PRODUÇÃO ONLINE
REVISTA CIENTÍFICA ELETRÔNICA DE ENGENHARIA DE PRODUÇÃO
ISSN 1676-1901

SELECTION OF A METHOD FOR FORECASTING FISH DEMAND FROM AQUACULTURE IN THE RIO DOCE BASIN IN MINAS GERAIS (MG) AND ESPÍRITO SANTO (ES), SOUTHEASTERN BRAZIL

SELEÇÃO DE UM MÉTODO DE PREVISÃO DE DEMANDA ORIUNDO DA AQUICULTURA NA BACIA DO RIO DOCE EM MINAS GERAIS (MG) E ESPÍRITO SANTO (ES)

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Abstract: Aquaculture is an activity on the rise in Brazil. In 2019, the state of Minas Gerais emerged as the fourth-largest fish producer, while in the state of Espírito Santo, a significant growth in its production was observed. It is necessary to use processes and methods to help contain future damage. With appropriate methods, it is possible to plan production, reduce losses, and optimize production processes, including demand forecasts and production sizing. The general objective of the study was to select a method for forecasting fish demand from aquaculture in the Rio Doce basin in Minas Gerais and Espírito Santo, both states in the southeast region of Brazil. A bibliographical review and analysis of public IBGE data related to aquaculture production were conducted. The processing of these data, the application of three demand forecasting methods (Simple Moving Average, Weighted Moving Average and Simple Exponential Smoothing), and the assessment of accuracy occurred using electronic spreadsheets. After the analysis, it was found that the best method for forecasting demand is Simple Exponential Smoothing, as it presents the best performance among the others.

Keywords: Rio Doce; Aquaculture; Fishing; Demand Forecast; Production.

Resumo: A aquicultura é uma atividade em ascensão no Brasil. Em 2019, o estado de Minas Gerais emergiu como o quarto maior produtor de pescado, enquanto no estado do Espírito Santo, conseguiu-se observar um crescimento significativo em sua produção. É necessário utilizar processos e métodos que auxiliem na contenção de danos futuros. Com métodos adequados, é possível planejar a produção, reduzir perdas e otimizar os processos produtivos, incluindo previsões de demanda e dimensionamento da produção. Portanto, o objetivo geral do estudo foi selecionar um método para previsão da demanda de pescado da aquicultura na bacia do Rio Doce em Minas Gerais e Espírito Santo, ambos estados da região Sudeste do Brasil. Para tanto, foi realizada uma revisão bibliográfica e análise de dados públicos do IBGE relacionados à produção aquícola. O processamento desses dados, a aplicação de três métodos de previsão de demanda (Média Móvel Simples, Média Móvel Ponderada e Suavização Exponencial Simples) e a avaliação da acurácia ocorreram por meio de planilhas eletrônicas. Após a análise, constatou-se que o melhor método para previsão de demanda é a Suavização Exponencial Simples, pois apresenta o melhor desempenho entre os demais.

Palavras-chave: Rio Doce; Aquicultura; Pesca; Previsão de Demanda; Produção.

1 INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) indicates that in aquaculture, the cultivation of aquatic organisms can include crustaceans, fish, mollusks and even plants, with the main objective of sale and human consumption. The activity can be performed in both fresh and salt water, if it is always under controlled conditions. According to data released by FAO, by the year 2025, Brazil should register a 104% growth in fishing and aquaculture production. Furthermore, the year 2014 was marked by national aquaculture production of 562 thousand tons, with emphasis on freshwater fish (FAO, 2022; Wagner; Coelho; Travassos, 2022).

Considering specifically the area of the present study, the state of Minas Gerais (MG) emerged, in 2019, as fourth place in the ranking of largest fish producing states, with production of 36,217 tons and a share of 6.2% (Minas Gerais, 2020). In parallel, the state of Espírito Santo (ES) has great potential for carrying out aquaculture activities, as, according to the Capixaba Institute for Research, Technical Assistance and Rural Extension (Incaper), it has a favorable climate and good water availability. It is stated that fish production in ES has been growing year after year. In 2019 there was an increase of 4.9% compared to 2018: around 14,230 tons were produced in 2019 compared to 13,180 tons in 2018 (Espírito Santo, 2020).

With this constant productive growth, in addition to the consolidation of its position as one of the emerging sectors of agribusiness in Brazil, (Rocha *et al.,* 2012; Brazil, 2010; Pedroza Filho; Ferreira Filho; Júnior, 2020; Viana, 2020), and the possibility of lack of productive control and/or interference caused by public or private managers, it is necessary to use processes and methods to help (Souza, 2014; Xie *et al.,* 2014; Ferro *et al.,* 2019). With the appropriate means and procedures, it is possible to plan where, when and how much to produce and to check whether everything is in accordance with what was planned. Thus, these methods would have the purpose of contributing to decision-making, avoiding losses, reducing waste and costs, in addition to obtaining the best results in production processes. It is observed that there is space to plan and generate adequate demand forecast for the study region, as well as sizing the storage capacity of the fish produced (Moreira, 2012; Rodrigues *et al.*, 2016; Leite; Brito, 2020; Ackermann; Sellitto, 2022).

Considering the above discussion, there is a need to conduct a better assessment of future demand, to forecast resources that can meet it and try to respond in a timely manner if the real demand does not correspond to the forecast. This study will select an appropriate forecasting method for aquaculture products in municipalities located in the Rio Doce basin, in the states of Minas Gerais and Espírito Santo.

2 THEORETICAL BACKGROUNDS

According to Slack *et al.* (2009), to prepare the demand forecast, it is initially necessary to classify type of forecast, which are: qualitative; time series analysis; causal relationship; and simulation. Decisions surrounding defining the forecast focus will consist of determining the level of detail, scope of the forecast, and identification of information sources.

According to Souza *et al.* (2008), the business costs incurred by inaccurate forecasts can be high. Discrepancies between predicted values and those found in the market can cause serious problems, such as lack of installed capacity or even oversizing resulting from erroneous forecasts. The main motivator of a forecasting project should be the savings that can occur when sales and production balance at the same level, because of more accurate forecasts.

Chopra and Meindl (2011) propose a basic approach to demand forecasting, which consists of six stages that guide the process of carrying out an effective forecast. Initially, the objective of the forecast must be understood, as it will support decision-making in the supply chain. In the second stage, demand planning and forecasting will be integrated, linking capacity, production, promotion and purchasing planning to demand forecasting. In the third stage, the objective will be to understand

and identify customer segments, with the importance of grouping them by: service requirements, demand volume, order frequency or seasonality.

This way, the company will be able to use different types of forecasts for each customer segment, obtaining greater accuracy of results (Chopra; Meindl, 2011). The last three steps will be: identifying the factors that influence the demand forecast, checking whether demand has seasonality and trends, and on the supply side, checking whether there is a source of supply; determining the appropriate forecasting technique, initially understanding the geographic area, product group and customers; and finally, establishing performance and error measures for forecasting, which must be correlated with the forecasting objectives (Chopra; Meindl, 2011).

According to Lemos (2006), to determine the methods, the most important selection criteria should be analyzed, such as availability and type of data; the knowledge of experts; the existence of conflicts; and whether conceptual changes are expected in the future. The author also states that two macro criteria are used to determine quantitative or qualitative methods, namely: industrial level of prediction and the stage of the product’s life cycle. Then, more detailed criteria will be used to choose the most appropriate demand forecasting method.

Finally, Gonçalves (2007) mentions that after selecting the method, it will be necessary to study its main characteristics to confirm whether the selected forecasting method suits the situation analyzed.

3 METHODOLOGY

The present study covers the following municipalities: Mariana, Ponte Nova, Barra Longa, Rio Doce, Santa Cruz do Escalvado, Rio Casca, Sem-peixe, São Pedro dos Ferros, São José do Goiabal, Raul Soares, São Domingos da Prata, Dionísio, Córrego Novo, Pingo D'água, Marliéria, Bom Jesus do Galho, Timóteo, Caratinga, Ipatinga, Santana do Paraíso, Ipaba, Belo Oriente, Bugre, Iapu, Naque, Periquito, Sobrália, Fernandes Tourinho, Alpercata, Governador Valadares, Tumiritinga, Galiléia, Conselheiro Pena, Resplendor, Itueta, and Aimorés, all located in Minas Gerais. In Espírito Santo, it comprises the municipalities of Marilândia, Baixo Guandu, Colatina, Linhares, Aracruz, and Fundão.

To researching, analyzing and evaluating scientific production activities related to the proposed topic, the available databases from the Scopus, Web of Science – WoS, Scielo and Google Scholar platforms were used as secondary data. These databases were chosen because they cover a series of highly relevant articles, coming from journals with greater visibility within the academic community (Jankowsky *et al.,* 2021).

Data collection was conducted by utilizing the graphically displayed data available on the Brazilian Institute of Geography and Statistics (IBGE) website, related to aquaculture. This data includes the quantity and value of production and is dated from 2013 to 2021. Data prior to 2013 could not be used as the IBGE only started to include these numbers from 2013 onwards (IBGE, 2014).

In the continuation of the study, three statistical methods were used to forecast demand applied to previously collected time series, as they are based on historical projection methods. One of them is the Simple Moving Average (Equation 1), which, according to Tubino (2017), uses several periods that are previously determined to generate the forecast. For each new forecast period, the oldest data is replaced by the most recent one. This method is advantageous for its operational simplicity and ease of understanding (Tubino, 2017; Guerrini, 2018).

$$Mm_n = \frac{\sum_{i=i}^{n} D_i}{n} \quad (1)$$

Mm_n= Moving average of n periods;

D_i= Demand occurred in period i;

n = Number of periods;

i = Period index (i = 1, 2, 3, ...).

The second method used was the Weighted Moving Average (Equation 2), it being a variation of the Simple Moving Average. It weighs the relevance of forecast periods with the attribution of weights, as long as, when added together, they result in 1. One of the advantages that this method has over the previous one is that the most recent demand values are given greater importance (Moreira, 2012; Guerrini, 2018).

$$Mmp_n = \frac{\sum_{i=1}^{n} w_i D_i}{\sum_{i=1}^{n} w_i} \quad (2)$$

Mmp_n= Weighted moving average of n periods;

D_i= Demand occurred in period i;

w_i= assigned weight;

n = Number of periods;

i = Period index (i = 1, 2, 3, ...).

As for Simple Exponential Smoothing (Equation 3), the last method used, the applied weight decreases exponentially over time. New forecasts are obtained from the previous forecast, increased by the previous error and corrected by a smoothing coefficient. In turn, the coefficient (α) varies in a range between 0 and 1. The higher its value, the model may have many variations; the lower its value, the predictions may be outdated (Moreira, 2012; Tubino, 2017; Guerrini, 2018; Santos, Silva and Sobral, 2020).

$$M_t = M_{t-1} + \alpha(D_{t-1} - M_{t-1}) \quad (3)$$

M_t= Forecast for period t;

M_{t-1}= Forecast for period t – 1;

α = Weighting coefficient;

D_{t-1}= Demand for period t – 1.

To calculate the demand forecast, electronic spreadsheets were used, as well as the Solver optimization software, to find the smoothing constants (Equation 3) and the assigned weights (Equation 2) necessary for the calculations made.

The Mean Absolute Deviation (MAD) (Equation 4) was used to evaluate the performance of the models, which, according to Sarmento *et al.* (2017), is calculated to indicate whether the forecast model being used is suitable for the situation being analyzed. It measures data dispersion and is the most used due to its easy understanding, indicating a measure of average error per period (Tubino, 2017; Guerrini, 2018).

$$MAD = \frac{\sum|D_{atual} - D_{previsão}|}{n} \quad (4)$$

D_{atual} = Demand occurred in the period;

$D_{previsão}$ = Expected demand in the period;

n = Number of periods.

The second method used was the Weighted Moving Average (Equation 2), being a variation of the Simple Moving Average. It weighs the relevance of forecast periods with the attribution of weights, as long as, when added together, they result in 1. One of the advantages that this method has over the previous one is that the most recent demand values are given greater importance (Moreira, 2012; Guerrini, 2018).

As for Simple Exponential Smoothing (Equation 3), the last method used, the applied weight decreases exponentially over time. New forecasts are obtained from the previous forecast, increased by the previous error and corrected by a smoothing coefficient. In turn, the coefficient (α) varies in a range between 0 and 1; the higher its value, the model may have many variations; the lower its value, the predictions may be out of date (Moreira, 2012; Tubino, 2017; Guerrini, 2018; Santos, Silva and Sobral, 2020).

To carry out demand forecast calculations, it was necessary to use electronic spreadsheets, as well as the Solver optimization software, to find the smoothing constants (Equation 3) and the assigned weights (Equation 2) necessary for the calculations carried out.

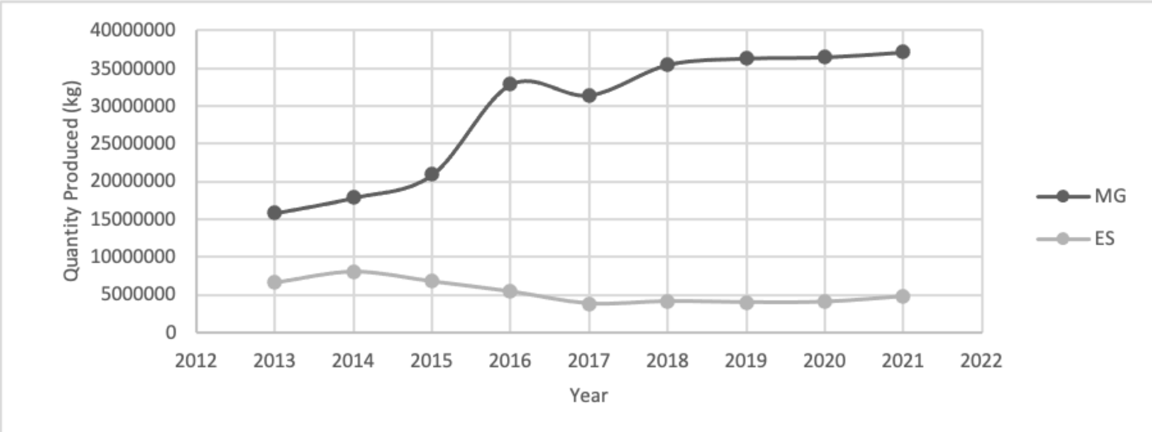
To evaluate the performance of the models, the Mean Absolute Deviation (MAD) (Equation 4) was used, which according to Sarmento *et al.* (2017), is calculated to indicate whether the forecast model being used is suitable for the situation being analyzed. Furthermore, it measures data dispersion and is the most used due to its easy understanding, indicating a measure of average error per period (Tubino, 2017; Guerrini, 2018).

4 RESULTS AND DISCUSSION

4.1 Aquaculture production

The quantity of aquaculture products produced in the state of Minas Gerais has been growing progressively, according to data from IBGE (Graph 1). There is a growth of around 134% in production, if compared with the amount from 2013 until the most recent report made available by the Institute in 2021. In Espírito Santo, growth is less progressive, with a reduction of around 28% in production between 2013 and 2021. However, stability has been observed in recent years, that is, production maintained a slight growth of 18% between 2020 and 2021. Therefore, as seen in Graph 1, there is the constant growth of aquaculture activity in Minas Gerais and a stability in Espírito Santo. With this, there is the need to forecast future events, making a connection with decision making, planning, and formulating strategies to deal with any difficulties that may arise (Makridakis *et al.,* 1998; Pellegrini; Fogliatto, 2001; Ferro *et al.,* 2019; Zhuang; Yu; Chen, 2022).

Graph 1 - Total quantity produced (in kg) of aquaculture products in the states of MG and ES



Source: Instituto Brasileiro de Geografia e Estatística (2022).

The demand forecasting techniques, or forecasting, are directly linked to decision making, a factor that is of great importance to business management, and have great value in terms of observing behavior, and are effective. Furthermore, these techniques provide relevant information for planning and controlling the functional areas of organizations (Pellegrini, 2001; Rocha *et al.,* 2012; Ferro *et al.,* 2019; Leite; Brito, 2020). According to the study by Ackermann and Sellitto (2022), the performance of demand forecasts in different areas of management generates motivation for planning, a detail that the study of Petropoulos *et al.* (2018) adds to the fact that demand forecasts contribute to generating a business plan with information on variables related to raw materials and labor.

Furthermore, it was clear that the fish industry is expanding due to consumer demand and technological innovation. The need for storage and processing arises, considering that fish is different from other foods of animal origin due to its unique characteristics, requiring appropriate processing as it tends to deteriorate. Considering these factors, an appropriate storage and sizing method is required (Minozzo, 2011).

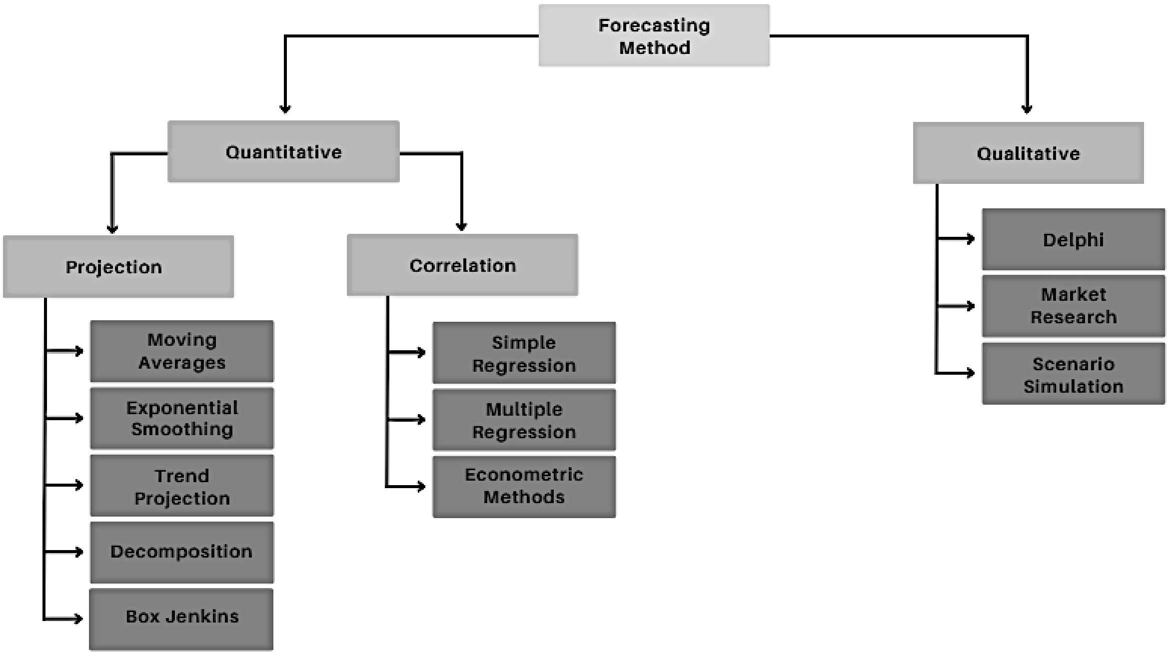
According to Smith and Hanna (1990), the sizing of a fleet's fishing capacity can be established considering four fundamental elements: technical efficiency; the number of vessels; the dimensions of each boat; and the time dedicated to fishing by each unit. Technical efficiency is the most difficult to estimate and monitor, as there are different strategies for fishing. The lack of data in this area leads to the association of fishing power with measures such as the size of vessels, the type of equipment used, the presence of engines, the power of the engines and the number of boats (Bonomo; Bellumat; Freitas, 2019).

However, according to Brazil (2008), the enterprise has no guarantees regarding the quality and quantity of what they will obtain. Thus, the impossibility of controlling certain variables that involve the activity makes it sensitive for analysis. Therefore, the storage chambers need to be sized, checking the storage capacity for fish production in the defined study area. According to Moreira (2009), another factor limiting production capacity is external factors, such as product quality standards required by customers, environmental factors, and anti-pollution legislative factors, which may cause problems in the short or long term, until the organization adapts to meet these requirements.

4.2 Selection and application of demand forecasting methods

To make the correct selection of forecasting methods, it is necessary to analyze some factors and criteria, such as availability and type of data, knowledge about the forecasting methods and whether there is a possibility of changes in the future. These items act as the first filters that must be evaluated to guide the choice of quantitative and/or qualitative forecasting methods (Figure 1).

Figure 1 - Main demand forecasting methods



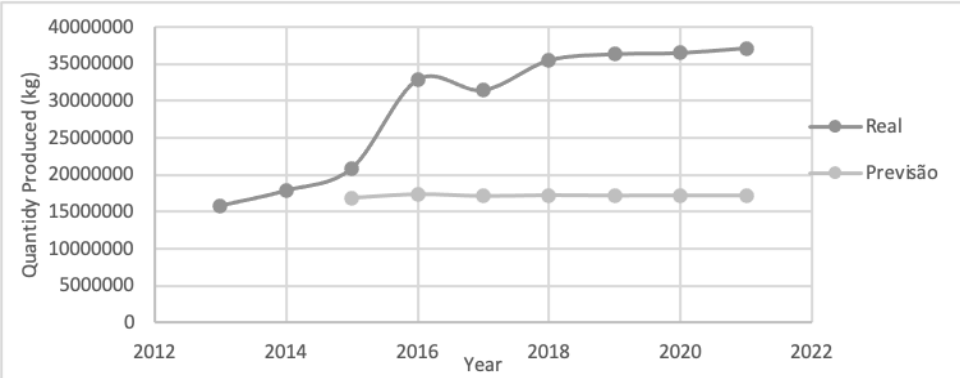
Source: Leite & Brito (2020), adapted from Lustosa *et al.,* (2008)**.**

To proceed with a quantitative bias, it is necessary to verify whether the case in question has the availability of numerical data. When the case does not have sufficient data for mathematical modeling or when the use of simpler models is preferred, the use of qualitative methods is preferred. Once the method has been defined and applied, it is essential to check whether its efficiency is satisfactory for the case, and it is necessary to evaluate the accuracy of the prediction, examining whether there is a very large error horizon (Sampron, 2005; Lemos, 2006; Tubino, 2009; Leite; Brito, 2020; Meira; Oliveira; Jeon, 2020; Zhuang; Yu; Chen, 2022).

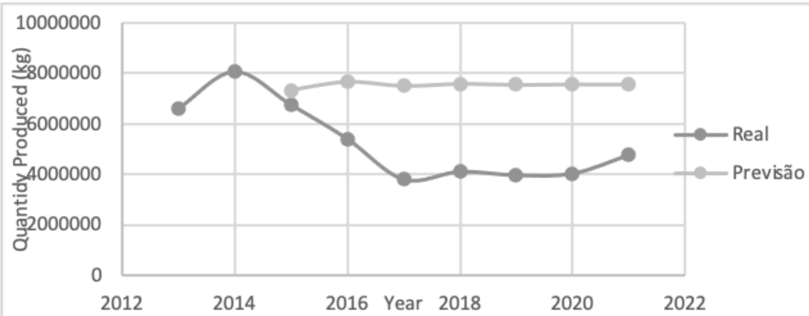
Considering the quantitative data obtained from IBGE and following the selection flowchart of forecasting methods, it was found that the study continues to have a bias in forecasts based on historical projection methods, of the total quantity of aquaculture products in the states of Minas Gerais and Espírito Santo. Therefore, the models used are justified regarding the Simple Moving Average, Weighted Moving Average and Simple Exponential Smoothing, or First Order, methods.

To apply the Simple Moving Average, the first two observed periods were used, and it was noted that for the Minas Gerais region (Graph 2), the method did not adapt to demand, with the forecast proving to be far from the real one. The same can be observed for the Espírito Santo region, where the observed forecast proved to be higher than actual demand (Graph 3), which is justified due to the drop-in production between 2015 and 2017, which may have influenced the projection based on the simple average of the chosen and observed periods. Furthermore, it was found that production may have been affected by a strong water crisis that devastated the state and consequently these activities in 2015 and 2016 (IJSN, 2018).

Graph 2 - Application of the Simple Moving Average Method in the Minas Gerais region

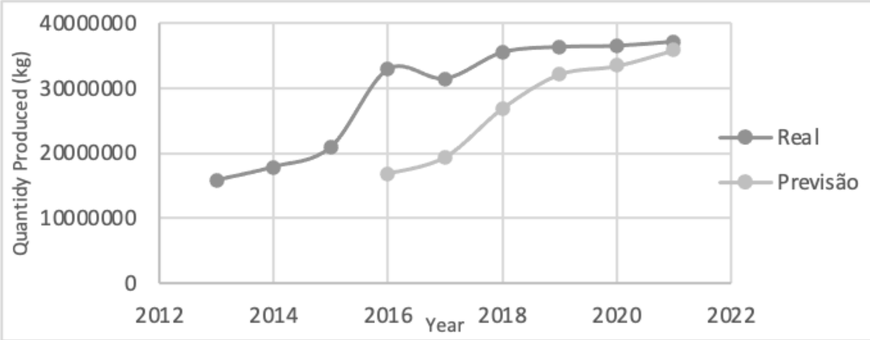


Graph 3 - Application of the Simple Moving Average Method in the Espírito Santo region

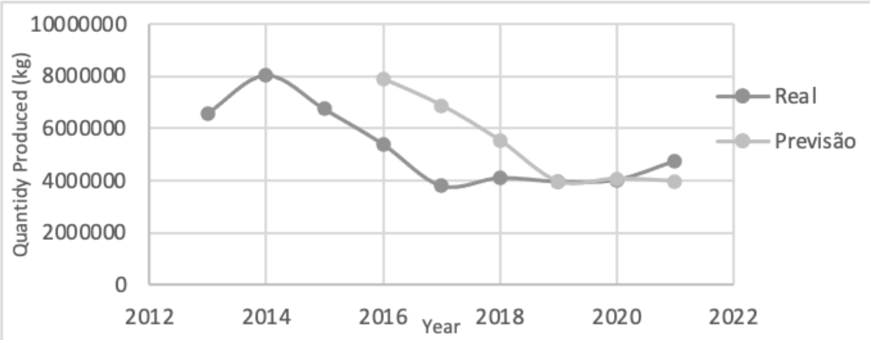


Moving on to the application of the Weighted Moving Average method, an evolution in the adequacy of the series was observed, compared to the previous one. For Minas Gerais (Graph 4), the forecast was lower than the real one in the first periods observed but followed demand in the last ones. For the Espírito Santo region (Graph 5), the forecast followed the real in 2019 and 2020, with little variation between both.

Graph 4 - Application of the Weighted Moving Average Method in the Minas Gerais region

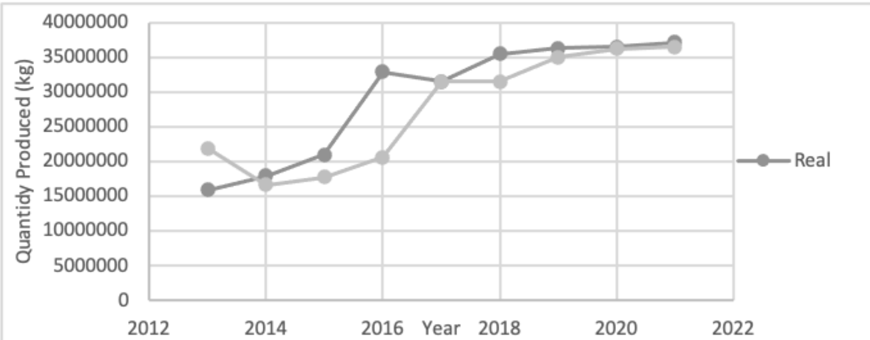


Graph 5 - Application of the Weighted Moving Average Method in the Espírito Santo region

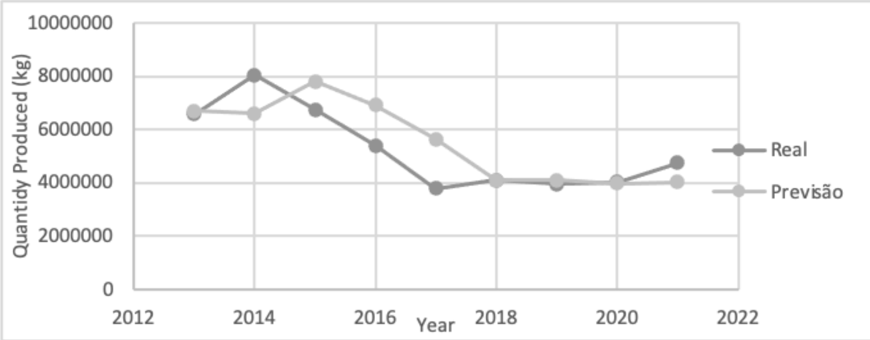


After determining the smoothing constant α by Solver, it was possible to apply the Simple Exponential Smoothing method. It can be observed that when compared with previous methods, it was the one that best suited the series in both regions (Graphs 6 and 7), with the forecast being close to real demand.

Graph 6 - Application of the Simple Exponential Smoothing Method in the Minas Gerais region



Graph 7 - Application of the Simple Exponential Smoothing Method in the Espírito Santo region



4.3 Evaluation and discussion of model performance

After applying the methods, the Mean Absolute Deviation was used to determine the best method that suits the quantity of aquaculture products produced in the studied regions. For a better visualization, Tables 1 and 2 were prepared with the results found for each method previously applied, for Minas Gerais and Espírito Santo, respectively.

Table 1 -Performance Assessment of Models Applied in Minas Gerais

Mean Absolute Deviation (MAD) - Minas Gerais	
Simple Moving Average	15784496
Weighted Moving Average	7508873
Simple Exponential Smoothing	**3248510**

Table 2 - Performance Assessment of Models Applied in Espírito Santo

Mean Absolute Deviation (MAD) - Espírito Santo	
Simple Moving Average	2857849
Weighted Moving Average	1311357
Simple Exponential Smoothing	**772263**

It should be noted that for both cases, the Simple Moving Average method was the one that obtained inferior results, both for the graphical analysis and for the performance evaluation analysis. The same can be seen for the Weighted Moving Average model. What may have happened is that, according to Viletti *et al.* (2016), the method does not present good results when there are historical series that show a trend or seasonality, which occurs in aquaculture production (Portella *et al.,* 2021).

Fernandes *et al.* (2023) also highlight that for the Weighted Moving Average method, when demand is unstable and subject to frequent changes, lower values are likely to produce better results. Therefore, subsequent predictions involve the addition of new data and the disregarding of previous data. After applying the method by Candeias, Olivo and Lemos (2020), it was identified that it has high prediction errors, using a time interval that demonstrated a large margin of error.

The same can be observed in the study by Oliveira, Dourado and Mello (2017), in which it was found that there is only a 29% chance that the forecast obtained with this model will meet demand. In Silva, Silva and Bueno (2022), the simple moving average, by disregarding trends and seasonality, produced a forecast based on the last four months that does not align with real data. Many times, there were optimistic forecasts when the actual values were pessimistic and vice versa. This type of result was also found in Rangel *et al.* (2022), when the forecast often contradicted the actual result, predicting peaks when valleys occurred and vice versa. In the study by Fogaça, Leite and Filho (2021), the method has a slow response to changes in demand and cannot predict peaks, as it smoothest the results, losing the maximum and minimum values.

However, it was possible to observe that using the Simple Exponential Smoothing method the results were more positive in planning, with better precision and superior accuracy in forecasting demand for aquaculture products in the municipalities located in the Rio Doce basin, in the states of Minas Gerais and Espírito Santo. The method was also effective in the study by Frizzo, Cyrne and Ramaswami (2000), in which it presented the smallest error compared to other methods used, allowing the creation of an advantageous strategy for the aggregate production planning of the company analyzed. The authors emphasize that using this method was essential to improve production through effective planning in the purchase of inputs and raw materials. Fernandes *et al.* (2023) justify the use of the method, as it has the advantage of exponentially reducing the weight of older data over time. However, as a disadvantage, it does not deal well with trends or seasonality, resulting in uncertainty.

As pointed out in the study by Oliveira, Dourado and Mello (2017), the smoothing models, due to the constants that allow adjusting the seasonality and/or trend components, obtained satisfactory results. Furthermore, they are simple to apply and understand. In their analysis, Oliveira *et al.* (2023) indicate that when using the simple exponential smoothing method, there was an improvement in forecast accuracy compared to the simple moving average, due to the influence of the constant α, which allows the impact of the most recent demands to be considered in future projections.

5 CONCLUSIONS

The main objective of the study was to select a demand forecast method, considering the sizing of storage and processing capacity for fish from aquaculture in the Rio Doce basin in the states of Minas Gerais and Espírito Santo. With the historical series from IBGE from 2013 to 2021, six forecasts were made using three different methods, related to each region of the Rio Doce basin, in Minas Gerais and Espírito Santo. The chosen methods were related to historical projection, namely: Simple Moving Average, Weighted Moving Average and Simple Exponential Smoothing.

The method that presented the best results was Simple Exponential Smoothing, and the one that presented the lowest results in comparison was the Simple Moving Average. To reach this conclusion, the performance of these models was verified by applying the Mean Absolute Deviation (MAD) for each projection made. Thus, as the main contribution to the need for decision-making for planning growing activities, such as aquaculture, it is highlighted that demand forecast analyzes avoid lack of production control, reduce losses, and optimize processes.

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Artigo recebido em: 08/07/2024 e aceito para publicação em: 04/07/2025
DOI: https://doi.org/10.14488/1676-1901.v25i3.5336