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TSUKAMOTO FUZZY IN OPTIMIZING THE CREDITWORTHINESS ASSESSMENT PROCESS AT SAVINGS AND LOAN COOPERATIVES

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ABSTRACT

Savings and loan cooperatives are one of the non-bank institutions whose business activity is the provision of loan. In its business activities, problems often arise, namely non-performing loans, which cause no turnover of funds which leads to losses. One of the causes of non-performing loans is the lack of objective creditworthiness assessment. The purpose of this study is to optimize the process of assessing the feasibility of loan applications at savings and loan credit with assessment criteria: loan value, total income, loan term, and collateral value. The Tsukamoto fuzzy method was used in this study. The Tsukamoto fuzzy method consists of four steps.: fuzzification, forming fuzzy rules, application of implication functions using the MIN function, and defuzzification using the weighted average calculation method. In this research, it was found that Tsukamoto's fuzzy method can be applied to the creditworthiness assessment process at the savings and credit cooperatives. This is because the accuracy rate of the decision results from the Tsukamoto method is 93.75%. A total of 60 out of 64 data are in accordance with the eligibility decision at one of savings and loan cooperatives in West Java, Indonesia. The Tsukamoto fuzzy method can optimize the credit assessment process in savings and loan cooperatives because the eligibility assessment process becomes more efficient and objective.

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1. INTRODUCTION

The development of financial institutions in Indonesia has grown very rapidly along with the increasingly high economic needs of the community. There are two types of financial institutions: bank financial institutions and non-bank financial institutions. Based on statistical data in 2021, there are 107 banks with 32,366 bank offices, for non-bank financial institutions include 223 multi finance institutions, 149 insurance companies, 223 insurance intermediary companies, 208 pension fund companies, and 120 pawnshop companies [1]. In addition, there are 127,846 cooperatives active as non-bank financial institutions [2].

A cooperative is a legal entity established by individuals or cooperative legal entities by segregating the members' assets as capital to operate a business that meets common aspirations and needs in the economic, social, and cultural spheres. A cooperative in accordance with the values and principles fulfilled. A savings and loan cooperative is a cooperative whose sole business is the savings and loan business[3]. In some countries, savings and loan cooperatives are called credit unions.

As happens in financial institutions in general, in savings and loan cooperatives the problem that often occurs is non-performing loans. Non-performing loans are uncollectible loans that have been given. The average of non-performing loans in savings and loan cooperatives in Indonesia in 2020 was 28 debtors [4]. One of savings and loan cooperatives in West Java Indonesia has an increasing number of non-performing loans every year. Based on the number of non-performing loans for the period 2017 to 2020, the highest number is in 2020 which reached 54 debtors.

One of the factors that influence the occurrence of non-performing loans is an internal factor, the creditworthiness assessment process which had not been optimal [5]. Based on research by Dewi & Yuliana [6], internal and external factors simultaneously affect the potential for bad credit with a determination level for internal factors of 31.9% and external factors of 15.5%. In savings and loan cooperatives, the creditworthiness assessment has still proceeded manually, so credit analysts still have difficulty prioritizing prospective members who are entitled to receive loans due to the large number of loan applications. Therefore, it takes a lot of time to make decisions about whether the submission is feasible or not. In order to facilitate credit analysts in conducting feasibility assessments and avoiding the intuition (subjective) assessment process, which can result in non-performing loans, a tool is needed to assess creditworthiness by considering several criteria, including loan value, total income, loan term, and collateral value.

Fuzzy Tsukamoto is the research method used in this study. The Tsukamoto fuzzy method uses machine language to mimic human expertise and translate ambiguous statements into more logical terms [7]. The problem of determining a loan's feasibility, which is regarded as an obscure classification issue, prompted the selection of this method. As a result, this approach will classify difficult-to-analyze gray areas into clusters that are simpler to comprehend. Tsukamoto fuzzy will use the information about the potential customer to determine the value of the creditworthiness after the officer has entered the data. Two final decisions will be made at the conclusion: either eligible or not. Survey officers can accurately and efficiently complete each survey with the assistance of these results.

The Tsukamoto fuzzy method is regarded as an efficient and accurate approach to decision-making in numerous studies [8-10]. This approach has the advantage of having a high degree of adaptability due to its simplicity in meeting the authors' criteria[11]. Therefore, the Tsukamoto fuzzy method is the best one to use in this situation.

2. RESEARCH METHODS

This research used a quantitative descriptive approach by analyzing and compiling existing data according to the needs of researchers. The sampling technique used is probabilistic sampling with purposive sampling, where the sample used as testing data is credit application data at one of savings and loan cooperatives in West Java, Indonesia on January 2020.

The research method used in this study is Fuzzy Logic Tsukamoto. Fuzzy logic was first introduced by Prof. Lotfi A. Zadeh in 1965. His paper describes the mathematics of fuzzy subsets and by extension mathematics of fuzzy logic. The basis of fuzzy logic is fuzzy set theory. The role of the degree of membership as a determinant of the existence of elements in a set is very important. The value of membership is the main

characteristic of reasoning with this logic [11]. All this is binary in nature in classical logic, and there are two possibilities: "right or wrong, "yes or no", etc. Therefore, the membership value can be either 1 or 0. However, a membership value of 1 or 0 consists of only two values: "True and false", "yes and no" exist at the same time, but whether they belong to the weight of the membership process or not depends on the magnitude of the value. Fuzzy logic is an infinite valued logic in which truth values can range from zero to one. Like classical logic, fuzzy logic is concerned with the truth of propositions. However, in the real-world, propositions are often only partly true. [12]

The reason for using fuzzy logic is as follows: (a) it is easy to understand because the mathematical set theory as the basis of fuzzy is easy to understand, (b) it is flexible for modification and uncertainty issues, (c) it has acceptance on the data that is less precise, and d) it uses language that is easy to understand [11].

Fuzzy sets have two attributes: (a) Linguistic is the naming of a group which stands for a particular condition with natural language [13]. All numbers empowered to perform operations on fuzzy variables form a world of conversation. A fluffy set domain is any proven number that exists in the discourse universe and can work with fuzzy sets. A membership function is a function in which the degree of membership for each input variable is between 0 and 1.The letter (x) denotes the membership level-specific variable x. In order to reach a conclusion, Each rule should consider the value of membership in determining the effect of time estimation[11]. There are two primary applications for fuzzy systems:1) in the circumstances involving highly complex systems whose behaviors are not well understood, and 2) in the circumstances requiring an approximate but expedient solution [14].

Tsukamoto fuzzy method consists of three steps:

1. Fuzzification

Fuzzification is the process of making a crisp quantity fuzzy [15]. The variables that will be used must be defined first. Each variable has a fuzzy set. A membership value is obtained by expressing each fuzzy set with a membership function. There are six functions available: Display of straight lines, triangular curves, shoulder curves, S-curves, trapezoidal curves, and elliptical curve.

B. Inference

Inference is a continuous relationship between explicit input values and explicit output values expected by a particular rule. These rules determine the system's response to various conditions of system settings and interruptions. The rule used is IF-THEN [16]. After deciding which rule to use, the membership value of each fuzzy set is used to calculate the previous membership or refractory value (α) for each rule and the estimate of the goods produced (z).

C. Defuzzification

Defuzzification is a process of converting fuzzy sets into crisp values [17]. A determinant of the sharp output value is the number of goods (Z) produced by changing the input (in the form of a fuzzy set derived from the configuration of fuzzy rules) to the number of fuzzy sets in the domain. The defuzzification method used in Tsukamoto's method is the central mean method. This formulation determines the output value of the crisp, which is the number of goods produced (Z), by inputting several fuzzy sets in the domain (in the form of fuzzy sets derived from the construction of fuzzy rules).

This is the centered average method equation:

$$Z = \frac{\alpha \text{pred}_1 * z_1 + \alpha \text{pred}_2 * z_2 + ... + \alpha \text{pred}_{81} * z_{81}}{\alpha \text{pred}_1 + \alpha \text{pred}_2 + ... + \alpha \text{pred}_{81}} \quad (1)$$

3. RESULTS AND DISCUSSION

3.1. Tsukamoto Method Fuzzy Logic Calculation Process

a. Fuzzification (Formation of fuzzy sets)

Fuzzification aims to convert explicit input data into fuzzy. In this study, several criteria are used to assess the feasibility of granting credit to the prosperous core cooperative. The formation of fuzzy

sets is used to define explicit input values. The variables used include collateral value variable, total income variable, total income variable, loan term variable, and eligibility result variable as output.

Table 1. Fuzzy sets of input and output variables

Functions	Variable	Linguistic expression	Range	Interval
INPUT	Value of the loan	Low Medium High	[2-20]	[2.5-6] [5-12] [11-20]
	Amount of income	low medium High	[3-15]	[3-5] [4.5-9.5] [7,5-15]
	Term of the loan	Short Medium long	[3-18]	[3-8] [6-12] [10-18]
	Value of collateral	Low Medium High	[2-20]	[2-6] [5-11] [10-20]
OUTPUT	Creditworthiness	Eligible Ineligible	[0-10]	[0-6] [5-10]

Based on Table 1, the membership function of each variable can be formed as follows:

- Variabel value of the loan

  In the loan application value variable, it is defined in 3 fuzzy sets: low, medium and high. The loan value is represented by a left shoulder curve for the low set, a triangular curve for the middle set, and a right shoulder curve for the high set.

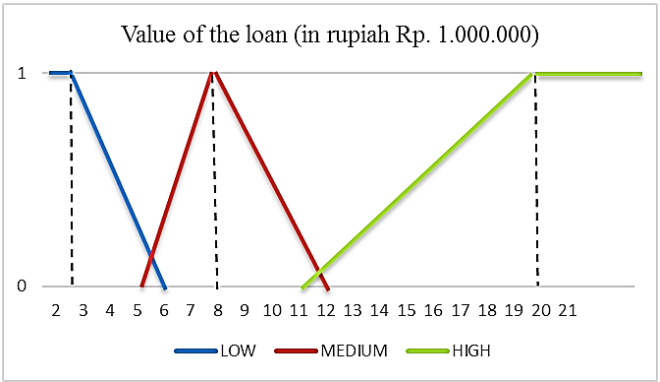


Figure 1. Value of the loan membership function

The membership function for the value of the loan variable is expressed as:

$$\mu_{\text{Low}}(x) = \begin{cases} 1 & ; \quad x \le 2.5 \\ \dfrac{(6-x)}{(3.5)} & ; \quad 2.5 \le x \le 6 \\ 0 & ; \quad x \ge 6 \end{cases} \tag{2}$$

$$\mu_{\text{Medium}}(x)=\begin{cases}0 & ; \quad x\le 5 \text{ or } x\ge 12\\ \dfrac{(x-5)}{(3)} & ; \quad 5\le x\le 8\\ \dfrac{(12-x)}{(4)} & ; \quad 8\le x\le 12\end{cases} \tag{3}$$

$$\mu_{\text{High}}(x)=\begin{cases}0 & ; \quad x\le 11\\ \dfrac{(x-11)}{(9)} & ; \quad 11\le x\le 20\\ 1 & ; \quad x\ge 20\end{cases} \tag{4}$$

- Variable amount of income

The variable amount of income is defined with 3 fuzzy sets: low, medium and high. To represent the variable amount of income, a left shoulder curve is used for the low fuzzy set, a triangle curve for the medium fuzzy set and a right shoulder curve for the high fuzzy set.

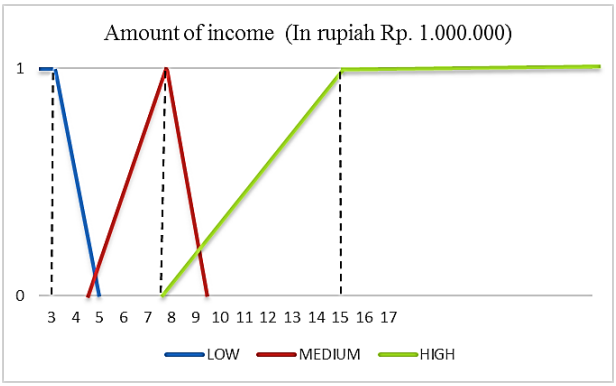


Figure 2. Amount of income membership function

The membership function for the amount of income variable is expressed as:

$$\mu_{\text{Low}}(x)=\begin{cases}1 & ; \quad x\le 3\\ \dfrac{(5-x)}{(2)} & ; \quad 3\le x\le 5\\ 0 & ; \quad x\ge 5\end{cases} \tag{5}$$

$$\mu_{\text{Medium}}(x)=\begin{cases}0 & ; \quad x\le 4.5 \text{ or } x\ge 9.5\\ \dfrac{(x-4.5)}{(3)} & ; \quad 4.5\le x\le 7.5\\ \dfrac{(9.5-x)}{(2)} & ; \quad 7.5\le x\le 4.5\end{cases} \tag{6}$$

$$\mu_{\text{High}}(x)=\begin{cases}0 & ; \quad x\le 7.5\\ \dfrac{(x-7.5)}{(7.5)} & ; \quad 7.5\le x\le 15\\ 1 & ; \quad x\ge 15\end{cases} \tag{7}$$

- Variable term of the loan

The variable term of the loan is defined with 3 fuzzy sets, namely fast, medium, and slow. To represent the variable amount of income, a left shoulder curve is used for the short fuzzy set, a triangle curve for the medium fuzzy set and a right shoulder curve for the long fuzzy set.

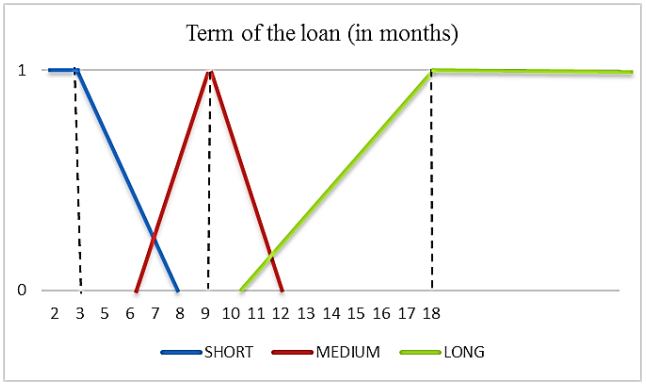


Figure 3. Term of the loan membership function

The membership function for the term of the loan variable is expressed as:

$$\mu_{\text{Short}}(x) = \begin{cases} 1 & ; \quad x \le 3 \\ \dfrac{(8-x)}{(5)} & ; \quad 3 \le x \le 8 \\ 0 & ; \quad x \ge 8 \end{cases} \tag{8}$$

$$\mu_{\text{Medium}}(x) = \begin{cases} 0 & ; \quad x \le 6 \text{ or } x \ge 12 \\ \dfrac{(x-6)}{(3)} & ; \quad 6 \le x \le 9 \\ \dfrac{(12-x)}{(4)} & ; \quad 9 \le x \le 12 \end{cases} \tag{9}$$

$$\mu_{\text{Long}}(x) = \begin{cases} 0 & ; \quad x \le 10 \\ \dfrac{(x-10)}{(15)} & ; \quad 10 \le x \le 18 \\ 1 & ; \quad x \ge 18 \end{cases} \tag{10}$$

- Variable value of collateral

  To represent the loan value variable, a left shoulder curve is used for the low fuzzy set, a triangle curve for the medium fuzzy set and a right shoulder curve for the high fuzzy set.

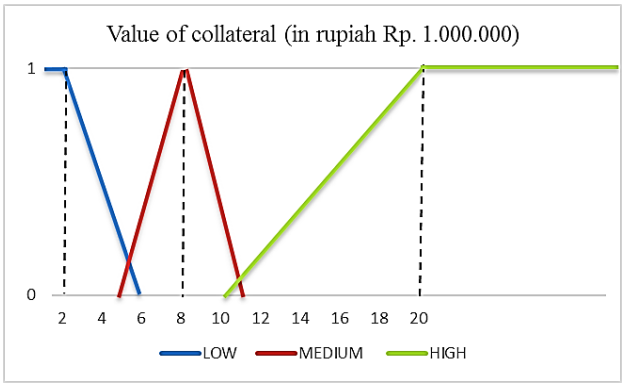


Figure 4. Value of collateral membership function

The membership function for the value of collateral variable is expressed as:

$$\mu_{\text{low}}(x)=\begin{cases}1 & ; \quad x\le 2\\ \dfrac{(6-x)}{(2)} & ; \quad 2\le x\le 6\\ 0 & ; \quad x\ge 6\end{cases} \tag{11}$$

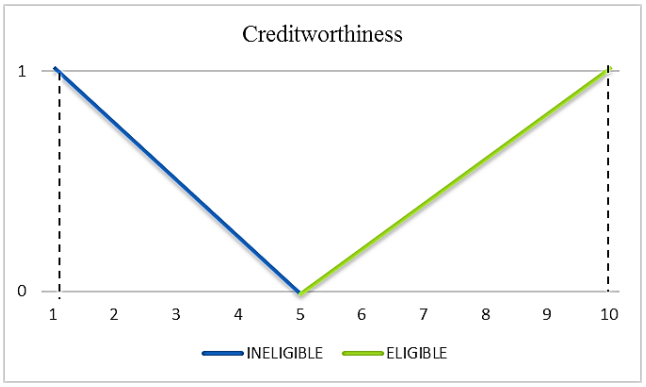
$$\mu_{\text{Medium}}(x)=\begin{cases}0 & ; \quad x\le 5 \text{ or } x\ge 11\\ \dfrac{(x-5)}{(3)} & ; \quad 5\le x\le 8\\ \dfrac{(11-x)}{(4)} & ; \quad 8\le x\le 11\end{cases} \tag{12}$$

$$\mu_{\text{High}}(x)=\begin{cases}0 & ; \quad x\le 10\\ \dfrac{(x-10)}{(10)} & ; \quad 10\le x\le 20\\ 1 & ; \quad x\ge 20\end{cases} \tag{13}$$

- Creditworthiness

The creditworthiness variable is defined with 2 fuzzy sets: nonfeasible and feasible. To represent the creditworthiness variable, a linear downward membership function is used for unfit credit and a linear upward function for unfit credit.

Figure 5. Creditworthiness membership function



The membership function for the creditworthiness variable is expressed as:

$$\mu_{\text{Eligible}}(x)=\begin{cases}0 & ; \quad z\le 5\\ \dfrac{(z-5)}{(5)} & ; \quad 5\le z\le 10\\ 1 & ; \quad z\ge 10\end{cases} \tag{14}$$

$$\mu_{\text{Uneligible}}(x)=\begin{cases}1 & ; \quad z\le 1\\ \dfrac{(5-z)}{(4)} & ; \quad 1\le z\le 5\\ 0 & ; \quad z\ge 5\end{cases} \tag{15}$$

b. Fuzzy rules formatting

These rules are formed to express the connection between inputs and outputs. The formation of this rule results from the combination of each condition is known as a decision rule. Each rule consists of four antecedents and 1 consequent, using the operator "and", and the map between input and output is "if" "then". The number of rules formed based on 3 fuzzy sets is 81 rules as follows.

Table 2. Fuzzy rules

Rule	Value of the loan	Amount of income	Term of loan	Value of Collateral	Creditworthiness
R1	Low	Low	Long	Low	Ineligible
R2	Low	Low	Long	Medium	Eligible
R3	Low	Low	Long	High	Eligible
R81	High	High	High	High	Eligible

3.2. Application of Tsukamoto Fuzzy Logic on Credit Assessment of Savings and Loan Cooperative

In January 2020, there was a submission with the following data details; customer Mariyam with a loan value of IDR 5,500,000, total income of IDR 5,000,000, a loan period of 18 months and a guarantee value of IDR 5,000,000.

a. Based on the membership function that has been determined, based on the details of customer data Mariyam obtained the following membership degree values

Value of the loan variable IDR 5,500,000

$$\mu A_1 \text{Low}\,[5.5] = \frac{(6-5.5)}{3.5} = 0.14$$

$$\mu A_1 \text{Medium}\,[5.5] = \frac{(5.5-5)}{3} = 0.17$$

$$\mu A_1 \text{High}\,[5.5] = 0$$

Amount of income variable IDR 5,500,000

$$\mu A_2 \text{Low}\,[5] = 0$$

$$\mu A_2 \text{Medium}\,[5] = \frac{(5-4,5)}{3} = 0,17$$

$$\mu A_2 \text{High}\,[5] = 0$$

Loan term of 18 months

$$\mu A_3 \text{Short}\,[18] = 0$$

$$\mu A_3 \text{Medium}\,[18] = 0$$

$$\mu A_3 \text{Long}\,[18] = 1$$

Value of collateral IDR 5,500,000

$$\mu A_4 \text{Low}\,[5.5] = \frac{(6-5.5)}{4} = 0.13$$

$$\mu A_4 \text{Medium}\,[5.5] = \frac{(5.5-5)}{3} = 0.17$$

$$\mu A_4 \text{High}\,[5.5] = 0$$

b. Inference

Based on the rules that have been made, the next stage of the creditworthiness assessment process using the Tsukamoto fuzzy logic method is to calculate the α-predicate value of each rule using the MIN implication function.

R10 IF the loan value is **LOW** and the amount of income is **MEDIUM** and the term is **LONG** and the collateral value is **LOW** THEN the credit assessment is **ELIGIBLE**

$$\alpha\text{-predicate} = \text{MIN}(\mu\text{Low} \cap \mu\text{Medium} \cap \mu\text{Long} \cap \mu\text{Low})$$
$$= \text{MIN}\ (0.14;\ 0.17;\ 1;\ 0.14)$$
$$= 0.13$$

Membership function of creditworthiness is ELIGIBLE

$$\frac{z-5}{5} = 0.13 \quad \rightarrow \quad z_1 = 5.65$$

R11 IF loan value is **LOW** and the amount of income is **MEDIUM** and term is **LONG** and collateral value is **MEDIUM** THEN credit assessment is **ELIGIBLE**

$$\alpha\text{-predicate} = \text{MIN}(\mu\text{Low} \cap \mu\text{Medium} \cap \mu\text{Long} \cap \mu\text{Medium})$$
$$= \text{MIN}\ (0.14;\ 0.17;\ 1;\ 0.17)$$
$$= 0.14$$

Membership function of creditworthiness is ELIGIBLE

$$\frac{z-5}{5} = 0.14 \quad \rightarrow \quad z_2 = 5.70$$

R37 IF loan value is **MEDIUM** and the amount of income is **MEDIUM** and term is **LONG** and collateral value is **LOW** THEN credit assessment is **INELIGIBLE**

$$\alpha\text{-predikat} = \text{MIN}(\mu\text{Medium} \cap \mu\text{Medium} \cap \mu\text{Long} \cap \mu\text{Low})$$
$$= \text{MIN}\ (0.14;\ 0.17;\ 1;\ 0.13)$$
$$= 0.13$$

Membership function of creditworthiness is INELIGIBLE

$$\frac{5-z}{4} = 0.13 \quad \rightarrow \quad z_3 = 4.50$$

R38 IF loan value is **MEDIUM** and the amount of income is **MEDIUM** and term is **LONG** and collateral value is **MEDIUM** THEN credit assessment is **ELIGIBLE**

$$\alpha\text{-predikat} = \text{MIN}(\mu\text{Medium} \cap \mu\text{Medium} \cap \mu\text{Long} \cap \mu\text{Medium})$$
$$= \text{MIN}\ (0.17;\ 0.17;\ 1;\ 0.17)$$
$$= 0.17$$

Membership function of creditworthiness is ELIGIBLE

$$\frac{z-5}{5} = 0.17 \quad \rightarrow \quad z_4 = 5.85$$

c. Defuzzification

The next step after the implication function application process is defuzzification with centered average method

$$Z = \frac{\alpha\text{pred}_1 * z_1 + \alpha\text{pred}_2 * z_2 + ... + \alpha\text{pred}_{81} * z_{81}}{\alpha\text{pred}_1 + \alpha\text{pred}_2 + ... + \alpha\text{pred}_{81}}$$

$$\cdot\ Z = \frac{(0.13*5.65) + (0.14*5.70) + (0.13*4.50) + (0.17*5.85)}{0.13 + 0.14 + 0.14 + 0.17}$$

$$= \frac{3.11}{0.57} = 5.46$$

Based on the provisions of the savings and loan cooperative with interviews, if the Z value is ≥ 5, the credit application is said to be feasible. From the results of defuzzification of credit applications, Mariyam obtained a Z result of 5.65, so the credit application is eligible.

3.3. Discussion

After the process of inputting the value of each variable from each customer, performing fuzzification, inference to defuzzification using Microsoft excel, the following results are obtained:

Table 3. Decision Result Comparison

No	Name (initials)	Cooperative result	Tsukamoto fuzzy logic	Linguistics
1	AR	Eligible	6.33	Eligible
2	SW	Eligible	5.83	Eligible
.	-	-	-	-
64	ST	Eligible	5.43	Eligible

Based on the results of calculations using Tsukamoto fuzzy logic with the help of Microsoft Excel from 64 loan applications at the Self-help Core Prosperous Cooperative, the results of 60 customer data are said to be feasible and 4 other customer data are not feasible, so the accuracy value is obtained as follows:

$$\text{Accuracy} = \frac{64-4}{60} \times 100\% = 93{,}75\%$$

The calculation of the accuracy of Tsukamoto fuzzy logic in the credit assessment process in the savings and loan cooperative is 93.75%. Based on testing of 64 samples that have been approved, there are 4 data that according to Tsukamoto fuzzy logic calculations are ineligible because they have low income while the loan value has a medium membership value and a long loan period and medium collateral value. Due to the Tsukamoto fuzzy recommendation, is not feasible so that an alternative solution to decide whether or not a loan application is accepted is to reduce the loan value so that it enters into low membership.

Previous research by Ginting [18] The input variables used are Age, Nominal Loan, and Installment Period. In his study, 90% accuracy was achieved after analysis using Tsukamoto's fuzzy logic algorithm to determine the feasibility of a loan implemented as an Android application. As a result, Fuzzy Tsukamoto's method has been successful in providing accurate predictions of eligibility, and surveyors can use the application to work quickly and effectively during the survey process.

Based on previous research, Tsukamoto's application of fuzzy logic can also be applied to the process of credit evaluation in savings and loan associations, with variable inputs for the loan amount, income level, loan term, and loan amount ratio. 93.75% accuracy to help credit analysts' credit scoring. According to the tests performed, fuzzy sets and rule bases need to be validated by the right personnel in order to make the data more accurate, and for best results, additional you need to add variables.

4. CONCLUSIONS

Tsukamoto Fuzzy logic can be used to check creditworthiness of savings and loan cooperative. This is because according to the test results, the accuracy rate of decision making by Tsukamoto's logic is 93.75%.

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