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RESEARCH ARTICLE

Trend and future perspective of milk production in Karnataka

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Abstract: The present study was conducted to understand the present and future perspective of milk production in Karnataka and to develop a suitable model for prediction of milk production in the state. The present study is having advantage as the past trends of milk production in the state have been impressive with growth, contributing significantly to overall milk production in the country. The Auto-Regressive Integrated Moving Average (ARIMA) and Artificial Neural Network (ANN) models were applied to the data sets of different dairy units for modeling and forecasting milk production in the state. The milk production of different dairy units has indicated a significant and positive trend over the years (Mann Kendal and Sen's estimator). The purpose of the study was based on the accuracy criteria to identify the best ARIMA and ANN models for forecasting. It was found that the ARIMA model predicted cows, goats, and total milk production with better R-Square, MAPE and percentage prediction error compared to ANN models. ANN model performed better in predicting the buffalo's milk yield compared to the ARIMA model. The best-identified models were used for out-sample forecast.

Keywords: ARIMA, ANN, Milk Production, Statistical Modeling, Trend Estimation,

Introduction

Milk is a complete source of nutrients for overall growth and development of the human body. In the world, total protein intake through milk and other dairy products is around 10.3 %. India is a leading country in milk production with an annual production of 187.7 million ton in 2018-19 with a per capita availability of 394 gm/day of milk. Indian dairy sector contributes up to Rs. 3.6 lakh crores through milk and milk products (DAHD & F, 2014) and has a recorded growth of 6.7 percent during 2017-18 (Anon, 2018). Despite the significant growth in export of milk and other dairy products during 2019-20 (US $ 280 million), it was lesser as compared to the export of 2018-19 (US$ 483 million). The countries *viz*., China, Algeria, Indonesia, Brazil, and Russia are the leading importer of milk and milk products (FICCI, 2020). India is at the top position in the production of buffalo's milk (66 million ton) as well as goat milk (5 million tons) production while second in cow milk production (54 million tons) next to USA. Even though at present, India is self-sufficient in dairy sector, but it may not be so soon due to the rapid growth rate in human population which may lead to substantial increase in demand for milk and milk products.

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For figures kindly visit website (Supplementary file)

Karnataka is an agrarian state where most of its population is dependent on Agriculture and allied activities. The dairy sector is practiced and having capacity of generating 8 billion liters of milk. Karnataka state is the seventh largest dairy market in India which provides enough opportunity for those practicing dairy. The cow and buffalo milk account for most of the total milk production in the state.

Forecasting plays a vital role in many fields of science *viz*., plant production (Dahikar and Rode, 2014), animal husbandry (Mgaya, 2019; Suresh et al. 2019), economics and engineering etc. Time series models are used for forecasting purposes and these models are widely used by the researchers and policy makers. The ARIMA (Auto-Regressive Integrated Moving Average) is a forecast engine used to analyze the milk yield through understanding the current and predicted behaviors. Therefore, forecast from the developed models would be extremely helpful for the decision makers in the dairy sector for policy implementation related to price support to farmers during excess milk yield, expanding the export capability to the new destination, to maintain the quality of the products and to expand the storage capacity. Hence, the present study will be helpful to the policy makers to plan and strategize future milk production in the state through the implementation of developed Autoregressive Integrated Moving

Average (ARIMA) and Neural Network Autoregressive models (NNAR).

Materials and Methods

The analysis has been carried out using 33-year (1986-2017) time series data for cow, buffalo, goats and total milk production in the Karnataka state of India. The secondary data was collected from the publicly available database maintained by the state veterinary department (Commissionerate Animal Husbandry and Veterinary Services, Karnataka, 2017-18). The above data has been utilized for model development, whereas 2018-19 data on total milk production (https://www.nddb.coop/information/stats/milkprodstate) has been used for model validation.

Trend analysis was performed using non-parametric techniques such as Mann-Kendal's Z (Kendal, 1975) and Sen's slope (Sen, 1968). The data has been tested for white noise, subsequently analyzed for ARIMA (Auto regressive Integrated Moving Average) and NN (neural network) model. The prediction efficiency of NN and ARIMA models have been analyzed using accuracy criteria like root mean square error (RMSE), MAPE (Mean Absolute Percentage Error), Akaike Information criteria (AIC) (Akaike, 1974), Schwartz Information Criteria/ Bayesian Information criteria (SBC/BIC) and R-Square.

Choosing the best models

The data was analyzed using R-Studio (R-Core Team, 2020) and SAS (SAS 9.3 ver.) environment. The R-packages like forecast, t-series were utilized to build forecast models. The models were automatically built using auto.arima function which gives the best models tested among different combination of p, d, q parameters based on the least AIC and SBC values. The feed forward neural network i.e.., NNAR was analyzed using 'forecast package' function called 'nnetar' which works similar to an auto.arima function. The estimated coefficients of the ARIMA models were tested at 5% level of significance.

Trend Analysis

The data series of cow, buffalo, goat, and total milk production has been analyzed using nonparametric Mann Kendal's Z and Kendal's Q to identify the existing trend in the data series.

The Mann-Kendal test mainly used to test whether a univariate time series data has monotonic trend (Upward or Downward), and it assumes in the data that, there should not be any autocorrelation. The hypothesis under this test is as follows.

H_0 = No trend

H_1= There exists a trend (Upward or Downward)

Test statistic is given by

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(x_j - x_i)$$

Where x_j and x_i sequential data values. Variance of S is given as follows

$$Var = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{t} f_t(f_t-1)(2f_t+5)\right]$$

Where t-varies over set of tied ranks and f_t is the frequency that rank t appears and the test statistic will be

$$z = \begin{cases} \frac{(s-1)}{se}, & S > 0 \\ 0, & S = 0 \\ (s+1) & S < 0 \\ /se, & \end{cases}$$

Where se=Standard deviation: if there is no monotonic trend.

Sen's slope Q

The magnitude of the trend can be estimated using Sen's Slope Q, which is based on the median values of variables (X_{ij}). The test statistics is given by

$$Q = \begin{cases} \beta_{\frac{(N+1)}{2}} & \text{Where N is odd} \\ \frac{1}{2}\left(\beta_{N/2} + \beta_{\frac{(N+2)}{2}}\right) & \text{Where N is even} \end{cases}$$

A positive Q values indicates upward trend and Negative represents downward trend. After trend analysis, the data has been checked for unit root presence using ADF test and found all dairy units' data series has unit root (ACF & PACF plots). Therefore, data is differenced to make stationery.

Auto regressive Integrated Moving Average (ARIMA): It is an important time series technique given by Box and Jenkins (Box and Jenkin, 1970). This model uses the linear combination of lagged values and errors.

The ARIMA model can be represented as

$$Y_t = \emptyset_0 + \varphi_p Y_{t-1} + \cdots + \varphi_p Y_{t-p} + et - \emptyset_1 e_{t-1} - \cdots - \emptyset$$

Where, Y_t are the actual values and e_t is the random error at time t and è, and ö are the model parameters to be estimated and p and q are the integer values. In ARIMA model, it is assumed that the underlying data should be white noise and error component is identically and independently distributed with constant variance and zero mean (e ~ iid (0, $ó^2$)). The ARIMA models are used by the various researchers of allied field to predict the milk production and other dairy related products (Sagar and Paramasivam, 2016; Deluyker et al. 1990; Lark et al. 1999; Sankar and Vijayalakshmi, 2017; Sánchez et al. 2014; Mgaya, 2019), and to predict various agricultural interrelated phenomenon (Paul et al. 2014). These models are sophisticated and better than any other models when the underlying data is linear.

ANN models have become more popular in the late 90's and then neural networks were used for a wide variety of applications. It is used in many fields of science including agriculture, veterinary, medical science, and other science related fields. Many researchers have applied the ANN technique (Shahriary and Mir, 2016; Dahikar and Sandeep, 2014) for predicting the various agriculture and allied products, animal genetics, and diet formulation, (Shahinfar et al. 2012; Saxena and Parasher, 2019; Ferna´ndez, 2006; Ehret, et al. 2015). The comparative analysis of ANN and other linear models includes multiple linear regression (Gandhi. et al. 2010) and ARIMA models etc. (Murphy et al. 2014; Adebiyi et al. 2014; Li et al. 2018) are also being conducted. In the present study, the models were chosen based on the accuracy criteria viz., root mean square error (RMSE), akaike information criteria (AIC), bayesian information criteria (BIC), coefficient of determination (R-Square), mean absolute percentage error (MAPE), and percentage prediction error (PPE).

Results and Discussion

Trend analysis of milk production from different dairy units in Karnataka was performed using mann kendal's Z and sen's slope Q statistic. The results of the trend analysis along with the descriptive statistics of the data series is shown in table 1. The time series data of cow, TMP and goats were found to be positively skewed while time series data of buffalo was negatively skewed distribution and except goat's data all other found to have flat curve which is indicated by negative coefficient of kurtosis values; therefore, time series data of all dairy unit have non normal distribution. The goats milk production was highly inconsistent (CV- 66.05%) followed by cow (CV- 44.547 %), TMP (CV- 35.137 %) and then buffalo milk production (CV- 21.17%). The data series of all dairy units were non-stationary according to augmented dickey fuller test values (Table 1).

The evidence from the Mann-Kendal's and Sen's Slope estimators, the time series data of all dairy units has a positive and significant trend. The values of Mann-Kendal's Z reveal that the rate of increase in milk production due to cow was higher (7.545) and for buffalo (5.33) was lesser compared to other units. It can be concluded that the rate of increase of total milk production (7.204) in Karnataka is attributed to rate of increase in the milk production from cows. The sen's slope estimator results revealed that the rate of total milk production was 145.870 MT/ year while cow milk production was increasing at a rate of 113.717 MT/year. The rate at which the buffalo (27.633 MT/year) and goat's milk production (2.210 MT/year) were progressing in the state was comparatively less and its contribution to the overall milk production was significantly lesser.

The ARIMA models of different p, d, q parameters fitted to milk production data of dairy units (Table 2) were selected based on lower AIC, SBC criteria and the residuals characteristics of the models. The ARIMA model with parameters p-1, d-1 and q-0 was best fitted to the cow milk production and exhibited least AIC (406.919), SBC (409.851) values, and the residuals from fitted model were found to be independent (x^2 = 0.995 at Lag 12). The parameters of the model found significant (MU-141.002, AR1 - 0.556) at 5% significance level. The autocorrelation and partial autocorrelation function plots for residuals from the model showed that the spikes were well within 5% significance level (Fig.2). The observed values of cow yield closely predicted by the model (1,1,0) which is depicted Fig 1.

For the buffalo's milk production ARIMA with first differencing (d-1) parameter found good fit (Fig. 3 &4) and this model had lowest AIC (398.195), SBC (401.127) values and the residuals were independent ($\mathbf{x^2}$ =0.883 Lag-12). The differencing (MU-25.369, t-value- 0.92) and autoregressive (AR- 0.249, t value- 1.38) parameter of the model was non-significant and therefore, the

Table 1: Descriptive, trend analysis and stationary test of milk production in Karnataka during 1985-86 to 2017-18

Variables	Mean	Standard Deviation	Median	Skewness	Kurtosis	C.V (%)	Mann-Kendal's Z value	Sen's Slope Q Value	ADF Significance
Cows (MT)	2591.86	1154.60	2598	0.464	-0.628	44.547	7.545	113.717	-0.483 (0.976)
Buffaloes (MT)	1468.93	311.03	1427	-0.128	-1.080	21.174	5.330	27.633	-2.062 (0.548)
TMP (MT)	4099.46	1440.45	4124	0.265	-0.788	35.137	7.204	145.870	-.210 (0.532)
Goats (MT)	38.65	25.53	39.00	1.171	2.137	66.049	6.749	2.210	-0.927 (0.933)

* CV-Coefficient of Variation, MT-Metric Tonnes, Values in the parenthesis are *p* value

model failed to produce better accuracy criteria. For predicting the goat (Fig.5) and total milk production (Fig.7) in Karnataka, ARIMA (1,2,0) and ARIMA (1,1,0) found best fit models and these models produced better accuracy criteria, respectively. The model parameters of ARIMA (1, 2, 0) and ARIMA (1, 1, 0) AR-1.00 and AR-0.533 found significant (*t-value* = 5.84 (Goat's), *t-value*= 3.15 (Total Milk Production)) at p-0.01 significance level, respectively. The model information criteria viz., AIC and SBC values showed that the models were best fit to the data set (Table-2 & 3). The graphical representation also showed that these models closely predicted the observed series of Goat and Total Milk production. The ACF and PACF plots showed that the residuals were within the limit (Fig. 4, 6 & 8). As per the model forecast, the total milk production from three dairy units is

Table 2: ARIMA models fitted along with their respective information criterion (AIC, SBC) for Milk production in Karnataka during 1985-86 to 2017-18

Variables	ARIMA Model	AIC	SBC	Ch-Square p-value for residuals
Cows (MT)	ARIMA (1,1,0)	406.919	409.851	0.995 (lag-12)
Buffaloes (MT)	ARIMA(1,1,0)	398.195	401.127	0.883 (Lag-12)
TMP (MT)	ARIMA(1,1,0)	427.100	430.032	0.923 (Lag 12)
Goats (MT)	ARIMA(1,2,0)	217.0915	219.9595	0.871 (Lag-12)

* AIC- Akaike Information Criterion, SBC-Schwartz Information Criterion, MT-Metric Ton

Table 3: Parameter estimates and significance of ARIMA models fitted to milk production in Karnataka during 1985-86 to 2017-18

Sl. No	Variables	Parameters of ARIMA	Model Estimate	Error Estimate	t-value
1	Cow	MU	141.002	52.150	2.70*
		AR1,1	0.556	0.214	2.60*
2	Buffaloes	MU	25.369	27.56	0.92
		AR 1,1	0.249	0.181	1.38
3	TMP	MU	166.416	66.995	2.48*
		AR1,1	0.533	0.169	3.15**
4	Goat	MU	0.78466	7.778	0.10
		AR1,1	1.00	0.171	5.84**

p-value * - 0.05 level, ** - 0.01 level

Table 4: Out sample forecast of ARIMA for Milk Production in Karnataka from 2018-19 to 2022-23

Units	Year	Forecast ('000 Tonnes)	Std Error	95% Confidence Limits	
Cow	2018-19	5637.572	135.497	5372.002	5903.142
	2019-20	5936.195	250.625	5444.979	6427.412
	2020-21	6164.842	355.931	5467.229	6862.454
	2021-22	6354.578	450.421	5471.770	7237.386
	2022-23	6522.678	535.153	5473.798	7571.559
Buffalo	2018-19	1791.634	118.231	1559.905	2023.363
	2019-20	1808.127	189.241	1437.221	2179.034
	2020-21	1831.280	244.704	1351.668	2310.893
	2021-22	1856.096	290.729	1286.277	2425.915
	2022-23	1881.328	330.622	1233.319	2529.336
TMP	2018-19	7522.743	185.727	7158.725	7886.761
	2019-20	7805.799	340.021	7139.371	8472.228
	2020-21	8034.445	479.210	7095.211	8973.680
	2021-22	8234.062	602.921	7052.359	9415.766
	2022-23	8418.192	713.178	7020.388	9815.995
Goats	2018-19	124.920	7.779	109.674	140.166
	2019-20	167.220	11.001	145.659	188.781
	2020-21	169.340	19.053	131.996	206.684
	2021-22	211.640	24.598	163.429	259.851
	2022-23	213.760	33.906	147.306	280.214

expected to achieve 8034.445 Metric tons by 2020-21. The cow milk production 6164.842 MT, Buffalo milk production 1831.280 MT and Goat's milk production expected to reach 169.34 million ton by 2020-21 (Table-4) with the 95 % significance level. Out sample forecasts was depicted in the table 5 from NNAR model. The total milk production for Karnataka during 2018-19 was 7901 MT (National Dairy Development Board, 2019) and the ARIMA (1, 1, 0) closely predicted the value (7805.79 MT for 2018-19) with 4.79 % prediction error, which means the models were better in predicting the milk production in Karnataka (Ranjit Kumar Paul et al. 2014).

ANN model with a single hidden layer was fitted to dairy unit's under study and linear activation function in the hidden layer. The results of the equipped NNAR models were the average of twenty networks fitted simultaneously to the data set. Nonlinear Autoregressive (NNAR) model with a single input, hidden and output model found better for predicting cow, goat, and total milk production while for buffalo, network with two input and two hidden units being used. In case of cow, goat and total milk production the single input i.e., 1 lag period (Y_{t-1}) being used as an input to build the forecasting network while 2 (Y_{t-2}) lag periods were used for building prediction model for buffalo milk yields. The fitted models exhibited better accuracy measures (RMSE), model fitted to total milk production had high RMSE value (203.575) followed by NNAR (1, 1) for cow (131.622), NNAR (2,2) for buffalo (66.356) and NNAR (1,1) for goat's (7.193) milk production (Table 6). The predicted values from NNAR models were plotted against the observed values which is shown in the figures (Fig.9,10,11).

On comparing ARIMA and NNAR models, ARIMA model performed better in predicting Cow's, total milk production and Goat's milk production based on R-Square and MAPE values. While Buffalo milk production was predicted accurately by NNAR model (Fig.12) than the ARIMA (1, 1, 0) model both in terms of R-Square (0.945) and MAPE (3.143) values (Table-7). Total milk production for 2018-19 was validated and found that the NNAR (1,1) predicted the milk production with prediction error 5.61 % which is slightly higher than that of prediction error for ARIMA model.

The ARIMA models performed better in explaining variation in the data series and prediction power especially when the data is stationary(Kumar and Lyngdoh, 2020). When the data is not stationary, differencing may make the data stationary (Jai Sankar and Vijayalakshmi, 2017). The fitted ARIMA models performed better in terms of accuracy criteria viz., AIC, BIC, RMSE, MAPE (Sánchez et al. 2014) and R-Square values except in the case of forecasting of buffalo milk production. The residuals of the fitted ARIMA models were independent. When the data is non linear and complex, ANN models usually perform better than linear time

Table 5: Out sample forecast of NNTAR for Milk Production ('000 tonnes) in Karnataka from 2018-19 to 2022-23

Year	Cow Milk Production	Buffalo Milk Production	Total Milk Production	Goat Milk Production
2018-19	5543.402	1573.521	7457.845	189.825
2019-20	5876.919	1482.109	7784.027	302.898
2020-21	6200.688	1532.715	8109.538	355.302
2021-22	6501.138	1624.260	8426.666	358.888
2022-23	6766.826	1725.561	8727.486	359.013

*Milk production in Metric Tons

Table 6: Fitted Neural Networks and their performance indicator in predicting milk production in Karnataka

Variables	Neural Network Type	Model	Output-Activation function	RMSE
Cow	NNAR(1,1)	1-1-1	Linear	131.622
Buffaloes	NNAR(2,2)	2-2-1	Linear	66.356
TMP	NNAR(1,1)	1-1-1	Linear	203.575
Goat	NNAR(1,1)	1-1-1	Linear	7.1935

*RMSE- Root mean square error

Table 7: Comparison of prediction performance of ARIMA and Artificial Neural Network model for milk production in Karnataka

Variables	R-Square		MAPE	
	ARIMA	ANN	ARIMA	ANN
Cow	0.988	0.986	3.237	3.7462
Buffaloes	0.876	0.945	4.652	3.1425
TMP	0.984	0.978	2.619	3.204
Goat	0.920	0.918	11.395	12.996

* MAPE-Mean Absolute Percentage Error

series models, since ANN models have a faster learning rate and convergence capacity than those linear models (Adebiyi et al. 2014; Li et al. 2018, Lahane, 2008).

Conclusion

It was found that the milk production in the Karnataka state is on significantly increasing trend across dairy units and the ARIMA, and ANN networks were able to capture the variability efficiently in the data sets. The fitted ARIMA models i.e., ARIMA (1, 1, 0) for cow's total milk production and ARIMA (1, 2, 0) for goat's milk production captured the data variation accurately. These model parameters could be used for future prediction of milk production in Karnataka. ANN models also provided consistent predictions but fell short compared to ARIMA model, however, ANN (NNAR [2,2]) model predicted the buffalo milk production with better accuracy than ARIMA models. Therefore, the above models could be potentially utilized by the policy makers for efficient management and while taking policy decisions for the development of dairy industry in the state of Karnataka.

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