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The Analysis of Fuzzy Logic Method and Multiple Linear Regression in Determining National Rice Production to Improve Food Self-Sufficiency in Indonesia.

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Abstract. Indonesia in 2023 targets rice self-sufficiency. To be included in the category of rice self-sufficiency, Indonesia's total rice production should be 82 million tons in accordance with Government Regulation No.2 of 2015. The amount of rice production is uncertain. One way to calculate uncertainty in forecasting is by using the Fuzzy Logic of the Mamdani method and the Linear Regression of the Least Squares method. In the Fuzzy Logic Mamdani method there are 4 steps namely; 1) Fuzzy set formation; 2) Application of Implication functions; 3) Composition of Rules; and 4) Defuzzification. Rice Harvested Area, Rice Production and National Rice Consumption are the input variables and National Rice Production is the output variable. The data used are secondary data from the Central Statistics Agency (BPS) and the Ministry of Agriculture Annual Report 2006 - 2017. The data analysis process also uses matlab and minitab software. From the research results obtained that the Fuzzy Logic of the Mamdani method and the Linear Regression of the Smallest Square method can be used to predict the amount of national rice production. For the results of predictions of Fuzzy Logic the Mamdani method has a relatively large error compared to the Linear Regression of the Smallest Squares method. Furthermore it is also known that there is a significant relationship between harvested area and consumption. These two variables will be the determining factors for realizing rice self-sufficiency in Indonesia.

1. Introduction

Rice self-sufficiency is an effort to meet the country's own food needs. According to Government Regulation No.2 of 2015 concerning the National Medium-Term Development Plan for 2015-2019, to be included in the category of rice self-sufficiency, the number of Indonesia's rice production should be 82 million tons. Since 1984, Indonesia has no longer been capable of being self-sufficiency in rice. The deficit that occurred as a result of large amount of demand caused the government to import rice from the Philippines and Thailand.

There are so many factors that cause rice self-sufficiency cannot be realized. For example, it may be caused by poor agricultural infrastructure in Indonesia, government policies, lack of land for opening new fields and also lack of labors. This is very ironic, considering that Indonesia is a vast tropical region and also has abundant human resources. The government is still trying to find a solution so that the problem of rice self-sufficiency can be overcome and the welfare of the people of Indonesia can be increased. Therefore, the government must re-evaluate every policy decided whether it can succeed in the rice self-sufficiency program.The success of government policy will have an impact on the increasing of the amount of rice production.

The amount of rice production is something that is uncertain, one way to calculate uncertainty in forecasting using the Fuzzy Logic of the Mamdani method [1]. All this time, the forecasting method commonly used is linear regression. Linear regression is used to form an equation of some independent variables (input variables) that are considered to have a relationship with the dependent

variable (output variables). The factors that need to be considered in determining the amount of rice production in Indonesia are the Rice Harvested Area, Rice Production and National Rice Consumption.These three factors are the input variables and the output variable is National Rice Production.

Based on the analysis and observations which has been conducted, there are several problems that the writer can formulate as follows ; How is the use of the application of Mamdani Fuzzy Logic method in determining the amount of national rice production. And how is the use of Multiple Linear Regression of The Least Squares method in determining the amount of national rice production. The purpose of this study is as follows ; To find out the use of the application of Mamdani Fuzzy logic method in determining the yield of rice production in Indonesia. And to find out the use of Multiple Linear Regression of the Least Squares method in determining the yield of rice production in Indonesia.

2. Methodology

A term is said to be fuzzy (blurred) if the term cannot be defined explicitly or surely so that it requires affirmation. Fuzzy logic is an appropriate way to map the input space into an output space [2].

Fuzzy logic was first introduced by Prof. LA. Zadeh (1965). In principle, the fuzzy set is the expansion of the crisp set (firm), the set which divides a group of individuals into two categories, namely members and non-members.

In the crisp set (firm), is there are only two possibilities of the membership value, namely 0 or 1. In the fuzzy set, the membership value is in the range of 0 to 1. If x has a fuzzy membership value $\mu_A[x] = 0$, it means that x does not become A set, and so if x has a fuzzy membership value $\mu_A[x] = 1$. It means that x becomes a full member of the A set.Fuzzy set has 2 attributes [3], namely:

a. Linguistics, namely naming a group that represents a certain condition or condition using natural language, such as : YOUNG, MIDDLE-AGED, OLD

b. Numerical, which is a value (number) that indicates the size of a variable, such as : 40, 25, 50, and so on.

The membership function is a curve that shows the mapping of data input points into membership values that have intervals from 0 to 1. One method that can be used to obtain membership value is through a function approach. There are several functions that can be used ; Linear Representation, Triangle Curve Representation, Trapezoid Curve Representation, Shoulder Shape Curve Representation, S-Curve Representation and Bell Curve Representation.

As with any conventional sets, there are several operations that are specifically defined to combine and modify fuzzy sets. Membership values as a result of two sets of operations are often known as fire strength or α-predicate. There are three basic operators created by Zadeh, namely : AND Operators, OR Operators and NOT Operators.

Each rule (proposition) on the fuzzy knowledge base will be associated with a fuzzy relation. The general form of the rules used in the implication function is

$$IF\ x\ is\ A\ THEN\ y\ is\ B$$

where x and y are scalars, A and B are fuzzy sets. Proposition that follow IF is called antecedents, while proposition that follow THEN is called consequent. This proposition can be expanded by using fuzzy operator, such as:

$$IF\ (x_1\ is\ A_1) \circ (x_2\ is\ A_2) \circ (x_3\ is\ A_3) \circ \ldots \circ (x_n\ is\ A_n)\ THEN\ y\ is\ B.$$

where ∘ is an operator (e.g. : OR and AND). Generally, there two implication function which can be used, namely:

a. Min (Minimum) ; This function will cut the fuzzy set output.

b.   Dot (product) ; This function will scale the fuzzy set output.

The Mamdani method is often known as the Max-Min Method. This method was introduced by EbrahimMamdani in 1975. To get the output, there are 4 steps required [4]:

a. The formation of a fuzzy set.

In the Mamdani Method, both input and output variables are divided into one or more fuzzy sets.

b. Application of Implication function

In Mamdani method, the implication function used is Min.

c. Rule Composition

Unlike monotonous reasoning, if the system consists of several rules, then inference is obtained from the collection and correlation between rules. Inference is a process of combining many rules based on available data.

There are 3 methods used in fuzzy system inference, namely max, additive and probabilistic OR (**probor**).

i.   Max Method (Maximum)

In this method, the fuzzy set solution is obtained by taking the maximum value of the rule, then using it to modify the fuzzy region and apply it to the output by using the OR (union) operator.If all propositions have been evaluated, the output will contain a fuzzy set that reflects the contribution of each proposition. Generally, it can be written as follow :

$$\mu_{sf}(x_i) = \max\ (\mu_{sf}(x_i),\quad \mu_{kf}(x_i))\quad \dots \quad (1)$$

where :

$\mu_{sf}(x_i)$ = fuzzy solution membership value up to rule-**i**.

$\mu_{kf}(x_i)$ = fuzzy consequence membership value i-rule

ii. Additive Method (Sum)

In this method, the fuzzy set solution is obtained by bounded-sum to all fuzzy area output. It is generally written as follow :

$$\mu_{sf}\ (x_i) = \min(\ 1, \mu_{sf}(x_i) + \mu_{kf}(x_i))\quad \dots \quad (2)$$

where :

$\mu_{sf}(x_i)$ = fuzzy solution membership value up to rule-**i**.

$\mu_{kf}(x_i)$ = fuzzy consequence membership value i-rule

iii. Probabilistic Method OR (probor)

In this method, the fuzzy set solution is obtained by doing *product* to all fuzzy area output. It is generally written as follow :

$$\mu_{sf}(x_i) = \left(\mu_{sf}(x_i) + \mu_{kf}(x_i)\right) + \left(\mu_{sf}(x_i) * \mu_{kf}(x_i)\right) \dots (3)$$

where :

$\mu_{sf}(x_i)$ = fuzzy solution membership value up to rule-**i**.

$\mu_{kf}(x_i)$ = fuzzy consequence membership value i-rule.

d.   Affirmation (*defuzzy*)

The input of the defuzziffication process is a fuzzy set which is obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. So if it is given a fuzzy set within a certain range, then a certain crisp value must be taken as output.
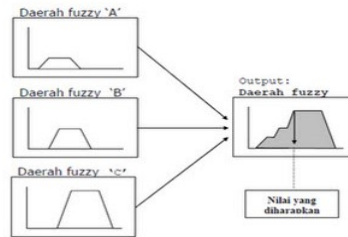
Figure 1. Defuzziffication process

One method of defuzzyfication is the centroid method. Centroid which can be called as *Center of Area (Center of Gravity)* is the most common and most proposed method by many researchers to be used. In this method, a crisp solution is obtained by taking the center point (z*) of the fuzzy region. It is generally formulated as:

$$z^* = \frac{\int_z z\mu(z)\,dz}{\int_z \mu(z)\,dz}, for\ continuous\ variables \dots (4)$$

$$z^* = \frac{\sum_{j=1}^n z_j\mu(z_j)}{\sum_{j=1}^n \mu(z_j)}, for\ discrete\ variables \dots (5)$$

In multiple linear regression, forecasting the value of the dependent variable (Y) is obtained by forming an equation that connects more than one variable, namely $x_1, x_2, \dots, x_n$.. In general, the multiple regression equation can be formulated as [5]:

$$\hat{Y}_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + \cdots + b_n x_{ni} + \varepsilon \dots (6)$$

This research consists of one independent variable Y and three variables X namely x_1, x_2, x_3. Then the multiple regression equation is:

$$\hat{Y}_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + b_3 x_{3i} + \varepsilon \dots (7)$$

The coefficient values of b_0, b_1, b_2 and b_3 can be obtained by using the least squares method, by first minimizing the remaining squares as follows:

$$S = \sum_{i=1}^n e_i^2 = \sum_{i=1}^n (Y_i - \hat{Y}_i)^2 = \sum_{i=1}^n (Y_i - b_0 - b_1 x_{1i} - b_2 x_{2i} - b_3 x_{3i})^2 = 0 \dots (8)$$

Then, equation (8) is differentiated to each coefficient b_0, b_1, b_2 and b_3, so the following equations are obtained:

$$\sum_{i=1}^n Y_i = nb_0 + b_1 \sum_{i=1}^n x_{1i} + b_2 \sum_{i=1}^n x_{2i} + b_3 \sum_{i=1}^n x_{3i}$$

$$\sum_{i=1}^n x_{1i}Y_i = b_0 \sum_{i=1}^n x_{1i} + b_1 \sum_{i=1}^n x_{1i}^2 + b_2 \sum_{i=1}^n x_{1i}x_{2i} + b_3 \sum_{i=1}^n x_{1i}x_{3i}$$

$$\sum_{i=1}^n x_{2i}Y_i = b_0 \sum_{i=1}^n x_{2i} + b_1 \sum_{i=1}^n x_{1i}x_{2i} + b_2 \sum_{i=1}^n x_{2i}^2 + b_3 \sum_{i=1}^n x_{2i}x_{3i}$$

$$\sum_{i=1}^{n} x_{3i}Y_i = b_0 \sum_{i=1}^{n} x_{3i} + b_1 \sum_{i=1}^{n} x_{1i}x_{3i} + b_2 \sum_{i=1}^{n} x_{2i}x_{3i} + b_3 \sum_{i=1}^{n} x_{3i}^2 \dots (9)$$

Relative error is a measure of error in relation to measurement. Relative error is defined by :

$$e_r = \left| \frac{X_s - X_a}{X_s} \right| \qquad \dots (10)$$

where:

        e_r = relative error
        X_s = true value
        X_a = calculation value

To see the average relative errors that occur in a data, can be stated by :

$$Average\ Relative\ Error\ = \frac{number\ of\ relative\ error}{amount\ of\ data} \dots (11)$$

3. Result and Discussion

In predicting rice production in Indonesia, researchers used two calculations. Firstly, calculation by using the Fuzzy logic of Mamdani method and secondly by using multiple linear regression analysis of the least square method. In the Fuzzy logic Mamdani method, it requires 4 stages namely; Fuzzy set formation, Application of Implication function, Rule Composition and Defuzzification. The data analysis process also uses Matlab and Minitab software.

The data used to predict rice production in Indonesia are secondary data which are obtained from the Central Statistics Agency (BPS) and Ministry of Agriculture Annual Report 2006 – 2017.

Table 1. Rice Production Data

Year	Harvest Area (Ha)	Total Population (million)	Consumption (ton)	Rice Production (ton)
2006	11.786.430	224.179	21.496.757	54.454.937
2007	12.147.637	227.521	20.583.388	57.157.435
2008	12.327.425	230.913	21.576.527	60.325.925
2009	12.883.576	234.356	21.397.141	64.398.890
2010	13.253.450	238.519	21.503.662	66.469.394
2011	13.203.643	241.991	21.652.602	65.756.904
2012	13.445.524	245.425	21.409.667	69.056.126
2013	13.835.252	248.818	21.277.431	71.279.709
2014	13.797.307	252.165	21.340.203	70.846.465
2015	14.115.475	255.462	22.285.201	76.361.248
2016	14.449.372	258.705	22.568.131	77.049.958
2017	14.701.998	261.891	22.846.053	79.175.945

The Fuzzy logic of Mamdani method

The Mamdani method is also called the Max-Min method. To get the output which is a prediction of Rice Production in Indonesia, 4 stages are needed:

    a.   Formation of Fuzzy Set

This is the first step taken in using the Mamdani method. There are four Fuzzy variables to be modeled, i.e Harvest Area with Fuzzy set ; small, medium and large, Number of Population with Fuzzy set ; few and many, Consumption with Fuzzy set ; decrease and increase. And Rice Production with little, medium and much.

Table 2. Determination of Variable and Speaker Universe

Function	Variable	Universal Speaker (thousand)	Explanation
Input	Harvest Area	11.786 – 14.701	Production Area (Ha)
	Number of Population	224.000 – 262.000	Number of National Population (head)
	Consumption	21.496 – 22.846	Number of Consumption (Ton)
Output	Rice Production	54.454 – 79.175	Number of Rice Production (Ton)

Determine the domain of Harvest Area, Population, Consumption and Rice Production at Fuzzy leadership as follows

Table 3. Fuzzy Set

| Function	Variable	Fuzzy Set	Universal Speaker	Domain
Input	Harvest Area	small	11.786 – 14.701	11.786 – 13.244
		medium		12.758 – 13.730
		large		13.244 – 14.701
	Number of Population	few	224.000 – 261.000	224.000 – 242.500
		many		242.500 – 261.000
	Consumption	decrease	21.496 – 22.846	21.496 – 22171
		increase		22.171 – 22.846
Output	Rice Production	low	54.454 – 79.175	54.454 - 66.814
		medium		62.694 – 70.934
		high		66.814 -79.175

   i.   Harvest Area
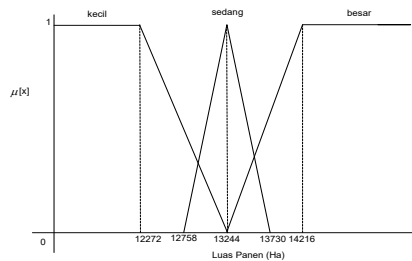
Figure 2. Fuzzy set curve for harvest area variable or
Representation of harvest area variable

Membership function:

$$\mu_{LP\ Small}\ (x) = \begin{cases} 1, x\ \leq 12.272 \\ \dfrac{13.244 - x}{13.244 - 12.272} = \dfrac{13.244 - x}{972}; 12.272 \leq x \leq 13.244 \\ 0, x \geq 13.244 \end{cases} \dots (12)$$

$$\mu_{LP\ Medium}\ (x) = \begin{cases} 0;\ x\ \leq 12.758\ or\ x\ \geq 13.730 \\ \dfrac{x - 12.758}{486}; 12..758 \leq x \leq 13.244 \\ \dfrac{13.244 - x}{486}; 13.244 \leq x \leq 13.730 \end{cases} \dots (13)$$

$$\mu_{LP\ Large}\ (x) = \begin{cases} 0;\ x\ \leq 13.244 \\ \dfrac{x - 13.244}{972}; 13.244 \leq x \leq 14.216 \\ 1;\ x \geq 14.316 \end{cases} \dots (14)$$

If the harvest area is 14.701.998 Ha, then the value of Fuzzy membership in each set is
$$\mu_{LP\ Small}[14.701.998] = 0$$

$$\mu_{LP\ Medium}[14.701.998] = 0$$

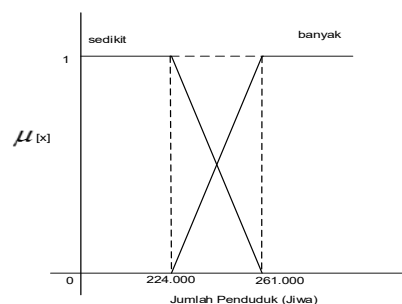$$\mu_{LPLarge}[14.701.998] =\ 1$$

  ii.   Number of Population

Figure 3. Fuzzy set curve for the number of population's variable or

Representation of number of population's variables

Membership function:

$$\mu_{JP\ Few}\ (x) = \begin{cases} 1;\ x\ \le 244.000 \\ \dfrac{261.000 - x}{37.000};244.000 \le x \le 261.000 \dots (15) \\ 0;\ x \ge 261.000 \end{cases}$$

$$\mu_{JP\ Many}\ (x) = \begin{cases} 0;\ x\ \le 244.000 \\ \dfrac{x - 224.000}{37.000};244.000 \le x \le 261.000 \dots (16) \\ 1;\ x \ge 261.000 \end{cases}$$

If the total population is 261.891.000, then the value of Fuzzy membership in each set is,
$$\mu_{JP\ Few}[261.891.000] = 0$$
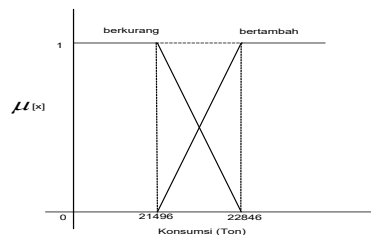$$\mu_{JP\ Many}[261.891.000] = 1$$

iii. Consumption

Figure 4. Fuzzy set curves for consumption variables or
Representations of consumption variables

Membership Function:

$$\mu_{K\ Decrease}(x) = \begin{cases} 1;\ x\ \le 21496 \\ \dfrac{22.846 - x}{1.350};21.496 \le x \le 22.846 \dots (17) \\ 0;\ x \ge 22.846 \end{cases}$$

$$\mu_{K\ Increase}\ (x) == \begin{cases} 0;\ x\ \le 21.496 \\ \dfrac{x - 21.496}{1350};21.496 \le x \le 22.846 \dots (18) \\ 1;\ x \ge 22.846 \end{cases}$$

If the consumption is 22,846,053 tons, then the value of Fuzzy membership in each set is
$$\mu_{K\ Decrease}[22.846.053] = 0$$
$$\mu_{K\ Increase}[22.846.053] = 1$$
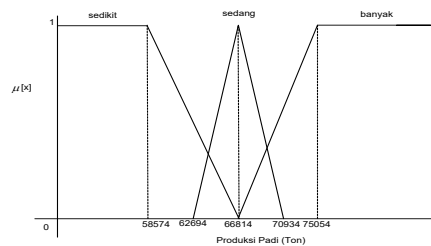
iv. Rice Production

Figure 5. Fuzzy set curves for Rice Production variables or Representations of Rice Production variables

Membership Function:

$$\mu_{PP\,Low}(x) = \begin{cases} 1; \ x \leq 58.574 \\ \dfrac{66.814 - x}{8.240}; 58.574 \leq x \leq 66.814 \\ 0; \ x \geq 66.814 \end{cases} \dots (19)$$

$$\mu_{PP\,Medium}(x) = \begin{cases} 0; \ x \leq 62.694 \ or \ x \geq 66.814 \\ \dfrac{x - 62.694}{4.120}; 62694 \leq x \leq 66.814 \\ \dfrac{70934 - x}{4.120}; 66.814 \leq x \leq 70.934 \end{cases} \dots (20)$$

$$\mu_{PP\,High}(x) = \begin{cases} 0; \ x \leq 66.814 \\ \dfrac{x - 66.814}{8.240}; 66.814 \leq x \leq 75.054 \\ 1; \ x \geq 75.054 \end{cases} \dots (21)$$

If rice production is 79.175.945 tons, then the value of Fuzzy membership in each set is

$$\mu_{PP\,Low}[79.175.945] = 0$$

$$\mu_{PP\,Medium}[79.175.945] = 0$$

$$\mu_{PP\,High}[79.175.945] = 1$$

b. Application of Implication function

The rules in the form of qualitative statements which are written in the form of IF **THEN** so that they are easy to understand. From 3 variables and 10 sets, 36 rules are obtained, as below:

[1] **IF** the harvest area is small **AND** the number of population is few **AND** the consumption is reduced **THEN** the rice production will be low

[2] **IF** the harvest area is small **AND** the number of population is few **AND** the consumption is reduced **THEN** the rice production will be medium.

[3] **IF** the harvest is small **AND** the number of population is few **AND** the consumption is reduced **THEN** the rice production will be high.

[4] **IF** the harvest area is small **AND** the number of population is few **AND** the consumption is increased **THEN** the rice production will be low.

[5] IF the harvest area is small **AND** the number of population is few **AND** the consumption is increased **THEN** the rice production will be medium.

[6] IF the harvest area is small **AND** the number of population is few **AND** the consumption is increased **THEN** the rice production will be high.

[7] IF the harvest area is small **AND** the number of population is many **AND** the consumption is decreased **THEN** the rice production will be low.

[8] IF the harvest area is small **AND** the number of population is many **AND** the consumption is decreased **THEN** the rice production will be medium.

[9] IF the harvest area is small **AND** the number of population is many **AND** the consumption is decreased **THEN** the rice production will be high.

[10] IF the harvest area is small **AND** the number of population is many **AND** the consumption is increased **THEN** the rice production will be   low.

[11] IF the harvest area is small **AND** the number of population is many **AND** the consumption is increased **THEN** the rice production will be medium.

[12] IF the harvest area is small **AND** the number of population is many **AND** the consumption is increased **THEN** the rice production will be high.

[13] IF the harvest area is medium **AND** the number of population is few **AND** the consumption is decreased **THEN** the rice production will be low.

[14] IF the harvest area is medium **AND** the number of population is few **AND** the consumption is decreased **THEN** the rice production will be medium.

[15] IF the harvest area is medium **AND** the number of population is few **AND** the consumption is decreased **THEN** the rice production will be high.

[16] IF the harvest area is medium **AND** the number of population is few **AND** the consumption is increased **THEN** the rice production will be low.

[17] IF the harvest area is medium **AND** the number of the population is few **AND** the consumption is increased **THEN** the rice production will be medium.

[18] IF the harvest area is medium **AND** the number of the population is few **AND** the consumption is increased **THEN** the rice production will be high.

[19] IF the harvest area is medium **AND** the number of the population is many **AND** the consumption is decreased **THEN** the rice production will be low.

[20] IF the harvest area is medium **AND** the number of the population is many **AND** the consumption is decreased **THEN** the rice production will be medium.

[21] IF the harvest area is medium **AND** the number of the population is many **AND** the consumption is decreased **THEN** the rice production will be high.

[22] IF the harvest area is medium **AND** the number of the population is many **AND** the consumption is increased **THEN** the rice production will be low.

[23] IF the harvest area is medium **AND** the number of the population is many **AND** the consumption is increased **THEN** the rice production will be medium.

[24] IF the harvest area is medium **AND** the number of the population is many **AND** the consumption is increased **THEN** the rice production will be high.

[25] IF the harvest area is big **AND** the number of the population is few **AND** the consumption is decreased **THEN** the rice production will be low.

[26] IF the harvest area is big **AND** the number of the population is few **AND** the consumption is decreased **THEN** the rice production will be medium.

[27] IF the harvest area is big **AND** the number of the population is few **AND** the consumption is decreased **THEN** the rice production will be high.

[28] IF the harvest area is big **AND** the number of the population is few **AND** the consumption is increased **THEN** the rice production will be low.

[29] IF the harvest area is big **AND** the number of the population is few **AND** the consumption is increased **THEN** the rice production will be medium.

[30] IF the harvest area is big **AND** the number of the population is few **AND** the consumption is increased **THEN** the rice production will be high.

[31] IF the harvest area is big **AND** the number of the population is many **AND** the consumption is decreased **THEN** the rice production will be low.

[32] IF the harvest area is big **AND** the number of the population is many **AND** the consumption is decreased **THEN** the rice production will be medium.

[33] IF the harvest area is big **AND** the number of the population is many **AND** the consumption is decreased **THEN** the rice production will be high.

[34] IF the harvest area is big **AND** the number of the population is many **AND** the consumption is increased **THEN** the rice production will be low.

[35] IF the harvest area is big **AND** the number of the population is many **AND** the consumption is increased **THEN** the rice production will be medium.

[36] IF the harvest area is big **AND** the number of the population is many **AND** the consumption is increased **THEN** the rice production will be high.

In manually calculating using 2017 data, the rule used is rule 36 [R 36] viz **[36] IF** the harvest area is big **AND** the number of population is many **AND** the consumption is increased **THEN** the rice production will be high. The minimal α-predicate value using the above rules is as follows :

$$\alpha - predicate = (\ \mu_{LP\ Big} \cap \mu_{JP\ Many}\ \cap \mu_{K\ Increased} \cap\ \mu_{PP\ High})$$

$$= \min\ (\mu_{LP\ Big}[14.701.998] \cap \mu_{JPMany}\ [261.891] \cap \mu_{K\ Increased}[22.846.053] \cap\ \mu_{PP\ High}\ [79.175.945])$$

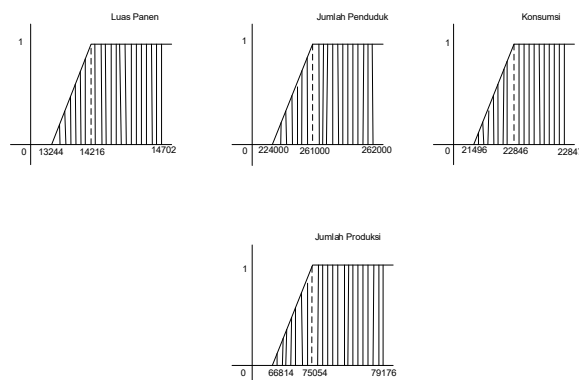$$= \min imal(\ 1\ ;1\ ;1\ ;1\ ) = 1$$

Figure 6. Application of Implication function for Rule [36]

c.   Aggregation (Rule Composition)
Formation of the rule composition is done by taking the maximal value on α-predicate.
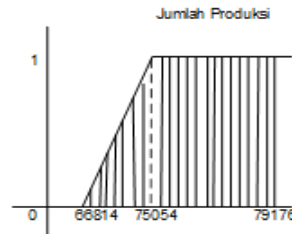
$$\mu\,(z) = \max\,\{\,R\,36\,\} = \max\,\{\,1\,\} = 1$$

Figure 7. The Area of Composition Result

$$\mu\,(z) = \begin{cases} 0;\ z \leq 66814 \\ \dfrac{z - 66814}{8240};\ 66814 \leq x \leq 75054 \\ 1;\ z \geq 75054 \end{cases} \dots (22)$$

d.   Defuzzification

The affirmation method used is the centoid method. Because it's the first calculated moment for each region:

$$m1 = \int_{66814}^{75054}\left(\frac{z-66814}{8240}\right) z\,dz = \int_{66814}^{75054}\frac{z^2-66814\,z}{8240}\,dz = \int_{66814}^{75054}\frac{z^2}{8240} - \frac{66814\,z}{8240}\,dz = \frac{1}{3}\frac{z^3}{(8240)} -$$

$$\frac{1}{2}\frac{66814\,z^2}{8240}\Big|_{66814}^{75054} = \frac{z^3}{24720} - \frac{33407z^2}{8240}\Big|_{66814}^{75054}$$

$$= [17103030188{,}40873 - 22837993824{,}61310]$$
$$- [12065739699{,}07540 - 18098609548{,}61310]$$

$$= -5734963636{,}2043 + 6032869849{,}5377 = 297906213{,}3333$$

$$m2 = \int_{75054}^{79176} 1z\,dz = \frac{1}{2}z^2\ \Big|_{75054}^{79176} = \frac{1}{2}[(79176^2) - (75054^2)]$$

$$= \frac{1}{2}[(6268838976) - (5633102916)] = \frac{1}{2}(635736060) = 317868030$$

Then calculate the area of each region:

$$A_1 = \frac{1}{2}(75054 - 66814).1 = \frac{8240}{2}.1 = 4120$$

$$A_2 = (79176 - 75054).1 = 4122$$

The central point can be obtained from:

$$Z = \frac{M1 + M2}{A1 + A2} = \frac{297906213{,}333 + 317868{,}030}{4120 + 4122}$$

$$= \frac{615774243{,}3333}{8242} = 74711{,}74998 = 74.711.750\ ton$$

So, the amount of rice production in Indonesia in 2017 using the Fuzzy count is 74.711.750 tons. By entering the membership function value of each variable into the Fuzzy rules using

the Fuzzy application are obtained the forecast result as in Table 11 below. The results obtained between the manual and the application are differences that are far different because the level of accuracy of the parameters results in the manual calculation is not so effective and efficient. So we use forecast results with the Fuzzy application only.
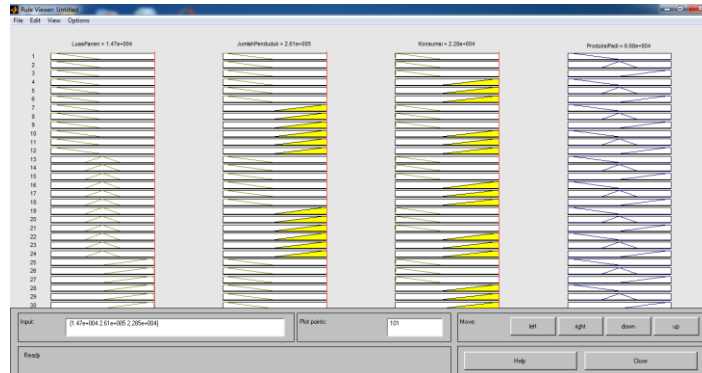

Figure 8. Variable curve $\hat{Y}$ in Matlab

Multiple Linear Regression Analysis

For multiple linear regression, the equation is obtained by eliminating the equations of the least squares method (9). The coefficients of b_0, b_1, b_2 and   are b_3 obtained with the help of Minitab software.

```
The regression equation is
Y = - 56669133 + 7.83 X1 + 0.017 X2 + 0.729 X3


Predictor        Coef     SE Coef        T        P
Constant    -56669133    10065662    -5.63    0.000
X1              7.826       1.562     5.01    0.001
X2             0.0172      0.1169     0.15    0.887
X3             0.7292      0.5063     1.44    0.188


S = 706560    R-Sq = 99.4%    R-Sq(adj) = 99.2%
```

Figure 9. Coefficient values using Minitab software

So the equation produced is as follows:

$$\hat{Y}_i = -56669133 + 7{,}83\, x_1 + 0{,}017 x_2 + 0{,}729 x_3$$

If each of the variables x_1, x_2 and x_3 is substituted with the above equation, then the forecast result of rice production ($\hat{Y}_i$) using the multiple linear regression method is

Table 4. Results of Rice Production Forecasting with Fuzzy Logic and Multiple Regression

Year	Harvest Area (X1)	Number of Population (X2)	Consumption (X3)	Rice Production (Y)	Fuzzy Rice Production $(\widehat{Y})$	Regression Rice Production $(\widehat{Y}_t)$	Fuzzy Relative Errors	Regression Relative Errors
2006	11.786.430	224.179.000	21.496.757	54.454.937	66.800.000	55100792,75	0,226702365	0,011860371
2007	12.147.637	227.521.000	20.583.388	57.157.435	66.800.000	57320011,56	0,16870185	0,002844364
2008	12.327.425	230.913.000	21.576.527	60.325.928	66.800.000	59509413,93	0,107318233	0,013535044
2009	12.883.576	234.356.000	21.397.141	64.398.890	66.800.000	63791834,87	0,037284959	0,009426484
2010	13.253.450	238.519.000	21.503.662	66.469.394	66.800.000	66836373,1	0,004973808	0,005521024
2011	13.203.643	241.991.000	21.652.602	65.756.904	66.800.000	66613985,55	0,015862912	0,013034092
2012	13.445.524	245.425.000	21.409.667	69.056.126	66.800.000	68389192,16	0,032670903	0,009657852
2013	13.835.252	248.818.000	21.277.431	71.279.709	66.800.000	71402043,36	0,062846904	0,001716258
2014	13.797.307	252.165.000	21.340.203	70.846.465	66.800.000	71207593,8	0,057115976	0,005097344
2015	14.115.475	255.462.000	22.285.201	75.361.248	66.800.000	74443801,78	0,11360279	0,012173979
2016	14.449.372	258.705.000	22.568.131	77.049.958	66.800.000	77319602,26	0,133030027	0,003499603
2017	14.701.998	261.891.000	22.846.053	79.175.945	66.800.000	79554430,98	0,156309407	0,004780315

From the above table, it is obtained that the forecast results of Rice Production using Fuzzy Logic for a number of years are 66.800.000 tons, the number is stable for twelve years of rice production in Indonesia. While for the forecast results of Rice Production using Multiple Linear Regression, the resulting numbers are vary and are close to the actual data results.

4. Conclusion

Based on the analysis conducted, it can be concluded that ;

a. Fuzzy logic Mamdani method and Multiple Linear Regression can be used to predict the yield of rice production in Indonesia. Forecasting the amount of rice production using Fuzzy Logic from 2006 - 2017 amounted to 66.8 million tons, while the Multiple Linear Regression results are almost the same as the actual data. That's why the relative error of using Multiple Linear Regression is smaller than that of Fuzzy Logic.

b. It was found that the relationship between the harvest area variable and the consumption variable significantly affected the amount of rice production in Indonesia. So to increase rice production in Indonesia, related parties, in this case the government, must try to open new fields and find alternative staple foods. These are all efforts to realize rice self-sufficiency in 2023.

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