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# FUZZY TIME SERIES IN FORECASTING EXPORT PERFORMANCE OF INDONESIAN SEAWEED PRODUCTS

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***ABSTRACT***

*This study applies the Fuzzy Time Series method to forecast the export performance of Indonesian processed seaweed, one of the country's main export commodities, contributing significantly to foreign exchange earnings. The Fuzzy Time Series method is employed for its simplicity and effectiveness in handling time series data with high variability and uncertainty—characteristics often found in export data. Unlike traditional statistical methods, Fuzzy Time Series does not require strict assumptions such as stationarity or normality, making it suitable for real-world applications. Although more appropriate for short-term forecasting, the method still provides meaningful insights for planning and policy. The analysis uses monthly export data from January 2013 to December 2021 to generate forecasts for January to December 2022. The results indicate a positive trend in export performance, with projections showing an increase from 1,707,070 kg in December 2021 to approximately 1,759,763 kg in January 2022. Despite Indonesia's processed seaweed still lagging behind some competitors in terms of competitiveness, its steady growth and rising demand abroad highlight its strong development potential. The forecasting results can be a strategic reference to optimize the commodity's development, increase its added value, and ultimately enhance the country's foreign exchange income.*



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## 1. INTRODUCTION

Forecasting is a process of predicting future values based on available data from the past. Uncertainty and variability make forecasting important in various fields, such as economics, business, weather, and production planning. One method that is widely used to predict is the Fuzzy Time Series method. The Fuzzy Time Series method is a forecasting approach that combines the concept of fuzzy logic with time series. The idea of fuzzy logic was first introduced by Lotfi A. Zadeh in 1965 as an alternative to crisp logic [1]. In this method, time series data is not treated absolutely, but is represented in the form of fuzzy values (uncertain values) to reflect the uncertainty in the phenomenon being studied.

This approach is beneficial when the available historical data is incomplete or has a lot of uncertainty, so the use of traditional forecasting methods based on definite numerical data becomes less effective. The Fuzzy Time Series method can overcome these problems in a flexible and more adaptive way to uncertainty. One of the main reasons for using this method is its ability to deal with uncertain data, where the relationship between variables is not always linear or straightforward. In addition, this method also reduces errors that may arise due to small fluctuations in the data, which can lead to very varied results if traditional forecasting methods such as ARIMA or linear regression are used. Therefore, the fuzzy time series is a more appropriate choice in many situations where the existing data is complex and cannot be analyzed using conventional statistical methods.

The Fuzzy Time Series method can serve as an alternative approach for short-term forecasting, as it has demonstrated reasonably good accuracy in previous applications. However, its specific application to predicting Indonesia's seaweed export performance remains unexamined. This research aims to explore the application of the Fuzzy Time Series method in predicting the performance of Indonesian seaweed exports. The findings from this study can serve as a foundation for enhancing the development of this commodity. This could lead to greater added value, improved export outcomes, and increased contributions to national foreign exchange earnings. Seaweed is one of Indonesia's mainstay commodities, has great export opportunities, and is a source of foreign exchange [2]. From 2010 to 2019, its export volume increased with an average of 194,407 tons. This commodity is exported in international trade as raw materials and processed products [3]. Based on UN-Comtrade data, the export volume of raw materials and processed seaweed products has increased from 2010 to 2019 [4]. The amount of raw materials exported is always greater than the processed products. However, when viewed from its growth, the export volume of processed products is greater than that of raw materials. There was an increase in the volume of processed products of 306.991% in 2012-2019, but only an increase of 120.864% in raw materials. Although seaweed exports are still predominantly in raw form, the growth of processed products is higher. According to the research results of Asshidiq and Agustina (2010-2019), on average, exports of processed Indonesian products to Germany have the highest competitiveness compared to other central export destination countries [5]. In addition, the competitiveness of commodities in the seven central export destination countries shows an increasing trend, which means that Indonesian processed seaweed products are in great demand abroad and have prospects for further development. Strengthened by the research results of Arthatiani, which show that seaweed exports in processed form have the potential to continue to be developed during the Covid-19 pandemic, due to the increasing demand during that period [6].

Processed seaweed products are diverse and commonly exploited by the food and non-food industries. The products serve as food additives in the food industry because they contain good nutrition and can be used to prevent or treat cardiovascular disease [7]. According to Stokvis [8], processed seaweed is one of the additional nutrients in broiler feed, while Gullón [9] found that it is suitable as a sustainable food ingredient in the future, such as a substitute for salt, since it can reduce environmental damage [10]. In the non-food industries, seaweed produces paints, textiles, toothpaste, and cosmetics such as lotions, soaps, and shampoos. Furthermore, the products are helpful in the pharmaceutical industry in manufacturing capsule shells and agar media. It is important to note that solid and liquid waste from the processing can be used for fertilizers, plant media, and lightweight bricks. Concerning sustainable agricultural practices, seaweed extract is a new, environmentally friendly compound that can increase plant immunity against pathogens [11].

It has been discovered that exporting processed products is more profitable in terms of added value compared to when they are in the raw form. Through the Ministry of Industry, the Indonesian government seeks to increase seaweed's added value to become a derivative product with a significant market share, both for domestic and export needs. One of the steps is to optimize the role of the processing industry to have a broad impact on the national economy and the welfare of the community, particularly the farmers [12]. Also, the government is trying to promote the downstream of the seaweed processing industry. Caraka found that Micro, Small, and Medium Enterprises (MSMEs) in Indonesia are developing rapidly and play an essential role in the modern economy [13]. This indicates that MSMEs can be a medium for the development of the industry by paying attention to product improvements, such as processing and packaging innovations that can be implemented to meet minimum standards and improve quality [14].

On average, the competitiveness and promising export market for processed seaweed show that Indonesian products in Germany are highly competitive compared to other major exporting countries from 2010 to 2019. This simply denotes that the competitiveness and export market of the products is still promising among the seven main export countries [13],[3]. Henidar and Firmansyah's research using Revealed Comparative Advantage (RCA) competitiveness analysis shows that Indonesian seaweed in the main export destination countries has a comparative advantage or strong competitiveness [15]. Therefore, it is important to forecast and predict the export performance of seaweed-processed products. Several methods are used when forecasting, including time series data analysis. Also, the soft computing approach applied to the time series is the Fuzzy Time Series (FTS), which combines fuzzy logic with time series analysis [16]. Singh found that the FTS can deal with situations containing higher uncertainty due to large fluctuations and is easy to implement [17].

Some studies have applied the Fuzzy Time Series to predict future data. Wen and Yang [18] predicted rainfall in Taiwan. Septiyana [19] applied this method to predict water consumption. Patria [20] predicted the number of confirmed cases of COVID-19 patients in Indonesia. Ula [21] applied this method in predicting clothing stock. Moreover, Vivianti [22] used the technique to forecast the number of visitors at Fort Rotterdam, and Qalb [23] compared the FTS with the ARIMA model in order to predict inflation data. Meanwhile, Biringallo [24] compared the accuracy level of the Fuzzy Time Series Markov-chain and Cheng methods in forecasting the number of traffic accidents. Sofhya [25] also conducted a Comparison of Fuzzy Time Series Chen and Cheng to Forecast Indonesian Rice Productivity. Julida and Murni [26] compared the Chen model Fuzzy Time Series method with the Markov Chain model to predict rainfall. The results showed that the Markov Chain model was better, with a MAPE value of 36%, compared to the Chen model, which had a MAPE of 57%. Fikri et al. [27] compared the performance of the Fuzzy Time Series Markov Chain (FTSMC) and the Cheng Model in forecasting inflation in Indonesia. The forecast results showed that FTSMC provided higher accuracy than Cheng’s Model. Based on the success achieved by these various studies, as well as the ability of the fuzzy time series to handle data uncertainty and variability, this method of forecasting is becoming increasingly relevant and interesting to apply in various fields.

Based on the increasing competitiveness and demand for seaweed products, this study aims to forecast the export performance in Indonesia using the FTS method. This study does not include a comparative validation with other forecasting methods, only using the FTS method. The interval length is determined using the average-based method and the Sturges method. Widiyani et al. [28] argued that the FTS process does not require complicated systems such as genetic algorithms and neural networks; hence, it is easy to develop, and can solve the problem of forecasting historical data in linguistic values. This study’s results are expected to provide information for the Indonesian government on how to formulate policies regarding processed seaweed products to optimally develop and deliver higher added value in its export activities. Consequently, the industry can be further improved and maximized regarding human resources and technological use.

## 2. RESEARCH METHODS

### 2.1 Data

This study uses secondary data in the form of monthly time series from January 2013 to December 2021 sourced from UN Comtrade (*https://www.unctad.org*). The performance of the product was estimated from the export volume of Indonesian processed seaweed.

### 2.2 Fuzzy Logic

Managing uncertainty has been widely explored through fuzzy logic, which provides a framework for reasoning in environments with imprecise or vague information. As introduced by Zadeh, fuzzy logic systems offer a methodology for 'computing with words'—that is, using linguistic variables instead of precise numerical values [29].

### 2.3 Fuzzy Time Series

Fuzzy time series (FTS) is a method introduced by Song and Chissom in 1993 [30], and it employs the basic concept of fuzzy sets to determine a scenario where historical data is formed into linguistic values [22]. FTS forecasting works by processing previous data saved to generate a new value to be displayed in the future. In FTS, the Interval length significantly impacts the formation of fuzzy relationships, which provide prediction results. For example, the difference in the interval length significantly affects forecasting results and error rate. Therefore, its determination need not be too large or small because it can cause fluctuations or crisp sets [30]. The methods for determining the number of intervals on fuzzy include:

1. Automatic Clustering

   Automatic Clustering is the process of making groupings so that each partition member has similarities based on specific matrices. In other words, it involves grouping numerical data into intervals.

2. Determination of the average-based interval (Average-Based)

   Average-Based is an algorithm that can be used to adjust the interval length determined in the initial forecasting stage when using FTS [1].

3. Sturges Rule

   Sturges rule determines the number of classes in a frequency distribution [31]. Sturges rule can be expressed by Equation (1).

$$K = 1 + 3.3 \times \log n \tag{1}$$

   Where $K$ represents the several classes formed and $n$ is the amount of historical data used.

In this study, the interval determination method employs mathematical approaches. Therefore, the determining number of intervals utilizes the Average-Based method and Sturges Rule.

The stages in the FTS analysis include [32]:

1. Determining the universal set or universe of discourse by finding the minimum and maximum values of the actual data, as shown in Equation (2).

$$U = [D_{min} - D_1, D_{max} + D_2] \tag{2}$$

   with $D_{min}$ is the smallest data in real data, $D_{max}$ is the largest data in real data set, and D is an arbitrary positive number value.

2. The formation of intervals as shown in Equation (3).

$$I = \frac{R}{K} \tag{3}$$

   with $I$ is interval, $R$ is data range ( $D_{max} - D_{min}$), and $K$ is number of classes.

3. Defining a fuzzy set on the universal set.
4. Fuzzification of historical data.
5. Determining Fuzzy Logical Relationship (FLR).
6. Classifying FLR into Fuzzy Logical Relationship Group (FLRG).
7. Defuzzification and forecasting.

Defuzzification is changing the output from the fuzzy logic rules into a firm value using a membership value when fuzzification is performed [33]. The inference process's fuzzy output set is converted back into a crisp output value.

In forecasting, accuracy is regarded as a rejection criterion, which ultimately shows how far the prediction method is able to reproduce the data obtained. Some of the criteria used when testing forecast accuracy include Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) [34] [20] [30]. These accuracy measurements follow the Equation (4), Equation (5), Equation (6), and Equation (7) below:

$$MAE = \frac{\sum_{t=1}^{n} |Y_t - F_t|}{n} \tag{4}$$

$$MSE = \frac{\sum_{t=1}^{n} (Y_t - F_t)^2}{n} \tag{5}$$

$$RMSE = \sqrt{MSE} \tag{6}$$

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{Y_t - F_t}{Y_t} \right|}{n} \times 100\% \tag{7}$$

where $Y_t$ represents the actual data at period $t$, and $F_t$ denotes the forecasted data for period $t$. The interpretation of MAPE results is a mean to judge the accuracy of the forecast—less than 10% is highly accurate forecast, 11% to 20% is a good forecast, 21% to 50% is a reasonable forecast, and 51% or more is an inaccurate forecast [35]. It is important to mention that the optimum forecasting value has the smallest error rate [36]. In other words, the accuracy of a forecasting model in making predictions is determined by the smallest accuracy value. This is consistent with Nur [32], Qalbi [23], and Widiyani [28], who show that a good forecasting method has the smallest data accuracy.

## 3. RESULTS AND DISCUSSION

Based on the descriptive statistics in Table 1, the processed seaweed export volume data reached a respective minimum and maximum value of 301,695 and 1,806,775. The universal set of the minimum and maximum data consists of all the intervals formed. The defined value of $D_1$ is 95, while $D_2$ is 25, and they are both determined with the assumption of being able to produce an interval length that makes it easy to divide the set into classes. According to Equation (2), the universal set is obtained as $U = [301{,}600, 1{,}806{,}800]$. The average-based method produced the number of classes, $K = 16$, and interval $I = 94.075$; hence, the class division of the set and the mean value are obtained as shown in Table 1. When the Sturges method was used, the number of classes $K = 8$, and the interval length is $= 188{,}150$. Table 2 shows the class division of the set and the mean value obtained.

**Table 1. Class Division and the Middle Value of the Average-Based Method**

| Class | Lower limit | Upper limit | Middle value |
|---|---|---|---|
| 1 | 301,600 | 395,674 | 348,637 |
| 2 | 395,675 | 489,749 | 442,712 |
| 3 | 489,750 | 583,824 | 536,787 |
| 4 | 583,825 | 677,899 | 630,862 |
| 5 | 677,900 | 771,974 | 724,937 |
| 6 | 771,975 | 866,050 | 819,012 |
| 7 | 866,051 | 960,125 | 913,088 |
| 8 | 960,126 | 1,054,200 | 1,007,163 |
| 9 | 1,054,201 | 1,148,275 | 1,101,238 |
| 10 | 1,148,276 | 1,242,350 | 1,195,313 |
| 11 | 1,242,351 | 1,336,425 | 1,289,388 |
| 12 | 1,336,426 | 1,430,500 | 1,383,463 |
| 13 | 1,430,501 | 1,524,575 | 1,477,538 |

| Class | Lower limit | Upper limit | Middle value |
|---|---|---|---|
| 14 | 1,524,576 | 1,618,650 | 1,571,613 |
| 15 | 1,618,651 | 1,712,725 | 1,665,688 |
| 16 | 1,712,726 | 1,806,800 | 1,759,688 |

**Table 2. The Class Division of the Set and the Middle Value of the Sturges Method**

| Class | Lower limit | Upper limit | Middle value |
|---|---|---|---|
| 1 | 301,600 | 489,749 | 395,675 |
| 2 | 489,750 | 677,899 | 583,825 |
| 3 | 677,900 | 866,049 | 771,975 |
| 4 | 866,050 | 1,054,199 | 960,125 |
| 5 | 1,054,200 | 1,242,349 | 1,148,275 |
| 6 | 1,242,350 | 1,430,499 | 1,336,425 |
| 7 | 1,430,500 | 1,618,649 | 1,524,575 |
| 8 | 1,618,650 | 1,806,800 | 1,712,725 |

**Table 3** shows the result of the fuzzy set definition from the universal set, the historical frequency of each interval, and the fuzzification outcome.

**Table 3. Class Fuzzification**

| Class | Average Based Frequency | Sturges Frequency | Fuzzification |
|---|---|---|---|
| 1 | 3 | 9 | A1 |
| 2 | 6 | 32 | A2 |
| 3 | 14 | 31 | A3 |
| 4 | 18 | 24 | A4 |
| 5 | 13 | 5 | A5 |
| 6 | 18 | 2 | A6 |
| 7 | 19 | 1 | A7 |
| 8 | 6 | 4 | A8 |
| 9 | 2 | | A9 |
| 10 | 3 | | A10 |
| 11 | 0 | | A11 |
| 12 | 2 | | A12 |
| 13 | 0 | | A13 |
| 14 | 1 | | A14 |
| 15 | 1 | | A15 |
| 16 | 3 | | A16 |

The next stage is historical data fuzzification based on the obtained fuzzy set. **Table 4** shows the data fuzzification result, denoted with linguistic numbers.

**Table 4. Fuzzification Results of Order 1 Export Volume of Processed Seaweed**

| Month | Data | Average Based Fuzzification | Sturges Fuzzification |
|---|---|---|---|
| Jan-13 | 1,115,649 | A9 | A5 |
| Feb-13 | 426,011 | A2 | A1 |
| Mar-13 | 867,441 | A7 | A4 |
| ⋮ | ⋮ | ⋮ | ⋮ |
| Aug-21 | 1,191,509 | A10 | A5 |
| Sep-21 | 1,806,775 | A16 | A8 |
| Oct-21 | 1,683,644 | A15 | A8 |
| Nov-21 | 1,745,862 | A16 | A8 |
| Dec-21 | 1,707,070 | A16 | A8 |

The fuzzified data is formed into a Fuzzy Logic Relationship (FLR) with a time series, and the results are shown in **Table 5**.

**Table 5. Results of First Order FLR Export Volume of Processed Seaweed**

| Month | FLR Order 1 Average Based | FLR Order 1 Sturges |
|---|---|---|
| Jan-13 | - | - |
| Feb-13 | A9→A2 | A5→A1 |
| Mar-13 | A2→A7 | A1→A4 |
| Apr-13 | A7→A7 | A4→>A4 |
| May-13 | A7→A5 | A4→A3 |
| ⋮ | ⋮ | ⋮ |
| Oct-21 | A16→A15 | A8→A8 |
| Nov-21 | A15→A16 | A8→A8 |
| Dec-21 | A16→A15 | A8→A8 |

Furthermore, FLR is classified into FLRG by grouping fuzzy sets with the same current state. The FLRG is determined using Lee's method, in which each repetition is weighted by calculating the mean or defuzzification. The classification results of FLR into FLRG are shown in**Table 6**.

**Table 6. Results of Order 1 FLRG Export Volume of Processed Seaweed**

| Current State | Next State Average Based | Next State Sturges | FLRG |
|---|---|---|---|
| A1 | A6, A7(2) | A1, A2, A3(3), A4(4) | G1 |
| A2 | A2, A3, A5, A6, A7(2) | A1(3), A2(16), A3(8), A4(4), A5(1) | G2 |
| A3 | A1(2), A3(5), A4(3), A5, A7(2), A9 | A1(4), A2(10), A3(10), A4(7) | G3 |
| A4 | A2, A3(3), A4(5), A5(4), A6(3), A8(2) | A2(4), A3(10), A4(8), A5(2) | G4 |
| A5 | A1, A3, A4(3), A6(3), A7(4), A8 | A1, A2, A4, A6, A8 | G5 |
| A6 | A2(3), A3, A4(5), A5(4), A6(3), A7(2) | A6, A7 | G6 |

| Current State | Next State Average Based | Next State Sturges | FLRG |
|---|---|---|---|
| A7 | A3(2), A4, A5(3), A6(5), A7(4), A8(2), A10(2) | A5 | G7 |
| A8 | A3, A6(2), A7(2) | A8(3) | G8 |
| A9 | A2, A4 | | G9 |
| A10 | A7, A12, A16 | | G10 |
| A12 | A12, A14 | | G12 |
| A14 | A10 | | G14 |
| A15 | A16 | | G15 |
| A16 | A15(2) | | G16 |

Before defuzzification, the mean of each interval needs to be calculated. The middle value of the group becomes the first-order forecast value. The FTS technique utilized was the Lee method; hence, weighting was performed to determine the group's mean. Furthermore, the mean of each class was defuzzified for easy forecasting.

Table 7 shows the defuzzification result for the predicted export volume of processed seaweed products from January 2013 to December 2021 and the future.

**Table 7. Forecasting Results of Order 1 Export Volume of Processed Seaweed**

| Month | Actual Data | FLRG Average Based | FLRG Sturges | Average Based Forecast | Forecasting Sturges |
|---|---|---|---|---|---|
| Jan-13 | 1,115,649 | - | - | - | - |
| Feb-13 | 426,011 | G9 | G5 | 536,787.23 | 997,754.87 |
| Mar-13 | 867,441 | G2 | G1 | 724,937.41 | 792,880.32 |
| Apr-13 | 870993 | G7 | G4 | 296,790.13 | 834,691.45 |
| May-13 | 721,980 | G7 | G4 | 296,790.13 | 834,691.45 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Aug-21 | 1,191,509 | G14 | G7 | 1,195,312.86 | 1,148,274.95 |
| Sep-21 | 1,806,775 | G10 | G5 | 1,352.104.67 | 997,754.87 |
| Oct-21 | 1,683,644 | G16 | G8 | 1,665,688.31 | 1,712,725.25 |
| Nov-21 | 1,745,862 | G15 | G8 | 1,759,763.40 | 1,712,725.25 |
| Dec-21 | 1,707,070 | G16 | G8 | 1,665,688.31 | 1,712,725.25 |
| Jan-22 | - | G15 | G8 | 1,759,763.40 | 1,712,725.25 |

Forecasting is done by looking at the fuzzification of the previous data, so that the export volume of processed seaweed products for January 2022 using the average-based interval determination method produces a predictive value of 1,759,763.40 Kg, while the Sturgess method produces a predictive value of 1,712,725.25 Kg.

The same steps were carried out in Lee's Fuzzy Time Series forecasting with the second and third orders. The results of the second-order forecast based on the export volume of processed seaweed products for January 2022 are 1,759,763 Kg, while the Sturgess method produces a predictive value of 1,712,725.25 Kg. The third order for Average Based cannot be done because no FLRG was found for January 2022. The results of the third-order forecasting of the export volume of processed seaweed products for January 2022 with the Sturgess method are 1,759,763 Kg. Fourth-order forecasting is impossible for the Average Based and Sturgess methods because the FLRG in January 2022 was not found. Then, to determine the forecasting method with the best order, it is necessary to compare the accuracy of the forecasting results shown in Table 8.

Based on Table 8, the second-order average-based Fuzzy Time Series (FTS) model exhibits the lowest values across all error metrics—MAE, MSE, RMSE, and MAPE—compared to other forecasting methods. This performance indicates that the FTS model is the most accurate among the alternatives. Notably, the MAPE value of 13.32% places it within the 'Good Forecast' accuracy category, further confirming its superior forecasting capability. Forecasting results for January 2022 to December 2022 use the Second Order Fuzzy Time Series method with Average Based, which can be seen in **Table 9**.

**Table 8. Comparison of Forecasting Accuracy Levels of Export Volume of Processed Seaweed with FTS Order 1, 2, and 3**

| Size Accuracy | FTS Order 1 | | FTS Order 2 | | FTS Order 3 | |
|---|---|---|---|---|---|---|
| | Average Based | Sturgess | Average Based | Sturgess | Average Based | Sturgess |
| MAE | 204,829 | 144,989 | 90,140 | 120,802 | - | 89,165 |
| MSE* | 81,488 | 38,463 | 15,159 | 24,960 | - | 14,631 |
| RMSE | 285,904 | 196,121 | 123,125 | 157,989 | - | 120,959 |
| MAPE | 27.346% | 21.191% | 13.320% | 17.987% | - | 13.343% |

*1,000,000×

**Table 9. Result of Forecasting Export Volume of Processed Seaweed with Second Order Fuzzy Time Series Method with Average Based**

| Month | Fuzzification | FLR | FLRG | Forecasting |
|---|---|---|---|---|
| Jan-22 | A16 | A16, A16→A16 | G52 | 1,759,763 |
| Feb-22 | A15 | A16, A16→A15 | G51 | 1,665,688 |
| Mar-22 | A16 | A16, A15→A16 | G52 | 1,759,763 |
| Apr-22 | A15 | A15, A16→A15 | G51 | 1,665,688 |
| May-22 | A16 | A16, A15→A16 | G52 | 1,759,763 |
| Jun-22 | A15 | A15, A16→A15 | G51 | 1,665,688 |
| Jul-22 | A16 | A16, A15→A16 | G52 | 1,759,763 |
| Aug-22 | A15 | A15, A16→A15 | G51 | 1,665,688 |
| Sep-22 | A16 | A16, A15→A16 | G52 | 1,759,763 |
| Oct-22 | A15 | A15, A16→A15 | G51 | 1,665,688 |
| Nov-22 | A16 | A16, A15→A16 | G52 | 1,759,763 |
| Dec-22 | A15 | A15, A16→A15 | G51 | 1,665,688 |

**Figure 1** shows a graph comparing actual data and forecasting results using the Second Order Fuzzy Time Series method with Average-Based. The results show that the forecasted data has a relatively similar pattern to the actual data.

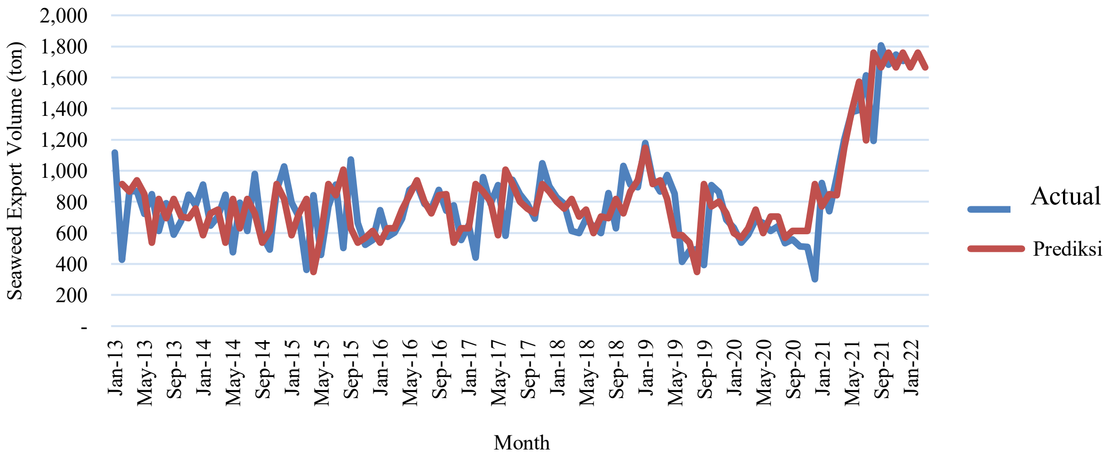


**Figure 1. Comparison of Actual Data and Forecasting Results Using the Second Order Fuzzy Time Series Method with Average Based**

The high demand and value of the products are an opportunity for Indonesia as the world's largest seaweed producer. Export performance can be seen by predicting processed products. It is hoped that these products can be developed more optimally to generate more value for the country's export activities. The forecasting results using Lee's second-order FTS with the Average-based method showed increased exports. In December 2021, the export performance of the commodity reached 1,707,070, and is expected to grow to around 1,759,763 in January 2022. This reinforces the need for the government to be more attentive to enhance the performance of seaweed production.

It was also observed that the potential distribution of the commodity in Indonesia is extensive, both those growing naturally and cultivated in the sea. According to Arthatiani, seaweed is one of Indonesia's leading fishery commodities, most of which are exported in a dried form to China [6]. Opportunities for developing its industries are still open regarding the cultivation of land potential, availability of raw materials, and demand for processed products.

As reported by Khaldun [37], the Government's role in increasing the competitiveness of these products can be categorized into three, namely:

1. Support policy role: The Indonesian Government is expected to issue domestic policies to increase the competitiveness of seaweed products in the global market. Some of these policies are designed for business owners to gain access to information, financial assistance, tax subsidies, and several other benefits.
2. Competitive policy role: In this aspect, the Government must support the increase in the competitiveness of Indonesian seaweed products in the global market through its policies.
3. International policy role: The Indonesian Government can influence international policies to support the development of domestic product competitiveness. The Government needs to develop a policy scheme through relevant ministries based on their roles and duties to provide a clear picture and flow of the policy implementation process, which does not contradict itself.

The Ministry of Maritime Affairs and Fisheries plays a role in developing various innovations to conserve marine and fisheries resources to provide economic, social, and environmental sustainability benefits. In 2014, the ministry created higher competitiveness through continuous innovation and efficiency, undertook development without damaging the environment, established new industries in the marine and fisheries sector, and provided job opportunities by utilizing the marine and fisheries sector. In improving the competitiveness of the commodity, general guidelines were issued for the industrialization of the Marine and Fishery to upgrade the competitiveness of the commodity in the global market. Additionally, through fiscal policy, the Ministry of Finance assisted the seaweed commodity sector by providing financial assistance in setting loan interest rates or giving tax breaks for the companies [37]. This ease in capital allows the company to increase its products in the global market.

Referring to Industry Law Number 3 of 2014, the Ministry of Industry, as the mandate holder of Article 8 paragraph 1, regulates issues related to the National Industrial Development Master Plan (RIPIN). It is important to note that this Ministry is responsible for developing Indonesian seaweed industries through the Industrialization Mechanism. Furthermore, Law no. 3 of 2014 stated that the industry has the potential to become one of the future priorities. The policy was issued as part of the efforts to increase the competitiveness of the country's seaweed products in the global market.

The Ministry of Trade also played a role in setting and regulating policies related to export and import policy issues to increase the competitiveness of the commodity in the global market. Furthermore, it controls the marketing and policies related to import and export. Trade Diplomacy was the main guideline to open market access for the country's products in the global market. Based on the regulations for seaweed import and export, the guidelines can increase the competitiveness of the products in the worldwide market.

As private actors, seaweed business owners played the most crucial role alongside the government in increasing competitiveness. For example, they greatly influenced the policies issued by the government from the upstream, from the cultivation stage to the downstream or industry. The policies issued by the Indonesian government to increase the competitiveness of the commodity in the global market impact the actors running the system from the business side and the government from the bureaucratic aspect. Therefore, the government needs to improve several policy strategies to help develop the industries, particularly at the center of the production areas, and improve business scale. It is important to note that the diversification of processed seaweed products and encouraging cooperation between the processing industries and users can also optimize the product's usage. Based on Law Number 3 of 2014, the Indonesian Seaweed Association (ARLI) is a cooperative institution between industry owners in collaboration with government elements. The ARLI acts as the main forum for all business owners from upstream to downstream sectors, and also incorporates their aspirations about all activities from cultivation, development, to trade.

Institutions or universities also have a role to control, provide input as well as additional information for the government and seaweed business owners in order to assist in making good improvements when determining and implementing policies, as well as in improving the cultivation and business side of the commodity. For business owners, universities provide information and knowledge on the product development from the cultivation to the industrial stage. This infers that there is a need to promote study collaboration and technological innovation as it helps to develop the commodity for both government and business owners.

## 4. CONCLUSION

The second-order average-based Fuzzy Time Series model is the most effective for forecasting the seaweed export performance, as it demonstrates the highest level of accuracy, indicated by the lowest values of RMSE, MAE, and MAPE. Forecasting results for January to December 2022 showed that the average Export performance of processed seaweed products has increased compared to the previous period. In December 2021, the export performance reached 1,707,070 and is expected to increase to about 1,759,763 in January 2022. This implies there is an improvement in the export performance of the commodity, thereby reinforcing the need for more attention from the government through various policies, industry owners, institutions, universities, and other related parties. It has been observed that Indonesia is one of the largest seaweed-producing and exporting countries in the world. This implies that there is a possibility for the development of the industries, which can be further improved in terms of the potential for cultivation areas, the availability of raw materials, and the demand for processed products. Therefore, the government needs to improve several policy strategies to promote the increased export performance of processed seaweed products, such as increasing its productivity and quality, developing the processing industries, particularly at the center of the production areas, and developing business scale. To optimize the use of the commodity, there is a need to diversify the product and encourage cooperation between the processing industry and users. Another policy is to promote study cooperation and technological innovation in developing processed products with domestic and foreign study institutions. Future research should include a comparative analysis of forecasting accuracy using alternative methods, such as ARIMA, machine learning approaches, or other forecasting techniques.

## AUTHOR CONTRIBUTIONS

Neli Agustina: Conceptualization, Investigation, Formal Analysis, Writing - Original Draft. Isna Aissatussiri Asshidiq: Data Curation, Formal Analysis. Robert Kurniawan: Investigation, Validation, Writing - Review and Editing. All authors discussed the results and contributed to the final manuscript.

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## CONFLICT OF INTEREST

The authors declare no competing interest.

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