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Forecasting of Indonesian Annual Protein Demand for Nile Tilapia (*Oreochromis niloticus*) Using Exponential Smoothing

Royani Liza Hayati[1,*], Luchman Hakim[2], Asep Awaludin Prihanto[3], Nurjannah[2]

[1]Doctoral Program of Environmental Science, Graduate School Program, Universitas Brawijaya, East Java, Indonesia
[2]Faculty of Mathematics and Natural Science, Universitas Brawijaya, East Java, Indonesia
[3]Faculty of Fisheries and Marine Science, Universitas Brawijaya, East Java, Indonesia

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Abstract The need for protein or the amount of protein needed by the fish sector in Indonesia has never been recorded and known. Although the demand for protein in aquatic feeds is very high, data related to protein requirements for fish feed in Indonesia need to be known for determining the urgency of providing protein substitutes in feed. So, it is necessary to predict feed and protein demand based on a series of fish production data. This study predicted the protein demand for Nile tilapia (*Oreochromis niloticus*). Three exponential smoothing approaches, namely, single, double, and triple exponential smoothing, were applied to obtain the best model for production estimation. The protein demand was analyzed based on feed conversion ratio and standard protein content in the Nile feed by knowing the production. Production decreased dramatically in 2020. The best approach for predicting is triple exponential smoothing, which predicted a gradual increase of Nile production in 2021. The protein demand for the next five years (2025) is about 345,331.50 to 690,663.00 tons in the scenario of FCR 1.2 and 2.0. It is the first report on predicting protein demand for the production of Nile tilapia. Thus, the government needs to prepare the fulfillment of protein needs for the tilapia fish.

Keywords Annual, Feed, Forecasting, Nile Tilapia (*Oreochromis nilotocus*), Protein Demand

1. Introduction

Global Nile tilapia (O. niloticus) production has gradually increased, even though in early 2020, most of the global output experienced a decline in production [1]. According to FAO, in 2010, Nile tilapia reached 4.3 million tons and is expected to increase to 7.3 million tons by 2030. Indonesia is the second-largest exporting country and contributes 22% to the world's Tilapia fish market [1, 2].

It is important to provide adequate feed in fish farming both qualitatively and quantitatively [3]. Economically, the cost of purchasing feed for fish farming is relatively high. The high cost of feed is due to the protein in the feed composition component from fish meals. The highest cost of fish farming is on the purchase of feed [4]. At the same time, the highest cost of feed is due to the purchase of protein ingredients. About 50-60% of aquaculture cost is feed [5]. Protein becomes an important limitation in fish feed because of its role in growth. One of the critical feed nutrients needed by fish is protein and fat [6]. Protein is an energy source other than carbohydrates for survival and growth, while fat is the largest energy source for fish's bodies. Furthermore, the availability of fish meals in Indonesia still relies on imports. Feed is necessary for growth, fish health, and increasing production quality.

Aquaculture is required to be a major contributor in increasing national fishery production by increasing the production target of aquaculture. Nile tilapia (Oreochromis niloticus) is a fish that has been widely cultivated in Indonesia [7]. This fish has an increased demand due to primarily healthy and taste reasons [8]. Tilapia has a good nutritional value, so it is often used as a cheap and readily available source in the market. Therefore, this fish has great potential to be developed and cultivated.

The number of protein demands related to fish farming is still not available. Meanwhile, these data are fundamental. It is because the protein of the feed usually comes from the fish meal [9]. However, the price of fish meals is one of the reasons why farmers and scientists need to replace fish meals with other unconventional sources of protein from plants and animals [10, 11]. Plant proteins such as soybean, cottonseed, and sunflower meal are currently under investigation [12, 13]. Unfortunately, with this important meaning, the data of protein demand in Indonesia are still absent. Therefore, it is necessary to analyze the needs and predict protein requirements for fish feed, especially Nile tilapia.

Forecasting is an activity to predict a matter or condition that will occur in the future within a certain period, wherein predicting a certain thing requires accurate data in the past, which will be used as a measure so that in the future period, it is under the target. Forecasting is one of the techniques that can be used to predict a value in the future by utilizing data or information in the past to reference the preparation of planning and decision making [14]. The exponential smoothing method has a lower prediction error compared to the percentage of average prediction errors using the Brown exponential smoothing method [15, 16]. This study uses an exponential smoothing method to predict the protein requirement for Indonesia's annual fish feed in tilapia (O. niloticus). In addition, this research is expected to help the central and regional governments prepare protein availability for a fish feed so that there is no shortage of supply in the following years.

2. Materials and Methods

2.1. Data Collection

The data for Nile tilapia production were obtained from the Ministry of Marine and Fisheries (MMF) of the Republic of Indonesia. The data used is data on the number of tilapia aquaculture production data from 2011 to 2020.

2.2. Forecasting the Nile tilapia (*O. niloticus*) Production

Method of Exponential smoothing was applied to predict the production of Nile tilapia. The analysis follows the technique of Ginting and Agustian [17, 18]. The methods used for the prediction, namely, single, double, double, and triple exponential smoothing, were used to approach the best prediction method.

2.2.1. Single Exponential Smoothing (SES)

This method requires minimum computation. The method is applied when the data pattern is usually horizontal due to mainly the data without the history of cyclical, season, and trend [19]. The general formula is as follows.

$$F_{t+m} = \alpha y_t + (1-\alpha)F_t \; F_{t+m} = \alpha y_2 + (1-\alpha)F_t \quad (1)$$

Where F_{t+m} is exponentially smoothed value in period t+m,

Yt is the actual value in the period, α is Constanta (0-1), F_t is the forecast and smoothed value.

2.2.2. Double Exponential Smoothing (DES)

This method is used if the data show a trend. Measurement with this method is the same as single exponential smoothing, but data is assumed to be updated and smoothed following period and trend levels.

$$F_{t+m} = \alpha y_t + (1-\alpha)F_t F_{t+m} = \alpha y_t + (1-\alpha)F_t \; \alpha_{t+m} = 2S_t - S_t$$

$$F_{t+m} = \alpha y_t + (1-\alpha)F_t F_{t+m} = \alpha y + (1-\alpha)F_t \; \alpha_t = 2S_t - S_t$$

$$b_t = \frac{\alpha}{1-\alpha}(St - St')$$

$$S_t = \alpha y_t + (1-\alpha)S_{t-1}$$

$$S_{t'} = \alpha S_t + (1-\alpha)S'_{t-1} \quad (2)$$

Where S_t is the exponentially smoothed value of y_t at time t, S'_t is double exponentially smoothed value of y_t at time t, α_t computed the difference between the exponentially smoothed value, b_t is computed the adjustment factor, F_{t+m} is the forecasting form step ahead period.

2.2.3. Triple Exponential Smoothing (TES)

The triple exponential smoothing method is used when data show seasonal trends and behaviors. The general equation of the triple exponential smoothing method is as follows [20].

$$S_t = \alpha \frac{Xt}{Ct - L.} + (S_{t-1} + b_{t-1})$$

$$b_t = \beta(S_t - S_{t-1}) + (1-\beta)b_{t-1}$$

$$C_t = \gamma \frac{Xt}{Ct - L} + (1-\gamma)C_{t-1}$$

$$F_{t+m} = (S_t + mb_t)C_{t-1+m} \; F_{t+m} = (S_t + mb_t)C_{t-1+m} \quad (3)$$

Where St is the smoothing of the entire t-period, b_t is the smoothing of the trend of the period C_t is a seasonal period to t, α is the data smoothing Constanta (0-1), β is the smoothing Constanta for trend estimation (0-1), γ is the smoothing constant for seasonal estimation (0-1), L is seasonal length, X_t is data to t, m is the number of forecast periods. Finally, ft is the forecast value the next time.

2.3. Choosing the Best Prediction

The best prediction method was chosen by considering the value of Mean absolute percentage error (MAPE), Mean absolute deviation (MAD), and mean squared deviation (MSD). Therefore, the lowest value of those three would be chosen as the best model for predicting fish production.

2.3.1. Predicting the protein demand

The mathematical approach was used to analyze the demand for protein for Nile tilapia (*O. niloticus*). The first mathematical formula was used to diagnose the demand for food based on the amount of fish production. The formula used is as follows:

$$y = \alpha . xy = \alpha . x \quad (4)$$

Where y is a feed demand, a is feed conversion ratio (FCR), and x is fish production. After obtaining the feed demand data, we can predict the protein demand. The protein demand follows this formula:

$$z = b . yz = b . y \quad (5)$$

Where z is a protein composition, and b is a standard for protein content in specific fish, Nile tilapia.

$$z = b . y = b . \alpha . x$$

$$z = a . b . xz = a . b . x \quad (6)$$

The protein demand was calculated based on the above formulation.

3. Results and Discussion

3.1. Production of Nile tilapia (*O. niloticus*)

The vision of the Ministry of Marine and Fisheries (MMF) is to make Indonesia the largest producer of fishery products. Data on total tilapia production in Indonesia from 2011 to 2020 in 34 provinces in Indonesia can be seen in Table 1.

Table 1. Time series production of Nile tilapia (*O. niloticus*) 2011 – 2020

Year	Nile tilapia (Ton)
2011	567,081
2012	695,063.3
2013	914,778.1
2014	999,695
2015	1,084,281
2016	1,114,156
2017	1,288,735
2018	1,169,145
2019	1,337,832
2020	364,747.1

The production decrease is due to restrictions on the movement of the population by the government and decreased purchasing power of the people due to the economy, which also declined [21]. In addition, the health constraints of fish farming workers and the movement of workers and transportation also show their effects on fishery production [22].

The result of the data pattern description and the data plotting is depicted in Figure 1.

The province with the highest Nile tilapia production is West Java Province, from 2011 to 2020 obtained at 2,067,899.37 tons. This is due to the development of the fish farming business in West Java being very intense. The most factor of this high production is a great place for culturing this fish. River, lake, and other water reservoirs with a cage culture system are the most dominant method to produce Nile tilapia [23, 24].

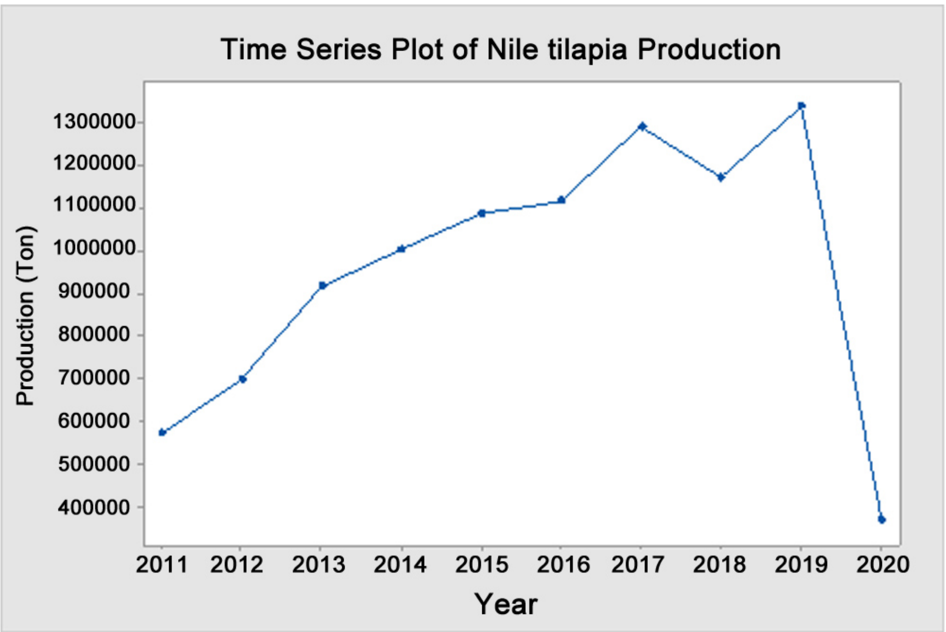

Figure 1. Nile tilapia (*O. niloticus*) production from 2011 to 2020

3.2. Prediction of the Production of Nile Tilapia (*O. niloticus*)

Production predictions can estimate the need for protein for its feed. Production predictions over five years are carried out using a single, double dam triple exponential smoothing approach. The exponential smoothing calculation and analysis results can be seen in Figure 2.

Forecasting using SES generates large values for MAPE, MAD, and MSD with 3.79036E+01, MAD 2.17638E+05, MSD 1.05200E+11 consecutively. The α on single exponential smoothing is 0.623380. The smallest values MAPE, MAD, and MSD were obtained from the analysis using triple exponential smoothing with 3, 18218, and 1090816887, respectively. This α value was chosen because it has the smallest MAPE among others. The smaller MAPE, the better its forecasting capabilities [25]. The data above can also be seen in the estimated total production of tilapia in the following year, which is from 2021 to 2025. It is estimated that the total production of tilapia fish will tend to remain or stay constant, which is about 709,517 tons. This forecast figure shows an increase in total output from the previous year, which only produced 364,747.1 tons. The data obtained on the estimated production of tilapia fish for the next year will make it easier to calculate the protein feed needs of tilapia (*O. niloticus*). The supply of the protein needs of the tilapia fish can be adequately prepared. Protein needs in tilapia range from 25 - 30%, and protein requirements for red tilapia to grow optimally range from 28 - 35% [26, 27].

The analysis of forecasting tilapia production using double exponential smoothing predicts that the total output of tilapia from 2021 to 2025 tends to stagnate until it increases slowly. In 2021 the forecasting results showed an increase to 1,119,999 tons and continued to grow until 2025 but only to 1,204,364 tons. When compared to SES, DES is a greater MAPE value which means the error value is greater than the SES.

Triple exponential smoothing analysis produces the smallest MAPE, MAD, and MSD values among other exponential analyses. Based on the results of testing using the winter method or TES obtained a value of α (level) 0.9 γ (trend) 0.9 and δ (seasonal) 0.9. From the data using TES above, the results of forecasting the total production of tilapia can also be seen, wherefrom the data there is an increase in fish production every year, from 2021 which is expected to produce total tilapia production of 608,922 tons and in 2025 will produce 1,151,105 tons. Therefore, the TES forecast indicated that tilapia production would increase every year.

This increase is evidenced in the first quarter of 2021 which showed an increase in production of 5%. This is addressed by the continuing improvement of the world's handling of the covid 19 outbreak [28]. Therefore, based on MAPE values, MAD and MSD can be concluded that the restoration using the triple exponential smoothing method (winter's method) is most appropriate. Therefore, this method is considered the best way to predict the total production of tilapia in the future.

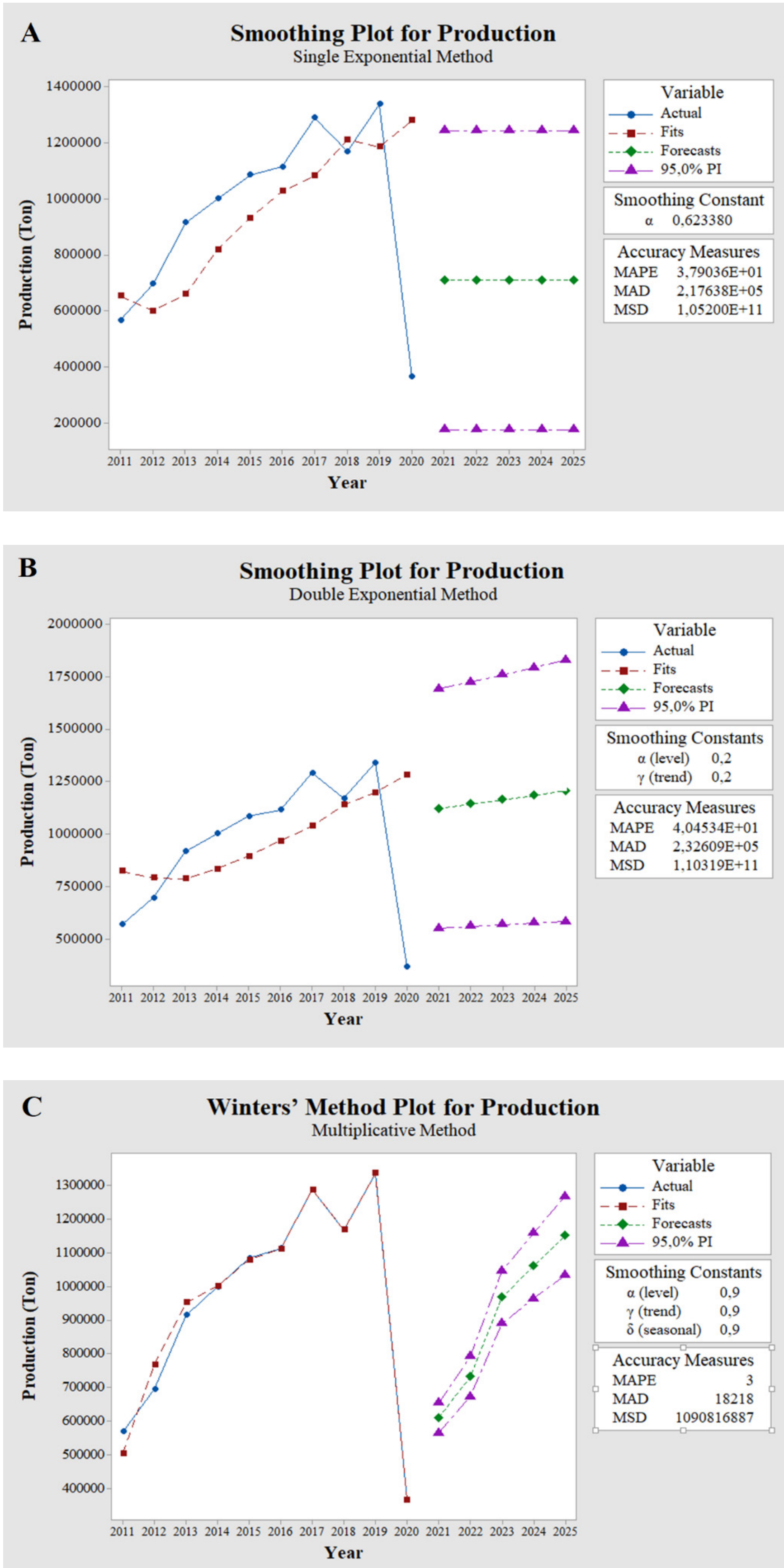

Figure 2. Forecasting result using Exponential smoothing. A. Single, B. double, C. Triple exponential smoothing

Table 2. Prediction of protein demand with various FCR scenarios (Tons per year)

Year	Prod	FCR 1.2		FCR 2.0	
		25%	30%	25%	30%
2021	608,922	182,676	219,211	304,461	365,353
2022	731,553	219,465	263,359	365,776	438,931
2023	967,931	290,379	348,455	483,965	580,758
2024	1,061,191	318,357	382,028	530,595	636,714
2025	1,151, 105	345,331	414,397	575,552	690,663

3.3. Protein Demand

The calculation of protein needs is used with the standard fish, FCR, and protein production approach for Nile tilapia feed. The feed conversion rate (FCR) compares the amount of feed given and the weight of fish produced. It is widely known that the smaller feed conversion, the more efficient is the feed utilization rate [26]. The lower conversion rate value also leads to less feed needed, reducing the cost of feed production and increasing profits. Feed conversion can also estimate feed needs in one maintenance period. According to the Decree of the Minister of Fisheries and Marine Affairs [29], the feed conversion ratio (FCR) of larasati tilapia fish size 3-12 cm has a standard FCR of 1.2 - 1.38. The FCR value of fish in general ranges from 1.5 - 2.5 [21]. The smaller the FCR value, the greater the profit obtained. In good FCR, fish is between 1.5 and 2. This analysis will use two scenarios, with the lowest FCR value and the highest FCR value based on the Ministry of Marine Affairs and Fisheries standards and the standard value of general FCR. Therefore, in this study, we use FCR values 1.2 and 2.0. While the protein content in the values of the fish, according to Zulkhasni and Aziz [26, 27], is approximately 25-30%. Therefore, this study also used two different scenarios, namely fulfilling feed needs with 25% and 30% protein content. The prediction of the protein demand based on the scenario of FRC25% and FCR 30% is shown in Table 2.

The need for fish in Indonesia is enormous. In 2021, the need for protein is in the range of 182,676,60 to 365,353,20 tons. This is corroborated by the production target by MMF that the aquaculture production in 2021 is 19.47 million tons, of which 7.92 million tons are fish and shrimp production. With this count, the availability of fish feed is estimated to reach 9.6 million tons consisting of 1.8 million tons of shrimp feed and 7.8 million tons of fish feed [29]. The highest demand of protein is in 2025. The protein demand is estimated about 345,331.50 - 690,663.00 tons in all scenario of FCR. The high FCR will need the high feed [30].

Nile tilapia fish commodity (*O. niloticus*) plays about 4.36 - 8.72 % of protein needs nationally. These results indicated that the demand for protein would increase, so strategies must fulfill feed proteins. The increase in protein demand is triggered by an increase in fish production. After the covid era, fish farmers were able to increase production by learning production management during the pandemic [31]. This is triggered by the success of the vaccination program and an improvement on the market in Indonesia.

4. Conclusion

Nile tilapia (*O. niloticus*) production has suffered a production decline in 2020. But it began to increase in 2021 and will continue to increase within three years, with a production value of around 1.15 million tons. The implications of the Nile production, Indonesia require the preparation of protein raw materials with a capacity of a maximum 690,663.00 tons in 2025. The amount ranges from 4.36 - 8.72 % of protein needed for aquaculture production in general. The capacity of this protein must be adequately prepared so as not to be counterproductive to efforts to provide food protein for humans. This report is the first report for protein demand in Indonesia to produce Tilapia (*O. niloticus*) fish until 2025.

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