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Prediction of Cow Milk Yield in Himachal Pradesh and Northern Himalayan Province of India

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ABSTRACT: Animals are an integral part of our farming system. Livestock production plays a major economic as well as cultural role in the rural community. It provides an indirect means of insurance against the risk of crop failure due to natural calamities such as drought and flood. This paper makes an attempt to predict the yield of cow milk in Himachal Pradesh Northern Himalayan state of India so that they can enhance the production of cow milk. Secondary data on cow milk production from 1993 to 2014 (22 years) of Himachal Pradesh were used for the purpose and different linear and non linear models were applied. The data were subjected to regression analysis and trend value of milk yield was also assessed. Various models such as Linear, Quadratic, Cubic and Compound models were fitted to predict the cow milk yield. $\overline{R^2}$, RMSE and Theil's U statistic were used for selection of model. Quadratic model turned out to be best fit for cow milk yield. Validation using F- Chow Statistics was carried out to ensure reliability and consistency of results.

Keywords: Statistical model, linear model, quadratic model, RMSE, adjusted R^2, F-chow, Autoregressive model.

INTRODUCTION

Despite the decline in the contribution of agriculture to national GDP from 50 per cent to 15 per cent, India's economy continuous to be agrarian with 60 per cent of population employed in the agriculture sector employing around. In the future agriculture will certainly remain the major means of livelihood for our population in the future (Bulbul *et al*., 2012).

Livestock means inventory (items of property) comprising farm animals, with the exception of poultry which is used for production of items for domestic consumption (Jha, 2004). In India the livestock production is of vital importance for the rural masses as the chief source of income and service (Birthal and Negi, 2012). In addition to increasing agricultural production by supplying manure, animals convert crop residues into highly nutritious proteins, thereby contributing to the nation's dietary requirements. 70 percent of the livestock are in the care of marginal farmers (Annonymus, 2012). India holds the distinction of the having world's highest milk production. The World milk yield during 2017-18 was projected at 843 million tonnes, with India contributing 176.3 million tonnes and Himachal Pradesh, 1.33 million tons. In terms of quality milk production by Indian states, Uttar Pradesh (22.33 million tonnes) top the list followed by Rajasthan, Andhra Pradesh, Gujarat and Punjab. The world cattle population is estimated at around 1.3 billion, out of which around 282 million come from India (Annonymus, 2019).

There could be number of factors which influenced to increasing pattern in milk production. The factors incorporated improvement in milk yield, shift in composition of dairy herd (Arya and Rawat, 1990; Shah and Dave, 2010; Kumar *et al.*, 2013), herd efficiency ratio (Chand and Raju, 2008), better supervision of animal stock, superior market access, rising urbanization and farm mechanization (Ganter *et al*., 2008), better access to groundwater irrigation, crops diversification, expansion of veterinary facilities and artificial insemination centres (Banu *et al.*, 2010), growing smallholder dairy production systems, development of road network, setting up of cooperatives, development of milk processing and milk collection facility (Cankaya *et al*., 2011) mounting income, per capita income and rise in milk prices (Birthal and Rao, 2004; Kishore *et al.,* 2016). The above review shows that the studies on dynamics of milk production trends are very much limited (Khalandar *et al*., 2019; Deluyker *et al*., 1990).

The present study was conducted with an aim to find the best model corresponding to prediction and validity of annual milk yield of cows in Himachal Pradesh**.** In general the pattern is linear or quadratic. The major seasonal variability variables are: (a) climate and weather conditions, and (b) social customs and practices. The goal of the seasonal variations analysis is to determine the impact of seasonal swings on the value to forecast and eradicate short-term fluctuations for the study of cyclic and irregular variability of the given phenomenon.

METHODOLOGY

A. Regression Analysis

It is a statistical technique for investigating and modelling the relationship between response variable and predictor variable. It can be used to predict the value of the response variable in terms of the regressor variable. The appearance of errors while using equations to predict the values of the response variable, indicate the presence of unknown variables not included in the model such as climate and weather factors prevailing during the period of study.

Regression analysis was performed with linear, quadratic, cubic and compound models. Autoregressive models of first, second and third orders were also used to study the trend in the data. By considering the time as an independent variable, various linear and nonlinear regression models were used for prediction of cow milk production.

(i) Linear Model: $Y_t = a + bt + e_t$

(ii) Quadratic Model: $Y_t = a + bt + ct^2 + e_t$

(iii) Cubic Model: $Y_t = a + bt + ct^2 + dt^3 + e_t$

(iv) Compound Model: $Y_t = ab^t + e_t$

where,

Y_t = time series values of dependent variable. (Area and Production)

t = time period

a = intercept

b, c and d = regression coefficients

e_t = Error term

B. Autoregressive Models

Sometimes when the regression analysis consists of time series data, the lagged values of the response variable are considered as the regressors (independent variables). Ordinary least square method is not appropriate for these models. However, if the errors are uncorrelated, these estimates are consistent. If the error terms are correlated then this is not always true. Based on the order of lagged values, various autoregressive models can be written as follows:

(i) First order autoregressive model: $Y_t = \phi_1 Y_{t-1} + e_t$

(ii) Second order autoregressive model: $Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + e_t$

(iii) Third order autoregressive model: $Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \phi_3 Y_{t-3} + e_t$

RESULTS

A. Estimation of cow milk production

(i) **Regression analysis of Cow milk production.** As depicted in Table 1, the t–statistic revealed the presence of significant regression coefficients in linear, quadratic, cubic and compound models. $\bar{R}^2$ values ranged between 0.907 in linear model and 0.950 in the quadratic model. On the basis RMSE and Theil's U statistic values the quadratic model was found the best fit (as indicated by lowest values of RMSE and Theil's inequality coefficient) followed by cubic and compound models. The linear model out of these four models was found unsuitable for estimating the of cow milk yield. Non-significant F values in the Chow test revealed the validity of quadratic model for prediction. Although quadratic, cubic and compound models could all be used for prediction, quadratic model (Fig. 1 and 2) was the best fit as supported by lowest values of RMSE (30.558) and Theil's inequality coefficient (0.062). Cow milk production for any given year can be estimated using $\hat{Y}_t$ = 287.448 + 2.337 (t) + 0.819 (t^2).

Table 1: Statistical parameters of linear, quadratic, cubic and compound models for prediction of total milk production of cow.

Statistical Model	Regression Coefficients		Standard error	t – statistic	$\bar{R}^2$	RMSE	Theil's U	F (Chow test)
Linear	A	212.133	19.390	10.940*	0.907	42.872	0.088	7.15*
	B	21.165	1.476	14.337*				
Quadratic	**A**	**287.448**	**22.569**	**12.763***	**0.950**	**30.558**	**0.062**	**0.395**
	B	**2.337**	**4.520**	**0.517**				
	C	**0.819**	**0.191**	**4.289***				
Cubic	A	300.461	33.455	8.981 *	0.948	30.317	0.063	0.208
	B	-3.783	12.318	-0.307				
	C	1.469	1.230	1.195*				
	D	-0.019	0.035	-0.536				
Compound	A	256.015	8.403	30.465 *	0.942	33.578	0.069	0.265
	B	1.047	0.003	400.130 *				

The actual and predicted cow milk production values obtained from a twenty year long study conducted during the period spanning 1993 to 2014 using linear, quadratic, cubic, compound models are shown in Table 2. As is clear from the values shown in the table, the difference between the actual and predicted cow milk production is lesser for the quadratic model as compared to the other three models.

Table 2: Estimated milk production of Cow by linear, quadratic, cubic and compound models.

Year	Actual Production (Thousand Tonnes)	Predicted milk production of Cow (Thousand Tonnes)			
		Linear	Quadratic	Cubic	Compound
1993	292.271	233.298	290.603	298.128	268.095
1994	303.558	254.464	295.395	298.620	280.745
1995	302.842	275.629	301.826	301.826	293.991
1996	323.597	296.795	309.893	307.630	307.863
1997	310.578	317.960	319.597	315.920	322.390
1998	326.385	339.126	330.939	326.583	337.601
1999	335.086	360.291	343.918	339.505	353.531
2000	349.620	381.456	358.535	354.574	370.212
2001	350.548	402.622	374.788	371.677	387.681
2002	372.705	423.787	392.679	390.699	405.973
2003	374.889	444.953	412.207	411.529	425.129
2004	499.993	466.118	433.373	434.052	445.188
2005	505.593	487.284	456.176	458.156	466.194
2006	500.005	508.449	480.616	483.727	488.192
2007	507.333	529.614	506.693	510.653	511.227
2008	528.361	550.780	534.407	538.820	535.349
2009	512.604	571.945	563.759	568.116	560.609
2010	542.100	593.111	594.748	598.426	587.061
2011	679.971	614.276	627.374	629.637	614.761
2012	690.966	635.442	661.638	661.638	643.768
2013	697.822	656.607	697.539	694.314	674.144
2014	714.963	677.772	735.077	727.552	705.954

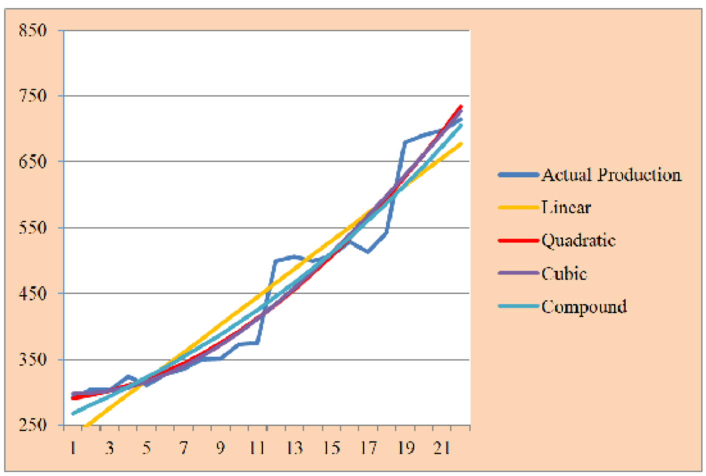

Fig. 1. Predicted values of cow milk production by different models.

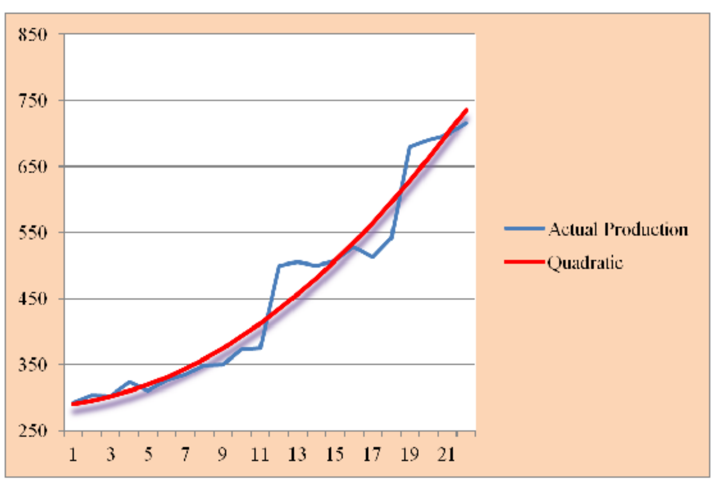

Fig. 2. Predicted values of cow milk production by Quadratic model.

B. Autoregressive models for Cow milk production

The autocorrelation coefficients for various lags along with their standard errors have been presented in Table 3. Since the first four autocorrelation values were significant, autoregressive models up to the fourth lag were found to be fit for prediction milk production of cow. Autoregressive models up to third order only were found to be significant. It can also be observed from Table 3. The maximum value of autocorrelation was 0.848 for the first lag and decreased with an increase in lag and consequently, the corresponding values for the second, third and fourth lags were 0.696, 0.543 and 0.387 respectively.

Table 3: Autocorrelation of different lags for the cow milk production.

Lag	Autocorrelation	Standard Error
1	0.848	0.199*
2	0.696	0.195*
3	0.543	0.190*
4	0.387	0.185*

Table 4 presents the coefficients of autoregressive models with their standard error and t-statistic values, $\overline{R}^2$, RMSE, Theil's inequality coefficient, F value obtained in chow test. The t-statistic was used to test the significance of coefficients in autoregressive models. The significant coefficients in the first, second and third order models were found to be Φ_1, Φ_2 and Φ_3 respectively. $\overline{R}^2$ value was 0.923 for the first order, 0.903 for the second order and 0.883 for the third order autoregressive models. The lowest value of RMSE i.e. 32.331 was detected in case of second order model followed by 34.986 and 35.733 for the third and first order models respectively. The lowest Theil's U statistic value was found for the first order autoregressive model the ranged from 0.045 to 0.114 for various models. The first order model showed a significant change in regression coefficients over the time as indicated by significant F value in chow test. Both the second and third order autoregressive models were found to be well fitted and valid for forecasting the milk yield for any given year. However, the second order model was preferred over the third order model for the prediction purpose due to the former's lower value of RMSE. It is also evident from Table 1 and 4 that the quadratic model had lower RMSE value (30.558) than the second order autoregressive model (32.331). Hence the quadratic model was found to be the best fit for cow milk production. Cow milk production can be predicted by using $\hat{Y}_t = 0.790(Y_{t-1}) + 0.100(Y_{t-2})$.

The actual and estimated cow milk production values are clearly depicted in the Table 4. It is evident from the table that the actual cow milk production is nearest to the estimated milk production of cow in case of first autoregressive model as compared to second and third autoregressive models.

Table 4: **Statistical parameters of autoregressive models for prediction of milk yield of Cow.**

Autoregressive Models	Coefficients		SE	t-statistic	$\overline{R}^2$	RMSE	Theil's U	F(Chow test)
First order	Φ_1	0.911	0.059	15.475*	0.923	35.733	0.045	6.14*
Second order	Φ_1	**0.790**	**0.238**	**3.324***	**0.903**	**32.331**	**0.106**	**2.81**
	Φ_2	**0.100**	**0.225**	**0.445**				
Third order	Φ_1	0.713	0.239	2.987	0.883	34.986	0.114	1.33
	Φ_2	-0.098	0.301	-0.326				
	Φ_3	0.232	0.224	1.034				

Table 5: Trend in milk production of Cow using auto regressive model.

Year	Actual production (Thousand tonnes)	Estimated milk production of Cow (Thousand tonnes)		
		First AR	Second AR	Third AR
1993	292.271	-	-	-
1994	303.558	297.672	-	-
1995	302.842	297.025	297.383	-
1996	323.597	315.924	298.892	300.027
1997	310.578	304.066	313.982	294.468
1998	326.385	318.464	305.280	314.206
1999	335.086	326.389	318.634	305.389
2000	349.620	339.627	326.958	319.177
2001	350.548	340.472	338.529	324.174
2002	372.705	360.654	341.477	339.581
2003	374.889	362.643	359.194	338.579
2004	499.993	476.594	373.426	383.148
2005	505.593	481.695	472.785	373.752
2006	500.005	476.605	476.642	461.130
2007	507.333	483.280	472.968	467.368
2008	528.361	502.433	480.858	467.537
2009	512.604	488.081	495.889	467.054
2010	542.100	514.947	486.394	490.426
2011	679.971	640.526	523.472	508.238
2012	690.966	650.541	633.453	518.320
2013	697.822	656.786	642.822	617.157
2014	714.963	672.399	649.950	628.298

CONCLUSION

In the present investigation linear, quadratic, cubic and compound models were fitted for estimation cow milk production, using 22 years of data. Among these the quadratic model was found best for estimation milk production of cow on the basis of the lowest RMSE and Theil's U statistics values. Non-significant F values in the Chow test revealed the validity of quadratic model for prediction. Autoregressive models till the 4th order were also fitted to predict milk yield of cow. Both 1st and 3rd order AR models were found to be well fitted and valid for the given year but the 1st order AR model was preferred to the 3rd order model for prediction purpose as per lower value of RMSE. The study further showed that quadratic model had lower RMSE value as compared to the 1st order AR model. Hence, the quadratic model was found to be the best fit and valid model for estimation of cow milk production in Himachal Pradesh, the northern Himalayan state of India. The same may be demonstrated by using the following equation:

$$\hat{Y}_t = 287.448 + 2.337\,(t) + 0.819\,(t^2)$$

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Conflict of Interest. None.

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