Journal of Applied and Natural Science 8 (4): 1766-1769 (2016)

JANS

Nonlinear modelling of sheep and goat populations in India

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Received: January 21, 2016; Revised received: June 14, 2016; Accepted: October 3, 2016

Abstract: The objective of this paper was to study the trend in population of sheep and goat populations during 1951 to 2012 in India. The data were compiled from various issues of BAHS (Basic Animal Husbandry Statistics) for the period 1951 to 2012. Different nonlinear growth models such as Parabolic/Sikka, Brody, Brody modified, Wood, Logistic and Gompertz models were fitted to the census data of sheep and goat population. The goodness of fit of the models was tested by Coefficient of determination (R^2), Adjusted coefficient of determination ($\underline{R}^2$), Mean Square Error (MSE), Mean Absolute Error (MAE) and Akaike Information Criteria (AIC). The populations of sheep and goat in India during the year 1951 were 39.10 million and 47.20 million numbers respectively and reached 135.17 million and 65.06 million respectively in the year 2012. Based on the various measures of goodness of fit we observed that the Parabolic/Sikka model was the best fitted model for studying the pattern in the populations of sheep and goat in India. This model has been used to project the sheep and goat population in India during 2020, 2025 and 2030. If the present pattern of growth continued in near future then the projected sheep population will be 102.37 million numbers whereas goat population will be 151.57 million numbers in the year 2030. The present study will provide the pattern in which the changes have been observed in sheep and goat populations in India during 1951 to 2012.

Keywords: Adjusted R^2, AIC, Durbin Watson test, MAE, MSE, Nonlinear models

INTRODUCTION

Animal husbandary, dairying and fisheries activities play an important role in national economy and in socio-economic development of the country. These activities contributed to the food basket, nutrition security, and household income of the farmers and play a significant role in generating gainful employment in the rural areas, particularly among the landless, small and marginal farmers and women, besides providing cheap and nutritious food, livestock are the best insurance for farmers against vagaries of nature like drought and other natural calamities (GOI, 2013). The livestock sector has emerged as one of the key component of agriculture growth in developing countries in recent year. The livestock wealth of our country is highly impressive. The livestock sector alone contributes nearly 25.6% of value of output at current prices of total value of output in Agriculture, Fishing & Forestry. The overall contribution of livestock sector in total GDP was nearly 4.11% at current prices during 2012-13. The total goat in the country is 135.17 million numbers in 2012 and the goat population declined by 3.82% over the previous census. The total sheep in the country was 65.06 million numbers in 2012 and sheep population declined by about 9.07% over previous census 2007. The Goat population has declined by 3.82 per cent and the total Goat population in the country was 135.17 million numbers in 2012 (GOI, 2014). Sheep are raised profitably with low investment (Bhatia *et al*., 2005, Singh *et al.,* 2006, Suresh *et al.,* 2011, Kumar *et al.,* 2013) and make a valuable contribution to the livelihood of the shepherds through sale of wool and animals. It is movable assets of high liquidity and a source of household nutrition and income generation (Kumar *et al*., 2013). The contribution of this system in livelihood security of households especially after new economic policy has gone down after interplay and intermixes of various actors and factors (Kumar *et al.,* 2007). The nonlinear model play an important role for forecasting of animal population, import and export of the commodities and agricultural production in the country. A special features of these models is that they are Mechanistic in nature as the parameters of these models have specific biological interpretation. The present investigation was carried out to study the nonlinear modelling of sheep and goat population in India. The present study will be helpful for forecasting of the sheep and goat population in India in near future.

MATERIALS AND METHODS

Data on the population of sheep and goat during the

ISSN : 0974-9411 (Print), 2231-5209 (Online)

years 1951 to 2012 were compiled form various livestock census reports and Basic Animal Husbandary Statistics (2014). For analysing the growth pattern of sheep and goat populations following nonlinear models were used.

1. Gompertz Model: $Y_t = a \exp\left[-b \exp(-ct)\right] + e$
2. Monomolecular model: $Y_t = a(1+b \exp(-ct) + e$
3. Logistic model: $Y_t = a/\ 1+b \exp(-ct) + e$
4. Parabolic/Sikka Model (1950): $Y_t = a \exp\left(bt-ct^2\right) + e$
5. Brody Model (1923): $Y_t = ae^{-ct} + e$
6. Brody Modified Model (1924): $Y_t = ae^{-bt} - ae^{-ct} + e$
7. Wood Model (1967): $Y_t = a \exp\left(bt-ct^2\right) + e$

The goodness of fit of the models was checked by coefficient of determination (R^2), adjusted coefficient of determination ($\bar{R}^2$) Mean square error (MSE), mean absolute error (MAE) and Akaike information criterion (AIC). To test the assumption about autocorrelation Durbin Watson test was used.

RESULTS AND DISCUSSION

The populations of sheep and goat in India were 39.10 million and 47.20 million numbers in the year 1951 and became 135.17 million and 65.06 million numbers respectively in the year 2012. It is evident that the population of sheep and goat increased at different rates during several periods. To study the behaviour of the sheep and goat populations we have fitted different models. Out of the seven nonlinear models only Parabolic/Sikka, Brody modified and Wood models converged to the certain parameters in case of sheep population. However Brody, logistic and gompertz model could not converge to the parameter estimates in case of sheep population. We have observed that among all the fitted models the values of R^2=0.919 and R^2 (Adjusted)=0.92 were highest for the Sikka model for the sheep population. Also MAE=0.506, MSE=2.049 and AIC=50.484 were lowest for the Sikka model. Based on the goodness of fit criteria we observed that Parabolic/Sikka Model is the best fitted model for describing the trend in sheep population during 1951 to 2012. Hence Sikka model can be used for projection of the sheep population for future years. The parameter estimates and goodness of fit statistics are given in Table 1. The trend in the sheep population during the different census years (actual sheep population) and the predicted population based on Sikka model is given in figure 1.

Out of the seven nonlinear models only Parabolic/ Sikka, Brody modified, Wood, Gompertz and logistic models converged to the certain parameters in case of goat population. However Brody and Monomolecular models could not converge to the parameter estimates in case of goat population. We have observed that among all the fitted models the values of R^2=0.971 and R^2(Adjusted)=0.98 were highest for the Sikka model for the goat population. Also MAE=0.967, MSE=6.192 and AIC=119.05 were lowest for the Sikka model. Based on the goodness of fit criteria we observed that Parabolic/Sikka Model is the best fitted model and can be used for projection of the goat population for future years. The parameter estimates and goodness of fit statistics for the goat population are given in Table 2. The trend in the goat population during the different census years (actual goat population) and the predicted population based on Sikka model is given in figure 2. The nonlinear models have been used by many authors for the forecasting of agricultural production in India. Prajneshu and Chandran (2005) used the nonlinear models for the computation of growth rates in agriculture. Iquebal and Sarika (2013) used nonlinear models for describing the lentil production in India. Panwar *et al*. (2014) used nonlinear models for forecasting of growth rates of wheat yield of Uttar Pradesh. Singh *et al.* (2014) used nonlinear models for describing soybean production in Madhya Pradesh. Pal and Mazumdar (2015) used nonlinear growth models for forecasting groundnut production of India.

Projection of sheep and goat population : To study the trend in the sheep and goat population different nonlinear model were fitted to the time series data. We have observed that parabolic/Sikka model was the best fitted model for describing the sheep and goat population dur-

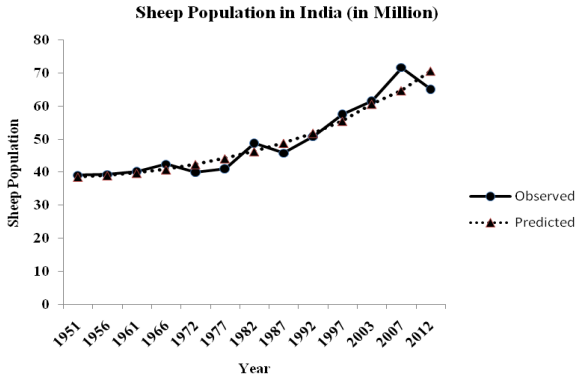

Fig 1. *Trend in observed and predicted sheep population during the different census years.*

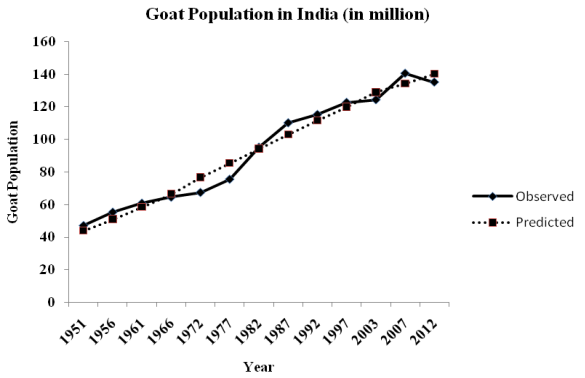

Fig 2. *Trend in observed and predicted sheep population during the different census years.*

Table 1. Parameter estimates of models and goodness of fit statistics for sheep population.

Nonlinear model	Parameter	Estimate	Std. Error	R^2	R^2 (Adj.)	MAE	MSE	AIC	DW
Parabolic /Sikka	a	38.4944	2.4901						
Model	b	0.00141	0.0042	0.919	0.92	0.506	2.049	50.484	2.277
	c	-0.0001	0.00006						
Brody Modified	a	34.307	1.914						
Model	b	-0.011	0.001	0.877	0.88	0.636	3.040	74.947	1.440
	c	31.384	0.000						
Wood	a	39.867	3.285						
Model	b	-0.88	0.043	0.913	0.92	0.565	2.166	53.942	2.102
	c	-0.015	0.002						

a= Asymptotic population, b=scaling parameter, c= growth rate

Table 2. Parameter estimates of models and goodness of fit statistics for goat population.

Nonlinear model	Parameter	Estimate	Std. Error	R^2	R^2 (Adj.)	MAE	MSE	AIC	DW
Parabolic /Sikka	a	42.6089	3.6264						
Model	b	0.03075	0.0048	0.971	0.98	0.967	6.192	119.050	1.354
	c	0.000186	0.00006						
Brody modified	a	52.666	3.606						
Model	b	-0.017	0.001	0.949	0.95	1.251	11.286	156.262	0.977
	c	2.115	1.377						
Wood	a	43.011	6.603						
Model	b	0.093	0.070	0.955	0.96	1.196	9.936	148.363	1.061
	c	-0.014	0.003						
Gompertz Model	a	256.137	99.960						
	b	1.787	0.328	0.968	0.97	1.029	6.972	126.399	1.291
	c	0.018	0.007						
Logistic Model	a	185.557	30.713						
	b	3.303	0.544	0.972	0.98	0.978	6.279	119.912	1.365
	c	0.038	0.008						

a= Asymptotic population, b=scaling parameter, c= growth rate

Table 3. Projected sheep and goat populations (Million numbers) in India.

Species	2020	2025	2030
Goat population	147.33	150.13	151.57
Sheep population	82.41	91.54	102.37

ing 1951 to 2012. Hence this model can be used for projection of sheep and goat population in future years. Table 3 represents the projected population of sheep and goat for the years 2020, 2025 and 2030. The sheep and goat populations in India will reach 82.41 million numbers and 147.33 million numbers respectively during the year 2020. The sheep and goat populations in India will be 102.37 million numbers and 151.57 million numbers respectively during 2030.

Conclusion

To study the trend in populations of sheep and goat population during 1951 to 2012 in India we have fitted different nonlinear models. We have observed that among the fitted models the values of R^2=0.919 and R^2(Adjusted) =0.92 were highest for the Sikka model for the sheep population. Also MAE=0.506, MSE=2.049 and AIC=50.484 were lowest for the Sikka model. Based on the goodness of fit criteria we observed that parabolic/ Sikka model was the best fitted model for describing the behaviour of sheep population in India. Similarly Sikka model was also the best fitted model based on the various measures of goodness of fit criteria for explaining the trend the in goat population in India during 1951 to 2012. We have used the best fitted models for the projection of the sheep and goat populations during the years 2020, 2025 and 2030. If the present pattern of growth continued in near future then the projected sheep population in the year 2030 will be 102.37 million numbers and goat population will be 151.57 million numbers.

ACKNOWLEDGMENTS

The authors are thankful to the learned referee and the Editor-in-Chief for their valuable comments on the original version of the paper.

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