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Research Paper

Modeling the number of pigs in Turkey through ARIMA models and Artificial Neural Networks

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ABSTRACT
The aim of this study is to make a production plan by using artificial neural networks (ANN) and time series analysis for establishing suitable models and forecasting the pig population in Turkey over the years.
The years parameter was used as an input parameter in the development of ANN and time series analysis, and the number of pigs was used as an output parameter. Mean square error (MSE), root mean square error (RMSE) and mean error (ME) statistics were used to calculate the efficiency of the developed model. According to the results, the number of pigs will fluctuate between 2021 and 2025.
It has been observed that ANN models outperform time series analysis in predicting animal inventory.
KEYWORDS: *Artificial neural network, time series, forecasting, pigs.*

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I. INTRODUCTION

The pig (*Sus L.*), one of the world's most popular mammals, also has the largest share in the farm animal group (in terms of bovine and ovine). According to the studies carried out, the pig, one of the oldest cultural animals for breeding, was first started to be cultivated in Southwest Asia including Anatolia (the southeast in particular) (Sahin, 2019).

The pig (*Sus L.*) is a Eurasian animal from the Suidae (Piggies) family and non-ruminant suborder. Almost every nation on the planet has both wild and cultural races of it. The wild boar spread through much of Eurasia, including Turkey (*Sus scrofa*) characterized by its mostly rough and thick bristles, proboscis nose, teeth (Trophy) that protrude from its mouth, and double-clawed feet (Sahin, 2019).

In order to meet the demands of Christian citizens residing in Turkey and foreign visitors, a substantial amount of pork is consumed in the kitchens of hotels, restaurants and facilities in touristic areas. However, the fact that almost no legal cultivation is available, as well as unauthorized and unregulated slaughtering, reveals the importance of this problem in terms of public health (Cayukli and Ozgur, 2011).

When the inventory of pigs is analyzed by country, the countries with the most pig breeding in 2019 are China, the United States, Brazil, Spain, and Germany, respectively. These countries have a total of 316 068 540, 78 657 600, 40 556 892, 31 246 040, and 26 053 400 pigs, respectively (FAO, 2019a). The overall pig inventory in the said top five countries with the highest pig production in the world is 492 582 472. The cumulative number of pigs in the world is 850 320 154 in 2019. The number of pigs in the top five countries accounts for 57.93%, or more than half of the total number of pigs in the world. China has 37.17 percent of the global pig inventory. The number of pigs in Turkey has been steadily declining in recent years. The number of pigs decreased from 3400 in 2000 to 1896 in 2010. The number of pigs increased marginally in 2015 to 2655, after fluctuating between increases and decreases in previous years. The pig inventory, which was 1636 in 2019, was reduced to 990 in 2020 (FAO, 2019a; TIS, 2020).

According to the data of FAO 2019, chicken meat has the largest share of global meat export with 14 562 403 tons, followed by boneless beef with 7 393 791 tons and pork with 6 507 003 tons. When evaluated as export value (1000 $), boneless beef came in first with 40 396 750 000 dollars, followed by chicken meat with 22 637 886 000 dollars, and pork with 17 031 985 000 dollars (FAO, 2019b). Pork has a significant share and ranking in exports as observed.

Turkey's per capita beef consumption in 2019 was 13.6 kg, leaving many other nations behind. Poultry meat consumption of Turkey, remaining behind of many other countries, is 21 kg per capita. Red meat consumption in Turkey is higher as compared to values in developing countries such as China and Russia

(BESD-A, 2019). Excessive pork consumption in these countries plays an important role in the emergence of the presented outcome.

The present study aims to model the number of pigs in Turkey using time series analysis and the artificial neural network method and to make predictions for the coming years.

II. MATERYAL VE METOT

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The material of the study is 1961-2020 number of pigs values supplied from the www.tuik.gov.tr web address of Turkish Statistical Institute (TSI, 2020) and Food and Agriculture Organization of the United Nations (FAO, 2019c). The dependent variable was number of pig figures whereas the independent variable was year series. These variables were selected in order to be able to make reasonable estimations with the models to be performed using ANN and time series analysis methods.

METHOD

ARIMA Models

A pth-order autoregressive model AR(p) model is denoted as (Cooray, 2008).

$$y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + e_t$$

AR(p) model uses a linear combination of past values of the target to make forecasts.
A qth-order moving average process, expressed MA(q), is characterized by (Cryer, 1986).

$$y_t = -\theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q} + e_t$$

ARMA(p,q) model composed of a pth-order autoregressive and qth-order moving average process and it is characterized by (Hamilton, 1994).

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q}$$

In order for time series models to be applied, series must be stationary and white noise (Kadılar and Çekim, 2020).

Artificial neural networks (ANN)

The artificial neural network (ANN) consists of numerous interrelated simple processing elements called neurons. These neurons take on input signals from the environment. The signals are transformed by connecting weights and through a process of training, the neurons get activated by transfer functions to give a desired output (Pujol and Pinto, 2011; Schmidhuber, 2015).

ANN, which is a computational intelligence technique has been found to be more efficient than the standard empirical models. Neural networks have been very effective for modeling and for characterization of complex systems for a number of applications (Afrand et al., 2016; Meruelo et al., 2016).

One of the most common used type of ANN is the feedforward network. The architecture of a feedforward neural network is nonlinear. Therefore, the output is obtained from the input through a feedforward arrangement. The multi-layer perceptron (MLP) is a type of feedforward neural network, consisting of input, hidden and output layers (Beale et al., 2011; Moghaddam et al., 2016).
The used activation function in configuration of ANNs in the study is Hyperbolic tangent sigmoid function (Bouabaz and Hamami, 2008).

$$f = \frac{2}{1 + e^{-net_j}} - 1$$

Normalization method standardizes the values of the input variables. Min Max normalization: Implements a linear transformation on the actual data. It normalizes the data in the range 0 to 1 by the formula (Öztemel, 2012):

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

Where, X_i: Data value to be normalized, X': Normalized value of X_i, X_{min}: Minimum value, X_{max}: Maximum value.

To evaluate the precision of the predicted discharge volume, Square Mean Square Error (RMSE), Mean Square Error (MSE) and Mean Absolute Error (ME) were used (Eyduran *et al.*, 2019; Wang and Lu, 2018):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - y_{ip})^2}{n}}$$

$$MSE = \frac{\sum_{i=1}^{n}(y_i - y_{ip})^2}{n}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|(y_i - y_{ip})\right|$$

Here, y_i is the real value of the dependent variable (number of pig), y_{ip} is the predicted value of the dependent variable (number of pig) and n is the number of samples.

III. RESULTS AND DISCUSSION

The artificial neural networks and ARIMA method goodness of fit statistics (RMSE, MSE and MAE) of number of pig between the years 1961-2020 in Turkey are displayed in Table 1. The time series graph is shown in Figure 1.

Table 1. Model performance values

Fit Statistic	ARIMA(3,1,0)	ANN
MSE	2941173.550	1210524.639
RMSE	1714.985	1100.238
MAE	1247.491	828.814

Considering Table 1, when the time series analysis and artificial neural network methods are compared according to square mean square error (RMSE) values, MSE and MAE, artificial neural networks (ANN) with minimum RMSE, MSE and ME values (RMSE=1100.238, MSE=1210521.639 and MAE=828.814) are the most suitable model. The hyperbolic tangent function was used as activation function when creating a model with the ANN method. The number of neurons in the input layer, the hidden layer and the output layer was determined as 12-12-1 each. 1000 iterations were used for the ANN method in the data series consisting of 60 observations between 1961-2020.

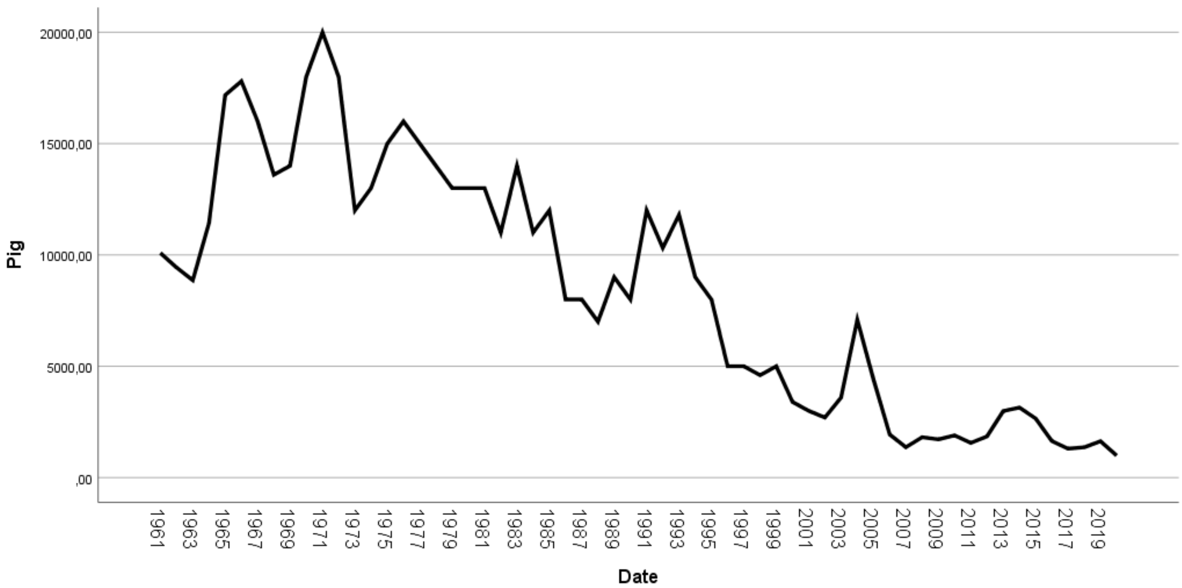

Figure 1. Time series graph

The parameter coefficient of the time series model modeled as ARIMA (3,1,0) is $\phi_3 = -0.518$ and shown as;

$$(1-B)(1+0.518B^3)X_t = e_t$$
$$(1-B)(1.518B^3)X_t = e_t$$

The model was found to be appropriate because its Ljung-Box statistics were 13.141 and p = 0.727> 0.05. However, as the ARIMA and ANN methods compared, it has been observed that the ANN method had better results (Table 1). Since the MSE, RMSE, and MAE values are lower in the ANN method, it is much more appropriate.
The estimated and residual values are presented in Table 2 together with the real values of the ANN method for 2000-2020 period.

Table 2. Observed, predicted and residual values

Years	Actual	Predicted	Residual
2000	3400	4993.590	-1593.590
2001	3000	5197.009	-2197.009
2002	2700	4444.876	-1744.876
2003	3595	4354.446	-759.446
2004	7090	3443.639	3646.361
2005	4399	3726.773	672.227
2006	1934	3212.175	-1278.175
2007	1362	2131.920	-769.920
2008	1813	2308.321	-495.321
2009	1717	2038.106	-321.106
2010	1896	1877.204	18.796
2011	1558	1722.817	-164.817
2012	1848	1801.737	46.263
2013	2986	2031.112	954.888
2014	3145	1883.979	1261.021
2015	2655	1729.842	925.158
2016	1642	1818.470	-176.470
2017	1299	1715.118	-416.118
2018	1361	1640.051	-279.051
2019	1636	1642.608	-6.608
2020	990	1561.826	-571.826

The graph of the observed and estimated values obtained with ANN method is presented in Figure 2.

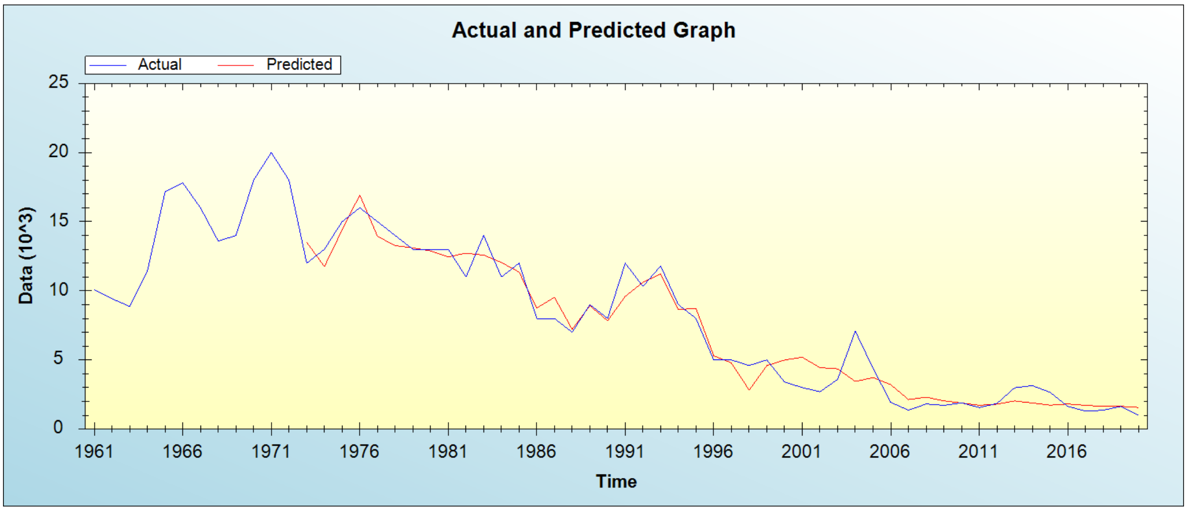

Figure 2. The combined graph of observed and estimated values for number of pig

In Figure 3, meantime the joint graph of observed and residual values was observed, residual and observed values were found to be scattered free from each other and randomly. This situation shows that important hypotheses regarding the model are provided.

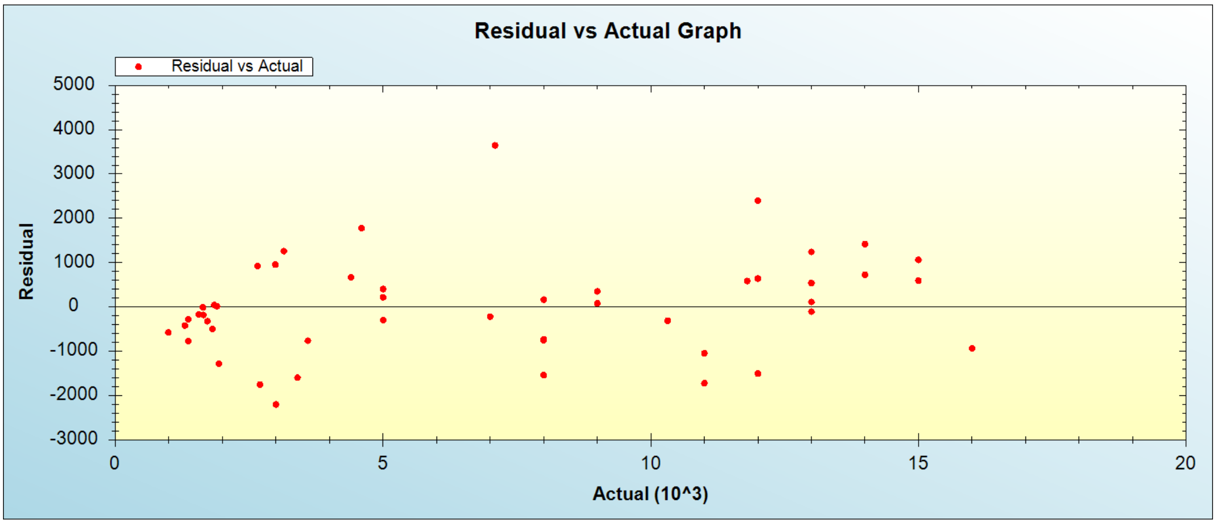

Figure 3. Joint graph of observed and residual values

The possible 2021-2025 number of pig forecasted with ANN and ARIMA(3,1,0) are given in Table 3.

Table 3. Number of pig forecasting

Years	ARIMA(3,1,0)	ANN
2021	958	1533
2022	845	1557
2023	1150	1637
2024	1167	1537
2025	1241	1566

Table 3 shows that the number of pigs will fluctuate between 2021-2025. The graph showing the actual and predicted values of the number of pig is shown in Figure 4.

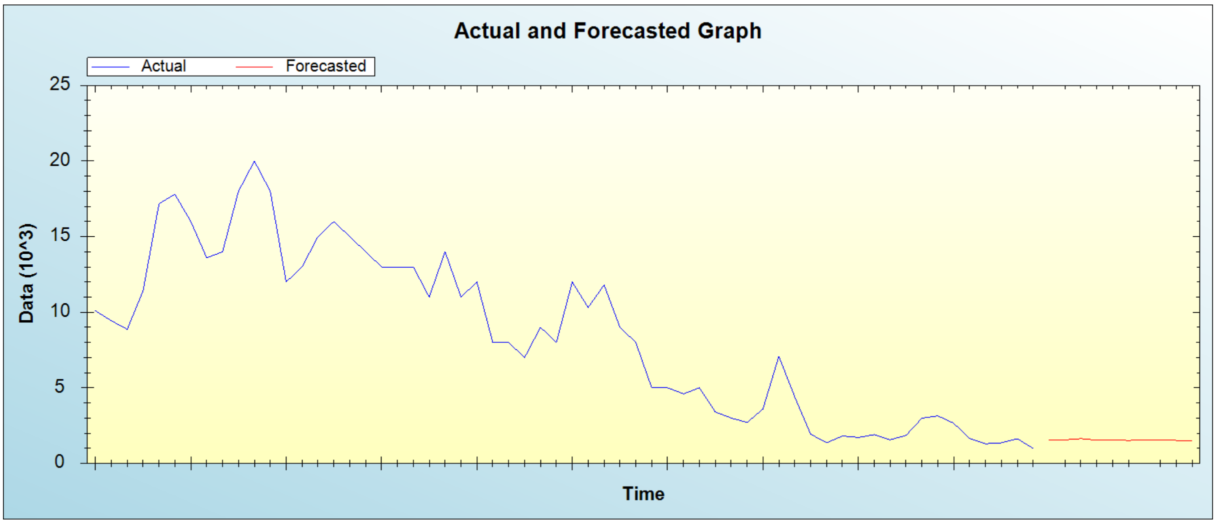

Figure 4. The joint graph of observed and estimated values

In our study, we have obtained an appropriate model for predicting ARIMA (3,1,0) and ANN.
Using these models, it is possible to predict that the number of pigs in the future will fluctuate.
There are some studies in the field of agriculture that employed artificial neural networks.
Eyduran et al. (2020), used exponential smoothing methods with ARIMA (0,1,1), ARIMA (1,1,0) and ARIMA (1,1,1) for the modeling of banana production forecast in Turkey. Brown's approach was selected as the most appropriate method in the study of authors. In another study, the modeling of Turkey's tobacco production has been made by employing artificial neural networks. In the said study, model suitability was tested according to MSE and ME, and a fluctuating course in tobacco production is predicted for the 2020-2025 period (Celik, 2020a). It is estimated that there will be a fluctuating course as suggested in this study. Another study used ARIMA models to analyze the production amount of some forage crops from 1969 to 2016, and a prediction was made between 2017 and 2025. The vetch plant was modeled as ARIMA (0,1,1) (Agirbas et al., 2019). As a result of time series analysis of the 1950-2010 period peanut production in Turkey, The ARIMA (0,1,1) model was obtained and the prediction between 2016-2030 was made according to this model. According to the prediction results, it was estimated that the amount of peanut production will increase in the period (Celik et al., 2017). ANN was used to model the production quantity of orange, tangerine, chickpea, and lentil plants (Celik, 2019a, Celik, 2019b, Celik, 2020b, Celik, 2020c).

IV. CONCLUSION

The number of pigs in Turkey was estimated by employing artificial neural networks and ARIMA models in this study. The input variables are the years (1961-2020), one independent variable, and the number of pigs as the output variable. For the next stage, the preparation, testing and verification processes of the network were carried out and the estimation process was carried out.

The results point out that the proven ANN method provides better estimates than ARIMA models. This is also supported by the low RMSE, MSE, and ME values in the preparation, testing, and verification phases.

Considering the prediction of the number of pigs, the said figure, which was 990 in 2020, is predicted to increase by 58.18% and reach 1566 in 2025. In the 2021-2025 period, there will be both an increase and a decrease. In other words, it is expected that the number of pigs would fluctuate.

In general, when compared to time series analysis, artificial neural networks are more effective in predicting available data. It is noted that good results in agriculture can be obtained by comparing artificial neural networks and alternative approaches in future prediction studies.

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