

Application of the Lee Fuzzy Time Series Method in Forecasting Retail Rice Prices in West Sumatra

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Abstract. Retail rice prices are one of the important food commodities that affect economic stability in West Sumatra Province. Fluctuations in rice prices occurring in each period require forecasting to support decision-making related to food policies. This study aims to forecast retail rice prices in West Sumatra using the Lee Fuzzy Time Series method and to measure the forecasting accuracy. One of the advantages of the Lee Fuzzy Time Series (FTS) method is that it does not require stationarity assumption testing. The Lee Fuzzy Time Series method is designed for short-term forecasting and can be applied to both stationary and non-stationary data. In addition, this method can handle uncertainty and fluctuations in the data. Therefore, the Lee Fuzzy Time Series method is suitable for forecasting rice prices, as rice price data are classified as time series data. The data used were monthly retail rice price data from January 2020 to December 2024 obtained from the Central Statistics Agency (BPS). The forecasting stages included determining the universe of discourse, interval formation, fuzzification, establishing Fuzzy Logical Relationships (FLR), forming Fuzzy Logical Relationship Groups (FLRG), and defuzzification. Forecasting accuracy was measured using Mean Absolute Percentage Error (MAPE). The results showed that the Lee Fuzzy Time Series method produced a MAPE value of 1.27%, which is categorized as very good. The forecasting result for January 2025 indicated that retail rice prices were predicted to increase compared to the previous period.

Keywords: Forecasting, Retail Rice Prices, Lee Fuzzy Time Series Method.

1 Introduction

Rice is the main food commodity that plays an important role in the lives of Indonesian people. As a staple food, the high level of rice consumption makes rice price stability one of the important factors in maintaining food security and economic stability. Fluctuating rice price changes can affect inflation rates and public welfare, especially for low-income communities and farmers. Excessive increases in rice prices can reduce people's purchasing power, while drastic price decreases can harm farmers because selling prices become lower than production costs. Therefore, efforts are needed to predict rice price changes in order to assist the government and society in making appropriate decisions [1]-[3].

West Sumatra Province is one of the regions with a relatively high level of rice consumption ranking 14th after West Kalimantan Province, with a consumption level of 90 kg per capita per year. This figure is also higher than the national average rice consumption, which is only around 80–83 kg per capita per year (BPS, 2020). In addition, according to data from the Central Statistics Agency (BPS, 2022), inflation was driven by price increases across eight expenditure groups. The group that contributed the most to inflation, accounting for approximately 2 percent, was the food, beverage, and tobacco group, particularly due to rising prices of staple food commodities such as rice. Retail rice price data in West Sumatra show an increasing trend from year to year with fluctuating patterns. This condition indicates price uncertainty, so a forecasting method capable of producing accurate predictions for future rice prices is needed [4], [5].

Time series is a modeling approach that seeks to forecast future events by using data from previous or past periods to estimate future conditions. Forecasting is a process of estimating future events based on historical data. In time series analysis, various methods can be used for forecasting, such as ARIMA, SARIMA, and Exponential Smoothing. However, these methods have several limitations, including the requirement for large historical datasets and certain assumptions that must be fulfilled. One alternative method that can be used is Fuzzy Time Series (FTS). This method uses the concept of fuzzy sets to handle uncertain and fluctuating data,

making it more flexible in the forecasting process. In solving the problem, the Lee method differs from other Fuzzy Time Series methods in its steps. The difference lies in the construction of the Fuzzy Logical Relationship Group (FLRG). This method is able to provide more accurate predictions compared to conventional methods because it takes into account uncertainty and variations in the data [6]-[9].

The Lee Fuzzy Time Series method is one of the developments of the FTS method designed to improve forecasting accuracy. The advantage of this method lies in the formation of Fuzzy Logical Relationship Groups (FLRG), which consider repeated relationships among data so that better prediction results can be obtained. In addition, the FTS Lee method can be applied to both stationary and non-stationary data and is effective for short-term forecasting [9]-[11].

Several previous studies have shown that the Fuzzy Time Series method can produce good forecasting accuracy for rice prices. Research by Kartika et al. showed that the FTS Cheng method produced rice price forecasting results with very low MAPE values [12]. Another study by Yanti also obtained forecasting results with a small error rate using the FTS Cheng method [13]. Based on these studies, the Fuzzy Time Series method is considered effective for predicting fluctuating data [12]-[14].

This study aims to forecast monthly retail rice prices in West Sumatra Province using the Lee Fuzzy Time Series method based on data from January 2020 to December 2024 and to evaluate the forecasting accuracy using Mean Absolute Percentage Error (MAPE) [15], [16].

2 Research Methods

This study belongs to the category of applied research using a quantitative approach. Applied research aims to obtain solutions to a particular problem. The research conducted is the application of the Lee Fuzzy Time Series method for forecasting retail rice prices in West Sumatra.

2.1 Type and Source of Data

The data used in this study are secondary data obtained from the official website of the Central Statistics Agency (BPS) of West Sumatra Province (2024). The data consist of monthly retail rice price data in West Sumatra, measured in IDR/kg, covering the period from January 2020 to December 2024.

2.2. Data Analysis Technique

The data analysis technique in this study was carried out using Microsoft Excel software. The stages of analysis are as follows:

- 1) Preparing the data to be analyzed, namely retail rice price data in West Sumatra from January 2020 to December 2024.
- 2) Modeling the data using the Lee Fuzzy Time Series method with the following stages:
 - a. Determining the universe of discourse (U).
 - b. Dividing the universe of discourse (U) into several intervals.
 - c. Determining fuzzy sets in the universe of discourse (U).
 - d. Performing fuzzification on retail rice price data.
 - e. Determining the Fuzzy Logical Relationship (FLR) from the fuzzified data.
 - f. Determining the Fuzzy Logical Relationship Group (FLRG) from the formed FLR based on the Lee model grouping.
 - g. Performing defuzzification and prediction based on the obtained FLR and FLRG.
 - h. Evaluating forecasting accuracy using MAPE to predict retail rice prices in West Sumatra.
 - i. Drawing conclusions.

3 Results and Discussion

3.1 Data Description

The data used in this study are retail rice price data in West Sumatra for the period 2020–2024, consisting of 60 observation periods.

Table 1. Retail rice price data in West Sumatra period January 2020 – December 2024.

Month	Year				
	2020	2021	2022	2023	2024
January	IDR 13,569	IDR 13,800	IDR 13,736	IDR 15,632	IDR 15,725
February	IDR 13,581	IDR 13,800	IDR 13,855	IDR 15,675	IDR 15,892
March	IDR 13,589	IDR 13,753	IDR 13,594	IDR 15,427	IDR 16,376
April	IDR 13,589	IDR 13,741	IDR 13,530	IDR 15,292	IDR 16,269
May	IDR 13,599	IDR 13,741	IDR 13,568	IDR 15,283	IDR 16,432
June	IDR 13,605	IDR 13,728	IDR 13,587	IDR 15,285	IDR 16,627
July	IDR 13,654	IDR 13,742	IDR 13,657	IDR 15,279	IDR 16,585
August	IDR 13,654	IDR 13,742	IDR 13,840	IDR 15,436	IDR 16,575
September	IDR 13,654	IDR 13,742	IDR 14,554	IDR 16,298	IDR 16,640
October	IDR 13,654	IDR 13,742	IDR 15,213	IDR 16,433	IDR 16,667
November	IDR 13,654	IDR 13,742	IDR 15,433	IDR 16,432	IDR 16,631
December	IDR 13,654	IDR 13,730	IDR 15,495	IDR 16,463	IDR 16,627

Source: BPS, 2024

3.2 Data Analysis

The analysis of retail rice price data in West Sumatra Province was conducted using the Lee forecasting model. Subsequently, the retail rice price data were forecasted using the Fuzzy Time Series (FTS) Lee model.

Determining the universe of discourse (U)

The universe of discourse was established using the maximum and minimum values of the retail rice price data in West Sumatra Province from January 2020 to December 2024. As presented in Table 1, the maximum retail rice price was *IDR 16,667*, whereas the minimum value was *IDR 13,530*. The parameters D_1 and D_2 researchers define real numbers used to extend the range of the universe of discourse. In this study, D_1 was assigned a value of -1 and D_2 a value of 1 , ensuring that the resulting interval encompasses all observed data values. Therefore, the universe of discourse is obtained using the following equation [17].

$$U = [U_{min} - D_1 ; D_{max} + D_2]$$

$$U = [13,530 - 1 ; 16,667 + 1]$$

$$U = [13,529 ; 16,668]$$

Based on the calculation results, the universe of discourse (U) for the retail rice price data in West Sumatra was obtained as $U = [13,529 ; 16,668]$. This indicates that all retail rice price data fall within the range of 13,529 to 16,668.

Class Interval Formation

The next step was interval formation by dividing the universe of discourse into smaller intervals with equal widths. To calculate the number of required intervals, the Sturges formula was used. Before forming the intervals, the data range was calculated first.

1) Calculating the range

$$\begin{aligned} R &= (U_{maks} + D_2) - (U_{min} - D_1) \\ &= (16,667 + 1) - (13,530 - 1) \\ &= (16,668) - (13,529) \\ &= (3,139) \end{aligned}$$

2) Calculating the number of interval classes (n) using the sturges formula:

$$n = 1 + 3.322 \log(N)$$

$$= 1 + 3.322 \log (60) = 6.9248 \approx 7$$

3) Calculating the interval for each interval class

$$l = \frac{R}{n} = \frac{36,43}{7} = 453.30$$

With seven interval classes and an interval width of 453.30, the universe of discourse U can be written as follows:

$$U = \{u_1, u_2, u_3, u_4, u_5, u_6, u_7\}$$

where u_1 represents the first interval class, u_2 represents the second interval class, and so on. The intervals of the formed universe of discourse are as follows:

Table 2. Interval classes using Lee FTS method.

u_i	Minimum value	Maximum value	Midpoint value (m_i)
u_1	IDR 13,529	IDR 13,982	IDR 13,756
u_2	IDR 13,982	IDR 14,436	IDR 14,209
u_3	IDR 14,436	IDR 14,889	IDR 14,662
u_4	IDR 14,889	IDR 15,342	IDR 15,116
u_5	IDR 15,342	IDR 15,795	IDR 15,569
u_6	IDR 15,795	IDR 16,249	IDR 16,022
u_7	IDR 16,249	IDR 16,702	IDR 16,475

Based on Table 2, the midpoint values of the first to the seventh fuzzy sets were obtained using the following formula:

$$m_i = \frac{(\text{lower limit } u_i + \text{upper limit } u_i)}{2}$$

The following is an example of calculating the first midpoint value (m_1):

$$m_1 = \frac{(13.529 + 13.982)}{2} = 13.756$$

Determining Fuzzy Sets in The Universe of Discourse

The membership definition of the fuzzy sets for A_i , is based on the fuzzy sets. Let the fuzzification values of the linguistic variable for the retail rice price data in West Sumatra are represented by $A_1, A_2, A_3, A_4, A_5, A_6, A_7$ and each fuzzy set u_i where $i = 1,2,3, \dots,7$ is defined with respect to A_i , the membership functions of the fuzzy sets for A_i as follows:

$$A_1 = 1/u_1 + 0.5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_2 = 0.5/u_1 + 1/u_2 + 0.5/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_3 = 0/u_1 + 0.5/u_2 + 1/u_3 + 0.5/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_4 = 0/u_1 + 0/u_2 + 0.5/u_3 + 1/u_4 + 0.5/u_5 + 0/u_6 + 0/u_7$$

$$A_5 = 0/u_1 + 0/u_2 + 0/u_3 + 0.5/u_4 + 1/u_5 + 0.5/u_6 + 0/u_7$$

$$A_6 = 0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0.5/u_5 + 1/u_6 + 0.5/u_7$$

$$A_7 = 0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0.5/u_6 + 1/u_7$$

The interpretation of A_1 is that 1 represents the membership degree of u_1 to A_1 and 0.5 represents the membership degree of u_2 to A_1 , and 0 represents the membership degree of u_3, u_4, u_5, u_6, u_7 , to A_1 . Likewise, the membership degrees of $u_1, u_2, u_3, u_4, u_5, u_6, u_7$ for A_2 are A_7 defined as above. Based on the definition of the fuzzy set membership degrees for A_i , the fuzzification results are obtained as follows:

Table 3. Fuzzification values.

Fuzzy sets	Linguistic value
A_1	Very low
A_2	Low
A_3	Moderately low
A_4	Medium
A_5	Moderately High
A_6	High
A_7	Very high

In this study, the researcher constructed seven linguistic values based on the data range of the universe of discourse $U = [13,529; 16,668]$ with the aim of achieving higher forecasting accuracy.

Performing Fuzzification on Retail Rice Price Data

The next step is the fuzzification process, in which the historical data are mapped into the corresponding fuzzy sets. Table 4 presents the class intervals used in the fuzzification process. For example, the retail rice price in January 2020 was IDR 13,569, which falls within the interval $u_1 = [13,529; 13,982]$. Based on the fuzzy sets established in step 3, u_1 has a membership degree of 1 in A_1 . Therefore, the fuzzified value for January 2020 is A_1 . The complete fuzzification results for the retail rice price data in West Sumatra are presented in Table 4.

Table 4. Fuzzification of retail rice prices.

No.	Period	Retail price of rice	Fuzzification
1	January 2020	IDR 13,569	A_1
2	February 2020	IDR 13,581	A_1
3	March 2020	IDR 13,589	A_1
4	April 2020	IDR 13,589	A_1
5	May 2020	IDR 13,599	A_1
⋮	⋮	⋮	⋮
56	August 2024	IDR 16,575	A_7
57	September 2024	IDR 16,640	A_7
58	October 2024	IDR 16,667	A_7
59	November 2024	IDR 16,631	A_7
60	December 2024	IDR 16,627	A_7

Based on Table 4, the retail rice price data in West Sumatra for January 2020 obtained a fuzzification value of A_1 because the retail rice price value of 13,569 was within the interval $u_1 = [13,529 ; 13,982]$. Likewise, the retail rice price data in West Sumatra for December 2024 obtained a fuzzification value of A_7 because the value was within the interval $u_7 = [16,249 ; 16,702]$.

Determining the Fuzzy Logical Relationship (FLR) from the Fuzzified Data

The next step is determining the Fuzzy Logical Relationship (FLR), namely yaitu $A_i \rightarrow A_j$, where A_i represents the current state $y_{(t-1)}$ and A_j represents the next state. Thus, the formed FLR is $A_2 \rightarrow A_2$. For example, January 2020 is considered the current state with a fuzzification of A_1 , and February 2020 is the next state

with a fuzzification of A_1 . Thus, the resulting FLR is $A_1 \rightarrow A_1$. The subsequent FLR are obtained using the same procedure. The following presents the FLR results in Table 5.

Table 5. Fuzzy logical relationship (FLR) using Lee FTS method.

No.	Period	Retail price of rice	Fuzzification	FLR
1	January 2020	IDR 13,569	A_1	-
2	February 2020	IDR 13,581	A_1	$A_1 \rightarrow A_1$
3	March 2020	IDR 13,589	A_1	$A_1 \rightarrow A_1$
4	April 2020	IDR 13,589	A_1	$A_1 \rightarrow A_1$
5	May 2020	IDR 13,599	A_1	$A_1 \rightarrow A_1$
⋮	⋮	⋮	⋮	⋮
56	August 2024	IDR 16,575	A_7	$A_7 \rightarrow A_7$
57	September 2024	IDR 16,640	A_7	$A_7 \rightarrow A_7$
58	October 2024	IDR 16,667	A_7	$A_7 \rightarrow A_7$
59	November 2024	IDR 16,631	A_7	$A_7 \rightarrow A_7$
60	December 2024	IDR 16,627	A_7	$A_7 \rightarrow A_7$

Fuzzy Logical Relationship Group (FLRG)

The FLRG values are determined by grouping the previously obtained FLR results. FLRG is formed by grouping data that have the same left-hand side value or $f(t - 1)$ and then combining them into one group of $f(t)$. The FLRG results are presented in Table 6.

Table 6. FLRG using Lee FTS method.

Group	FLRG
1	$A_1 \rightarrow (32)A_1$
2	-
3	$A_3 \rightarrow A_1$
4	$A_4 \rightarrow A_3, (3)A_4, A_5$
5	$A_5 \rightarrow (2)A_4, (4)A_5, A_7$
6	$A_6 \rightarrow A_5$
7	$A_7 \rightarrow A_5, A_6, (11)A_7$

Performing Defuzzification and Prediction Based On The Obtained FLR and FLRG

Defuzzification is the process of converting values represented in fuzzy sets, which are expressed as linguistic variables, into crisp values in the form of real numbers to obtain the forecasting results. For example, as shown in Table 5, the defuzzification value for the fuzzy set A_1 is calculated based on the fuzzy logical relationship group (FLRG) $A_1 \rightarrow (32)A_1$. Therefore, the defuzzification value of A_1 is obtained as follows:

$$\hat{y}_t = \frac{32(m_1)}{32} = \frac{(32)13,756}{32} = 13,755$$

The same procedure is applied to calculate the defuzzification values. The complete defuzzification results are presented in Table 7.

Table 7. Defuzzification using Lee FTS method.

No.	FLRG	Calculation	Predicted value
1	$A_1 \rightarrow (32)A_1$	$\frac{(32)m_1}{32}$	13,755
2	-	-	-
3	$A_3 \rightarrow A_1$	m_1	13,755
4	$A_4 \rightarrow A_3, (3)A_4, A_5$	$\frac{m_3 + (3)m_4 + m_5}{5}$	15,115

5	$A_5 \rightarrow (2)A_4, (4)A_5, A_7$	$\frac{(2)m_4 + (4)m_5 + m_7}{7}$	15,568
6	$A_6 \rightarrow A_5$	m_5	15,568
7	$A_7 \rightarrow A_5, A_6, (11)A_7$	$\frac{m_1 + m_6 + (11)m_7}{13}$	16,370

Based on Table 7, there are 32 FLR that appear in FLRG Group 1, namely $A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_1$ and so on. Therefore, the defuzzification of the prediction value for FLRG Group 1 was calculated using the corresponding equation, and the prediction value obtained for FLRG Group 1 was 13,775.

The next stage was calculating all forecasting values for retail rice prices during the period January 2020 – December 2024. For example, the fuzzification result for January 2020 belonged to the fuzzy set A_1 with a defuzzification value of 13,755. This value was used as the prediction for the retail rice price in February 2020, so the forecasting result for February 2020 was 13,755. The same procedure was applied to the following periods. The complete forecasting results for retail rice prices from January 2020 to December 2024 are presented as follows.

Table 8. Forecasting values using Lee FTS method.

No.	Period	Retail price of rice	Forecasting
1	January 2020	IDR 13,569	-
2	February 2020	IDR 13,581	13,755
3	March 2020	IDR 13,589	13,755
4	April 2020	IDR 13,589	13,755
5	May 2020	IDR 13,599	13,755
⋮	⋮	⋮	⋮
56	August 2024	IDR 16,575	16,370
57	September 2024	IDR 16,640	16,370
58	October 2024	IDR 16,667	16,370
59	November 2024	IDR 16,631	16,370
60	December 2024	IDR 16,627	16,370

Table 8 presents the forecasting results of retail rice prices in West Sumatra for the period January 2020 to December 2024. To obtain the forecast for January 2025, the fuzzification value for December 2024, namely y_{t-1} , was first identified. Based on this fuzzification value, the forecast for January 2025 was obtained as 16,370. The forecast for January 2025 can be interpreted by comparing it with the actual price in December 2024, which was 16,627. This comparison indicates a decrease in price at the beginning of 2025. It suggests that the retail rice price trend is expected to experience a slight decline after the previous period, although the change is relatively small and still reflects a stable price movement pattern.

Forecasting Accuracy using MAPE

After obtaining the forecasting results for retail rice prices in West Sumatra, the next step is calculating the forecasting accuracy. The is to evaluate how accurate the forecasting results are compared to the actual data. The accuracy measure used in this forecasting is Mean Absolute Percentage Error (MAPE). MAPE represents the average percentage error between the actual data and the forecasted data.

$$\begin{aligned}
 MAPE &= \frac{1}{n} \sum_{t=1}^n \left| \frac{x_t - y_t}{x_t} \right| \times 100\% \\
 &= \frac{(0.01285 + 0.01226 + 0.01226 + \dots + 0.01776 + 0.01564 + 0.01540)}{59} \times 100\% \\
 MAPE &= 1.27\%
 \end{aligned}$$

Description:

n = number of observations (data points)

x_t = actual value at time t

y_t = forecasting value at time t

The criteria for evaluating forecasting performance using MAPE are presented in Table 9.

Table 9. MAPE value.

MAPE value	Accuracy level
< 10%	Highly accurate
10% – 20%	Accurate
20% – 50%	Reasonably accurate
> 50%	Inaccurate

From the MAPE calculation results, the obtained MAPE value is 1.27%. This indicates that the forecasting accuracy falls into the very good category, as a MAPE value below 10% reflects a very small prediction error and shows that the forecast results are very close to the actual values. In addition, the forecast value for January is 16,370. When compared with the actual price in December 2024, which is 16,627, it shows a decrease in price. This indicates that the model predicts a slight decline at the beginning of the next period compared to the end of the previous period.

4 Conclusion

Based on the results of this study, the Lee Fuzzy Time Series method was proven to be effective in forecasting retail rice prices in West Sumatra Province, producing results that closely follow the pattern of the actual data. The forecasting process involved several stages, including determining the universe of discourse, fuzzification, establishing Fuzzy Logical Relationships (FLR), constructing Fuzzy Logical Relationship Groups (FLRG), and performing defuzzification to generate forecast values. The accuracy evaluation using the Mean Absolute Percentage Error (MAPE) yielded a value of 1.27%, indicating that the Lee Fuzzy Time Series method has a very high level of forecasting accuracy. Therefore, this method can be considered a reliable alternative for forecasting retail rice prices in West Sumatra and can support decision-making related to food policy and price control.

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