of Fuzzy Logic to Regulate Water Quality in Maintaining the Aquascape Ecosystem. *Journal of Applied Science, Technology & Humanities*, *1*(4), 303–314. https://doi.org/10.62535/dvbdxn84

Pujiharsono, H., & Kurnianto, D. (2020). Sistem inferensi fuzzy Mamdani untuk menentukan tingkat kualitas air pada kolam bioflok dalam budidaya ikan lele. *Jurnal Teknologi Dan Sistem Komputer*, *8*(2), 84–88.

Ramdani, F., Daryn Ramadhani Az Zahra, Herlambang Nurasyid Ramdhani, Mohamad Fikih Amar Dani, Fiqri Nurfadillah, Muhammad Danang Mukti Darmawan, & Nanda Octavia. (2025). Prediction of Water Quality in Ponds Based on Temperature, Water Clarity, pH, and Dissolved Oxygen Using Mamdani Fuzzy Logic. *Journal of Applied Science, Technology & Humanities*, *2*(2), 149–161. https://doi.org/10.62535/n729q614

Rana, D., & Rani, S. (2015). Fuzzy logic based control system for fresh water aquaculture: A MATLAB based simulation approach. *Serbian Journal of Electrical Engineering*, *12*(2), 171–182. https://doi.org/10.2298/sjee1502171r

Riadhi, L., Rivai, M., & Budiman, F. (2017). Sistem Pengaturan Oksigen Terlarut Menggunakan Metode Logika Fuzzy Berbasis Mikrokontroler Teensy Board. Jurnal Teknik ITS, 6(2). https://doi.org/10.12962/j23373539.v6i2.26014

Rizki, M., & Darnila, E. (n.d.). METHOMIKA: Jurnal Manajemen Informatika & Komputerisasi Akuntansi PENERAPAN LOGIKA FUZZY TSUKAMOTO PADA RANCANG BANGUN SISTEM DETEKSI KEKERUHAN AIR BUDI DAYA IKAN LELE. https://doi.org/10.46880/jmika.Vol9No1.pp112-120

Rochyani, N. (2018). Analisis Karakteristik Lingkungan Air Dan Kolam Dalam Mendukung Budidaya Ikan. *Jurnal Ilmu-Ilmu Perikanan Dan Budidaya Perairan*, *13*(1), 51–56. https://doi.org/10.31851/jipbp.v13i1.2856

Saputra, I., Kusuma Atmaja Putra, W., & Yulianto, T. (2018). Conversion Rate and Feed Efficiency of Silver Pompano Fish (Trachinotus blochii) With Different Frequency Giving. Journal of Aquaculture Science, 3(2), 72–84. https://doi.org/10.31093/joas.v3i2.56

Saskia, K. A., & Salamah, I. (2025). Pearl Catfish Pond Water Quality Monitoring System Using the ThingSpeak Server, *17*(2).

Sholihah, W., Hendriana, A., Kusumanti, I., & Novianty, I. (2022). Design of IoT Based Water Monitoring System (Simonair) For Arwana Fish Cultivation. *Eduvest - Journal of Universal Studies*, *2*(12), 2872–2884. https://doi.org/10.59188/eduvest.v2i12.708

Sugianti, E. P., & Hafiludin, H. (2022). Manajemen Kualitas Air Pada Pembenihan Ikan Lele Mutiara (Clarias gariepinus) di Balai Benih Ikan (BBI) Pamekasan. *Juvenil:Jurnal Ilmiah Kelautan Dan Perikanan*, *3*(2), 32–36. https://doi.org/10.21107/juvenil.v3i2.15813

Teng, S., & Alonzo, D. (2023). Critical Review of the Australian Professional Standards for Teachers: Where are the non-Cognitive Skills?. *International Journal of Instruction*, *16*(1). 605-624. https://doi.org/10.29333/iji.2023.16134a

Yanti, N., Nur, T., & Randis, R. (2022). Implementation of Fuzzy Logic in Fish Dryer Design. *ILKOM Jurnal Ilmiah*, *14*(1), 39–51. https://doi.org/10.33096/ilkom.v14i1.1092.39-51

Yudi Abdul Syawari, M., & Hartono. (2024). Sistem Inferensi Fuzzy Tsukamoto Untuk Menentukan Tingkat Kualitas Air Pada Kolam Budidaya Ikan Lele. Sienna, 5(1), 95–109. https://doi.org/10.47637/sienna.v5i1.1358

Yulianto, T., Solehah, I., Faisol, F., Amalia, R., & Tafrikan, M. (2023). Perbandingan Fuzzy Tsukamoto Dan Fuzzy Mamdani Dalam Memprediksi Intensitas Curah Hujan Di Kabupaten Sumenep. Jurnal Aplikasi Teknologi Informasi Dan Manajemen (Jatim), 4(1), 69-83.