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# Modeling Anchovy Fish Production in Turkey using Artificial Neural Networks and Simple Moving Average Methods

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## ABSTRACT
The aim of this study is to determine the production modeling by using artificial neural networks (ANN) and simple moving average (SMA) methods to model and predict the anchovy fish production in Turkey by years.
The study is based on anchovy production data spanning the years 2000-2022. In the development of ANN and SMA, the years variable was used as the input parameter, and the production quantity was used as the output parameter. Hyperbolic Tangent Function was used as activation function in ANN method.
The effectiveness of the developed model was determined by goodness of fit statistics such as Mean Square Error (MSE) and Mean Absolute Error (MAE). The MSE value was found to be 799 020.596 and 4 808 945 429.614 for ANN and SMA methods, respectively, and the MAE value was found to be 452.352 and 58 618.005 for ANN and SMA methods, respectively. When ANN and SMA were compared, the ANN method, which gave the smallest MSE and MAE values, gave better results.
As a result of the prediction made according to ANN, it has been shown that anchovy fish production will be in a fluctuating course in the period 2023-2027. In 2023, the amount of anchovy fish production is expected to increase slightly to 128062 tons, in 2024 it is expected to decrease slightly to 120963 tons and in 2025 the decrease is expected to continue. However, in 2026, anchovy production is expected to increase to 147177 tons, and in 2027, it is expected to decrease again to 107202 tons. It can be suggested that the use of ANN method in production modeling gives appropriate results.

**Keywords:** Artificial neural networks, moving average, anchovy, production.

## I. INTRODUCTION

Fishing has been an important source of food for humanity since time immemorial and has been an activity that provides economic gain and employment for those engaged in this activity.

The rate of consumption of seafood, which is very important in the healthy nutrition of people, is constantly increasing. The contribution of aquaculture to this increase is considerable. Approximately 111.2 million tons/year of aquaculture products are obtained by fishing in the world (FAO, 2019).

Total world aquaculture production (capture and aquaculture) has generally increased continuously in the last hundred years. As fishing in the seas and inland waters increases with the acceleration of technological developments, fish stocks tend to decrease. World aquaculture production, which was 4 million tons in 1910, reached 100 million tons in 1989. Aquaculture production declined to 96.9 million tons in 1991 (Ministry of Transportation, 2011). According to 2016 FAO data, world aquaculture production is approximately 170.9 million tons, of which 90.9 million tons are obtained from the seas through fishing and 80 million tons through aquaculture. In 2017, 172.66 million tons, of which 92.5 million tons were obtained from marine fisheries and 80.1 million tons from aquaculture. In 2018, 178.57 million tons, 96.44 million tons of which were obtained from the sea through fishing and 82.12 million tons through aquaculture. In 2019, 177.87 million tons, of which 92.51 million tons were obtained through marine fisheries and 85.36 million tons through aquaculture.

Elekon (2007), in his study comparing the fisheries management of Turkey and the EU, reported that pioneering studies on the regulation of the Turkish fishing fleet, establishment of a reliable data collection system, elimination of deficiencies in inspection, taking scientific stock assessment studies as a basis in the regulation of fishing, landing the catch from certain ports and recording them should be expanded.

Considering the importance of anchovy fish in Turkey's marine fish production and in the ecosystem, it is necessary to accurately determine and continuously monitor the stocks of this species in order to ensure the healthy management of its stocks (Mutlu, 1994).

Anchovy is the most important fish in the Mediterranean basin as well as in Turkey and the Black Sea fisheries. Anchovy constitutes more than 50% of the fish caught from the seas in Turkey. Anchovy is represented by 2 species in the Black Sea where it is abundant; these species are called Black Sea anchovy (*Engraulisencrasicolusponticus*) and Azov anchovy (*Engraulisencrasicolusmaeticus*) (Genç, 2007).

Many studies have been conducted on the catch, biology, population dynamics, and processing of anchovy fish, which has an important place in the fisheries sector (Duyar and Bayraklı, 2005; Bilgin et al., 2006; Yıldırım, 2006; Kalaycı et al., 2006; Erdoğan-Sağlam and Sağlam, 2013; Özdemir et al., 2018). Some studies conducted with artificial neural networks in the field of fisheries and agriculture are noteworthy (Benzer and Benzer, 2018; Civelek, 2021; Çelik, 2020; Çelik, 2021; Çelik, 2022).

The aim of this study is to analyze the production amount of the most caught anchovy fish in Turkey comparatively with artificial neural networks and moving average method and to make predictions for the future.

## II. MATERIAL AND METHODOLOGY

The material of the study consists of anchovy production amount (tons) between 2000-2023 (23 years) in Turkey. The data used in the study were obtained annually from www.tuik.gov.tr and https://biruni.tuik.gov.tr/medas/?kn=210&locale=tr websites of the Turkish Statistical Institute (TurkStat). Statistical analysis of the data was made with SPSS 25.0 and the Zaitun Time Series package program.

### Moving Average Method

Simple moving average or central moving average operations can be applied to eliminate or smooth out seasonal, cyclical, or irregular fluctuations (Kadılar, 2009). The simple moving average (SMA) method will be described here.

In the Simple Moving Average (SMA) process,

$$SMA = \frac{Y_t + Y_{t-1} + \cdots + Y_{t-(k-1)}}{k}$$

formula is used. Here, k is the number of stretching. Stretching is used to gradually remove fluctuations and flatten the graph of the series. The determination of the number of stretching is up to the researcher. If k is chosen larger, the series will flatten. In general, k is preferred to be the same size as the period. As the number of stretching increases, the number of missing observations will also increase (Kadılar, 2009). The calculation of moving averages is given in Table 1 (Serper, 2004).

**Table 1.** Triple and quadruple moving average calculation

| Period | Serial | Triple moving averages | Quadruple moving averages |
|---|---|---|---|
| 1 | $Y_1$ | … | |
| 2 | $Y_2$ | $\bar{Y}_2 = (Y_1 + Y_2 + Y_3)/3$ | |
| 3 | $Y_3$ | $\bar{Y}_3 = (Y_2 + Y_3 + Y_4)/3$ | $\bar{Y}_3 = (0.5Y_1 + Y_2 + Y_3 + Y_4 + 0.5Y_5)/4$ |
| 4 | $Y_4$ | $\bar{Y}_4 = (Y_3 + Y_4 + Y_5)/3$ | $\bar{Y}_4 = (0.5Y_2 + Y_3 + Y_4 + Y_5 + 0.5Y_6)/4$ |
| 5 | $Y_5$ | $\bar{Y}_5 = (Y_4 + Y_5 + Y_6)/3$ | $\bar{Y}_5 = (0.5Y_3 + Y_4 + Y_5 + Y_6 + 0.5Y_7)/4$ |
| 6 | $Y_6$ | $\bar{Y}_6 = (Y_5 + Y_6 + Y_7)/3$ | $\bar{Y}_6 = (0.5Y_4 + Y_5 + Y_6 + Y_7 + 0.5Y_8)/4$ |
| 7 | $Y_7$ | $\bar{Y}_7 = (Y_6 + Y_7 + Y_8)/3$ | $\bar{Y}_7 = (0.5Y_5 + Y_6 + Y_7 + Y_8 + 0.5Y_9)/4$ |
| 8 | $Y_8$ | … | … |
| 9 | $Y_9$ | … | … |
| … | … | … | $\bar{Y}_{n-3} = (0.5Y_{n-5} + Y_{n-4} + Y_{n-3} + Y_{n-2} + 0.5Y_{n-1})/4$ |
| n-2 | $Y_{n-2}$ | $\bar{Y}_{n-2} = (Y_{n-3} + Y_{n-2} + Y_{n-1})/3$ | $\bar{Y}_{n-2} = (0.5Y_{n-4} + Y_{n-3} + Y_{n-2} + Y_{n-1} + 0.5Y_{n-1})/4$ |
| n-1 | $Y_{n-1}$ | $\bar{Y}_{n-1} = (Y_{n-2} + Y_{n-1} + Y_n)/3$ | … |
| n | $Y_n$ | … | … |

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**Artificial neural networks (ANN)**

An artificial neural network is a flexible mathematical model inspired by the working principles of the human brain (Wang et al., 2010). With ANN, many operations that the human brain can perform can be done easily by eliminating the weaknesses of humans (hunger, fatigue, emotional breakdowns, etc.) (Aytekin, 2017).

At the heart of the working mechanism of artificial neural networks are elements called neurons, multidirectional connections are established between layers, and weighting is done according to the strength of this connection. Each neuron with its own activation function is first trained and then tested to get the most appropriate weight value (Abbasi, 2009).

There are three components in the structure of an artificial neural network: the neuron (artificial neural cell), the connections, and the learning algorithm. A neuron is the basic processing element of an artificial neural network. The neurons in the network receive one or more inputs according to the factors affecting the problem and output as many outputs as the number of expected results from the problem. In a general artificial neural network system, neurons coming together in the same direction form layers (Yıldız, 2001). The coming together of neurons through connections with each other forms the artificial neural network given in Figure 1 (Kurt et al., 2017).

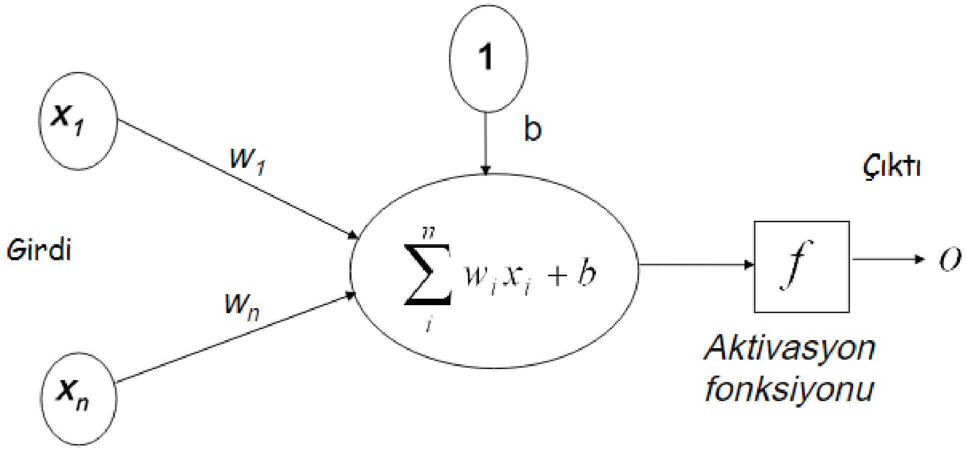


Figure 1. Artificial neural networks composed of artificial neural cells

In an artificial neural network, there are three layers of interconnected neural cells. These layers are the input layer, the output layer, and the hidden layer. The first layer is the input layer which allows external data to be received into the neural network. The input layer consists of the parameters that affect the problem and the number of neurons in the input layer is shaped according to the number of parameters. The hidden layer between the input layer and the output layer is the other layer. Hidden layers only receive signals from the input layer and send signals to the output layer. The last layer is the output layer which allows information to be transmitted to the outside (Benli, 2002).

**Sum function:** This function calculates the net input to the cell. Different functions are used for the sum function. The most common is the weighted sum function. This function is formulated as follows.

$$NET = \sum_{i}^{N} G_i A_i$$

Where G is the inputs, A is the weights, n is the number of inputs (process elements) (Öztemel, 2012; Alp and Öz, 2019).

**Activation function:** This function is the non-linear matching function between input and output. One of the most widely used activation functions is the Hyperbolic tangent function and is calculated by the following formula (Öztemel, 2012; Alp and Öz, 2019).

$$F(NET) = \frac{(e^{NET} - e^{-NET})}{(e^{NET} + e^{-NET})}$$

**Classification of Artificial Neural Networks and Appropriate Network Selection**

ANNs can be classified according to their learning methods and structures (Elmas, 2003; (Khare, 2007). According to their structure, ANNs are classified as feed-forward networks and non-feedback networks. Feed-forward networks consist of single-layer networks, multilayer networks, and radial basis function neural networks. Feedback networks consist of competitive networks, Kohenen network, Hopfield network and ART model.

**Perceptron:** It was proposed by Frank Rosenblat in the 1960s. The perceptron compares the sum of the weights of the inputs with a threshold value (θ). The weighted sum returns 1 if greater than or equal to the threshold value and 0 if less than the threshold value. Of the values obtained, 1 belongs to class A and 0 belongs to class B (Elmas, 2011). The input set of perceptrons is denoted as $X=(x_1, x_2,\ldots,x_n)$ and the output value corresponding to this input set is denoted as B. NET input value and output (y) are calculated as follows (Alp and Öz, 2019).

$$NET = \sum_{i=}^{m} w_i x_i$$

$$y = \begin{cases} 1, if\ NET \geq \theta \\ 0, if\ NET < \theta \end{cases}$$

**Scaling process**

Some researchers draw the values of the variables within a certain range using the following formula.

$$X' = \frac{X_i - X_{max}}{X_{max} - X_{min}}$$

Where X is the input value, X' is the scaled form of the input value, Xmin is the smallest value in the input set, Xmax is the largest value in the input set. The scaling of output values is as follows

$$X = X' * (X_{max} - X_{min}) + X_{min}$$

(Öztemel, 2012). This process is also called normalization. X' takes values between 0 and 1.

**Performance measure**

ANN model performance is usually determined by the Mean Squared Error (MSE) and Mean Absolute Error (MAE). MSE and MAE are calculated as follows (Singh et al., 2009).

$$MSE = \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{n}$$

$$MAE = \frac{\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|}{n}$$

Where $Y_i$: Observed values of the dependent variable, $\hat{Y}$: Estimated values of the dependent variable, n is the number of observations.

## III. RESULTS AND DISCUSSION

The numbers of input, hidden and output layers of ANN were determined as 1-12-1, respectively, and applied with Back Propagation Learning with 1000 iterations. In ANN method, hyperbolic tangent activation function was applied for anchovy production amount data. MSE=799020.596 and MAE=452.352 were calculated for ANN method. The predicted and observed values as well as the error term values as a result of ANN method are presented in Table 1.

Table 1. Observed, estimated and residual values

| Years | Actual | Predicted | Residual |
|---|---|---|---|
| 2011 | 100883,5 | 100611,7 | 271,848 |
| 2012 | 81074,3 | 80865,55 | 208,750 |
| 2013 | 103424,8 | 103496 | -71,164 |
| 2014 | 59601,9 | 59695,51 | -93,615 |
| 2015 | 90885,9 | 90821,69 | 64,205 |
| 2016 | 55731,6 | 57249,62 | -1518,02 |
| 2017 | 158093,8 | 158140,1 | -46,277 |
| 2018 | 96451,7 | 96696,02 | -244,323 |
| 2019 | 262544,4 | 259888,6 | 2655,808 |
| 2020 | 171253,2 | 171162,6 | 90,558 |
| 2021 | 151597,6 | 151755,9 | -158,26 |
| 2022 | 125980,4 | 125975 | 5,393 |

The course and distribution graph of actual and predicted values as a result of ANN application for anchovy production estimation is given in Figure 1.

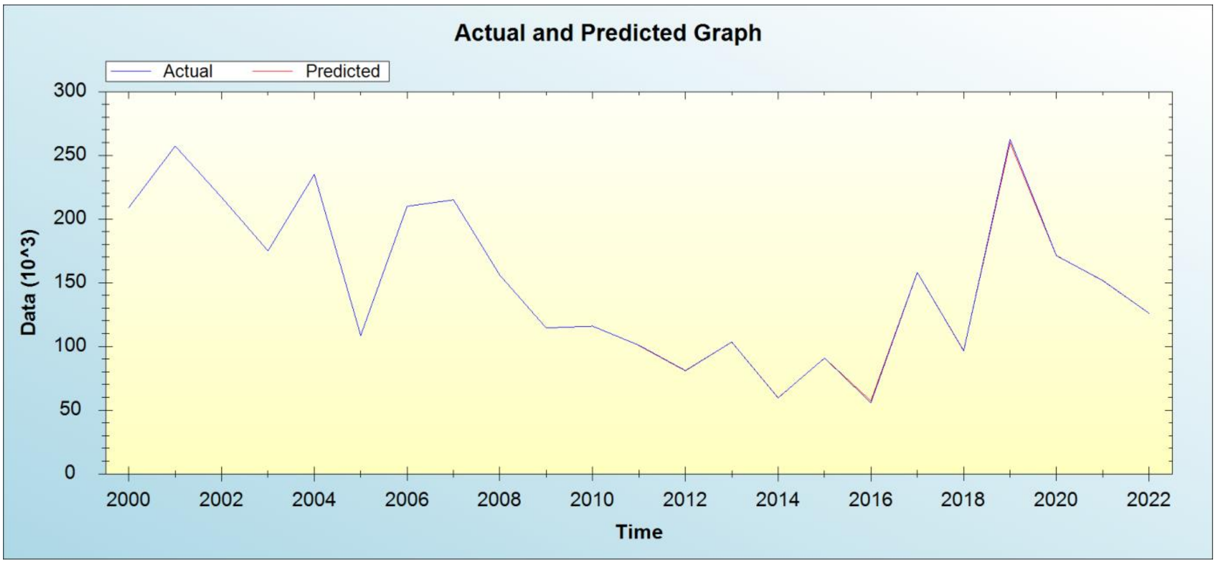


Figure 1. The graph of observed and predicted values

When Figure 1 is considered, the observed and predicted values are in accordance with each other. The graph of the residual terms obtained as a result of ANN application is presented in Figure 2.

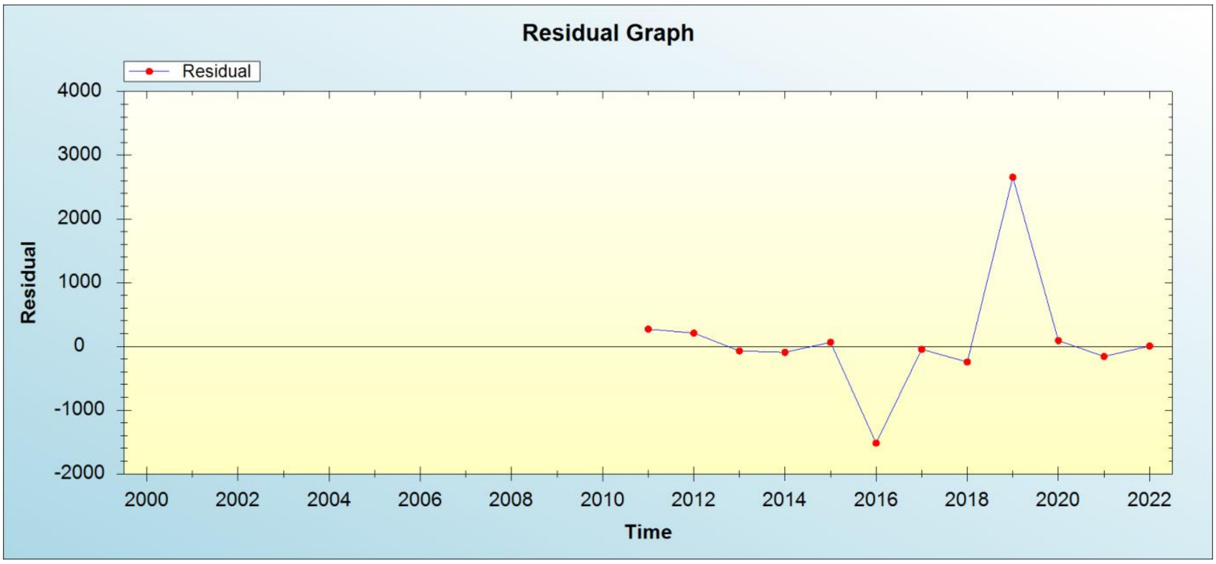


Figure 2. Residual term graph

Figure 2 shows that the residual values are randomly distributed. The graph of the error terms with the actual values of anchovy fish production is given in Figure 3. Actual values and residual values are independent of each other and randomly distributed. Figure 4 shows the graph of residual values and predicted values.

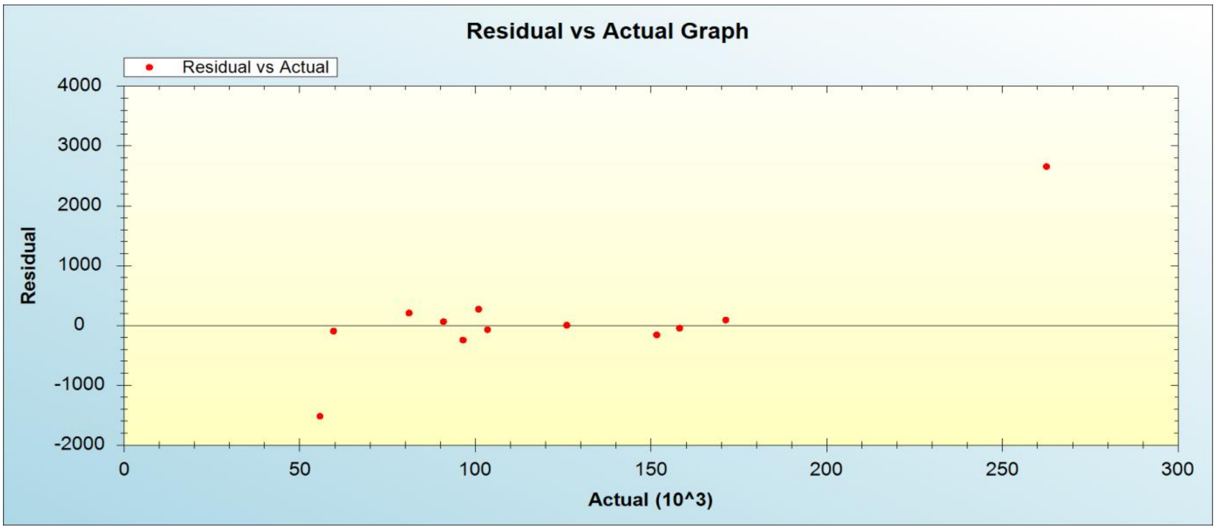


Figure 3. The graph of actual values and residual terms

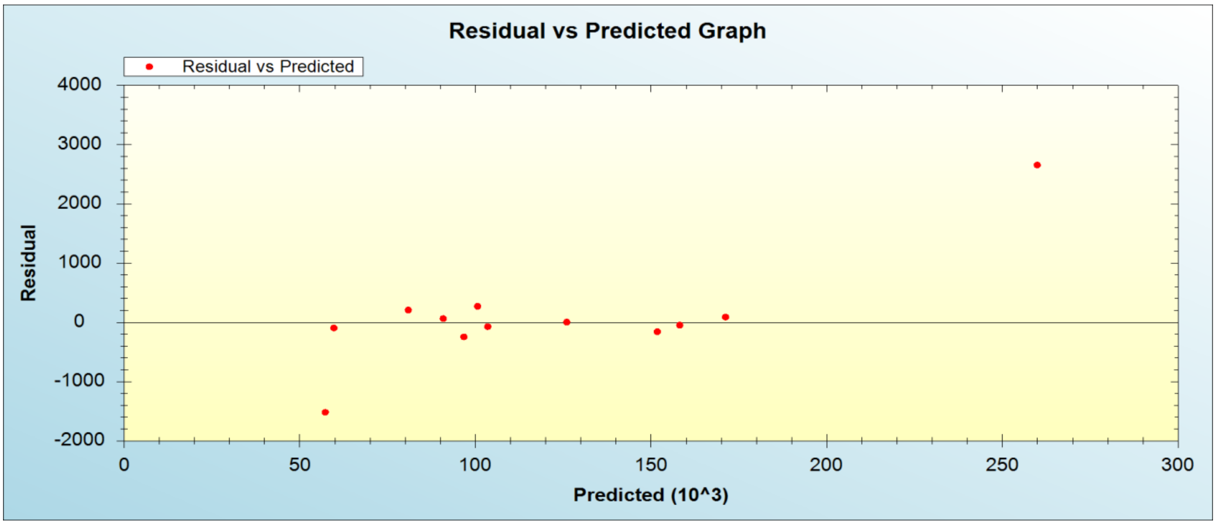


Figure 4. The graph of estimated values and error terms

After this stage, the anchovy production amount (tons) prediction for the years 2023-2027 was calculated and given in Table 3. The prediction graph obtained according to the most appropriate hyperbolic tangent function is shown in Figure 5.

Table 2. Anchovy quantity (tons) projection for the future period

| Years | Forecasting |
|---|---|
| 2023 | 128062 |
| 2024 | 120963 |
| 2025 | 118959 |
| 2026 | 147177 |
| 2027 | 47202 |

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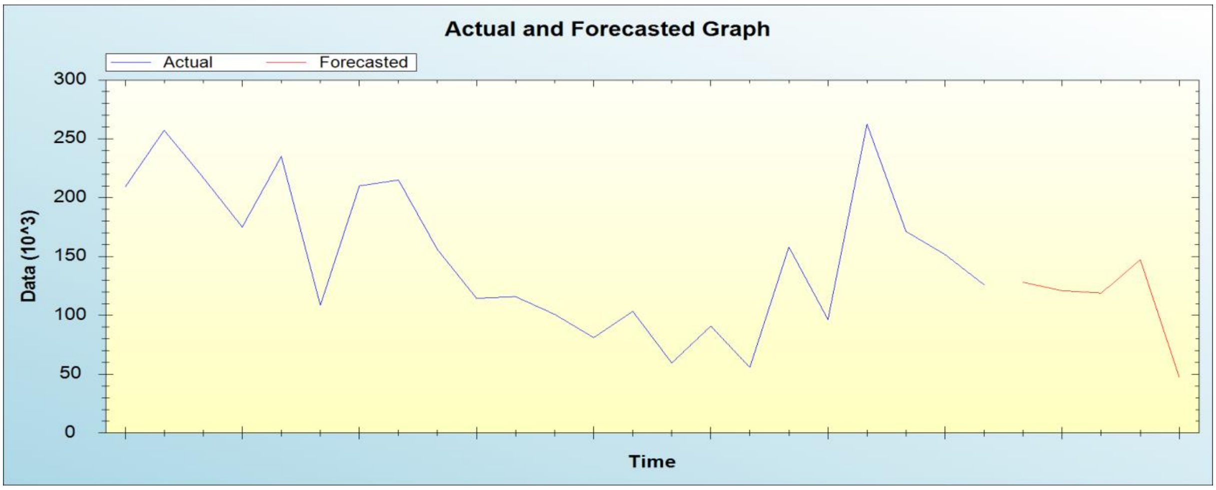

Figure 5. Actual values and forecast for the next period

In the simple moving average (SMA) method, the SMA series for k=3 lags, i.e. in triplicates, are presented in Table 3.

Table 3. Anchovy production series simple moving average

| Year | Actual | Single MA | Predicted | Residual |
|---|---|---|---|---|
| 2000 | 209000 | NaN | NaN | NaN |
| 2001 | 257245 | NaN | NaN | NaN |
| 2002 | 217000 | 227748,3333 | NaN | NaN |
| 2003 | 175000 | 216415 | NaN | NaN |
| 2004 | 235000 | 209000 | NaN | NaN |
| 2005 | 108569 | 172856,333 | 191557,778 | -82988,778 |
| 2006 | 210000 | 184523,000 | 119721,444 | 90278,556 |
| 2007 | 215000 | 177856,333 | 175982,778 | 39017,222 |
| 2008 | 155933 | 193644,333 | 176745,222 | -20812,222 |
| 2009 | 114488 | 161807,000 | 210250,556 | -95762,556 |
| 2010 | 115892 | 128771,000 | 129882,556 | -13990,556 |
| 2011 | 100883,5 | 110421,167 | 63498,111 | 37385,389 |
| 2012 | 81074,3 | 99283,267 | 63930,722 | 17143,578 |
| 2013 | 103424,8 | 95127,533 | 72199,511 | 31225,289 |
| 2014 | 59601,9 | 81367,000 | 82161,289 | -22559,389 |
| 2015 | 90885,9 | 84637,533 | 60249,133 | 30636,767 |
| 2016 | 55731,6 | 68739,800 | 79824,556 | -24092,956 |
| 2017 | 158093,8 | 101570,433 | 49723,178 | 108370,622 |
| 2018 | 96451,7 | 103425,700 | 134746,122 | -38294,422 |
| 2019 | 262544,4 | 172363,300 | 127786,478 | 134757,922 |
| 2020 | 171253,2 | 176749,767 | 265516,944 | -94263,744 |
| 2021 | 151597,6 | 195131,733 | 228556,789 | -76959,189 |
| 2022 | 125980,4 | 149610,400 | 222565,333 | -96584,933 |

In the SMA method, the graph of the actual and estimated values of anchovy quantity together is given in Figure 6.

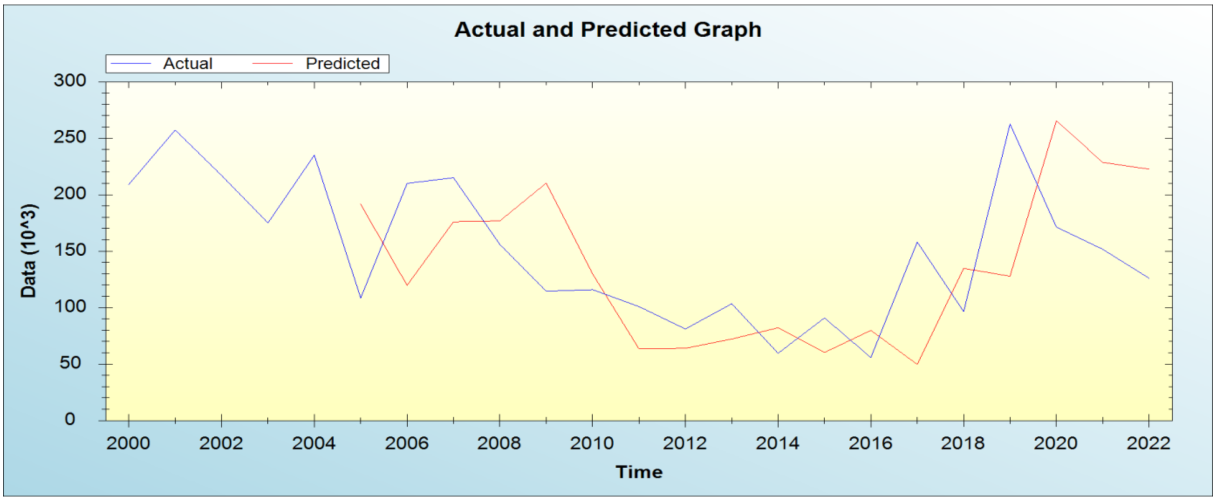


Figure 6. Observed and estimated anchovy production

The forecast values for 2023-2027 obtained according to the SMA method are presented in Table 4.

Table 4. Prediction obtained according to SMA method

| Year | Forecasted |
|---|---|
| 2023 | 101170 |
| 2024 | 76950 |
| 2025 | 52729 |
| 2026 | 28509 |
| 2027 | 4289 |

When the simple moving average method (SMA) was compared with ANN in analyzing the anchovy quantity, it was seen that the ANN method gave better results. MSE=4808945429.614 and MAE=58618.005 were calculated in the 3-way Simple Moving Average method. It shows that the MSE and MAE values obtained in the SMA method are much larger, that is, the good fit statistics values are worse. In this case, it would be more appropriate to evaluate the results obtained with ANN method.

## IV. CONCLUSION

In this study, the amount of anchovy production in Turkey is modeled using artificial neural networks (ANN) and simple moving average methods (SMA). Years (2000-2023) are used as input variables and anchovy quantity is used as output variable. Hyperbolic tangent functions were used as activation functions.

The results obtained from the analysis of both ANN and SMA methods revealed that the established ANN method gave better predictions. The low MSE and MAE values in the training, testing and validation phases also indicate this.

With ANN, the amount of anchovy in Turkey is expected to be between 128 062-47 202 tons in the period 2023-2027. Compared to 2022, the amount of anchovy is expected to decrease in the next 5 years. After 5 years, this decrease is expected to be 62.53%. It is hoped that using artificial neural networks and alternative techniques in future forecasting studies will give good results in seafood data.

## REFERENCES

[1]. Abbasi, B. 2009. A neural network applied to estimate process capability of non-normal processes. Expert Systems with Applications, 36:3093-3100.

[2]. Alp, S., Öz, E. 2019. Makine ÖğrenmesindeSınıflandırma Yöntemleri ve R Uygulamaları. Nobel Akademik Yayıncılık, Ankara.
[3]. Aytekin, A. 2017.Basit Düşün, Akış Diyagramları ile Programlama. Detay Yayıncılık, Ankara, 326 s.
[4]. Benli, Y. 2002. Finansal Başarısızlığın Tahmininde Yapay Sinir Ağı Kullanımı ve İMKB'de Bir Uygulama.Muhasebe Bilim Dünyası Dergisi, 4(4):17-30.
[5]. Benzer, R., Benzer, S. 2018. Balıkçılık Endüstrisinde Kullanılan Büyüme Modellerinde Geleneksel Yaklaşımlar ile Yapay Sinir Ağlarının Yaklaşımlarının Karşılaştırılması. 5th International Management Information Systems Conference, October 24-26 2018, Ankara.
[6]. Bilgin, S., Samsun, N., Samsun, O., Kalaycı, F. 2006. Orta Karadeniz'de 2004-2005 av sezonunda hamsinin, Engraulisencrasicolus L., 1758, boy-frekans analiz metodu ile populasyon parametrelerinin tahmini. Ege Üniversitesi Su Ürünleri Dergisi, 23(1/3): 259-364.
[7]. Civelek, Ç. 2021. Yapay Sinir Ağları Kullanarak Türkiye Traktör Satış Adedinin Tahmin Edilmesi. Avrupa Bilim ve Teknoloji Dergisi,31 (Ek Sayı 1): 375-381
[8]. Çelik, 2020. Modeling and forecasting of dry bean yield in Turkey usingArtificial Neural Networks and Time Series Analysis. Research Inventy: International Journal of Engineering and Science, 10(10): 8–13
[9]. Çelik, Ş. 2021. Estimation of the Quantity of Donkeys in Turkey via Artificial Neural Network and Time-Series Analysis. Research Inventy: International Journal of Engineering and Science, 11(9): 7–20
[10]. Çelik, Ş. 2022. Prediction of rabbit numbers in China with artificial neural networks. International Journal of Research in Engineering and Science (IJRES), 10(12): 511-516
[11]. Duyar, H.A., Bayraklı, B. 2005. Sinop İlinde Bulunan Su Ürünleri İşleme Tesislerinin Durumu, Sorunları ve Çözüm Önerileri. Su Ürünleri Mühendisleri Dergisi (SUMDER), 24(4): 53-56.
[12]. Elekon, H.A. 2007. Avrupa Birliği'nde Balıkçılık ve Ortak Balıkçılık Politikası Karşısında Türkiye'nin Durumu, Doktora Tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Ankara
[13]. Elmas, Ç. 2003. Yapay Sinir Ağları (Yapay Sinir Ağları-Bulanık Mantık-Genetik Algoritma), Seçkin Yayıncılık, Ankara.
[14]. Elmas, Ç. 2011. Yapay Zeka Uygulamaları (kuram, mimari, eğitim, uygulama. Seçkin Yayıncılık.
[15]. Erdoğan-Sağlam, N., Sağlam, C. 2013. Age, growth and mortality of anchovy Engraulis encrasicolus in the south-eastern region of the Black Sea during the 2010–2011 fishing season. Journal of the Marine Biological Association of the United Kingdom, 93(8): 2247-2255
[16]. FAO, 2019. Fishery and aquaculture statistics. Food and Agriculture Organization of the United Nations
[17]. Genç, Y. 2007. Son 20 yılda Türkiye'deki hamsi avcılığı. SÜMAE YUNUS Araştırma Bülteni, 7(2):4-7.
[18]. Kadılar, C. 2009. SPSS Uygulamalı Zaman Serileri Analizine Giriş. Bizim Büro Yayınevi, Ankara.
[19]. Kalaycı, F., Bilgin, S., Samsun, O., Samsun, N. 2006. Orta Karadeniz'de avlanan çaça (Sprattus sprattusphalericusRisso, 1826) balığı stokunun genel durumu ve balık endüstrisi içerisindeki yerinin araştırılması. Ege Üniversitesi Su Ürünleri Dergisi 23(1/3): 449-455
[20]. Khare, M.,Nagendra, S. M. 2007. Artificial Neural Networks in Vehicular Pollution Modelling, Springer.
[21]. Kurt, R.,Karayılmazlar, S., İmren, E., Çabuk, Y. 2017. Yapay Sinir Ağları İle ÖngörüModellemesi: Türkiye Kâğıt-Karton Sanayi Örneği. Bartın Orman Fakültesi Dergisi, 19(2): 99-106.
[22]. Mutlu, C. 1994. Doğu Karadeniz'deki Hamsi (Engraulisencrasicolus, Linneaus, 1758) Balıklarının Bazı Populasyon Özellikleri Üzerine Bir Araştırma. Yüksek Lisans Tezi. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Balıkçılık Mühendisliği Anabilim Dalı, 44 s.
[23]. Özdemir, S., Erdem, Y., Birinci Özdemir, Z., Erdem, E., Aksu, H. 2018. Estimation of growth parameters and mortality rates of sprat (Sprattussprattus L.) and anchovy (Engraulis encrasicolus, L.) captured in the Black Sea. Turkish Journal of Maritime and Marine Sciences, 4(2): 106-115
[24]. Öztemel, E. 2012. Yapay sinir ağları. PapatyaYayıncılık, İstanbul.
[25]. Serper, Ö. 2004. Uygulamalı İstatistik 2. Ezgi Kitabevi, Bursa.

[26]. Singh, K. P.,Basant, A., Malik, A., Jain, G. 2009. Artificial neural network modeling of the river water quality—A case study. Ecological Modelling, 220(6): 888-895.
[27]. TÜİK, 2023. Türkiye İstatistik Kurumu.Avlanan Deniz Ürünleri Miktarı (Ton), Hamsi,https://biruni.tuik.gov.tr/medas/?kn=210&locale=tr
[28]. Wang, S., Dong, X., Renjin Sun, R. 2010. Predicting saturates of sour vacuum gas oil using artificial neural networks and genetic algorithms.Expert Systems with Applications, 37:4768-4771.
[29]. Yıldırım, Ö. 2006. Sinop İli Balık Unu-Yağı Fabrikalarının Mevcut Durumu ve Türkiye Balık Unu-Yağı Üretimindeki Yeri. Fırat Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 18(2):197-203
[30]. Yıldız, B. 2001. Finansal Başarısızlığın Öngörülmesinde Yapay Sinir Ağı Kullanımı ve Halka Açık Şirketlerde Ampirik Bir Uygulama. İMKB Dergisi, 17:51-67.