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# Prediction of Fertilizer Receipt Amount Using Fuzzy Tsukamoto Method

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## Article Info

### Article history:

Received January 01<sup>th</sup>, 2024

Revised February 24<sup>th</sup>, 2025

Accepted March 01<sup>th</sup>, 2025

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### Keyword:

*Fuzzy Tsukamoto*

*Fertilizer Estimation*

*Inventory and Distribution*

*Decision Support System*

*MAPE (Accuracy*

*Validation)*

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## ABSTRACT

In Indonesia, many people work in agriculture. Fertilizers are one of the most important needs of farmers in the agricultural sector. UD. ARTO JOYO is an agricultural shop that sells various agricultural equipment, plant seeds, fertilizers, and other products for farmers. One of the most sought-after products by farmers is fertilizer. More than thousands of kilograms of fertilizer are distributed to farmers every month. However, because it depends only on feelings about the amount of fertilizer received, it is often unstable. By using the Fuzzy Tsukamoto method, this study aims to help solve this problem, namely to estimate the amount of fertilizer to be received. Inventory, distribution, and remainder are the input variables used, and receipts are the output variables sought. The results of the validation test with MAPE showed an error of 13.59%. These results indicate that the fertilizer estimation system with fuzzy Tsukamoto has a good level of validity.

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DOI: <https://doi.org/10.30736/ihees.v1i01.877>

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## I. Introduction

Agriculture is one of the livelihoods deeply rooted in Indonesian society. History records that agriculture existed in the ancient Mesopotamian era. The agricultural technology of that time transformed the fertile crescent region into arable land. Ancient Egypt also has an early history of agriculture, which underlies the development of irrigation systems and farming tools. UD. ARTO JOYO is an agricultural store located in the Karanggeneng District, Lamongan Regency. At UD. ARTO JOYO, various farmer needs are available, including agricultural equipment, plant seeds, and fertilizers. One of the products most in demand by consumers is fertilizer. Records show that the purchase and distribution of Phoskatani fertilizer at UD. ARTO JOYO reaches thousands of kilograms every month. However, due to the use of manual calculations, there are sometimes imbalances between the amount of incoming and outgoing fertilizer. For example, when fertilizer receipts are high, the following month's distribution might be very low. Conversely, there have been instances where fertilizer purchases exceed the amount of stock previously received. These issues regarding fertilizer

stock management have prompted this research. The Fuzzy Tsukamoto method was chosen as the research methodology, considering the findings from previous studies.

First, a study [1] used sales data for premium fuel from January 2016 to February 2017. The variables consisted of sales and inventory, with revenue as the output variable. This study concluded that fuzzy Tsukamoto could provide recommendations for fuel stock receipts with system accuracy of 84%. Second, a study [2] used data obtained from the Simpang Pulau Home Industry. The variables used were demand, inventory, and the amount of raw materials. This study achieved an accuracy value of 98.91%, leading to the conclusion that the accuracy of the production quantity using the fuzzy Tsukamoto method was very good. Third, an assessment of community health center services was conducted using input variables such as staff friendliness, service requirements, diagnosis results, supporting facilities, and the output was community health center services (comfortable, less comfortable, or uncomfortable). With the system trial results, the output showed a consumer satisfaction level of 73.33%, which means that customers were satisfied with the quality of service provided by the Peneleh Community Health Center Surabaya [3].

Fourth, predicting the market price of shallots, where the output variable (target) is the shallot price, is divided into five fuzzy sets: very low, low, medium, high, and very high. The results of the prediction experiment using the Tsukamoto fuzzy method with the last five months of testing data showed that the actual shallot prices for May, June, July, August, and September were 25,000, 20,000, 18,000, 17,000, and 16,000, respectively, and the predicted shallot prices were 25,335, 20,142, 18,994, 18,196, and 17,406, respectively. This means that the Tsukamoto fuzzy method for predicting shallot prices achieved a MAPE of 4.68%, indicating a prediction accuracy of 95% [4]. Fifth, utilizing report data from a point-of-sale (POS) application to generate stock predictions using the Tsukamoto fuzzy method. This prediction result allows business owners to further improve service quality in terms of inventory provision, which affects customer satisfaction and reduces business losses [5].

Sixth, developing an application to help predict the amount of production by considering incoming demand and the number of available workers. Based on the prediction results using fuzzy Tsukamoto, if the demand is 125 packages and the number of workers is 35, the amount of production that should be carried out is 140 packages. By obtaining a clear production number, this application greatly helps Rakik Julidar maximize production [6]. Seventh, the research [7] was conducted at UD. TIA Nagori Kandangan, Pematang Bandar subdistrict, Simalungun Regency. The variables used were demand, inventory, and distribution. The conclusion of this research was that the fuzzy Tsukamoto method can be used to predict the distribution of fish seeds by providing an input demand of 900 and an inventory of 300. The system can then generate a distribution output of 1360. Eighth, the research [8] used egg sales data from September 2020. The variables used consisted of sales, inventory, and purchases. This research concluded that the fuzzy Tsukamoto method can be used to predict purchases by utilizing inventory and sales figures. Based on the conducted research, the fuzzy Tsukamoto method can be used to predict with precise and accurate results. Therefore, the purpose of this study is to predict the amount of fertilizer received using the fuzzy Tsukamoto method, with input variables including inventory, distribution, remaining stock, and the target amount of fertilizer received by customers.

Artificial intelligence is a system that learns knowledge and is used by computers to enable a machine (computer) to perform reasoning. Meanwhile, fuzzy logic is a form of calculation in artificial intelligence based on the theory that the existence of an element in a set can be determined through membership degree indicators [9], [10]. The Fuzzy Tsukamoto method can estimate or predict the amount produced in rice harvests in the next period using variables such as the area of rice fields, rice seeds used, and fertilizer [11]. The Fuzzy Tsukamoto method can also be used to identify diseases [12], [13]. Tsukamoto is one of the methods used in fuzzy logic. The main characteristic of Fuzzy Tsukamoto is that the defuzzification value is obtained by calculating the average value [14]. Fuzzy logic involves several procedures that must be carried out to obtain a result. Fuzzification is the process of using membership functions to convert crisp values into linguistic variables. The formula used in the fuzzification process is adjusted according to the respective fuzzy membership curve. Figure 1 shows a line curve for a linear decreasing representation. The main feature of this curve is that at point a, the value is 1, and at point b, the value is 0. More specifically, when using this curve, the formula applied in fuzzification is as shown in Equation 1.

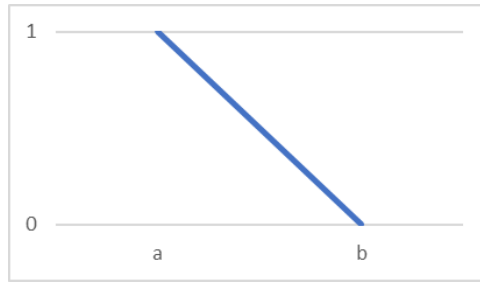


Figure 1. Decreasing Linear Curve

$$\mu(x) = \left\{ \begin{array}{l} \text{if } x \leq a \text{ then } 1; \\ \text{if } a < x < b \text{ then } \frac{(b-x)}{(b-a)}; \\ \text{if } x \geq b \text{ then } 0; \end{array} \right\} \quad (1)$$

Next,

Figure 2 shows the curve line for an increasing linear representation. Conversely, on the increasing linear curve, if the point is at a, the fuzzification value is 0. Meanwhile, if the point is at b, the value is 1. The formula used for the increasing linear curve is given in Equation 2.

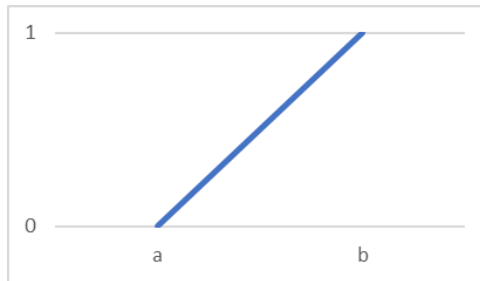


Figure 2. Upward Linear Curve

$$\mu(x) = \left\{ \begin{array}{l} \text{if } x \leq a \text{ then } 0; \\ \text{if } a < x < b \text{ then } \frac{(x-a)}{(b-a)}; \\ \text{if } x \geq b \text{ then } 1; \end{array} \right\} \quad (2)$$

Figure 3 is a representation of a triangular curve. Unlike a linear increasing or decreasing curve, this curve has points a, b, and c. If the value is at point a or c, the fuzzification value is 0. A value of 1 only applies when it is at point b. Therefore, for a triangular curve, the applicable fuzzification formula is as shown in Equation 3.

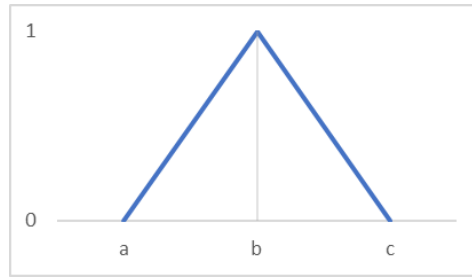


Figure 3. Triangle Curve

$$\mu(x) = \begin{cases} \text{if } x \leq a \text{ or } x \geq c \text{ then } 0; \\ \text{if } a < x < b \text{ then } \frac{(x - a)}{(b - a)}; \\ \text{if } b < x < c \text{ then } \frac{(c - x)}{(c - b)}; \\ \text{if } x = b \text{ then } 1; \end{cases} \quad (3)$$

After fuzzification, the next step is inference. There are two steps that need to be carried out in this process. The first is determining the (alpha) value. To find the  $\alpha$  (alpha) value, the degree of membership is required. The degree of membership is obtained based on the results of fuzzification and adjusted to the conditions of each rule. The inference process then continues by finding the z value. The formula used to find the z value is adjusted according to the rules of the output variable. The final step is defuzzification. The mean absolute percentage error (MAPE) method is one of the procedures for testing validity. This method assesses the validity of the system by calculating the error value. The formula used is as shown in Equation 4.

$$MAPE = \frac{\sum \frac{|x_i - F_i|}{x_i} \times 100\%}{n} \quad (4)$$

## II. Research Methods

**Error! Reference source not found.** presents the data used in this study. The data consist of the distribution and receipt records of phoskatani fertilizer from November 2020 to December 2021.

**Table 1. Data on Fertilizer Distribution and Receipt**

Date	Prs	Pny	Sis	Pen
Nov-2020	13520	9600	3920	20000
Dec-2020	23920	17250	6670	20000
Jan-2021	26670	18050	8620	20000
Feb-2021	28620	4844	23776	10000
Mar-2021	33776	5954	27822	15000
Apr-2021	42822	37676	5146	27000
May-2021	32146	19402	12744	20000
Jun-2021	32744	24401	8343	15000
Jul-2021	23343	3968	19375	20000
Agu-2021	39375	13590	25785	20000
Sep-2021	45785	33885	11900	18000
Oct-2021	29900	19463	10437	25000
Nov-2021	35437	27153	8284	15000
Dec-2021	23284	6328	16956	15000

(Prs = Inventory, Pny = Distribution, Sis = Remaining, Pen = Receipt)

The utilization of data is depicted in a graph based on the curve used.

Figure 4 shows the membership graph for the inventory variable. Based on this graph, there are three memberships for the inventory variable: low, medium, and high.

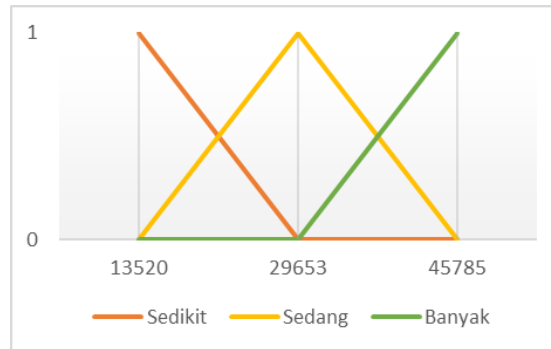


Figure 4. Inventory Chart

Next,

Figure 5 shows the graph for the distribution variable. It is similar to the inventory. Based on the graph, there are few, moderate, and many memberships.

Figure 6 shows the graph for the remainder variable. There is no difference in membership for the remainder compared to the previous two graphs.

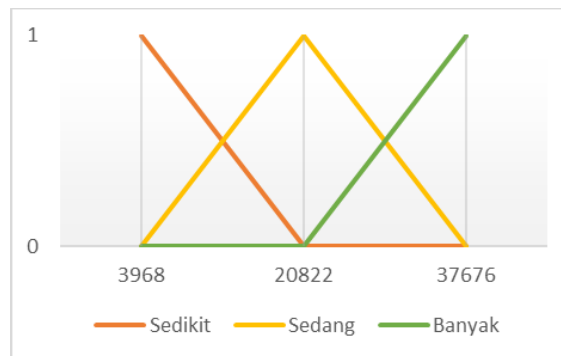


Figure 5. Distribution Chart

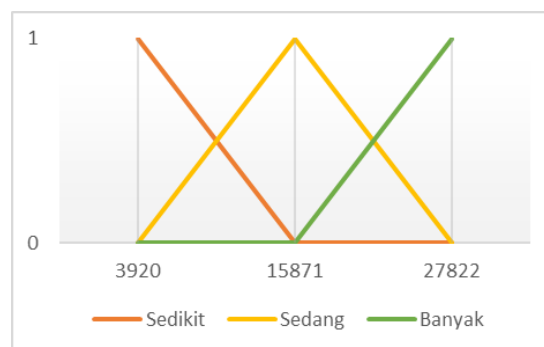


Figure 6. Remaining Chart

Finally,

Figure 7 shows the graph of the acceptance variable. Based on the graph, there are three memberships for the acceptance variable: few, moderate, and many.

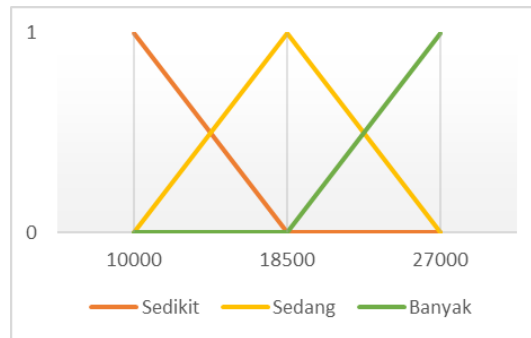


Figure 7. Receipt Chart

This study has three input variables with three membership combinations. Twenty-seven rules were established based on the number of variables and memberships, 27 rules were established. Table 2 lists the rules used in this study.

**Table 2 List of Rules**

No	Description
[R1]	IF Inventory is Low AND Distribution is Low AND Remaining Stock is Low THEN Receipts are High
[R2]	IF Inventory is Low AND Distribution is Low AND Remaining is Medium THEN Receipt is Medium
[R3]	IF Inventory is Low AND Distribution is Low AND Surplus is High THEN Receipt is Low
[R4]	IF Stock is Low AND Distribution is Moderate AND Remaining is Low THEN Receipt is Moderate
[R5]	IF Stock is Low AND Distribution is Moderate AND Remaining is Moderate THEN Receipt is Moderate
[R6]	IF Inventory is Low AND Distribution is Moderate AND Remaining Stock is High THEN Receipt is Low
[R7]	IF Inventory is Low AND Distribution is High AND Remaining Stock is Low THEN Receipt is High
[R8]	IF Inventory is Low AND Distribution is High AND Remaining is Moderate THEN Receipt is High
[R9]	IF Inventory is Low AND Distribution is High AND Remaining Stock is High THEN Reception is Moderate
[R10]	IF Inventory is Moderate AND Distribution is Low AND Remaining is Low THEN Reception is Moderate
[R11]	IF Inventory is Medium AND Distribution is Low AND Remaining Stock is Medium THEN Receipt is Medium
[R12]	IF Inventory is Medium AND Distribution is Low AND Remainder is High THEN Receipt is Medium
[R13]	IF Inventory is Medium AND Distribution is Medium AND Remaining is Low THEN Intake is High

[R14]	IF Inventory is Medium AND Distribution is Medium AND Remaining is Medium THEN Receipt is Medium
[R15]	IF Inventory is Medium AND Distribution is Medium AND Remaining Stock is High THEN Reception is Medium
[R16]	IF Stock is Moderate AND Distribution is High AND Remaining is Low THEN Receipt is High
[R17]	IF Stock is Moderate AND Distribution is High AND Remaining is Moderate THEN Receipt is High
[R18]	IF Inventory is Medium AND Distribution is High AND Remaining Stock is High THEN Intake is Low
[R19]	IF Inventory is High AND Distribution is Low AND Remainder is Low THEN Income is Medium
[R20]	IF Inventory is High AND Distribution is Low AND Remainder is Medium THEN Receipt is Medium
[R21]	IF Stock is High AND Distribution is Low AND Remaining Stock is High THEN Receipt is Low
[R22]	IF Inventory is High AND Distribution is Medium AND Remaining is Low THEN Receipt is Medium
[R23]	IF Inventory is High AND Distribution is Moderate AND Remaining Stock is Moderate THEN Receipt is Moderate
[R24]	IF Inventory is High AND Distribution is Moderate AND Remaining Stock is High THEN Receipts are High
[R25]	IF Inventory is High AND Distribution is High AND Remaining Stock is Low THEN Receipt is High
[R26]	IF Inventory is High AND Distribution is High AND Remainder is Medium THEN Reception is Medium
[R27]	IF Stock is High AND Distribution is High AND Remaining is High THEN Acceptance is Medium

### III. Results and Discussion

Table 3 presents the data used for the test. The test data were obtained from the distribution and receipt data of phoskatani fertilizer from July 2021 to June 2022.

**Table 3 Test Data**

Date	Prs	Pny	Sis	Pen
July-2021	23343	3968	19375	20000
Agu-2021	39375	13590	25785	20000
Sep-2021	45785	33885	11900	18000
Oct-2021	29900	19463	10437	25000
Nov-2021	35437	27153	8284	15000
Dec-2021	23284	6328	16956	15000
Jan-2022	31956	17458	14498	20000
Feb-2022	34498	10960	23538	18000
Mar-2022	41538	21689	19849	20000
Apr-2022	39849	20350	19499	20000
May-2022	39499	14350	25149	20000
Jun-2022	45149	14653	30496	15000

(Prs = Inventory, Pny = Distribution, Sis = Remaining, Pen = Receipt)

Figure 8 shows the implementation of the interface for conducting estimations. In this interface, there is a table for admissions. There is also a table containing the highest and lowest values from the admission data required in the estimation process. Subsequently, there is a special panel dedicated to estimating admissions. In addition, above the admissions table, there are buttons for managing admissions.

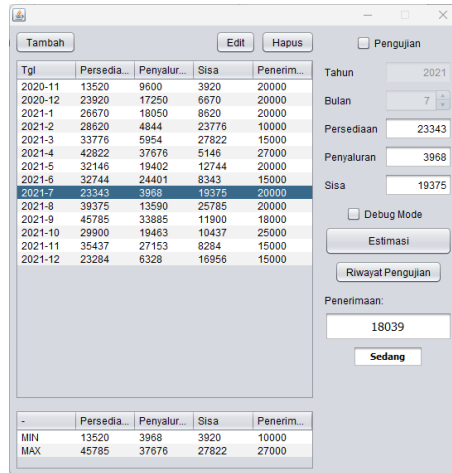


Figure 8. System Estimation Implementation

In the estimation testing, calculations using the fuzzy Tsukamoto system were performed utilizing the test data. Table 4 presents the estimation results of the fertilizer distribution and receipt data from July 2021 to June 2022.

**Table 4 Estimation Results**

Date	Actual Receipts	Estimated Receipt
<b>July-2021</b>	20000	18039
<b>Agu-2021</b>	20000	18987
<b>Sep-2021</b>	18000	19147
<b>Oct-2021</b>	25000	19937
<b>Nov-2021</b>	15000	20630
<b>Dec-2021</b>	15000	18415
<b>Jan-2022</b>	20000	18564
<b>Feb-2022</b>	18000	18500
<b>Mar-2022</b>	20000	19044
<b>Apr-2022</b>	20000	18952
<b>May-2022</b>	20000	19218
<b>Jun-2022</b>	15000	20611

Figure 9 illustrates the implementation of the interface for the testing page. In this interface, there is a table containing information on the date and actual and estimated amounts received. Additionally, the table includes the process of calculating the mean absolute percentage error (MAPE). Next to the table, there are buttons to view the debug history and delete the test data. Below the button for deleting test data, there is an additional procedure for MAPE (Mean Absolute Percentage Error). Further down is the result of the MAPE (Mean Absolute Percentage Error) calculation. At the bottom of the page, there is a button to display a line chart.

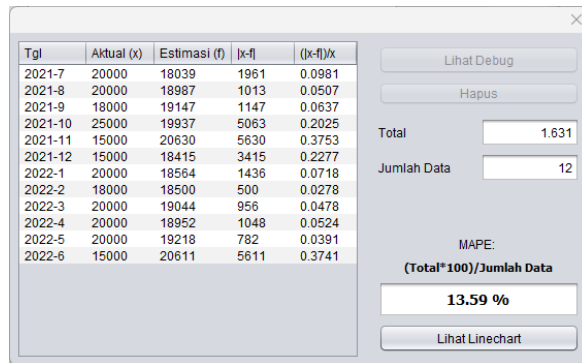


Figure 9. Implementation of Validation Test

Table 5 presents the manual validation testing process. The validation testing method used was mean absolute percentage error (MAPE). After testing was conducted using this data, it was found that the error rate of the fertilizer receipt estimation system was 13.59 % (MAPE).

**Table 5 Validation Results**

No	x	f	x-f	( x-f )/x
1	20000	18039	1960,603727	0,098030186
2	20000	18987	1013,274915	0,050663746
3	18000	19147	1147,266425	0,063737024
4	25000	19937	5062,680972	0,202507239
5	15000	20630	5629,560642	0,375304043
6	15000	18415	3414,727495	0,2276485
7	20000	18564	1435,712391	0,07178562
8	18000	18500	500	0,027777778
9	20000	19044	956,3474821	0,047817374
10	20000	18952	1048,232341	0,052411617
11	20000	19218	781,5088612	0,039075443
12	15000	20611	5611,105766	0,374073718

Note: (x = Actual receipts, f = Estimated receipts)

#### IV. Conclusion

Based on the research results, it can be concluded that fertilizer receipt estimation can be implemented using fuzzy Tsukamoto. The input variables used were inventory, distribution, and remaining stock. The output variable was the receipt. Each variable had three memberships: few, moderate, and many. After validation testing was conducted, the system error rate was found to be 13.59%. Based on these test results, it can be concluded that the fertilizer receipt estimation system had a good level of validity.

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