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FORECASTING RICE PRICES IN TRADITIONAL MARKETS IN BANYUMAS REGENCY USING FUZZY TIME SERIES CHEN

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ABSTRACT

Indonesia is one of those countries where a majority of its population earns a living through agriculture. One of Indonesia's largest commodities is rice. Rice prices are a significant indicator in the economy, especially in agrarian areas like Banyumas Regency. Fluctuating rice prices can impact the economic livelihoods of both farmers and consumers in the region. The rapid fluctuations in rice prices and the uncertainty in the future necessitate the need for rice price forecasting. This study employs fuzzy time series to forecast rice prices. The fuzzy time series model used is the Chen model, and the accuracy of the predictions will be evaluated using the MAPE value. Based on the forecasting results using the fuzzy time series method with the Chen model, the predicted rice price for May 2024 is Rp 14,082. Furthermore, the accuracy level of the rice price forecasting using the fuzzy time series method with the Chen model shows highly accurate predictions, with an error based on the MAPE value of 0.957539%. The limitations of this study lie in the use of limited historical data and the assumption that price patterns will follow similar trends in the future. The contribution of this study is the application of the fuzzy time series method to rice commodities in Indonesia, which demonstrates high accuracy in conditions of high price fluctuation, thus providing valuable insights for policymakers and market participants in economic planning within the agricultural sector.

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1. INTRODUCTION

An agrarian country is one whose economy depends on or is supported by the agricultural sector. Indonesia is one such country, with the majority of its population engaged in agriculture. One of Indonesia's largest commodities is rice. Rice is the main staple food in Indonesia. According to data from the Central Statistics Agency in 2023, around 92% of the Indonesian population consumes rice as their primary carbohydrate source [1]. With the rapid population growth, the national demand for food tends to increase yearly [2]. Generally, the price of rice increases or decreases every month. The rapid fluctuations in rice prices and the uncertainty of future prices necessitate the forecasting of rice prices [3], [4], [5]. Rice prices are an important indicator in the economy, especially in agrarian areas like Banyumas Regency. Fluctuations in rice prices can affect the economic livelihoods of farmers and consumers in that region.

Fluctuating rice prices can affect both farmers and consumers, potentially leading to increased poverty rates among vulnerable populations. To address these fluctuations and provide stability, accurate forecasting of rice prices is essential. Several methods can be used for forecasting, for example, exponential smoothing, regression, Autoregressive Integrated Moving Average, and others. When using some data forecasting methods, certain assumptions must be met. As a result, many researchers have developed new forecasting methods that do not require specific assumptions for their data, such as Time Series using Fuzzy. FTS, or fuzzy time series, has been an effective method for predictions. Using FTS can handle data fluctuations, uncertainty, and subjectivity in data compared to classical statistics [6]. Numerous FTS methods have been created, including Chen's fuzzy time series model. Chen's FTS is a method that is different from other fuzzy time series models, especially in the defuzzification process [7]. The defuzzification process in Chen's fuzzy time series model does not consider any repetition in the fuzzy logic relationship (FLR) when determining the fuzzy logic relationship group (FLRG) [8].

The best forecasting model is identified by the precision of its results. To determine the accuracy level of a forecasting model, several methods can be used, one of which is Mean Absolute Percentage Error (MAPE). This study utilizes MAPE to assess the precision of the forecasting technique. MAPE is among the most widely used metrics for evaluating forecasting accuracy [9]. In various research studies, forecasting methods are evaluated to achieve optimal outcomes using MAPE values as the benchmark. A method of prediction that results in a lower MAPE score is indicative of a more suitable and successful way to predict data. Research by [10] , which compared three fuzzy time series models for forecasting rainfall in Medan, demonstrated that the Chen model outperformed the other two based on MAPE values. Research by Putri [6] on forecasting the exchange rate of the Indonesian Rupiah against the US Dollar using FTS Chen also achieved a MAPE value of 1.6717%, demonstrating the excellent accuracy of FTS Chen's predictions. The study by [11] conducted forecasting for sugarcane production values using the Chen fuzzy time series and obtained a MAPE value of 8.63%. The study by [12] conducted forecasting for the monthly income of the Employees Cooperative of PT Telekomunikasi Indonesia using the Chen fuzzy time series method and obtained a MAPE value of 4.52% which means the forecasting using this method is very good. Other research related to the Chen fuzzy time series method can be found in [13], [14], [15], [16]. In considering the description given above, this research will discuss forecasting rice prices in traditional markets in Banyumas Regency using the Chen fuzzy time series method. This study aims to forecast rice prices in the traditional markets of Banyumas Regency using the Fuzzy Time Series Chen. The precision of the forecasts made by the model will be evaluated using MAPE. The study seeks to provide a reliable forecasting model that can assist in stabilizing rice prices, ultimately benefiting both farmers and consumers in the region. By doing so, it hopes to contribute to economic stability and food security in Banyumas Regency.

2. RESEARCH METHODS

The monthly rice prices in Banyumas Regency's traditional markets were the study's source of data, which came from Pusat Informasi Harga Pangan Strategis Nasional (PIHPS) Bank Indonesia. The data covers the period from January 2019 to April 2024. The data will be displayed in **Figure 1**.

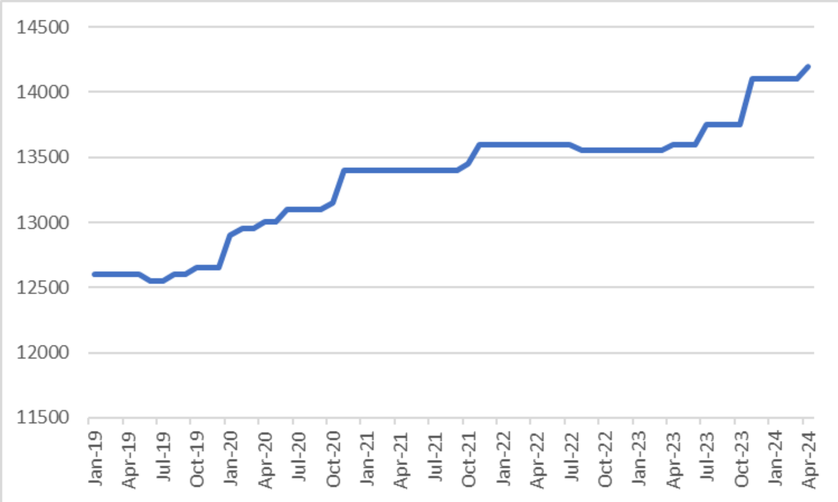

Figure 1. Plot of Rice Prices in Traditional Market of Banyumas Regency

2.1 Fuzzy Time Series Chen

A fuzzy time series is a forecasting method where past data is expressed in language terms. This means that actual data is displayed as real numbers, whereas historical data in fuzzy time series is characterized using linguistic values.

The Chen fuzzy time series method's steps are listed below [5]:

a. Apply the Equation (1) to determine the domain of discourse (U):

$$U = [X_{min} - R_1, X_{max} + R_2] \quad (1)$$

where X_{min} is the minimum data value and X_{max} is the maximum data value, while R_1 and R_2 are positive constant values set by the researcher.

b. Calculate the interval length. The interval length is calculated using Equation (2):

$$R = (X_{max} + R_2) - (X_{min} - R_1) \quad (2)$$

c. Determine the number of classes and the class length.

Equation (3), the Sturges formula, is used for obtaining the number of classes/intervals.

$$n = 1 + 3.3 \log N \quad (3)$$

To determine the length of each class, use the Equation (4):

$$r = \frac{n}{R} \quad (4)$$

d. Determine the fuzzy sets and fuzzyfication

e. Determine the Fuzzy Logical Relations (FLR) and Fuzzy Logical Relations Group (FLRG).

Determine the Fuzzy Logical Relationship (FLR) based on actual data. At this stage, identify the fuzzy logic relations, namely $A_i \to A_j$, where A_i represents the current state at the time D_{t-1} and A_j represents the next state at the time D_t. Next, determine the Fuzzy Logical Relationship Group (FLRG) by grouping fuzzifications that share the same current state and then combining them into a single group for the next state. In Lee's Fuzzy Time Series, all FLRs are organized into interconnected FLRGs. For example, if there are three Fuzzy Logical Relationships (FLR) and two of them are the same, namely $A_1 \to A_2$, $A_1 \to A_2$, and $A_1 \to A_3$, they form the FLRG $A_1 \to A_2, A_2, A_3$.

f. Determine defuzzification

Suppose $F(t)$ corresponds to $A_1, A_2, \dots, A_n$ and the maximum membership value occurs in the intervals $u_1, u_2, .., u_n$ where the median is $m_1, m_2, .., m_n$. The equation to determine the forecast value using the Chen model is derived as Equation (5):

$$F(t) = \frac{m_1 + m_2 + \cdots + m_n}{n} \tag{5}$$

2.2 Calculation of Model Accuracy

The forecasting method aims to produce highly accurate forecasts with minimal error. The smaller the error, the more precise the forecast, meaning the predicted value is closer to the actual value. This study used Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) to determine the accuracy of the model. MAPE is a metric for error assessment that computes the percentage difference between the data that was collected and the value that was predicted. MAPE is found by averaging the absolute errors for each period and dividing by the observed value for that period [17]. The equation to determine the criteria of accuracy is derived as [18]:

$$MAE = \frac{1}{n}\sum_{t=1}^{n}|X_t - F_t| \tag{6}$$

$$RMSE = \sqrt{\sum_{t=1}^{n}\frac{(X_t - F_t)^2}{n}} \tag{7}$$

$$MAPE = \frac{\sum_{t=1}^{N}\left|\frac{X_t - F_t}{X_t}\right|}{N} \times 100\% \tag{8}$$

With X_t represents the actual price of rice and F_t represents the forecast price of rice. If the MAPE value is less than 10%, therefore the forecasting method has excellent accuracy [18].

3. RESULTS AND DISCUSSION

3.1 Fuzzy Time Series Chen

The initial step involves establishing the universe of discourse. During this phase, the lowest and highest values of the actual data under study are identified. The universe of discourse $U = [X_{min}, X_{max}]$. The lower bound $X_{min} = 12{,}550$ and the upper bound $X_{max} = 14{,}200$ result in the universe of discourse $U = [12{,}550;\ 14{,}200]$. Next, determine the amount and range of the groups. Sturges' rule is used in this study to calculate the number of classes and intervals, dividing them into several intervals according to the calculation, although there are numerous methods for determining the number of intervals. Once the number of intervals is known, the next step is to calculate the interval width to divide the data into equal intervals. The number of classes given by Equation (3) is 6.9604, which can be rounded to 7 classes. The range of data from the maximum to the minimum is 1,670, so dividing by 7 classes gives an interval width of 238.6. The data will then be partitioned into 7 intervals. Next, determine the median of each interval. The result of partitioning the rice price data in traditional markets in Banyumas Regency into 7 intervals is presented in Table 1.

Table 1. The Result of Partitioning Data

Lower bound	Upper Bound	Median (m_i)
12,550	12,785.71	12,667.86
12,785.71	13,021.43	12,903.57
13,021.43	13,257.14	13,139.29
13,257.14	13,492.86	13,375.00
13,492.86	13,728.57	13,610.71
13,728.57	13,964.29	13,846.43
13,964.29	14,200	14,082.14

Finding the fuzzy sets for the discourse universe is the next stage. In this step, the crisp sets that make up the discourse universe are transformed into fuzzy sets based on intervals. Fuzzification of historical data is the term for this procedure. The membership values of each fuzzy set are ascertained at this stage using historical data. For example, the rice price data for January 2019 is 12,600, which falls into the first interval. Therefore, the fuzzification of this data is in class A_1. This step is applied to all rice price data. After fuzzification, the next step is to determine the fuzzy logical relationship (FLR). The FLR is based on actual data and is represented as $A_i \rightarrow A_j$, where A_i is called the current state and A_j is called the next state. For example, the fuzzification of data for December 2019 and January 2020 is A_1 and A_w, respectively. These two fuzzifications can be combined into an FLR, which is $A_1 \rightarrow A_2$. This step is applied to all rice price data. The fuzzified data and FLR results are shown in **Table 2** below.

Table 2. The Fuzzification Data And FLR

Period	Data	Fuzzification	FLR
1/19	12,600	A_1	$NA \rightarrow A_1$
2/19	12,600	A_1	$A_1 \rightarrow A_1$
3/19	12,600	A_1	$A_1 \rightarrow A_1$
4/19	12,600	A_1	$A_1 \rightarrow A_1$
5/19	12,600	A_1	$A_1 \rightarrow A_1$
6/19	12,550	A_1	$A_1 \rightarrow A_1$
⋮	⋮	⋮	⋮
12/23	14,100	A_7	$A_6 \rightarrow A_7$
1/24	14,100	A_7	$A_7 \rightarrow A_7$
2/24	14,100	A_7	$A_7 \rightarrow A_7$
3/24	14,100	A_7	$A_7 \rightarrow A_7$
4/24	14,200	A_7	$A_7 \rightarrow A_7$

The following step is to create the Fuzzy Logical Relationship Group (FLRG) once the FLR has been determined. Each detected relation's findings will be combined into an FLRG (fuzzy logistic relationship group). For example, the FLR for fuzzification A_1 is $A_1 \rightarrow A_1$, $A_1 \rightarrow A_2$, which can be combined into FLRG as $A_1 \rightarrow A_1, A_2$. This step is applied to all rice price data. **Table 3** below displays the findings of the FLRG for the data on rice prices.

Table 3. The Fuzzy Logical Relationship Group (FLRG)

FLRG		
A_1	$\rightarrow$	A_1, A_2
A_2	$\rightarrow$	A_2, A_3
A_3	$\rightarrow$	A_3, A_4
A_4	$\rightarrow$	A_4, A_5
A_5	$\rightarrow$	A_5, A_6
A_6	$\rightarrow$	A_6, A_7
A_7	$\rightarrow$	A_7

The next step is to determine the defuzzification based on the FLRG results using **Equation (5)**. Based on the calculations using **Equation (5)**, the forecasted data is presented in **Table 4**.

Table 4. Defuzzification for Each Interval

Defuzzification	
A_1	12,785.7
A_2	13,021.4
A_3	13,257.1
A_4	13,492.9
A_5	13,728.6
A_6	13,964.3
A_7	14,082.1

After performing defuzzification, the next step is to determine the forecast results for the rice price data. Table 5 displays the predicted results for the rice data using Equation (1). The data for January 2019 is not available (NA) because the forecasting process using the Chen FTS method requires previous data.

Table 5. The Fuzzification Data And FLR

Period	Data	Forecast
1/19	12,600	NA
2/19	12,600	12,785.71
3/19	12,600	12,785.71
4/19	12,600	12,785.71
5/19	12,600	12,785.71
6/19	12,550	12,785.71
⋮	⋮	⋮
12/23	14,100	14,082.14
1/24	14,100	14,082.14
2/24	14,100	14,082.14
3/24	14,100	14,082.14
4/24	14,200	14,082.14
5/24		14,082.14

Table 5 shows that Rp. 14,082 is the predicted price of rice for the upcoming period, which ends in May 2024.

3.2 Forecast Accuracy

After determining the forecasted values for rice prices in Banyumas Regency, the plot of the actual prices and forecasted prices can be seen in Figure 2.

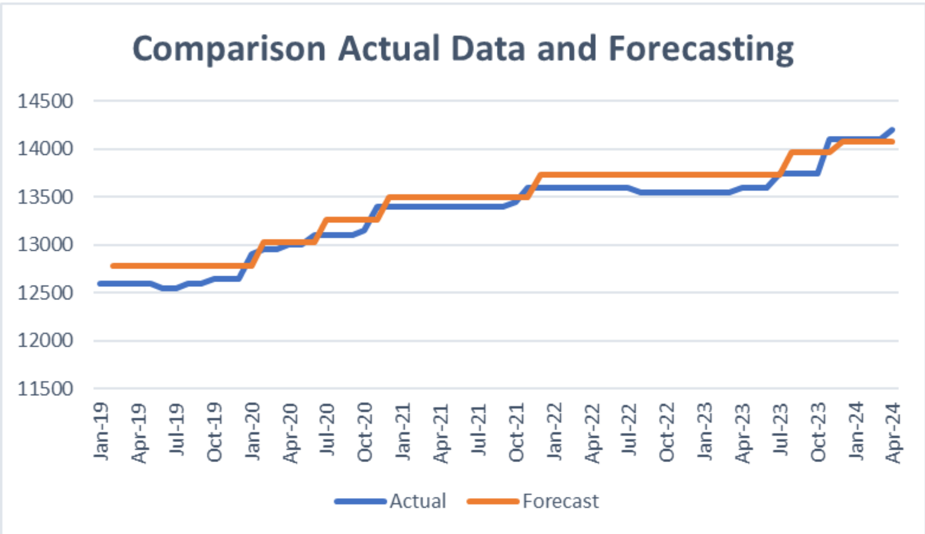

Figure 2. A Comparison Plot Actual Data and Predictions

Figure 2 illustrates how the expected and actual numbers are in close proximity to one another. Next, determine the accuracy of the prediction using the MAE, RMSE, and MAPE values. Table 6 shows the value of three accuracies (RMSE, MAE, and MAPE) of the Fuzzy Time Series Chen.

Table 6. Forecast Accuracy of Rice Prices

Method	MAE	RMSE	MAPE
FTS Chen	127.041	139.04	0.957539

Based on calculations using Equation (8), the MAPE value obtained is 0.957539%. This indicates that the prediction accuracy is very good. This means that forecasting using the Chen fuzzy time series model provides highly accurate predictions of rice prices in traditional markets in the Banyumas Regency, with a MAPE of less than 1%.

4. CONCLUSIONS

Based on the analysis, the predicted rice price in the traditional markets of Banyumas Regency for May 2024 is Rp. 14,082. Furthermore, the accuracy level of the rice price forecasting using the FTS Chen model shows highly accurate predictions, with an error based on the MAPE value of 0.957539%. This study's findings can serve as a reference for future research related to the Chen fuzzy time series model and provide valuable insights for policymakers and market regulators in developing strategies to stabilize rice prices and support economic planning in agrarian regions. However, there are limitations to the application of Chen's FTS model, such as reliance on historical data trends, which may not fully account for sudden market changes. Future research could explore hybrid forecasting models or integrate more dynamic variables to enhance the robustness of rice price predictions under varying economic conditions.

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