Fuzzy Logic Applications to Predict Total Production of PKO (Palm Kernel Oil)

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Abstract. The purpose of this study is to apply fuzzy logic to predict the amount of Palm Kernel Oil (PKO) production at PT. Weta-based AAI. This study uses the Tsukamoto method to anticipate the instability of palm oil production based on the existing demand and supply. The results showed that with the implementation of the fuzzy logic, the Tsukamoto method can affect the rate of more stable production and reduce the production of which is not in accordance with the market demand. The conclusion of this study is to apply the result of the predicted number of production PKO (Palm Kernel Oil) at PT AAI, in order to know the budget supply and demand thereafter.

1. Introduction

Oil palm is one of the main commodities affecting Indonesia's economic growth. The processing industry makes an important contribution in generating foreign exchange and employment. This is because palm oil is an upstream industry that is very important for various other industries, such as: food, cosmetics, soap and paint. Even lately there have been efforts to use palm oil as a raw material for making alternative fuels. This condition spurred the development of the palm oil processing industry; both the domestic and export needs. Also, industrial development is in line with the increasing area of oil palm plantations.

There are two kinds of oil derived from oil palm, which are namely: the oil derived from fruit flesh (mesocarp), which is released from boiling and squeezing and is known as Crude Palm Oil (CPO) and the other type is the oil from the core which is called Palm Kernel Oil (PKO).

Coconut oil and its relatives, palm oil and palm seeds, are considered unique because they are the best natural source of medium and short chain fatty acids, hence they can help in increasing the extraordinary health of individuals. The composition of palm kernel oil (PKO) is almost the same as the oil derived from coconut, namely the composition of fat (saturated fatty acids and unsaturated fatty acids). One of the advantage of Palm Kernel Oil is that it can be used to produce a Virgin Oil. To be able to produce pure oil that is derived from palm kernel oil (PKO), it must undergo a process via the use of the fermentation method (Helmi, 2009).

In the management of palm oil, a good corporate management in production planning is needed. Production planning at the factory is based on the estimated demand from the factory that requires CPO (Crude Palm Oil) and PKO (Palm Kernel Oil) in each period. However, in reality, companies are often faced with situations where there is a production mismatch with the volume of demand. In certain periods, because of the large demand for production, the factory cannot meet the demands of its customers. For this
reason, the need to implement a strategy in dealing with the market competition for CPO or PKO oil, arises. From an economic perspective, the price is relatively cheap as compared to other vegetable oils processed (Novia Larasati, 2016).

Production of Palm Kernel Oil (PKO) in the right time and with the right amount, is something that oil palm companies want, as well as PT AAI's companies; however determining the amount of PKO production in the future is not easy. Many of the factors involved in the calculation are obstacles that deal with the taking of policies to determine the amount of palm oil that will be produced. These factors are demand, inventory, and production.

One of the methods used in predicting palm oil production is the application of the fuzzy logic, because there are some data that can be used in calculating to get the predictions of the amount of the palm oil production. In this case, the researcher applied the Tsukamoto fuzzy logic method to predict the amount of palm oil production based on the inventory data and the number of requests. The production activities of a manufacturing firm or factory, is greatly influenced by the consumer needs for the products produced; an instance is the case of palm oil production at PT AAI, which is a factory that produces PKO that is reviewed from the palm oil inventories, obtained from the community palm oil purchases and own oil palm land. Furthermore, in oil palm production activities, there is often a gap between production and the level of sales which causes production instability. This is due to the absence of adequate management in estimating the next production figure reviewed from the results obtained previously. In the above problems, there is an effective solution to anticipate the instability of palm oil production by using fuzzy logic.

2. Literature

2.1. Fuzzy Logic

Fuzzy logic is a methodology for "counting" with a linguistic variable, instead of counting with numbers. The words used in fuzzy logic are not as precise as numbers, but such words are much closer to the human intuition. Hence, humans can immediately "feel" the value of the variable words that have been used on a daily basis (Indrabayu, 2012).

Fuzzy logic is the study of uncertainty. Fuzzy logic is also able to map an input space into an output space correctly. Fuzzy system theory is known as a Fuzzy system concept, that is used in prediction processes in general, consisting of four stages, namely: fuzzification (the process of converting firm numbers into Fuzzy numbers), the formation of a base rule (Fuzzy rule basis), inference system or Fuzzy reasoning, defuzzification (The process of converting Fuzzy numbers results from Fuzzy inference systems into firm numbers). However, one method in Fuzzy systems that can be used in predicting is the Sugeno method; this method is almost the same as the Mamdani method except that the output (consequent) is not a Fuzzy set but a constant or linear equation (Rahakbauw, 2015).

Fuzzy logic is basically the possibility of membership values that are between 0 and 1. This means that a situation can have two values "Yes and No", "True and False", "Good and Bad" simultaneously, but the value depends on the weight of membership it has (Dwi Martha Sukandy, 2011). In general, fuzzy logic is a methodology of "counting" with linguistic variables, instead of counting with numbers. The words used in fuzzy logic are not as exact as numbers, but the words are much closer to human intuition.

People who have never known fuzzy logic will surely think that fuzzy logic is something very complicated and unpleasant. However, once someone gets to know about it, such person will definitely be very interested and will become a newcomer to participate in learning the fuzzy
logic. Fuzzy logic is said to be an old new logic, because the knowledge of modern and methodical fuzzy logic was discovered only a few years ago, when in fact the concept of fuzzy logic itself had been around for a long time.

2.2 Fuzzy Inference System (FIS)

The Fuzzy Inference System (FIS), also known as the fuzzy inference engine, is a system that can reason with a similar principle as humans’ reason with their instincts (Rosario Agustina Lumbangaol, 2013). There are several types of FIS that are known, namely:

1. Tsukamoto method

According to Minarni., Et al. (2016), the Tsukamoto method is an extension of monotonous reasoning. In Tsukamoto's method, every consequence of rules in the form of if-then, must be represented by a fuzzy set with a monotonous membership function. As a result, the output of the inference results from each rule is given explicitly (crisp) based on the predicate. The end result is obtained using a weighted average that is given as:

\[
Z^* = \frac{\alpha_1 Z_1 + \alpha_2 Z_2 + \cdots + \alpha_i Z_i}{\alpha_1 + \alpha_2 + \cdots + \alpha_i}
\]

The advantages of the Tsukamoto Method is, having tolerance to data that is not right and easy to understand. In the Tsukamoto method, each rule is represented using fuzzy sets, with a monotonous membership function. To determine the output value that is firmly sought, is by converting the input into a number in the fuzzy set domain. In the Tsukamoto method, each consequence of an IF-THEN rule must be represented by a fuzzy set with a monotonous membership function. As a result, the output of the inference results of each rule is given strictly based on the \(z\)-predicate. The end result is obtained using a weighted average. Some rules can be formed to get the final z value. Supposedly, there are two rules used, namely:

[R1] IF (x is A1) and (y is B2) THEN (z is C1)
[R2] IF (x is A2) and (y is B1) THEN (z is C2)

2. Mamdani Method

The Mamdani method is often also known as the Max-Min Method. To get an output (Ahmad Mufid, 2012), 4 steps are needed which are:

- Formation of fuzzy sets
- Application function implications
- Composition of Rules
- Affirmation (defuzzy)

3. Sugeno Method

Reasoning with the Sugeno method is almost the same as the mamdani reasoning, except that the output (consequent) of the system is not in the form of a fuzzy set, but in the form of constants or linear equations. This method was introduced by Takagi-Sugeno Kang in 1985 (Muhammad Rofiq, 2013).
2.3 Fuzzy Data Analysis

The basic structure of the fuzzy inference system consists of:

- Base rules that contain a number of fuzzy rules that map fuzzy input values to fuzzy output values. This rule is often expressed in the if-then format.
- Database that contains the membership function of a fuzzy set that is used as a system variable value.
- Fuzzy reasoning mechanism that performs inference procedures.

3. Results and discussion

Data analysis is the most important stage in developing a system, processing data and assessing and identifying problems that will find solutions to solve the existing problems. Data analysis was obtained after making direct observations on the object of PT AAI's research in Air Rau, Kinali District, West Pasaman District, West Sumatra. The data obtained (data has been processed in 2018) which can be seen in Table 1 below:

| Month     | Inventory (kg) | Demand (kg) | Production (kg) |
|-----------|----------------|-------------|-----------------|
| January   | 34.679         | 614.525     | 622.800         |
| February  | 64.848         | 467.824     | 429.380         |
| March     | 54.079         | 454.485     | 482.160         |
| April     | 30.237         | 460.877     | 464.710         |
| May       | 34.778         | 558.156     | 566.530         |
| June      | 137.033        | 434.829     | 324.200         |
| July      | 181.183        | 872.969     | 718.190         |
| August    | 54.270         | 637.934     | 665.800         |
| September | 141.822        | 629.272     | 744.690         |
| October   | 218.294        | 468.330     | 660.220         |
| November  | 76.221         | 449.403     | 499.220         |
| December  | 92.566         | 409.592     | 343.430         |

3.1 Fuzzy Analysis

Fuzzy logic analysis is carried out as the basis for conducting the next fuzzy calculation. This fuzzy analysis includes the formation of fuzzy sets, rule formation, manual fuzzy method calculations, and comparative analysis of the results of the Tsukamoto method used in the system design.

3.2 Fuzzification

There are 2 main variables for input and 1 output variable to determine the amount of Kernel (Core Oil) production, represented as Inventory 1 and Input request 2. The output, for the Kernel production is depicted in table 2.
Table 2. Universe of Talk

| Function | Variable Name | Dimension       |
|----------|---------------|-----------------|
| Input    | Inventor      | [30.237 – 218.294] |
|          | Demand        | [409.592 – 872.969] |
| Output   | Production    | [324.200 – 744.690] |

1. Analysis for Inventory Variables
Inventory variables have values stated with low and many conditions, wherein each condition has a predetermined range of values from PT AAI. The set value ranges from the lowest value of 30,235 tons to the highest value of 218,295 tons. The fuzzy set for input 1 is shown in table 3.

Table 3. Fuzzy Inventory Set for Input 1

| Variable | Model MF | Set variable | Range         |
|----------|----------|--------------|---------------|
| Inventory| Trimf    | little       | 30.235 – 124.265 |
|          | Trimf    | Many         | 124.265 – 218.295 |

2. Analysis for Demand Variables
Inventory variable has a value stated with the condition of going down and up. Where each condition has a predetermined range of values from PT AAI. The set value ranges from the lowest value of 409,590 tons to the highest value of 872970 tons. The fuzzy set for input 2 is shown in table 4.3.

Table 4. Fuzzy Inventory Set for Input 2

| Variable | Model MF | Set variable | Range              |
|----------|----------|--------------|--------------------|
| Demand   | Trimf    | down         | 409.590 - 641.280  |
|          | Trimf    | Up           | 641.280- 872970    |

3. Analysis for Production Variables
The production variable has a value that is represented by Reduced and Increasing conditions. Where each condition has the lowest range of 324,200 cal to the highest value of 744,690 cal. The fuzzy set for the output is shown in table 5.

Table 5. Fuzzy Production Set for Output

| Variable | Model MF | Set variable | Range              |
|----------|----------|--------------|--------------------|
| Production| Trimf    | REDUCED      | 324.200 – 534.445  |
|          | Trimf    | Increase     | 534.445 – 744.690  |
3.3 Rule Formation

After determining the variable membership function, a fuzzy logic rule is formed. Based on existing data, the rules that can be formed are as follows:

[R1] IF LITTLE Inventory AND Demand DOWN THEN PRODUCTION REDUCED;
[R2] IF LITTLE Inventory AND Demand DOWN THEN PRODUCTION ADDED;
[R3] IF LITTLE Inventory AND Demand Increases THEN PRODUCTION REDUCES;
[R4] IF LITTLE Inventory AND Request Increases THEN PRODUCTION ADDED;
[R5] IF MANY Inventories AND Demand DOWN THEN PRODUCTION LOWERED;
[R6] IF MANY Inventory AND Demand DOWN THEN PRODUCT ADDED;
[R7] IF MANY Inventory AND Request for INCREASE THEN LOWERED PRODUCTION;
[R8] IF MANY Inventory AND Request UP TO THEN ADDED Production;

Of the 8 rules formed, rules are re-chosen according to the conditions of the company. The rules chosen are then arranged to form new rules which will then be used in the calculation process. From the selection of these rules, 4 new rules are formed as follows:

[R1] IF LITTLE Inventory AND Demand DOWN THEN PRODUCTION REDUCED;
[R2] IF LITTLE Inventory AND Request Increases THEN PRODUCTION ADDED;
[R3] IF MANY Inventories AND Demand DOWN THEN PRODUCTION REDUCED;
[R4] IF MANY Inventory AND Request for INCREASE THEN ADDED Production;

3.4 Fuzzy Logic Calculation

To determine the amount of kernel production at PT AAI in 2018, the calculation is carried out as follows: total demand of 650,000 kg and inventory of 35,000 kg, then crude oil production will be sought by the calculation process of Fuzzy Tsukamoto. The following is a manual calculation of the case.

1. Completion of the Tsukamoto Method

   a. Fuzzyfication

   Based on the criteria in the case, there are 3 fuzzy variables that can be modelled into membership charts as follows:

   a. Inventories consist of Little and Many

   \[ \mu_{\text{LITTLE}}[35.000] = \frac{(218.295 - 35.000)}{(218.295 - 30.235)} = 183.295/188060 = 0.975 \]

   \[ \mu_{\text{MANY}}[35.000] = \frac{(35.000-30.235)}{(218.295-30.235)} = 4.765 / 251.060 = 0.025 \]
b. Demand consists of Down and Up

\[ \mu_{\text{Down}}[650.000] = \frac{872.970 - 650.000}{872.970 - 409.590} = \frac{222.970}{463.380} = 0.5 \]

\[ \mu_{\text{UP}}[650.000] = \frac{650.000 - 409.590}{872.970 - 409.590} = \frac{240.410}{463.380} = 0.5 \]

Figure 1. Inventory Function Membership Variables

Stage 2: Formation of Rules

In this case the rules are formed according to what has been formed from the results Rule formation:

1. \([R1]\) IF LITTLE Inventories AND Demand DOWN THEN PRODUCTION REDUCED;
2. \([R2]\) IF LITTLE Inventory AND Request Increases THEN PRODUCTION ADDED;
3. \([R3]\) IF MANY Inventories AND Demand DOWN THEN PRODUCTION REDUCED;
4. \([R4]\) IF MANY Inventory AND Request UP TO THEN PRODUCT ADDED;

Stage 3: Inference Machine
In an inference engine, apply the MIN function to each rule in the application's implication function. 

[R1] IF LITTLE Inventories AND Demand DOWN THEN PRODUCTION REDUCED;

\[ \alpha_{\text{predikat}_1} = \mu_{\text{LITTLE}} \cap \mu_{\text{DOWN}} = \min(\mu_{\text{LITTLE}} \cap \mu_{\text{DOWN}}) = \min(0.975; 0.5) = 0.5 \]

See the REDUCED set on the production variable membership chart

\[ \frac{744.690 - z_1}{744.690 - 324.200} = 0.5 \]

\[ 744.690 - z_1 = 0.5 \times 324.200 \]

\[ Z_1 = 744.690 - 162.100 = 528.590 \]

[R2] IF Stock LITTLE AND Demand UP THEN Production INCREASE;

\[ \alpha_{\text{predikat}_2} = \mu_{\text{LITTLE}} \cap \mu_{\text{UP}} = \min(\mu_{\text{LITTLE}} \cap \mu_{\text{UP}}) = \min(0.975; 0.5) = 0.5 \]

See the INCREASE set in the Production variable membership graph,

\[ \frac{z_2 - 324.200}{744.690 - 324.200} = 0.5 \]

\[ Z_2 - 324.200 = 0.5 \times 420.490 \]

\[ Z_2 = 324.200 + 210.245 = 534.445 \]

[R3] IF Stock MANY AND Demand DOWN THEN Production REDUCED;

\[ \alpha_{\text{predikat}_3} = \mu_{\text{MANY}} \cap \mu_{\text{DOWN}} = \min(\mu_{\text{MANY}} \cap \mu_{\text{DOWN}}) = \min(0.02; 0.5) = 0.02 \]

See the REDUCED set in the Production variable membership graph,
\[
\frac{744.690 - z_3}{744.690 - 324.200} = 0.02 \\
744.690 - z_3 = 0.02 \times 324.200 \\
Z_3 = 744.690 - 6.484 \\
= 738.206 \\
\]

[R4] IF Inventory MANY AND Demand UP THEN Production INCREASE ;
\[
\alpha_{\text{predikat}_4} = \mu\text{MANY} \cap \mu\text{UP} \\
= \min(\mu\text{MANY}, \mu\text{UP}) \\
= \min(0.02; 0.5) \\
= 0.02 \\
\]

See the INCREASE set in the Production variable membership graph,
\[
\frac{z_4 - 744.690}{744.690 - 324.200} = 0.02 \\
Z_4 - 744.690 = 0.02 \times 420.490 \\
Z_4 = 744.690 + 8.410 \\
= 753.100 \\
\]

Stage 4: Defuzzification

The firm value \( z \) can be searched using a weighted average, presented below:
\[
Z = \frac{\text{apred}_1 \times z_1 + \text{apred}_2 \times z_2 + \text{apred}_3 \times z_3 + \text{apred}_4 \times z_4}{\text{apred}_1 + \text{apred}_2 + \text{apred}_3 + \text{apred}_4} \\
Z = \frac{0.5 \times 528.590 + 0.5 \times 534.445 + 0.02 \times 738.206 + 0.02 + 753.100}{0.5 + 0.5 + 0.02 + 0.02} \\
= \frac{264.295 + 267.223 + 14.764 + 15.062}{1.04} \\
= 561.344 / 1.04 \\
= 539.754 \\
\]

So the result of the prediction using Kernel’s fuzzy Tsukamoto production is 539,754 kg, hence the production decreases.

4. Conclusion

The conclusions of this study are:
- By using this application, PT AAI, which is located in Air Rau, Kinali District, West Pasaman Regency, West Sumatra, can predict the crude oil production (PKO) that will be produced in the future. This is so because this application successfully predicts crude oil production to become a reference for companies in making decisions. This can be done
via the process of selecting the found data/information in the form of the inventory data and demand data, which are used as factors in predicting the crude oil production at PT AAI.

- Using this application to predict crude oil production is easier and faster. This can be done by entering the inventory and demand data into the system; and the system will process the data needed and will produce decisions quickly.
- By using this application, PT AAI can reduce their production numbers to be more stable to reduce productions that are not in accordance with the demand, in order to reduce excessive production which can cause loss to the company.

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