

Business Management System Of Catfish Cultivation Using Fuzzy Inference System Tsukamoto Methods

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ABSTRACT

Catfish is a type of freshwater fish that is in great demand among people because it has high nutritional value. The high demand for catfish on the market is a promising business opportunity. The relatively fast maintenance period makes this cultivation much in demand. Management of a catfish farming business requires good strategy and planning so that the business process can provide optimal profits. Appropriate management practices, good planning can predict crop yields with minimal error rates. Based on past data from catfish farming businesses, catfish pond production results are influenced by several factors including pond area, number of seeds, and amount of feed. The catfish cultivation management system produces predictions of catfish harvest but ignores weather conditions, natural disasters and infectious diseases. The method used in crop yield prediction management is the Tsukamoto Fuzzy inference system. The Tsukamoto method applies monotonous reasoning and rules are built using expert knowledge, enabling the system to be able to conclude and manage predictions of catfish harvest based on data regarding pond size, number of seeds and amount of feed. System testing using 10 data shows prediction results obtained through manual calculations and system calculations, resulting in identical results. Further testing uses the white box method to ensure that the data implemented in the Tsukamoto fuzzy management system accurately produces logical decisions. Hence, it can be concluded that the management system using the Tsukamoto method is able to show effective performance in predicting harvest results based on data on pond area, number of seeds and amount of feed consumption. This management system is expected to be able to provide recommendations for catfish cultivation business planning for the community.

INTRODUCTION

Fish farming is very provitable. catfish farming remains the most significant part of agriculture and have resources to adapt to changing economic condition. Catfish have a mild flavor and are low in calories and protein.

The high consumption of catfish has encouraged the increase in catfish cultivation efforts. (Rusnandari Retno Cahyani, 2017) has stated that catfish cultivation can be done using tarpaulin as a pond lining. With knowledge and assistance in cultivating catfish in the yard it can effectively increase people's income. Catfish cultivation can also be developed aquaponically by being integrated with plants so that it can be maximizing land use in the same duration (Fadhilah, 2023).

Currently the fisheries industry in Indonesia is in a leading position globally, covering aquaculture and capture fisheries both at sea and on land, with a total production capacity reaching 67 million tons per year. According to 2018 production data, the capture fisheries sector in this country produced 7.36 million tons or 72.17% of total production, while the aquaculture sector produced 15.77 million tons or 27.76% of total production (Noviar, 2021). The cultivation process is one of the efforts of the fisheries sector that has a competitive advantage to encourage the growth of the number of fisheries and marine activities in Indonesia. Catfish cultivation provides a great opportunity for the community, because the capital costs of raising catfish do not require a lot of money. This makes catfish cultivation more accessible to farmers or small businesses to gain sustainable profits from catfish production (R.M. Putra, 2021). The high demand for catfish (*Clarias Gariepinus*) in the market means that the catfish farming business has good prospects. Various methods and strategies for making catfish ponds have been developed, from conventional catfish ponds to catfish farms using tarpaulin systems. (Fika Dewi Pratiwi, 2020) conducted research and assistance in catfish farming businesses using tarpaulin by applying technology that can improve water quality using Probio Fm. In 2017, an application for selecting freshwater fish seeds was developed as an effort to increase knowledge in fish cultivation (Muhammad Azhari, 2017).

The large number of catfish farmers has encouraged research to build a harvest prediction system by considering the size of the pond, the number of fish seeds, and the amount of feed consumed during the cultivation period. The



prediction results are the number of fish harvests. The prediction system does not consider the duration of the harvest period, weather changes, disease outbreaks, capital costs or employee wages. The research was conducted with the aim of building a catfish cultivation management system where the prediction results can be used by catfish farmers to plan their business by considering resources in the form of pond area, number of seeds, and amount of feed consumption. Thus, farmers can estimate income from catfish cultivation. The research would be assumed that the whole fish pond is cut together in single batch production, fingerling catfish are store and reared until almost all the fish have reached market size

Many people have made efforts to empower the community through optimizing resources, one of which is through empowering the community in terms of business management. This is done in order to improve community welfare. (Mohammad Riza Radyanto, 2020) has stated that there are opportunities for strong MSME business resilience and high competitiveness by providing business management assistance, both in terms of production, marketing, distribution and administrative management. From the research (Tejash U. Chaudari, 2023) it was found that the Tsukamoto method is the most effective method in evaluating performance, compared to the Mamdani, Larsen, and Tsukamoto methods with model accuracy analyzed using statistical average correlation. The time efficiency of the Tsukamoto method is proven to be more efficient.

According to the Big Indonesian Dictionary (KBBI, 2015) prediction is a prediction or forecast. Prediction is a process of systematically estimating something that is most likely to happen in the future based on the past and present information that is available, so that the error (the difference between something that happens and the predicted result) can be minimized. (Lenisa U, 2023) conducted research to predict chili prices using the Fuzzy Time Series, where past data is used to find prediction patterns.

Fuzzy logic according to Louthfi A. Zadeh is a development of classical logic which only accepts the membership of an object in 2 dichotomies (Kusumadewi, 2003). The degree of membership in the fuzzy system has a value between [0,1] so that it can accommodate the determination of the degree of membership in a number of linguistic objects (Sri Kusumadewi, 2010). Based on the problems above, this research was conducted with the title "catfish cultivation business management system using the Fuzzy Tsukamoto method". The use of the Fuzzy Tsukamoto method was chosen to make this management system capable of inferring and managing the prediction of catfish harvest results based on data on the condition of the pond area, number of seeds and amount of feed. So, by building this system, it is hoped that it can help farmers manage their catfish cultivation needs more effectively and efficiently

LITERATURE REVIEW

(Yudha Prasetya Anza, 2021) developed a web-based catfish cultivation feasibility management application which is used to diagnose harvest feasibility in catfish cultivation. The application also has a discussion feature for cultivators sharing.

There is a number of previous studies related to research currently being carried out, such as research using the application of the Fuzzy Tsukamoto method to predict a production quantities chili plants. The system was developed based on three variables, namely land area, number of seeds, and maintenance costs (Irmansyah, 2021). The creation of a management information system for catfish pond cultivation using the Research and Development method has been developed in research (A Fachri, 2021).

(Rozikin, 2021) has developed a catfish cultivation investment application based on Finite State Automata. Every entrepreneur who will run his business definitely expects a profit, so careful calculations need to be made before starting a business. Determining of profit, it is necessary to calculate the initial capital prepared, operational costs, and the proceeds from selling catfish during one harvest period so that the return on investment (ROI) of the business that will be run can be calculated.

A mobile application has been developed to support catfish cultivation using the human centered method designed by (Burhanuddin Alli Ahmadi, 2020). Catfish cultivation businesses need good and regular records, regular and timely feeding according to the amount needed at a certain age, so as not to cause disruption and problems with the harvest. This application helps farmers in setting catfish cultivation patterns

This research has built a catfish cultivation management system by planning the pond area, number of fish seeds, and amount of feed consumption as input variables and predicting harvest yields as output variables using the Tsukamoto method. Users of this application are assumed to be experienced cultivators, so the application is useful as a tool for planning the development of catfish cultivation ponds

METHOD

The system design stages are carried out following the prototyping model, adapted to analyzing the needs of prospective users, designing, developing and testing. The system design process starts from the system requirements analysis phase, interviews are conducted with related parties to gain knowledge about catfish pond cultivation. input variable data with the entire process shown in Figure 1.



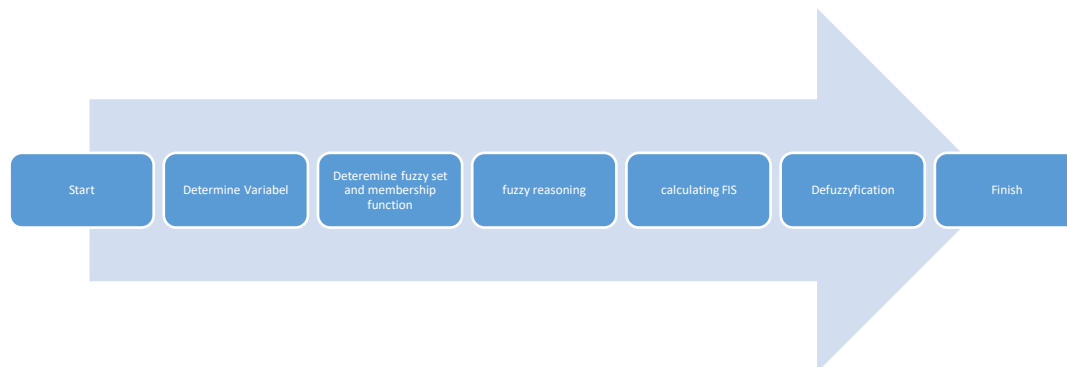


Figure 1. variable data with the entire process

Determine fuzzy variables, we might begin to designing fuzzy system by dividing the input variable, and output variables into membership sets (pond area, number of seeds, amount of feed, and harvest yield) and then from each of these a membership function will be created, following the form of an increasing function and a decreasing function with limitations as shown in Table 1.

Table 1. Fuzzy Variables

Variable	Fuzzy Variabel	Fuzzy Memberships	Universe	Range
Input	Pond area	Small	[0, ∞]	[0, 65]
	(m ²)	Large		[112, ∞]
	Number of seeds	Low	[0,∞]]	[0, 10.000]
	(fish)	High		[23.000, ∞]]
	Amount of Feeds	Low	[0, ∞]]	[0, 30]
	(sack)	High		[69, ∞]]
Output	Harvest yield	Low	[0, ∞]]	[0, 810]
	(kg)	High		[2070, ∞]]

The membership function of each input and output variable, following the form of an increasing function and a decreasing function, is described as follows:

$$\begin{aligned}
 \mu_{Pond\ area\ small} &= \begin{cases} 0, & \text{if } x > 112 \\ \frac{x - 65}{47}, & \text{if } 65 < x < 112 \\ 1, & \text{if } x < 65 \end{cases} \\
 \mu_{Pond\ area\ large} &= \begin{cases} 0, & \text{if } x > 112 \\ \frac{112 - x}{47}, & \text{if } 65 < x < 112 \\ 1, & \text{if } x < 65 \end{cases} \\
 \mu_{Number\ of\ seeds_{low}} &= \begin{cases} 0, & \text{if } x > 23000 \\ \frac{x - 10000}{47}, & \text{if } 10000 < x < 23000 \\ 1, & \text{if } x < 10000 \end{cases} \\
 \mu_{Number\ of\ seeds_{high}} &= \begin{cases} 0, & \text{if } x < 10000 \\ \frac{23000 - x}{13000}, & \text{if } 10000 < x < 23000 \\ 1, & \text{jika } x > 23000 \end{cases} \\
 \mu_{Number\ of\ feed_{low}} &= \begin{cases} 0, & \text{if } x > 69 \\ \frac{x - 30}{39}, & \text{if } 30 < x < 69 \\ 1, & \text{if } x < 30 \end{cases}
 \end{aligned}$$

$$\mu \text{ Number of feed}_{high} = \begin{cases} 0, & \text{if } x < 30 \\ \frac{69-x}{9}, & \text{if } 30 < x < 69 \\ 1, & \text{if } x > 69 \end{cases}$$

Let's consider to compute a sample input to the system, itss shown above

a. Pond area

In determining the area of the pond, it is divided into 2 sets, namely: Small and Large which are represented as follows:

$$\begin{aligned} \mu \text{ Pond area}_{Small} [85] &= \frac{112-85}{47} = \frac{27}{47} = 0,5744 \\ \mu \text{ Pond area}_{Large} [85] &= \frac{85-65}{47} = \frac{20}{47} = 0,4255 \end{aligned}$$

b. Number of seeds

Determine the number of seeds, they are divided into 2 sets, namely: Low and Large, which are represented as follows:

$$\begin{aligned} \mu \text{ Number of seeds}_{Low} [15000] &= \frac{23000-15000}{13000} = \frac{8000}{13000} = 0,6153 \\ \mu \text{ Number of seeds}_{High} [15000] &= \frac{15000-10000}{13000} = \frac{5000}{13000} = 0,3846 \end{aligned}$$

c. Amount of feed

Determine the amount of feed into 2 fuzzy sets,: Low and Large which are represented as follows:

$$\begin{aligned} \mu \text{ Amount of feed}_{Low} [49] &= \frac{69-49}{39} = \frac{20}{39} = 0,5128 \\ \mu \text{ Amount of feed}_{High} [49] &= \frac{49-30}{39} = \frac{19}{39} = 0,4871 \end{aligned}$$

d. Harvest Yields

Determine the harvest yield into 2 fuzzy sets, namely: Low and High which are represented as follows:

$$\begin{aligned} \mu \text{ Harvest Yield}_{Low}(z) &= \begin{cases} 1 & z \leq 810 \\ \frac{2070-z}{1260} & 810 \leq z \leq 2070 \\ 0 & z \geq 2070 \end{cases} \\ \mu \text{ Harvest Yield}_{High}(z) &= \begin{cases} 0 & z \leq 810 \\ \frac{z-810}{1260} & 810 \leq z \leq 2070 \\ 1 & z \geq 2070 \end{cases} \end{aligned}$$

Fuzzy inference system is a mapping that determines its output based on fuzzy reasoning and a set of fuzzy if-then rules. Hence, combining the fuzzy inputs according to the fuzzy rules to establish a rule strength, rule base in this process is a statement in fuzzy rules consisting of the condition "IF" (variable input) and the result "THEN" (variable output). Meanwhile, to connect input variables, use the "AND" operator as in Table 2.

Table 2. Fuzzy Rule Base Tsukamoto

Rule	Input						Output	
nun mer	IF	Pond Area	Op	Number of Seed	Op	Amount of Feed	THEN	Harvest Yield
R1	IF	Small	AND	Low	AND	High	THEN	Low
R2	IF	Small	AND	Low	AND	Low	THEN	Low
R3	IF	Small	AND	High	AND	High	THEN	High
R4	IF	Small	AND	High	AND	Low	THEN	Low
R5	IF	Large	AND	Low	AND	Low	THEN	Low
R6	IF	Large	AND	Low	AND	High	THEN	High
R7	IF	Large	AND	High	AND	Low	THEN	Low
R8	IF	Large	AND	High	AND	High	THEN	High

Inference system in this process will interpret the rule statement in the form of a minimum condition with the "AND" operator link which will then be combined in the fuzzy system using a single set of values 0 and 1. To calculate the output of the inference result (z) on the crop yield variable, it is determined based on the rules that have been set as follows:

[R1] IF Pond Area is Small AND Number of Seeds is Low AND Amount of Feed is High THEN Harvest Yield is Low

$$a - predikat_1 = \text{Min} (\mu_{pond\ area_{small}} \cap \mu_{Number\ of\ seed_{Low}} \cap \mu_{Amount\ of\ feed_{high}}) \\ = \text{Min} (0,5744; 0,6153; 0,4871) = 0,4871$$

In the results of the fuzzy rule for R1, because the harvest yield is low, the low graph is used with the formula:

$$a - predikat_1 = \frac{Z_{max} - z_1}{Z_{max} - Z_{min}} \\ 0,4871 = \frac{2070 - z_1}{1260} \\ 2070 - z_1 = 0,4871 \times 1260 \\ 2070 - z_1 = 613,746 \\ z_1 = 2070 - 613,746 = 1456,254$$

[R2] IF Pond Area is Small AND Number of Seeds is Low AND Amount of Feed is High THEN Harvest Yield is Low

$$a - predikat_2 = \text{Min} (\mu_{pond\ area_{small}} \cap \mu_{Number\ of\ Seed_{Low}} \cap \mu_{Amount\ of\ feed_{Low}}) \\ = \text{Min} (0,5744; 0,6153; 0,5128) = 0,5128$$

The results of the fuzzy rule for R2, the harvest yield is low then the low graph is:

$$a - predikat_2 = \frac{Z_{max} - z_2}{Z_{max} - Z_{min}} \\ 0,5128 = \frac{2070 - z_2}{1260} \\ 2070 - z_2 = 0,5128 \times 1260 \\ 2070 - z_2 = 646,128 \\ z_2 = 2070 - 646,128 = 1423,872$$

[R3] IF Pond Area is Small AND Number of Seeds is High AND Amount of Feed is High THEN Harvest Yield is High

$$a - predikat_3 = \text{Min} (\mu_{Pond\ area_{small}} \cap \mu_{Number\ of\ seed_{High}} \cap \mu_{Amount\ of\ feed_{High}}) \\ = \text{Min} (0,5744; 0,3846; 0,4871) = 0,3846$$

the results of the fuzzy rule that the yield is high, then:

$$a - predikat_3 = \frac{z_3 - Z_{min}}{Z_{max} - Z_{min}} \\ 0,3846 = \frac{z_3 - 810}{1260} \\ z_3 - 810 = 0,3846 \times 1260 \\ z_3 - 810 = 484,596 \\ z_3 = 484,596 + 810 = 1294,596$$

[R4] IF Pond Area is Small AND Number of Seeds is High AND Amount of Feed is Low THEN Harvest Yield is Low

$$a - predikat_4 = \text{Min} (\mu_{Pond\ area_{small}} \cap \mu_{Number\ of\ Seed_{High}} \cap \mu_{Amount\ of\ Feed_{Low}}) \\ = \text{Min} (0,5744; 0,3846; 0,5128) = 0,3846$$

The results of the fuzzy rule R4 since the Harvest yield is low is used with the formula:

$$a - predikat_4 = \frac{Z_{max} - z_4}{Z_{max} - Z_{min}} \\ 0,3846 = \frac{2070 - z_4}{1260} \\ 2070 - z_4 = 0,3846 \times 1260 \\ 2070 - z_4 = 484,596 \\ z_4 = 2070 - 484,596 = 1585,404$$

[R5] IF Pond Area is Large AND Number of Seeds is Small AND Amount of Feed is Small THEN Harvest Yield is Low

$$a - predikat_5 = \text{Min} (\mu_{LK\ besar} \cap \mu_{JB\ sedikit} \cap \mu_{JP\ sedikit}) \\ = \text{Min} (0,4255; 0,6153; 0,5128) = 0,4255$$

In the results of the fuzzy rule for R5, because the yield is low, the low graph is used with the formula:

$$a - predikat_5 = \frac{Z_{max} - z_5}{Z_{max} - Z_{min}} \\ 0,4255 = \frac{2070 - z_5}{1260} \\ 2070 - z_5 = 0,4255 \times 1260 \\ 2070 - z_5 = 536,13 \\ z_5 = 2070 - 536,13 = 1533,87$$

[R6] IF Pond Area is Large AND Number of Seeds is Low AND Amount of Feed is High THEN Harvest Yield is High

$$a - predikat_6 = \text{Min} (\mu_{Pond\ area_{Large}} \cap \mu_{Number\ of\ Seed_{Low}} \cap \mu_{Amount\ of\ Feed_{High}})$$

$$= \text{Min} (0,4255; 0,6153; 0,4871) = 0,4255$$

The results of the fuzzy rule for R6, the harvest yield is high, so:

$$\begin{aligned} a - \text{predikat}_6 &= \frac{z_6 - Z_{\min}}{Z_{\max} - Z_{\min}} \\ 0,4255 &= \frac{z_6 - 810}{1260} \\ z_6 - 810 &= 0,4255 \times 1260 \\ z_6 - 810 &= 536,13 \\ z_6 &= 536,13 + 810 = 1346,13 \end{aligned}$$

[R7] IF Pond Area is Large AND Number of Seeds is High AND Amount of Feed is Low THEN Harvest Yield is Low

$$\begin{aligned} a - \text{predikat}_7 &= \text{Min} (\mu \text{ Pond area}_{\text{Large}} \cap \mu \text{ Number of Seed}_{\text{High}} \cap \mu \text{ Amount of Feed}_{\text{Low}}) \\ &= \text{Min} (0,4255; 0,3846; 0,5128) = 0,3846 \end{aligned}$$

The results of the fuzzy rule for R7, when the harvest yield is low, so:

$$\begin{aligned} a - \text{predikat}_7 &= \frac{Z_{\max} - z_7}{Z_{\max} - Z_{\min}} \\ 0,3846 &= \frac{2070 - z_7}{1260} \\ 2070 - z_7 &= 0,3846 \times 1260 \\ 2070 - z_7 &= 484,596 \\ z_7 &= 2070 - 484,596 = 1585,404 \end{aligned}$$

[R8] IF Pond Area is Large AND Number of Seeds is High AND Amount of Feed is High THEN Harvest Yield is high

$$\begin{aligned} a - \text{predikat}_8 &= \text{Min} (\mu \text{ Pond area}_{\text{Large}} \cap \mu \text{ Number of Seed}_{\text{High}} \cap \mu \text{ Amount of Feed}_{\text{High}}) \\ &= \text{Min} (0,4255; 0,3846; 0,4871) = 0,3846 \end{aligned}$$

The results of the fuzzy rule for R8 when the Harvest yield is high, a high graph is used with the formula:

$$\begin{aligned} a - \text{predikat}_8 &= \frac{z_8 - Z_{\min}}{Z_{\max} - Z_{\min}} \\ 0,3846 &= \frac{z_8 - 810}{1260} \\ z_8 - 810 &= 0,3846 \times 1260 \\ z_8 - 810 &= 484,596 \\ z_8 &= 484,596 + 810 = 1294,596 \end{aligned}$$

The results of fuzzy inference calculations on R1-R8 shown in Table 3:

Table 3. Fuzzy inference calculation results

Rule	Input							Output	α -predikat	Z
N-th	IF	Pond area	Operator	Number of Seed	Operator	Amount of Feed	THEN	Harvest yield		
R1	IF	Small	AND	Low	AND	High	THEN	Low	0,4871	1456,254
R2	IF	Small	AND	Low	AND	Low	THEN	Low	0,5128	1423,872
R3	IF	Small	AND	High	AND	High	THEN	High	0,3846	1294,596
R4	IF	Small	AND	High	AND	Low	THEN	Low	0,3846	1585,404
R5	IF	Large	AND	Low	AND	Low	THEN	Low	0,4255	1533,85
R6	IF	Large	AND	Low	AND	High	THEN	High	0,4255	1346,13
R7	IF	Large	AND	High	AND	Low	THEN	Low	0,3846	1585,404
R8	IF	Large	AND	High	AND	High	THEN	High	0,3846	1294,596

Fuzzy rules are a collection of linguistic statements that describe how the FIS should make a decision regarding classifying an input or controlling an output. This process is reversing the fuzzification calculation which aims to change the results of the fuzzification process (which produces linguistic values) into firm or concrete values and is decided centrally with the following formula:

$$Z = \frac{a_1 * z_1 + a_2 * z_2 + a_3 * z_3 + a_4 * z_4 + a_5 * z_5 + a_6 * z_6 + a_7 * z_7 + a_8 * z_8}{a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8}$$

$$Z = \frac{(0,4871*1456,254)+(0,5128*1423,872)+(0,3846*1294,596)+(0,3846*1585,404)+(0,4255*1533,85)+(0,4255*1346,13)+(0,3846*1585,404)+(0,3846*1294,596)}{0,4871+0,5128+0,3846+0,3846+0,4255+0,4255+0,3846+0,3846}$$

$$Z = \frac{4.880,2731}{3,3893} = 1440 \text{ Kg}$$

System planning

The following are the stages in designing a catfish cultivation management system using the Fuzzy Tsukamoto method which aims to determine catfish harvest results, including use case diagrams, activity diagrams, context diagrams, DFD, interface design

Use Case Diagram

There are 2 levels of actors in this system, admin and user, admin can log in to the system to manage data during catfish cultivation. Next, the admin can input variable data such as pond area, number of seeds, and amount of feed that will be processed using Fuzzy Tsukamoto so that this data can determine the catfish harvest obtained. Admin can manage user data on anyone registered in the system and manage harvest reports during catfish cultivation. Meanwhile, users can only access and view information on harvest prediction data obtained during catfish cultivation.

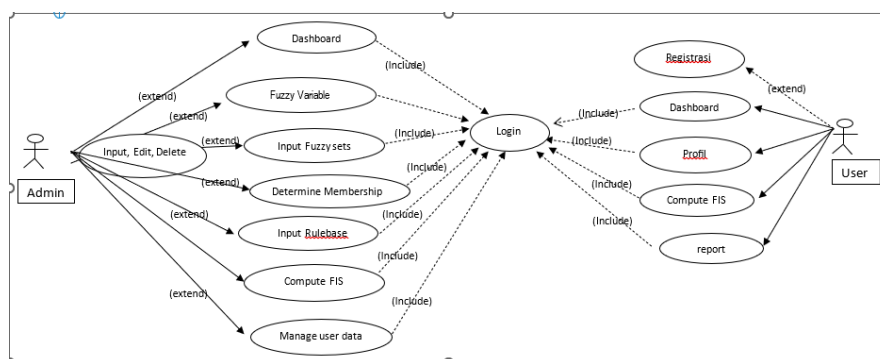


Figure 2. Use Case Diagram

Activity Diagram

In the activity diagram, admin can input Fuzzy variable, Fuzzy sets, Fuzzy Membership, and Rulebase to compute. It explains how to process calculation data which is processed using Fuzzy Tsukamoto. Admin have to manage the data user, to verification and validation account. Here the admin can input data, edit and delete calculation data. User can login to the system with their verified account, and then input data cultivation to compute the prediction.

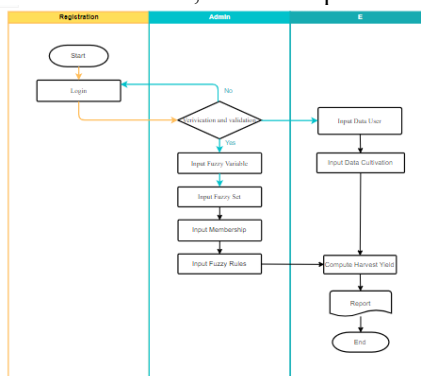


Figure 3. Activity Diagram

Context Diagram

In the context diagram there are 2 users, admin and user. Admins can manage the system such as adding, editing and deleting data, Fuzzy variable, Fuzzy sets, Fuzzy Membership, and Fuzzy Rules, while users will receive information regarding the results data obtained during cultivation on report

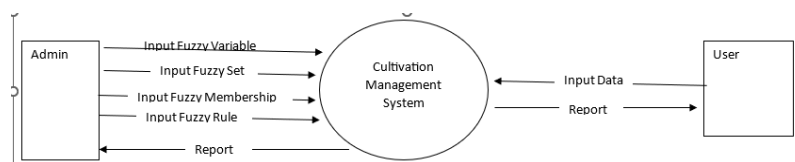


Figure 4. Context Diagram

Data Flow Diagram Level 0

Admins and users must carry out a login process before accessing the system, followed by a verification process for access rights. Username and password verification will be forwarded to the user table in the system database. Admins can manage system data stored in a database in the form of tables, namely the cultivation table stores cultivation data, the test data table stores variable test data, and the harvest results table stores harvest data that has been processed using Fuzzy Tsukamoto. Next, the admin can manage the harvest report and the user will receive predicted data on the catfish harvest that the admin has input.

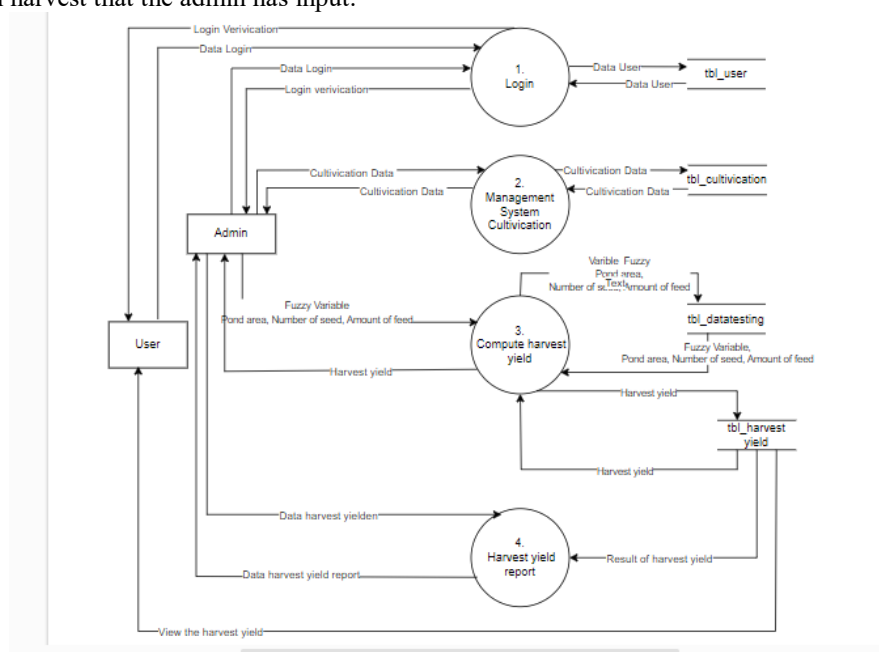


Figure 5. Data Flow Diagram level 0

Data Flow Diagram Level 1 Process 3

DFD Level 1 process 3 will describe the Fuzzy Tsukamoto calculation flow such as the fuzzyfication, inference and defuzzyfication processes in the system. The following is DFD Level 1 Process 3 in the catfish cultivation business management system using Fuzzy Tsukamoto.

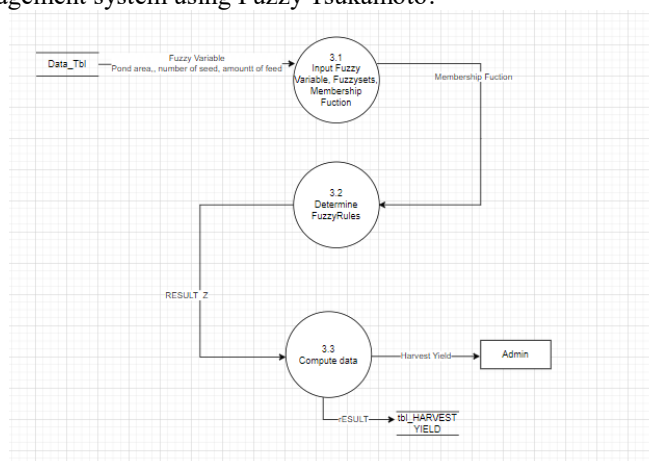


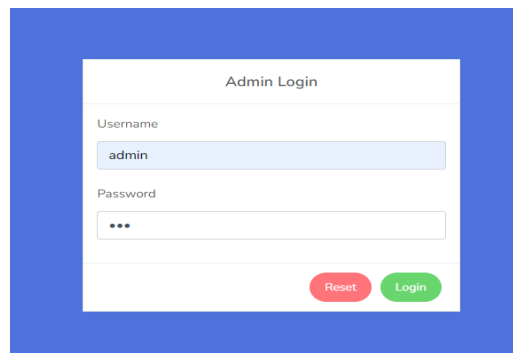
Figure 6. Data Flow Diagram Level 1 Process 3

RESULT

The system display in this research shows the results of designing a management system for catfish cultivation using the Fuzzy Tsukamoto method which was successfully implemented into the system, as in Figure 7. And datatesting was carried out to find out how well Fuzzy Tsukamoto can manage the prediction of harvest yields for catfish cultivation.

Admin Interface Page

The website page in Figure 7 show the main display in the form of a login page. The admin must first enter the username and password.



The image shows a web form titled "Admin Login" with a blue border. It contains two input fields: "Username" with the text "admin" and "Password" with three dots. Below the fields are two buttons: a red "Reset" button and a green "Login" button.

Figure 7. Admin Login Page

And the dashboard page in Figure 8. will display information regarding the catfish cultivation business.



The image shows a web dashboard titled "SISTEM MANAJEMEN BUDIDAYA IKAN LELE MENGGUNAKAN FUZZY TSUKAMOTO". It has a blue sidebar with links: "Dashboard", "User", "Input Data Perhitungan", and "Laporan". The main content area has a header "SELAMAT DATANG" and a large image of a person feeding fish in a pond. To the right of the image is a text block about catfish cultivation.

Figure 8. Admin Dashboard Page

The calculation data input page in Figure 9 will be used to determine the harvest yield of catfish cultivation based on the variables that have been determined and then the data will be processed using the Fuzzy Tsukamoto Method. Here the admin can input the harvest date, variable data such as pond area, number of seeds, and amount of feed.



The image shows a web form titled "Input Data" with a close button (X). It contains four input fields: "Tanggal Panen" (mm/dd/yyyy), "Luas Kolam (m²)", "Jumlah Bibit (ekor)", and "Jumlah Pakan (sak)". Below the fields are two buttons: a grey "Batal" button and a blue "Submit" button.

Figure 9. Calculation Data Input Page

The calculation results data page in Figure 10 will display the data from Fuzzy Tsukamoto's calculations. Here the admin can edit data, delete data, and view Fuzzy Tsukamoto calculation checks.

No	Tanggal Panen	Luas Kolam	Jumlah Bibit	Jumlah Pakan	Hasil Panen	Kategori	Aksi
1	16 September 2023	85	15,000	49	1,440	Benar	Cek Perhitungan, Edit, Hapus
2	17 June 2023	65	11,000	35	1,138	Benar	Cek Perhitungan, Edit, Hapus
3	15 March 2023	80	16,000	48	1,439	Benar	Cek Perhitungan, Edit, Hapus
4	15 December 2022	112	22,000	66	1,902	Salah	Cek Perhitungan, Edit, Hapus
5	15 December 2022	65	12,000	36	1,209	Benar	Cek Perhitungan, Edit, Hapus

Figure 10. Calculation Results Data Page

The harvest results report page in Figure 11. will display a menu for the admin which is used to view data reports on the harvest results of catfish cultivation which have previously been processed using Fuzzy Tsukamoto. On this page the admin can input the user name and the harvest date that he wants to search for by inputting the start date of the harvest to the end date of the harvest that he wants to search for and the automatic system will immediately print the report in PDF form.

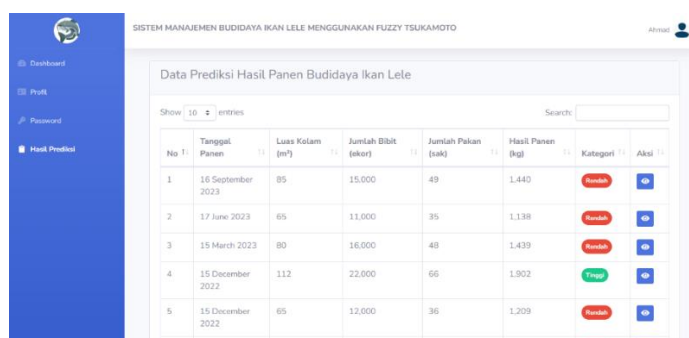
Figure 11. Harvest Results Report Page

User Interface Page

The main page in Figure 12 will display the login page for the user. The user must first register if they want to be registered in the system. After registering, the user can have access rights to log in to the system by inputting a username and password.

Figure 12. User Login Page

The prediction results page in Figure 13. will display information on predicted data on catfish cultivation harvest results for users who have previously input data by the admin. Here the admin can also see the detailed process of Fuzzy Tsukamoto's calculation results.



The screenshot shows a web application interface for catfish cultivation management. On the left is a blue sidebar with navigation links: Dashboard, Hasil, Password, and Hasil Prediksi. The main content area is titled 'Data Prediksi Hasil Panen Budidaya Ikan Lele' and contains a table with 5 entries. The table has columns for No, Tanggal Panen, Luas Kolam (m²), Jumlah Bibit (ekor), Jumlah Pakan (kg), Hasil Panen (kg), Kategori, and Aksi. The data rows are as follows:

No	Tanggal Panen	Luas Kolam (m²)	Jumlah Bibit (ekor)	Jumlah Pakan (kg)	Hasil Panen (kg)	Kategori	Aksi
1	16 September 2023	85	15.000	49	1.440	Hasil	[icon]
2	17 June 2023	65	11.000	35	1.198	Hasil	[icon]
3	15 March 2023	80	16.000	48	1.439	Hasil	[icon]
4	15 December 2022	112	22.000	66	1.802	Hasil	[icon]
5	15 December 2022	65	12.000	36	1.209	Hasil	[icon]

Figure 13. User Prediction Data Page

DISCUSSION

Testing on the catfish cultivation management system using the Fuzzy Tsukamoto method was carried out using white box testing via the deactive line method to find out how the system responded when one of the logic codes was disabled. This testing was carried out at the fuzzyfication, inference and defuzzyfication algorithm stages. After testing was carried out on one of the logic codes, several errors were found so error handling was carried out to correct these errors. The test scenario in the fuzzyfication process is that when the source code for one of the defining variables (pool area) is deactivated using forward slash (/) then that variable will not be processed at the inference and defuzzyfication stages. Variable data (pool area) will not be sent to the MySQL database, but for the fuzzyfication process of other variables (number of seeds and amount of feed) that are defined, the system will continue to run. The results of the white box testing that has been carried out show that the results are in accordance with the scenario.

The next test is the rule inference process with a scenario where one of the source code rules (R1) is disabled, the inference process will stop. Data will not be processed at the defuzzification stage and will not be sent to the MySQL database. The results of the white box testing that has been carried out show that the results are in accordance with the scenario. Testing at the defuzzification stage has a scenario where the defuzzification logic source code is disabled, then the "m" and "z" values from the fuzzyfication and inference stages will be 0. So no calculations will occur and data will not be sent to the MySQL database. So the results of system testing using the white box method have been carried out, it can be concluded that the source code of the fuzzy logic function runs according to the scenario. The function has successfully executed all logic commands correctly, including dealing with various scenarios that produce correct and incorrect output. Apart from that, the system managed to manage the internal data structure well and the validation process ran smoothly. Results Testing

In this test, a comparison was made between the results of manual calculations and system calculations using 10 data. The results of both calculation methods, between manual and system calculations using the same data input, show the same and appropriate results. As evidence of testing the comparison results between the two calculations, a table of test results was created. The comparison results for the calculation of each data are presented in Table 4.

Table 4. Manual and System Calculation Results

No	Data	Input			Manual Calculation	System Calculation	Keterangan
		Pond area	Number of Seed	Amount of Feed			
1.	August 2015	112	23000	69	2070 Kg	2070 Kg	Match
2.	March 2016	80	17000	50	1459 Kg	1459 Kg	Match
3.	June 2017	112	20000	60	1672 Kg	1672 Kg	Match
4.	March 2018	65	14000	43	1397 Kg	1397 Kg	Match
5.	September 2019	80	16000	48	1439 Kg	1439 Kg	Match
6.	June 2020	112	20000	60	1672 Kg	1672 Kg	Match
7.	March 2021	80	15000	45	1429 Kg	1429 Kg	Match
8.	Desember 2021	112	21000	63	1774 Kg	1774 Kg	Match
9.	June 2022	80	17000	51	1469 Kg	1469 Kg	Match
10.	September 2022	65	14000	42	1382 Kg	1382 Kg	Match

Referring to the results shown in both manual and system calculations, it can be shown that the design of the harvest prediction management system has gone well. The preparation of the rules is in accordance with past facts and

data from catfish farming practitioners. The size of the fish pond influences how many fish seeds can be cultivated because catfish cannot grow and develop well if the space for the fish to move is too limited. The amount of feed consumed also greatly influences the growth and development of catfish. Excessive amounts of feed can increase ammonia levels in pond water. Further research can be further developed by applying IoT to the pond water management system so that the control system in fish farming will be better.

CONCLUSION

According to manual calculations and sample calculations using the system, it is proven that the system based on fuzzy inference system Tsukamoto can predict the amount of harvest based on the criteria of pond area, number of seeds, and amount of feed consumption. So that the catfish cultivation management system can be used by users.

Furthermore, researchers can develop fish cultivation management systems and others using the criteria of pond area, number of seeds, amount of feed consumption, harvest period, and number of harvests along with capital and maintenance financing so that users can estimate the costs and profits that can be obtained from fish cultivation.

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