

TREND ANALYSIS AND SHORT-TERM FORECASTING OF GOAT AND SHEEP POPULATIONS AND THEIR MEAT PRODUCTION IN SRI LANKA USING SINGLE AND DOUBLE EXPONENTIAL SMOOTHING MODELS

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ABSTRACT

Trend analysis and forecasting have become important tools in different fields. The small ruminants sub-sector is an important part of animal production in Asia as well as in Sri Lanka. The present study was conducted to identify the best trend and the time series model to forecast the goat and sheep population and their meat production in Sri Lanka. The findings of the study were based on the goat population and sheep population data during the years from 1960 to 2018 and mutton production and numbers of slaughtered goats and sheep during the years 1991 to 2017. Data were analyzed and the best model was selected according to the mean absolute percentage error (MAPE). Single Exponential Smoothing and Double Exponential Smoothing models were used to perform the short term forecasting. Among the Exponential models, the Single Exponential model was fitted only for the sheep population while the Double Exponential model was fitted for the goat population, mutton production and numbers of slaughtered goats and sheep. Sheep population, mutton production and numbers of slaughtered goat and sheep animals showed a decreasing trend while goat population showed a decreasing trend after the year 1978.

Keywords: Goat, Mutton, Sheep, Sri Lanka, Trend Models

1. INTRODUCTION

The contribution of the livestock sector to the total GDP of Sri Lanka was about 0.6% in 2017 where it marked a 3.9% growth (DAPH, 2017). Livestock plays a major role in the econometrics of the small-scale farms in almost all agro-ecological zones in Sri Lanka. Goats and sheep are considered as small ruminants in the livestock sector. Small ruminants are reared for food production and are popular among the Asian countries including Sri Lanka (Devendra, 2007). Milk, meat, fiber products, and manure are the major products of goat and sheep farming. Although the products of small ruminants have a good market with a range of products from meat to cheese to fiber, the commercial production of goat and sheep commodities are limited in Sri Lanka (Devendra, 1986). Goat and sheep produce healthy and quality milk and meat which are rich in protein, fats and other nutrients (Miguel *et al.*, 2017). Protein content is the same in goat and sheep milk as that of cow milk, but their proportions and genetic polymorphs are different (Park *et al.*, 2007).

In 2018, the national goat and sheep populations in Sri Lanka were around 314,000 and 11,000, respectively (Department of Census and Statistics, 2018). Among

the farming community in Sri Lanka, extensive goat farming is considered as a traditional form of farming. As of 2017, there were 79,675 registered goat farms in Sri Lanka. In contrast, there were only 290 registered sheep farms. The majority of the goat farms in Sri Lanka are distributed in the Dry and Intermediate Zones (DAPH, 2017). Among the 25 administrative districts in Sri Lanka, Jaffna possess the highest goat population (DAPH, 2018). However, in Sri Lanka, sheep farming is not much popular as that of the goat farming.

It is generally accepted that although considerable attention has been devoted to the cattle farming in Sri Lanka, less attention has been given for goat and sheep farming. This has hinder the exact potential and importance of goat and sheep farming in the country despite its potential to uplift the resource-limited subsistence farming in the Dry Zone. Several research studies have been conducted on goat farming, including feeding and other management practices. However, only a few studies have been conducted on sheep farming (Piyadigama *et al.*, 2009). Policymakers, scientists, and goat and sheep farmers have faced enormous problems in decision-making due to the lack of significant research studies on goat

and sheep production forecasting since accurate forecasting is necessary in developing statistical models in addition to updating existing models.

Exponential Smoothing is a time series forecasting method for univariate data which is used to predict future values in short-term. If there is only one variable or one type of data, it is referred to as univariate data. There is only one variable in each time series for goat population, sheep population, mutton production and numbers of slaughtered goat and sheep animals. This study was aimed to develop forecasting models for Sri Lanka's goat and sheep populations, and their meat production using single and double exponential smoothing techniques.

2. MATERIALS AND METHODS

2.1. Data Collection

Annual goat and sheep populations in Sri Lanka over the period 1960 to 2018 were collected from the Department of Census and Statistics of Sri Lanka. The mutton production and numbers of slaughtered goats and sheep over the period 1991 to 2017 were collected from the Department of Animal Production and Health (DAPH), Sri Lanka.

2.2. Data Analysis

Different trend models and time series models were tested for the data using the MINITAB Statistical Software package. The best models were selected based on the Mean Absolute Percentage Error (MAPE).

2.3. Trend Models

In the first stage of analysis, trend analysis was performed using Linear, Exponential and Quadratic trend models to find out the most suitable trend. Non-seasonal exponential smoothing methods were considered in the current study for the model building of time series data.

2.4. Exponential Smoothing Models

Single Exponential models and double exponential models (Holt's linear exponential smoothing) were tested with different constant values.

The Single Exponential Smoothing model is the simplest form among the exponential smoothing methods and gives the forecast for a short term considering the data from the previous period. The data were adjusted using the forecast error.

[Forecast error = $(Y_t - F_t)$]

$$F_{t+1} = F_t + \alpha (Y_t - F_t)$$

Where,

Y_t = observed value for time period t

F_t = fitted value for time period t

α = weighting factor, which ranges from 0 and 1

t = current time period

The Double Exponential Smoothing method (Holt's linear exponential smoothing) has developed with two smoothing constants α and β (values between 0 and 1) and consists of three equations.

$$L_t = \alpha Y_t + (1 - \alpha)(L_{t-1} + b_{t-1}) \dots \text{(a)}$$

$$b_t = \beta(L_t - L_{t-1}) + (1 - \beta)b_{t-1} \dots \text{(b)}$$

$$F_{t+m} = L_t + b_t m \dots \text{(c)}$$

Where,

L_t = estimate of the level of the series at time t

b_t = estimate of the slope of the series at time t

α = smoothing constant for the data

β = smoothing constant for trend estimate

m = periods to be forecasted into the future

α and β (= 0.1, 0.2, ...0.9) are the smoothing and trend parameters

2.5. Model Selection and Validation

Best fitted models were selected based on the Mean Absolute Percentage Error (MAPE) value which is illustrated below.

$$\text{MAPE} = \frac{1}{n} \sum_{t=1}^n |\text{PE}_t|$$

Where, $\text{PE}_t = 100 * (Y_t - F_t) / Y_t$

Selected models were validated by conducting residual analysis for autocorrelation.

3. RESULTS AND DISCUSSION

3.1. Trend Analysis of Goats and Sheep Populations

Trend analysis was carried out for the production and the population data of goats and sheep considering the lowest MAPE value of the trend models (Linear, Exponential and Quadratic).

Table 1 shows the MAPE values for the tested trend models for the goat and sheep population and mutton production. Whereas, figures 1 - 2 show the selected fitted - trend curves based on the lowest MAPE values with the observed values for the goat population, sheep population and mutton production.

The goat population from 1960 to 1977 showed an increasing quadratic trend due to favourable conditions prevailed in the country for goat farming. There were abundant feeding resources and land for free grazing as well as the availability of labour. From 1978 to 2018, it showed a decreasing quadratic trend. This is due to the civil war that prevailed in the country which ceased in 2009. The sudden drop observed in 1990 was much more prominent. This is because cattle farming gained popularity during this period and farmers moved towards cattle farming due to higher production and more profits. Consequently,

The sheep population has given higher MAPE values for the tested trend models. Both exponential and quadratic trend models have given 19 as the MAPE value. MAD and MSD values for the quadratic trend model were given as 4,101 and 31,857,829 whereas, MAD and MSD values for the exponential model are 4,219 and 32,130,911 respectively. Since the quadratic trend model has significantly given the lower mean absolute deviation (MAD) and mean standard deviation (MSD) values, the quadratic trend model was selected as the best trend model for

Table 1. MAPE values obtained by trend analysis for the goat and sheep population and mutton production.

Model	Goat population	Sheep population	No: of slaughtered animals	Mutton production
Linear	10	20	9	13.3
Exponential	10	19	8	13.0
Quadratic	6	19	8	13.0

the contribution of goat farming was decreased over time. Lack of land availability for grazing due to urbanization is another major reason behind the declining trend of goat farming. Engagement of youth in goat farming also became less due to industrialization, attitudes, and educational level.

forecasting the sheep population.

MAPE values of both trend analysis plots of quadratic and exponential trend models were given as 8 for the numbers of slaughtered goats and sheep. However, MSD values were 100,092,838 and 101,653,693 respectively. The MSD value was significantly lower in the quadratic trend model and was selected as the best for the numbers of slaughtered goats and sheep.

The numbers of slaughtered goat and sheep and mutton production from 1991 to 2017 shows a decreasing quadratic trend. The MAPE values of both exponential and quadratic trend models were 13; however, MSD values were 18, 406.5 and 17, 814.4, respectively. Therefore, the best-fitted trend model was a quadratic trend model for mutton production due to the MAPE and MSD values. The main reason behind the decreasing trends in the numbers of goats and sheep slaughtered appeared to be the decreasing populations over the years. In turn, this has resulted in a proportionate decrease in mutton production.

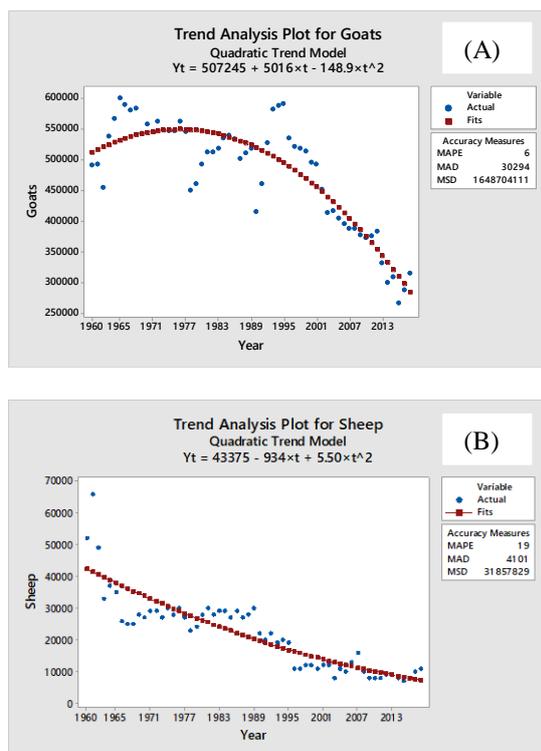


Figure 1. Trend models for Goats and Sheep Population (B).

3.2. Identification of the best model for short-term forecasting

Forecasted values of Single Exponential Smoothing method provide one year ahead. Whereas, for the forecasted values of the Double Exponential Smoothing method have given 3-years ahead. Tables 2 - 5 summarize the fitted and forecasted values of Single and Double Exponential Smoothing.

When MAPE values were concerned, both Single and Double Exponential Smoothing plots have given a MAPE of 5 for the goat population. Thus, a Double exponential smoothing plot was selected to forecast the goat population for 3 years ahead. The autocorrelation function of residuals of the goat population proved that residuals were uncorrelated (Figure 7).

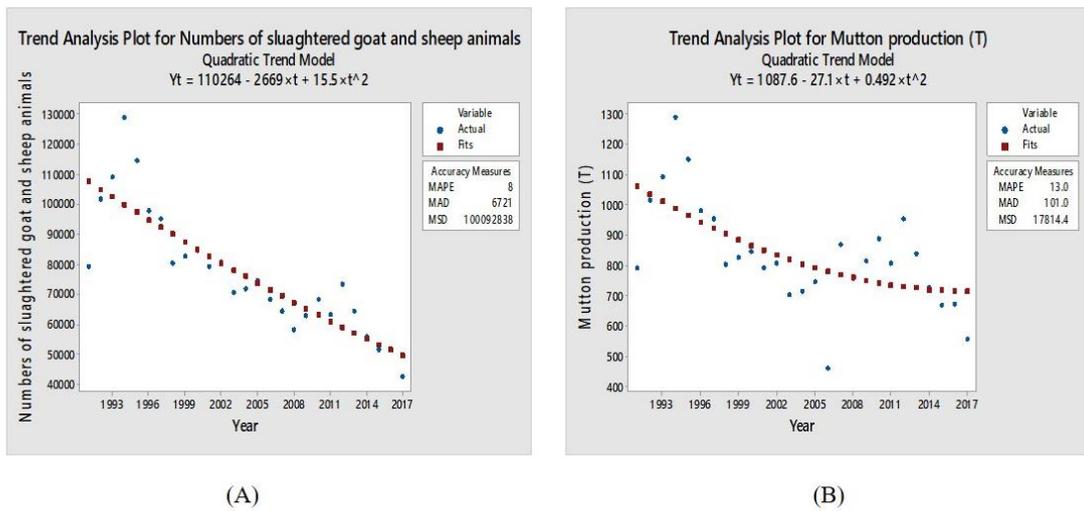


Figure 2. Selected trend models for number of slaughtered animals (A) and mutton production over the years (B)

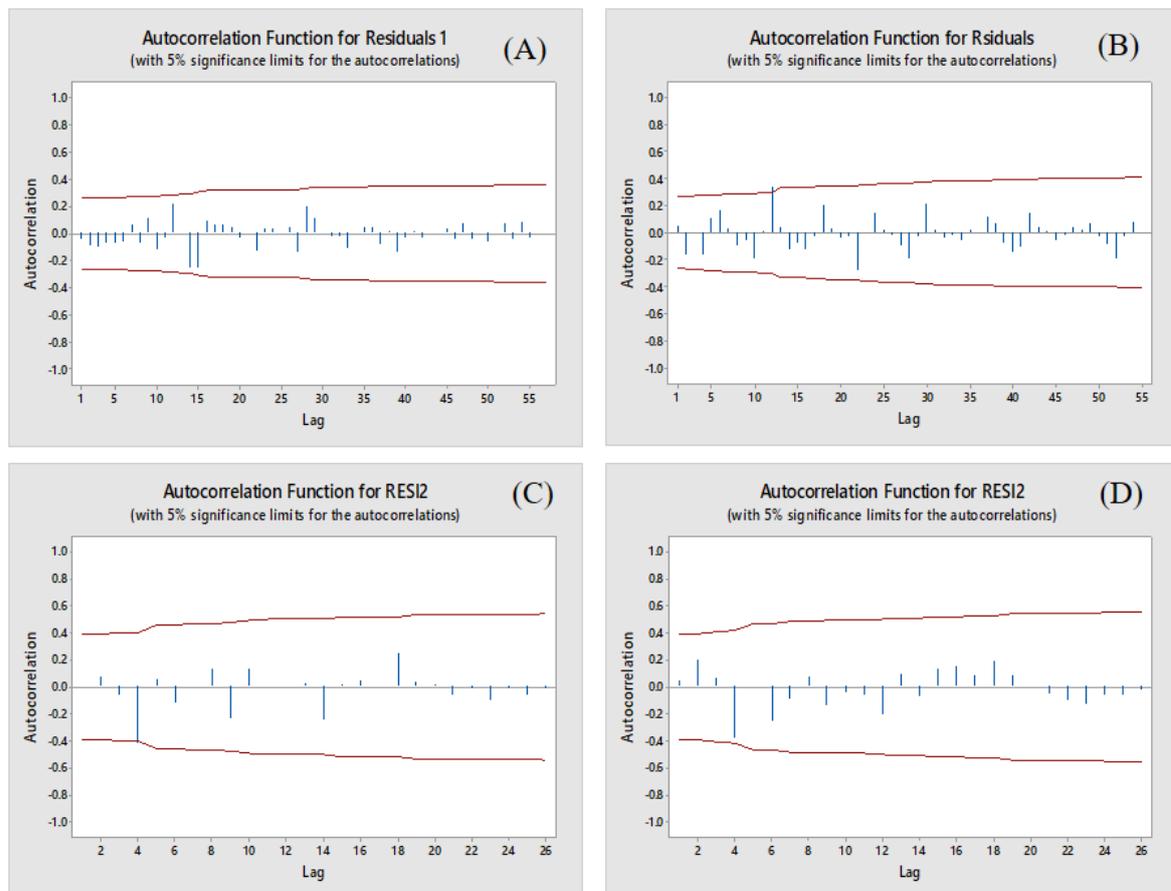


Figure 3. Autocorrelation function of the residuals graphs for goat population (A), sheep population (B), number of slaughtered animals (C), and mutton production (D).

The single Exponential Smoothing model gave a lower MAPE value of 12, and the Double Exponential

Smoothing model gave 19 for the MAPE value for the

forecasting of the sheep population. Therefore, the Single Exponential Smoothing model was used to forecast one year more precisely than the Double

Table 2. Fitted and forecasted values of goat population in Sri Lanka using SES and DES

Year	Observed values	Fitted/ forecasted values	
		SES	DES
2017	287,000		
2018	314,000		
2019		316,209	310,687
2020			305,313
2021			299,938

Table 3. Fitted and forecasted values of sheep population in Sri Lanka by SES and DES models

Year	Observed values (In 000)	Fitted/ forecasted values	
		SES	DES
2017	10,000		
2018	11,000		
2019		10,895	8,015
2020			8,694
2021			9,373

Table 4. Fitted/ forecasted values of numbers of slaughtered animals of goats and sheep in Sri Lanka using SES and DES models

Year	Observed values	Fitted/ forecasted values	
		SES	DES
2016	51,600		
2017	42,680		
2018		41,740	39,954
2019			37,805
2020			35,656

Table 5. Fitted/forecasted values of mutton production in Metric Tons in Sri Lanka

Year	Observed values (In Metric Tons)	Fitted/ forecasted values (In Metric Tons)	
		SES	DES
2016	671		
2017	555		
2018		590	566
2019			547
2020			529

Exponential Smoothing model. The autocorrelation function of the residuals of the sheep population showed that the residuals were uncorrelated (Figure 3B).

Both the Double Exponential Smoothing model and the Single Exponential Smoothing model have given the same MAPE value as 9 for forecasting the numbers of slaughtered goat and sheep animals. However, the MSD and the MAD values are lower in the Double Exponential Smoothing model. Therefore, the Double Exponential Smoothing model could be used to forecast three years ahead. The autocorrelation function of the residuals of the numbers of slaughtered goat and sheep animals showed that the residuals were uncorrelated (Figure 3C).

The single Exponential Smoothing model has given a MAPE value of 13 while the Double Exponential Smoothing model gave a MAPE of 12.9 for mutton production from 1991 to 2017. Hence, the Double Exponential Smoothing model was selected for the forecasting of mutton production three years ahead. Further autocorrelation function of the residuals of mutton production showed that the residuals were uncorrelated (Figure 3D).

5. CONCLUSION

Trend analysis for goat population data showed a decreasing trend after 1978. Sheep population, numbers of slaughtered goat and sheep animals, and mutton production data showed decreasing trends from the beginning to up to date. According to Single Exponential models and Double Exponential models, Double Exponential models are fitted more than Single Exponential models for the short term forecasting of goat population, numbers of slaughtered goat and sheep animals and mutton production data. The single exponential model was fitted with than Double Exponential model only for the short term forecasting of the sheep population. According to the MAPE values for the selected models, all the models give results above 95% accuracy level.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

W. A. D. V. Weerathilake: Conceptualization, Methodology, Writing – Reviewing and Editing; **G. L. I. Anuththara:** Software Data curation, Writing-original draft.

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