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Modelling of Sheep and Goat Breeding With Artificial Neural Networks: The Case of Bitlis Province

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ABSTRACT

An Artificial Neural Network (ANN) model was created for this study in order to simulate and forecast the quantity of sheep and goats in the Turkish province of Bitlis. With one hidden layer, twelve processing components (12-12-1), and a learning method that serves as the Levenberg-Marquardt back propagation algorithm, the ANN model is a network design. The number of sheep and goats was utilized as the output parameter and was studied independently throughout the building of the ANN model, while the time variable years was used as the input parameter. The number of sheep and goats in Turkey from 2004 to 2022 makes up the research data.

To get the best model, the hyperbolic tangent activation function was employed. The results of Mean Squares Error (MSE) and Absolute Mean Error (MAE) statistics were utilized to assess the model's efficacy. The study produced the MSE and MAE values that were the lowest. In the study of sheep numbers, MSE=4 047 734 432 and MAE=47095 were discovered; in the analysis of goat numbers, MSE=162 954 548 and MAE=7309 were discovered. The number of goats and sheep in Bitlis was estimated using the ANN to be between 2023 and 2027. It is anticipated that the number of sheep would decline and that this decline will stay within the range of 509445–489470, based on the forecast findings. During the same time frame, the number of goats will fluctuate.Goat populations are predicted to reach 273701 in 2027 from 305867 in 2023. The outcomes demonstrate how well the artificial neural network models can adjust to data on animals.

Keywords: *Artificial neural networks, activation function, sheep, goat, Bitlis.*

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I. INTRODUCTION

Considering that the driving force of the agricultural economy in developed and developing countries is animal husbandry, the production of forage crops in meadows and pastures needs to be increased. Animal husbandry is an important employment area and also provides raw materials for the food industry. The continuity in animal husbandry activities that would contribute to the economy of the region should be ensured. In Bitlis Province, sheep and hair goats have been preferred to provide the household's meat supply for a long time. Although sheep and goat meat production is mainly produced by small family enterprises, investments in the breeding of animal husbandry products have been increasing over recent years.

In sheep and goat breeding, which is a sub-branch of the animal husbandry sector, meat, milk, wool, hair, mohair, leather, etc., products manufactured by utilizing poor meadow pastures and fallow areas, stubble, and lands that are unsuitable for crop production have a wide range of uses from ice cream to the textile sector (Paksoy and Özçelik 2008; DAKA 2012).

The Republic of Türkiye is a convenient country for sheep and goat breeding because of its natural and economic conditions, agricultural structure, and traditions (Kaymakçı and Engindeniz, 2010).

Industrial animal husbandry has numerous negative consequences on the socio-economic structure, and animal and human health. These are as follows: increased susceptibility to diseases in animals due to the fact that they are tied or confined to narrow areas and move very little, the gases produced disrupt the natural balance, water, soil and air, and moving away from pasture negatively affects components such as fatty acids and insulin-like growth hormone in animal products (Kaymakçı, 2012).

According to TSI (Turkish Statistical Institute) Records for the year 2022, the provinces with the highest number of sheep in Turkey are Van (3106786), Konya (2770980) and Sanliurfa (2093967), respectively.

Bitlis is ranked 34th with 525735 sheep. In terms of the number of goats, Mersin ranks first with 857422 goats, Antalya ranks second with 763147 goats, Sirnak ranks third with 541102 goats, and Bitlis ranks 11th with 288543 goats. The top 10 provinces with sheep and goat numbers in Türkiye are given in Table 1 and Table 2, respectively.

Table 1. Provinces with high number of sheep in Turkey

	Provinces	Number of sheep
1	Van	3106786
2	Konya	2770980
3	Şanlıurfa	2093967
4	Diyarbakır	1711919
5	Ankara	1680217
6	Balıkesir	1272236
7	Iğdır	1258751
8	Ağrı	1253706
9	Eskişehir	1153901
10	Afyonkarahisar	1123633
…	…	…
34	Bitlis	525735
…	…	…
80	Rize	8749
81	Bartın	4308
	Total	44687888

Table 2. Provinces with high number of goat in Turkey

	Provinces	Number of goat
1	Mersin	857422
2	Antalya	763147
3	Şırnak	541102
4	Siirt	472329
5	Kahramanmaraş	450933
6	Mardin	442232
7	Adana	440437
8	Diyarbakır	374022
9	Ankara	333259
10	Van	306724
11	Bitlis	288543
…	…	…
80	Bartın	1357
81	Düzce	1015
	Total	11577862

In this study, it was aimed to model the sheep and goat population in Bitlis Province with artificial neural networks and to make future predictions.

II. MATERIAL AND METHOD

The material of the study consisted of sheep and goat numbers under the title of " Animal Husbandry (Livestock) Statistics" taken fromwww.tuik.gov.trweb address of the Turkish Statistical Institute (TUIK). In the study, data from 2004 to 2022 in Bitlis Province were utilized and analyzed with Artificial Neural Networks (ANN). After determining the most appropriate models, sheep and goat numbers in Bitlis Province were estimated for the period from 2023 to 2027.

Artificial Neural Networks (ANN) are able to learn and generalize through experimentation. ANN is an important method for predicting the future. ANN is capable of revealing unknown and difficult-to-recognise relationships between data. In order to train the ANN and reach the target outputs, a large number of inputs and output sequences related to the inputs are required. Similar to the functional characteristics of the human brain, ANN has been successfully applied in learning, optimization, analysis, classification, generalization and association (Öztemel, 2012).

ANN is generally based on the principle that information data, which can be found in many different structures and forms, is able to be identified and perceived very quickly. ANN is capable of revealing unknown and difficult-to-recognise relationships between data. It can provide non-linear modeling without the need for any prior knowledge between input and output variables and without making any assumptions (Kaastra and Boyd, 1996).

The smallest units that constitute the basis for the operation of the ANN are called artificial neural cells or processing elements. The artificial neural cell consists of five main components: inputs, weights, summation function, activation function and output.

The weights show the importance of the information coming to an artificial cell and its effect on the neuron (Öztemel, 2012). The weights (w1, w2, w3,..., wi) are the appropriate coefficients that determine the effect of the inputs received by the artificial neural on the neural (Elmas, 2003). The summation function calculates the net input to a cell. This function is formulated as follows:

$$z_i = \sum_{\dot{I}=1}^{n} (w_{ij}\, x_i + b_j)$$

Where w is the inputs, x is the weights, and n is the number of inputs (process element).
The output of the process element is calculated by passing the value obtained as a result of the sum function through a linear or non-linear differentiable activation function. This situation is as follows (Yavuz and Deveci, 2012):

$$y = f(z_i) = f\left(\sum_{\dot{I}=1}^{n} (w_{ij}\, x_i + b_j)\right)$$

One of the significant factors determining neuron behavior in the ANN is the activation function (Efe and Kaynak, 2000). In the ANN, the output amplitude of the neuron is limited between the desired values. These values are usually between [0, 1] or [-1, 1] (Sağıroğlu et al., 2003).
The activation functionprocesses the net input to the cell and determines the output that the cell will produce in response to this input. The activation function is usually selected as a non-linear function (Çayıroğlu, 2015).
In general, one of the most widely used activation functions is the hyperbolic tangent activation function. The output values of the hyperbolic tangent activation function vary between -1 and 1 (Çayıroğlu, 2015). This function is calculated as follows (Öztemel, 2012; Alp and Öz, 2019):

$$f(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

The Selection of Back-Propagation Algorithm

The back-propagation neural network model uses a feedback learning mechanism. Even though the structure of the neural network is feed-forward, feedback becomes an important factor in learning, since it is a learning resulting from the backward inhibition of error. This type of learning algorithm uses a continuous input type. The Levenberg-Marquardt (trainlm) learning algorithm is a very common algorithm in the relevant literature. After the selection of the learning algorithm, the number of neurons in the hidden layer must be determined. The number of neurons to be used in a layer should be as small as possible. While a small number of neurons increases the "generalization" ability of the artificial neural network, too many neurons cause the network to memorize the data (Stern, 1996).

Model Suitability Criteria

The ANN Model performance is often determined by the Mean Squared Error (MSE) and Mean Absolute Error (MAE). MSE is calculated as follows (Singh et al., 2009):

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

MAE is calculated as follows:

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

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

III. RESULTS

The numbers of input, hidden and output layers of the ANN were determined as 1-12-1, respectively and applied with Back Propagation Learning with 1000 iterations. In the ANN method, a hyperbolic tangent activation function was used for sheep and goat presence data. MSE and MAE statistics were used to evaluate the model performance. MSE=4 047 734 432 and MAE=47095 were found in the ANN method for sheep number in Bitlis. The predicted and observed values as a result of the ANN method and the error term values are presented in Table 3.

Table 3. Observed, Predicted and Residual Terms

Years	Observation	Estimated values	Residual Terms
2004	444000	NaN	NaN
2005	553850	463399.7	90450.29
2006	552180	525739.5	26440.53
2007	465000	524780.9	-59780.9
2008	380620	474684.8	-94064.8
2009	374463	433424.8	-58961.8
2010	437964	430890.5	7073.496
2011	633866	460264.3	173601.7
2012	607704	568206	39498.04
2013	546344	555267	-8923.02
2014	525915	521418.8	4496.19
2015	430224	509550.1	-79326.1
2016	430331	456322.1	-25991.1
2017	377531	456376	-78845
2018	415468	432144.5	-16676.5
2019	448489	449067.8	-578.781
2020	511020	465764.6	45255.37
2021	517545	500871.6	16673.36
2022	525735	504670.6	21064.38

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

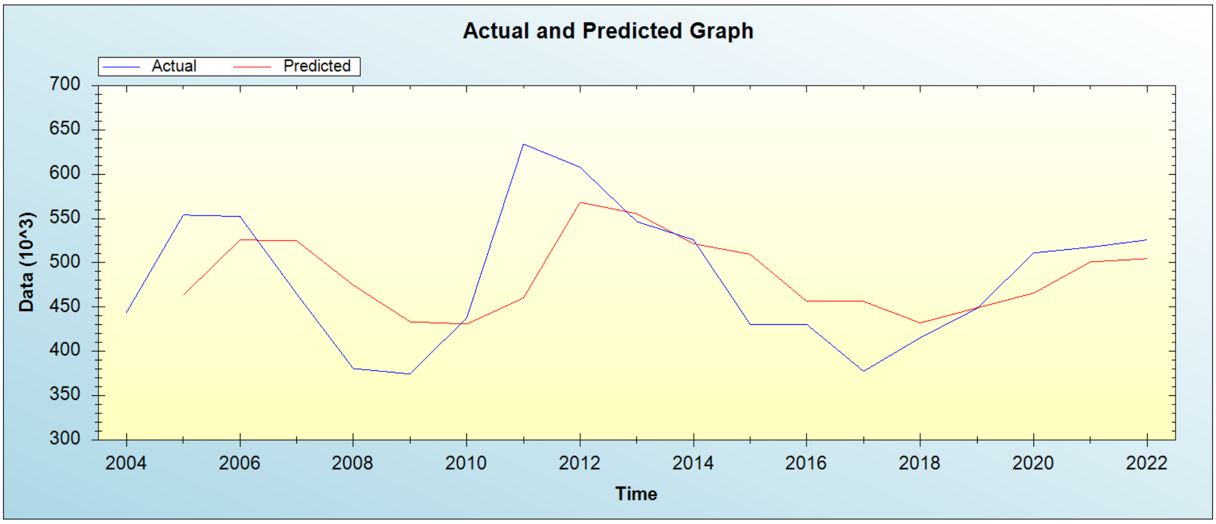

Figure 1. Graph of Observed and Predicted Values

The graph of error terms obtained as a result of ANN application is presented in Figure 2.

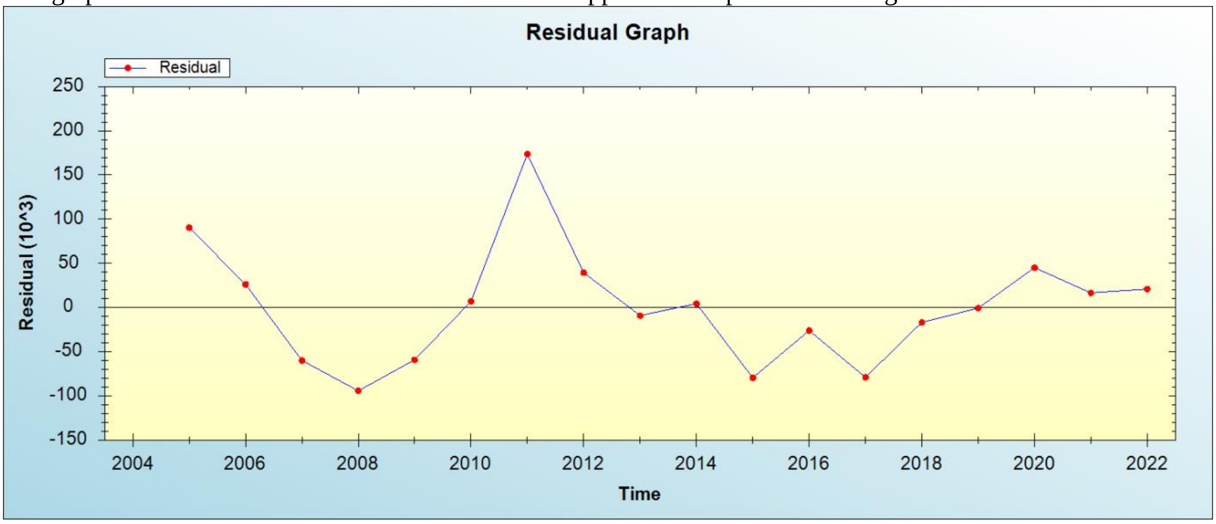

Figure 2. Graph of Residual Terms

Figure 2 shows that the error terms are randomly distributed. The graph of the actual values of the number of sheep and the error terms is given in Figure 3. Actual values and error terms are independent of each other and randomly distributed. Figure 4 shows the graph of error terms and predicted values.

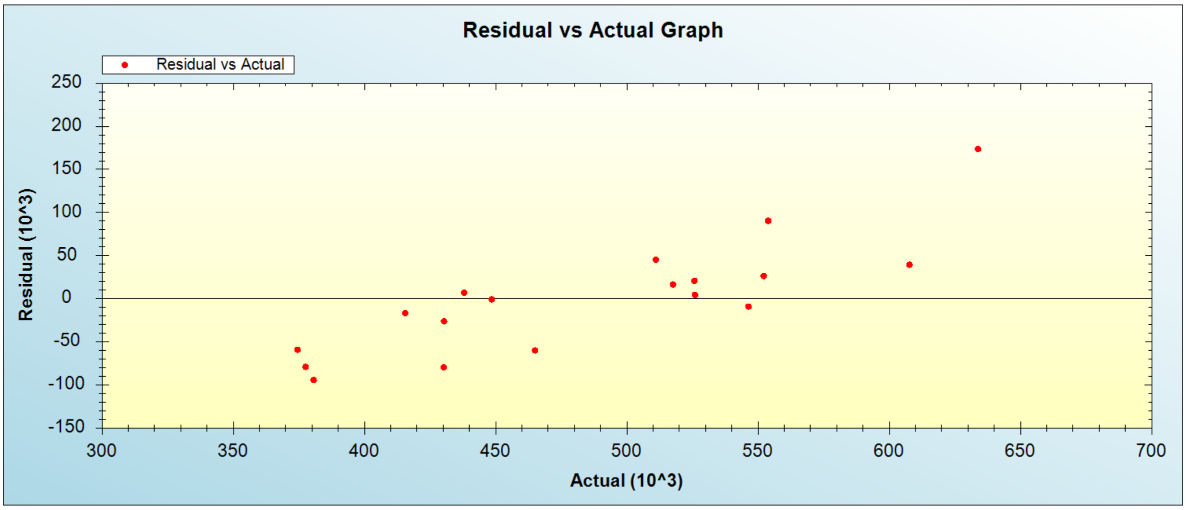

Figure 3. Graph of Actual Values and Residual Terms

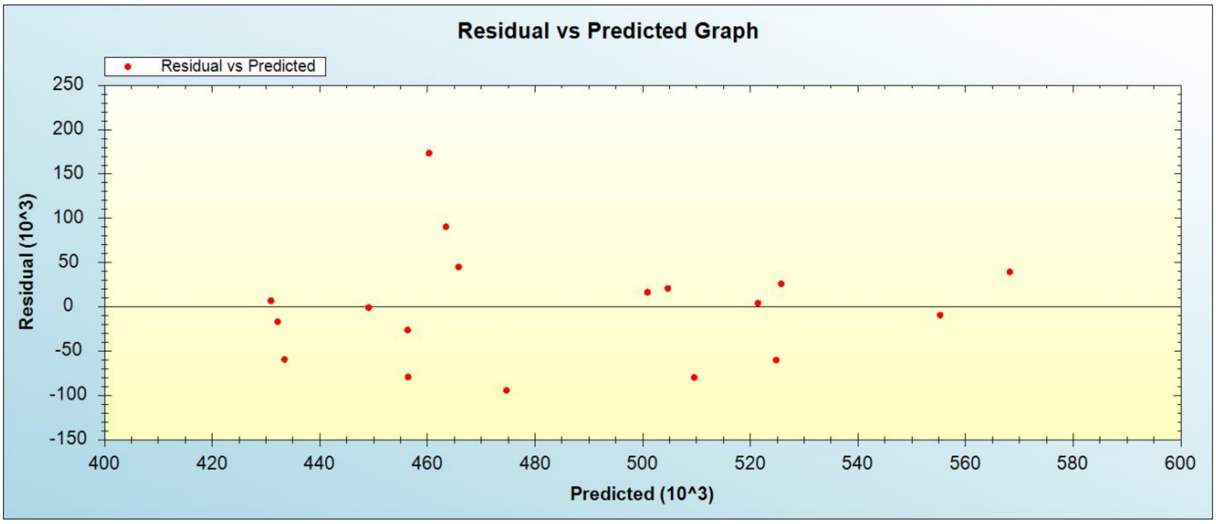

Figure 4. Plot of Estimated Values and Residual Terms

According to these results, sheep number projections for the years between 2023-2027 are given in Table 4.

Table 4. Sheep Numbers Forecation by Years

Years	Forecasting
2023	509445
2024	499956
2025	494457
2026	491288
2027	489470

As seen in Table 4, it is estimated that the number of sheep in Bitlis Province will be 509 445 in 2023 and this value will decrease in the following years and will be 489 470 in 2027.

For the number of goats in Bitlis, the numbers of input, hidden and output layers were determined as 1-12-1 respectively and applied with Back-Propagation Learning with 1000 iterations. MSE=162 954 548 and MAE=7309 were found in the ANN method. The predicted and observed values as well as the error term values are presented in Table 5.

Table 5. Observed, Estimated and Residual Terms

Years	Observation	Estimated values	Residual Terms
2004	131735	NaN	NaN
2005	118680	NaN	NaN
2006	125980	NaN	NaN
2007	121350	NaN	NaN
2008	140363	NaN	NaN
2009	128503	NaN	NaN
2010	177297	NaN	NaN
2011	256135	NaN	NaN
2012	279484	NaN	NaN
2013	282820	295050	-12230
2014	338101	304733	33368.4
2015	268581	287206	-18625
2016	286453	285840	612.738

2017	216944	217191	-246.91
2018	223298	224426	-1127.5
2019	236566	233202	3363.99
2020	257352	256908	443.759
2021	272797	272183	613.894
2022	287566	290022	-2455.5

The course and distribution graph of actual and predicted values as a result of ANN application for goat presence estimation is given in Figure 5.

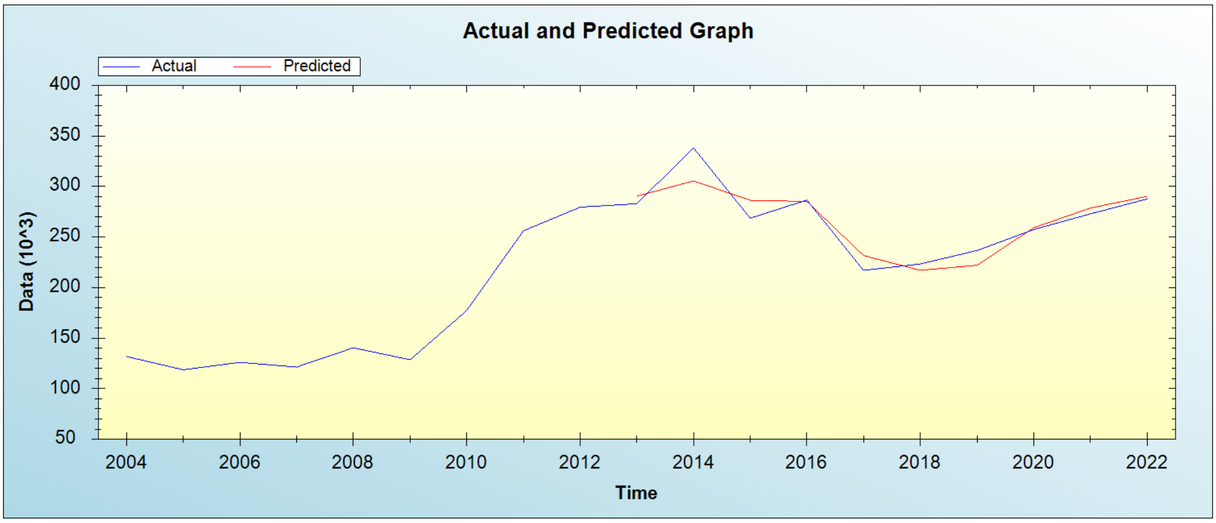

Figure 5. Graph of Observed and Predicted Values

The graph of the error terms obtained as a result of the ANN implementation for the number of goats is presented in Figure 6.

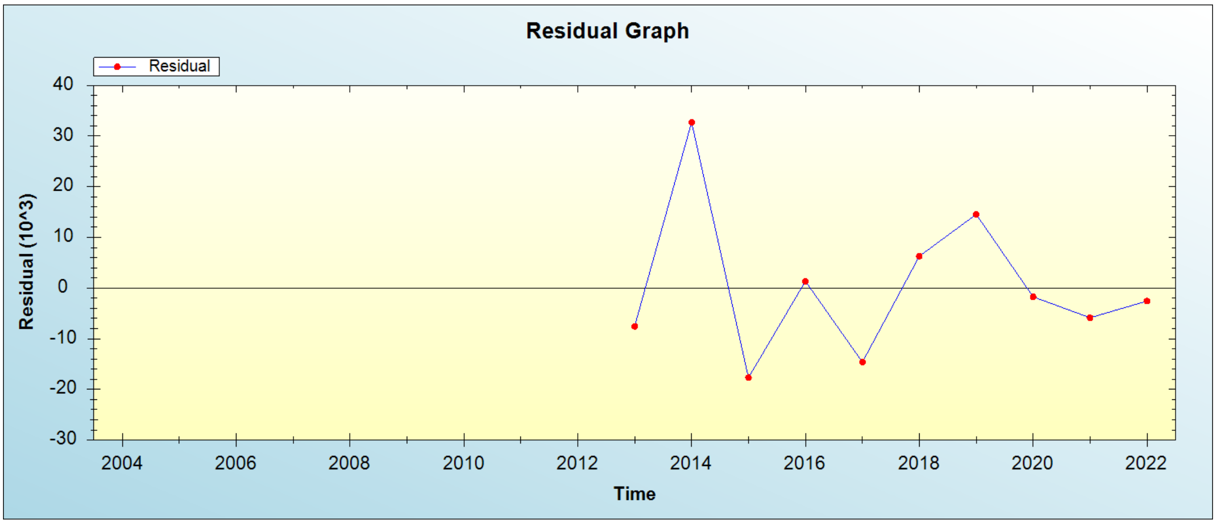

Figure 6. Graph of Residual Terms

Figure 7 shows that the error terms are randomly distributed. The graph of the actual values of the number of goats and the error terms is given in Figure 8. Actual values and error terms are independent of each other and randomly distributed. Figure 8 shows the graph of error terms and predicted values.

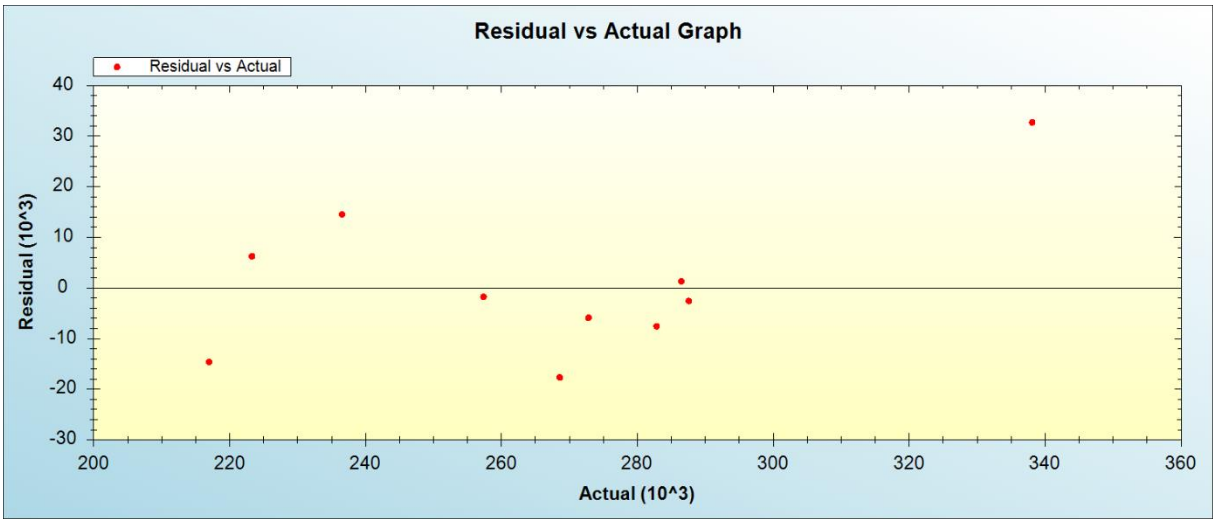

Figure 7. Graph of Actual Values and Residual Terms

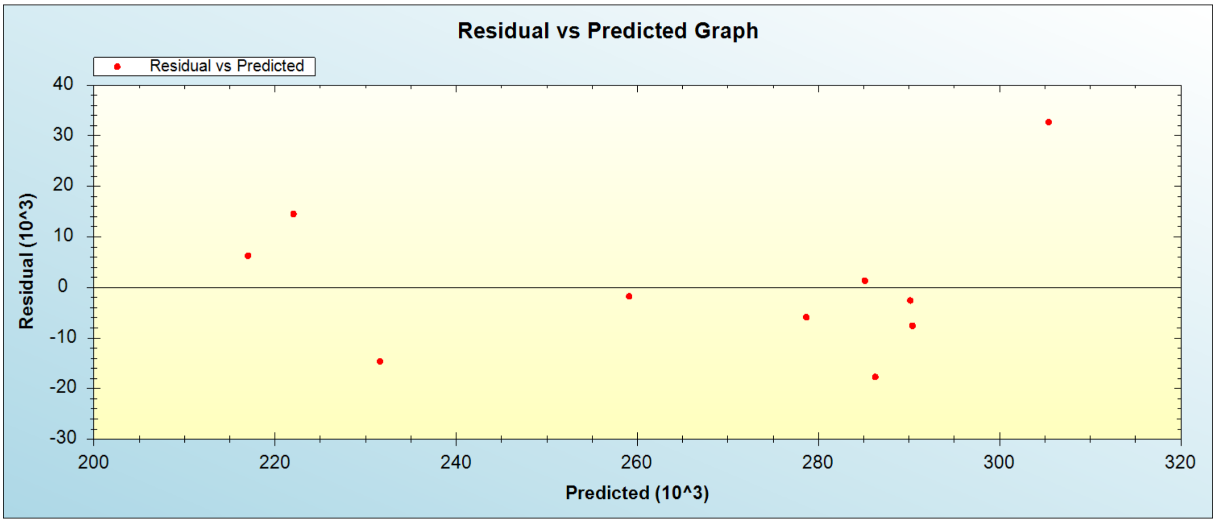

Figure 8. Plot of the Estimated Values and Residual Terms

According to these results, the prediction of the number of goats in Bitlis Province between 2023-2027 is given in Table 6.

Table 6. Prediction of Goat Numbers by Years

Years	Forecasting
2023	305867
2024	287207
2025	289940
2026	233451
2027	273701

IV. CONCLUSION

In this study, the number of sheep and goats in Bitlis Province was modeled with artificial neural networks. Years (2004-2022) were used as input variables, and the number of sheep and goats were used as output variables and modeled separately. The hyperbolic tangent function was used as an activation function.

With the ANN, it is expected that the sheep population in Bitlis Province in Türkiye would be between 509445 and 489470 in the period from 2023 to 2027. Compared to 2022, a decrease is expected in the sheep population in Bitlis in the next 5-year period. After 5 years, this decrease is expected to be 6.90%. In the same period, the goat population in Bitlis is expected to be between 305867 and 273701. According to 2022, a decrease is expected in the goat population in Bitlis in the next 5-year period. After 5 years, this decrease is expected to be 4.82%. This situation means that additional measures are required to be taken to protect the existence of small ruminant livestock in the region and to eliminate the defects. The residents should be encouraged to small sheep and goats breeding.

It is hoped that using artificial neural networks and alternative techniques in future forecasting studies will give good results in animal husbandry data.

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