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Growth, instability and forecasting of milk production in Assam: ARIMA application

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Abstract

The dairy industry is increasingly emerging as one of the most widespread and profitable industries due to its huge potential in fulfilling the nutritional demand worldwide. India holds first rank in terms of milk production in the entire world and Assam is the highest milk producing state in the North-Eastern Region (NER) of India with about 60 percent share of the total milk production in this region. The state registered a growth rate of about 2.97 percent in volume of milk production (GoI, 2019). Despite of registering a positive growth rate in terms of milk production, per capita availability of milk in Assam was estimated as only 73 grams per day in 2019, which is far below the Indian Council of Medical Research (ICMR) recommended intake of 300 grams per day. Under this backdrop, the present study was taken up with the twin objectives to study the trend and growth rate of milk production in Assam and to forecast the production of milk through ARIMA modeling. The study is based on time series data covering the period of 1995-96 to 2020-21. The growth rate of milk production in Assam was examined by estimating compound annual growth rate and among the parametric trend models linear trend model is found to adequately delineate trends in production of milk. Autoregressive Integrated Moving Average (ARIMA) was applied for modeling and forecasting of milk production of Assam. Augmented Dickey-Fuller (ADF) test was used to determine the stationarity of the model after which forecasting for future production was done. Data shows that production of milk displayed increasing trend and positive growth rate (1.27 percent per annum) and the production data showed low instability over the years. Moreover, the forecast from the fitted ARIMA model (2,1,0) shows that the milk production is expected to be 1024.04 million litres by 2026. Based on the findings, it is recommended to augment milk production with proper marketing and transport facilities in Assam to counter the consequences of low per capita availability of milk in the state and also promoting formation of dairy co-operative societies to restrict the milk flow through unorganized sector and regulate it through the organized sector to generate higher remuneration for the dairy farmers.

Keywords: ADF test, ARIMA, forecast, growth rate

Introduction

The Indian economy is primarily an agriculture-based economy as a large part of the country's rural population bank on agriculture, livestock rearing and allied activities for earning their livelihood. India is the largest milk producing country in the world with about 22% share of the total milk production around the globe, followed by USA, China, Pakistan and Brazil (FAO, 2019) [7]. The total volume of milk production in India was 195 Metric Ton (MT) in 2020 (FAO, 2021) [6]. The dairy sub-sector in India contributes the lion's share to overall livestock sector, contributing about 5% to the national economy and employing more than 8 crore farmers (Economic survey, 2021) [5]. Per capita availability of milk has been estimated as 427 grams per day in the country in 2020-21 (Economic survey, 2021) [5]. Though livestock rearing in the North-Eastern Region (NER) of India is considered as an indispensable part of the crop-livestock mixed farming system which has been in practice since time immemorial in this region, the present scenario of the development of milk production in the region is still not at the same level with the rest of the country. The total volume of milk production in the NER was recorded as of 1,455 MT ad per capita availability of milk was estimated to be of 119 grams per day in 2019 (GoI, 2019) [9], which was far below the national level of 427 grams.

Assam is the highest milk producing state in the NER with about 60% share of the total milk production in this region. The total volume of milk production in the state has been recorded as 882 MT in 2018-19 (GoI, 2019) [9]. The total livestock population in Assam has been estimated to be of 18.09 million in which cattle has the highest percentage share with 60.3% (Livestock Census, 2019) [11]. Despite Assam being the highest milk producing state in the NER,

per capita availability of milk in Assam was estimated as only 73 grams per day in 2019 (GoI, 2019) [9], which is far below the Indian Council of Medical Research (ICMR) recommended intake of 300 grams per day. The productivity of the milk producing animals too is low in Assam as compared to rest of India. For instance, average yield per milch animal in case of exotic cow in Assam is only 3.31 litres per day, while in India the same is 6.87 litres per day (Livestock Census, 2019) [11]. Keeping the above facts in view, the need for accurate and reliable forecast of milk production in Assam is indispensable and cannot be exaggerated. It will not only be beneficial for the dairy farmers but also for the policy makers in planning for future milk demand in the state. Though the dairy farmers usually make forecasts based on their past experiences, but statistical analysis of earlier data is believed to provide a more accurate and precise prediction. A wide number of time series forecasting models are available, among that the ARIMA (Auto Regressive Integrated Moving Average) model has emerged as one of the most popular models. ARIMA model has been used extensively by many researchers for forecasting the production of milk in India (Deshmukh and Paramasivam, 2016, Balan *et al*., 2019, Mishra *et al*., 2019) [4, 1, 12]. Under this backdrop, the present study has been taken up with the twin objectives which are (1) To study the trend and growth rate of milk production in Assam and (2) To forecast the production of milk in Assam through ARIMA modeling.

Material and Methods

The present study is based on secondary data on production of milk in Assam, which have been collected from different Issues of Integrated Sample Survey, Directorate of Animal Husbandry & Veterinary, Govt. of Assam. The data on milk production was collected for the years 1995-96 to 2020-21, *i.e*., a period of 26 years. The R statistical software (4.0.2) package has been used for analyzing the data and prediction of the future values.

Descriptive statistics

To examine the nature of time series data, statistical tools used are minimum, maximum, average, standard error, skewness, kurtosis.

Parametric trends models

To get an overall movement of the time series data, trend equations are fitted. In this exercise, different functional forms like: polynomial, exponential, linear, compound etc. were used for the purpose and linear form was found the best fit based on the highest value of coefficient of determination (R^2).

Compound annual Growth Rate (CAGR)

The performance of production of milk in Assam and the growth rate during the period under study are examined by estimating compound annual growth rate using the given formula:

$Y_t = a\ b^t$

Where,
Y_t = Production of milk
a = Constant
b = Regression coefficient
t = Time variable

After natural log transformation of the above function, it is estimated as:

$\ln Y_t = \ln a + t \ln b$

Compound annual growth rate has been calculated using the following formula:

$G = [\text{antilog}(\ln b) - 1] \times 100$

Instability Index

As simple CV does not explain properly the trend component inherent in the time series data. Alternatively, the Coefficient of variation around the trend (CV_t) rather than co-efficient of variation around the mean (CV) was suggested by Cuddy and Della (1978) [3] as a better measure of variability. The index of instability was constructed as follows:

$$CV_t = CV \times \sqrt{1 - R^2}$$

Where,
CV = coefficient of variation (in percent)
R^2 = coefficient of determination from a time-trend regression adjusted by the number of degrees of freedom.

The corresponding range and interpretation for the index is as follows:
Low instability: 0-15
Moderate instability: >15- Upto 30
High instability: Above 30

ARIMA

ARIMA, popularly called Box–Jenkins (BJ) methodology is a statistical tool in which future values explained by past values of the variable itself and random error terms (Gujarati and Porter, 2009) [10]. ARIMA stands for Autoregressive Integrated Moving Average. There are two basic assumptions which need to be fulfilled before applying this model *viz*., linearity and stationarity. A general ARIMA model is represented as:
ARIMA (p, d, q).

Where,
p = Number of autoregressive terms,
d = Number of times the series has to be differenced before it becomes stationary,
q = Number of moving average terms.
A generalized ARIMA model is of the form.

$\Phi(B)\ yt = (1-B)\text{-}d\ \Psi(B)et$

Where,
B= Backward shift operator such that Byt = yt–1.
yt = Actual value at time t.
et = Random error at time t.
Φi (i=1,2,….,p) and Ψj (j=1,2….q) are the model parameters.

The method consists of four steps

Identification

The tentative values of p, d and q are worked out with the help of Augmented Dickey-Fuller test and correlograms of autocorrelation (ACF) and partial autocorrelation (PACF) functions.

Estimation

At this stage, the tentatively chosen parameters of the ARIMA model are estimated based on the Akaike information criterion (AIC) and Bayesian information criterion (BIC) values.

$AIC = T \log(\sigma^2) + 2(p+q+1)$
$BIC = T \log(\sigma^2) + (p+q+1) \log T$

Where,
T= Number of observations used for estimation of parameters σ 2= Mean square error.

Diagnostic checking

For a model to be a reasonable ût to the data, the residuals from the fitted model are examined using the Shapiro-Wilk normality test, given by

$$W = \frac{[\sum_{i=x}^{n} aixi]^2}{(\sum_{i=x}^{n} xi - x)^2}$$

Where,
xi = Ordered random sample values.
ai = Constants generated from the covariances, variances and means of a normally distributed sample.

Forecasting

In this stage, to evaluate the accuracy of the fitted model, the one step ahead forecasting for the years 2016-17 to 2020-21 has been done after which the production of milk is forecasted for a period of five years from 2021-22 to 2025-26. Being satisfied with the performance of the selected model, the forecasting is done up to a period of five years in order to minimize the errors that may arise by increasing the period of forecasting.

Results and Discussion

Growth rate of milk production in Assam

Since 1995-96, the growth in total volume of milk production has increased from 699 million litres to 1004 million litres till 2020-21, registering an overall growth rate of 43.63% (Table 1). This increase in the milk production over the years can be mainly attributed to the effect of introduction of highly productive crossbred cattle in the state. The upgradation to crossbred cattle was facilitated owing to the increased awareness and realization among farmers about the economic value of cattle rearing.

Table 1: Volume of milk production in Assam (1995-96 to 2020-21)

Year	Milk (Million Ltr.)	Year	Milk (Million Ltr.)
1995-96	699	2008-09	827
1996-97	711	2009-10	830
1997-98	719	2010-11	832
1998-99	725	2011-12	839
1999-00	733	2012-13	845
2000-01	736	2013-14	857
2001-02	750	2014-15	873
2002-03	773	2015-16	888
2003-04	795	2016-17	904
2004-05	812	2017-18	925
2005-06	822	2018-19	946
2006-07	823	2019-20	975
2007-08	824	2020-21	1004

Source: Directorate of Animal Husbandry & Veterinary, Govt. of Assam

The mean value of milk production in Assam has been estimated as 825.65 million litres since 1995-96 to 2020-21. Kurtosis value (-0.382) of milk production indicates its platykurtic nature. Skewness (0.365) reveals that starting from the initial years of the period under investigation; a continuous increase was observed in the yield of milk. There has been substantial growth in milk production in the state of Assam during the period under investigation. Increased production of milk in Assam would not have been possible without an increase in the state bovine population.

Trends in milk production in Assam

To work out the trends in milk production in Assam, different parametric models like linear, logarithmic, quadratic, cubic, compound, growth, and exponential models were attempted among the competitive models. The best fit model was selected as linear on the basis of the highest value of coefficient of determination (R2=0.9509). The trend in production of milk in Assam for the past 26 years has been depicted in Fig.1. It is evident from the Fig. 1 that milk production has increased steadily over the past two decades in Assam. This rise in production of milk can be attributed to the increasing demand of raw milk and derived milk products in Assam, improved veterinary services over the years in comparison to other states in the NER. Moreover, the introduction of high yielding crossbred cattle breeds in the state in recent years has increased awareness level and realization among the farmers about the economic value of cattle rearing as animals of these breeds provided them higher milk productivity and higher net return.

Table 2: Descriptive statistics of milk production (1995-96 to 2020-21) in Assam

Particular	Production (million litres)
Mean	825.65
Kurtosis	-0.382
Skewness	0.365
Minimum	699
Maximum	1004

Source: Authors calculation based on secondary data

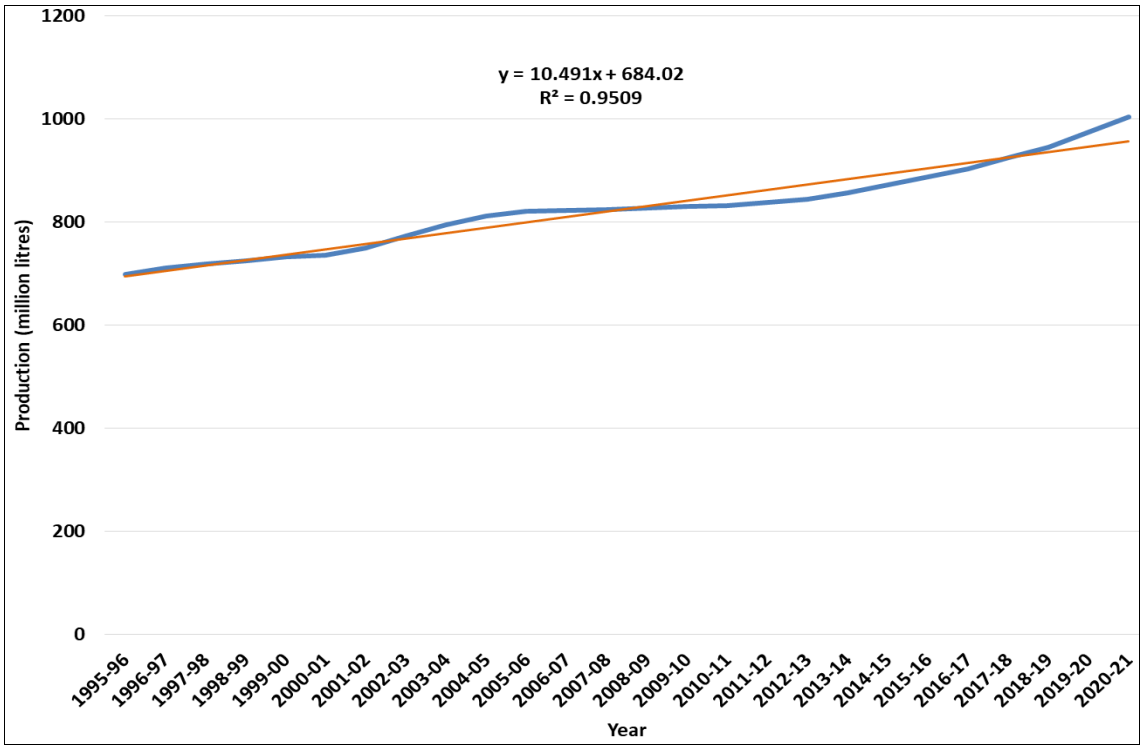

Fig 1: Trend in milk production in Assam (1995-96 to 2020-21)

The compound annual growth rate of milk production in Assam (1995-96 to 2020-21) is displayed in Table 3. The table depicts that over the last two decades, Assam's milk production volume has registered a positive and consistent growth rate of 1.27% per annum. Increase in the high yielding crossbred cattle breeds was the main reason of increased milk production rather than any dairy technological breakthrough in the state. This indicates that dairy farming in the state has been increasingly becoming a good source of generating additional income for the small and marginal farmers in Assam.

Table 3: Compound annual growth rate of milk production in Assam (1995-96 to 2020-21)

Particulars	CAGR
Volume of milk production	1.27***

Source: Directorate of Animal Husbandry & Veterinary, Govt. of Assam
Note: *** indicates significance at 1% level

Instability in milk production

The instability of production of milk in Assam is shown in Table 4. Production of milk in the state during the whole period under investigation has shown coefficient of variance of 9.967 and has an instability index of 2.79, which implies a very low degree of instability. This indicates that there is good remunerative return in continuing and expanding milk enterprise along with the traditional farming practices.

Table 4: Instability in milk production in Assam (1995-96 to 2020-21)

Measurement Statistics	Whole Period
CV	9.967
R^2	0.96
CV_t	2.79

Source: Directorate of Animal Husbandry & Veterinary, Govt. of Assam
Note: CV-Coefficient of variation, R2-Coeffecient of determination, CVt-Instability index

ARIMA

Model identification

At first, the study took unit root test for checking the unit root and stationarity of the original data series. Because the pre-requisite of the Box-Jenkins [2] ARIMA model is that the series should be stationary to estimate the parameter of the model. From Fig. 1 it is clear that the milk production shows a linear trend and the Augmented Dickey Fuller (ADF) test was taken to figure out if the data of milk production is stationary around a mean or linear trend or are non-stationary due to a unit root by regression of the given equation.

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{t=1}^{m} \propto t \, \Delta Yt - 1 + \epsilon t$$

Where,
$\in_t$ = White error term
$\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$ etc.

The null hypothesis for the ADF test is that H_0: $\delta=0$ (there is a unit root) and the alternative hypothesis is that H_1= $\delta<0$ (the data is stationary).

Table 5: ADF test for testing stationarity of the model

Order of the model	Dickey-Fuller Statistic	p-value
0	-1.2807	0.84
1	-3.9058	0.03

Source: Computed by author using R (4.0.2) software.

From Table 5, it has been found that the p value of the ADF test statistics for milk production is greater than 0.05 which implies that the original series has a unit root. So, the series is non-stationary at this level. So, to get a stationary series, we need to go for differencing the series so that there are no unit roots. After performing one differencing, we can see from the Table 5 that p value for ADF test is 0.03 which is less than 0.05. Thus, the Dickey-Fuller Statistic (τ) is significant at the 5% level and is greater than the critical value after first differencing and ultimately the time series data becomes stationary.

Furthermore, the time series data of milk production was plotted to identify any unusual observations. In this study, the last 26 years' data were used for the modeling purpose of milk production in Assam. The PACF plot of the data was used to identify the AR order and the ACF plots was used to identify the MA order of the ARIMA process. The plot of autocorrelation function (ACF) and the partial autocorrelation function (PACF) is given in Fig. 2 and Fig. 3 which gives a specific pattern about the autoregressive and moving average orders. Fig. 2 of the 1st differenced series of milk production revealed that there is some exponential decay after lag 0 in ACF and also exponential decay after lag 2 in PACF plot. It has also shown that for milk production, there is a significant spike at lag 0 in the ACF and exponential decay after lag 2 in PACF suggesting that the possible AR order might be 2 and MA order might be within 0 to 2 range.

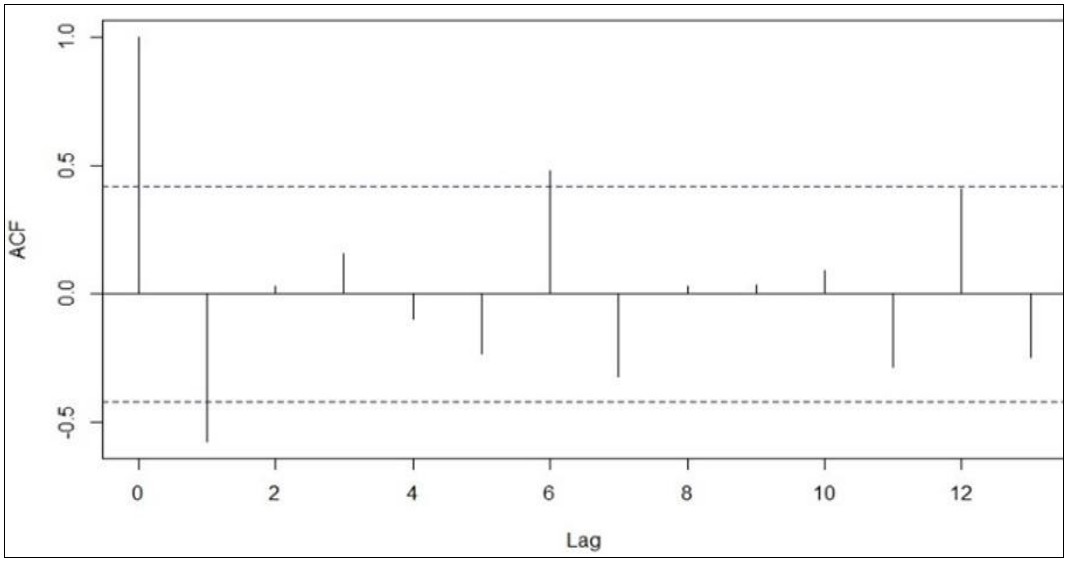

Fig 2: Correlogram of ACF

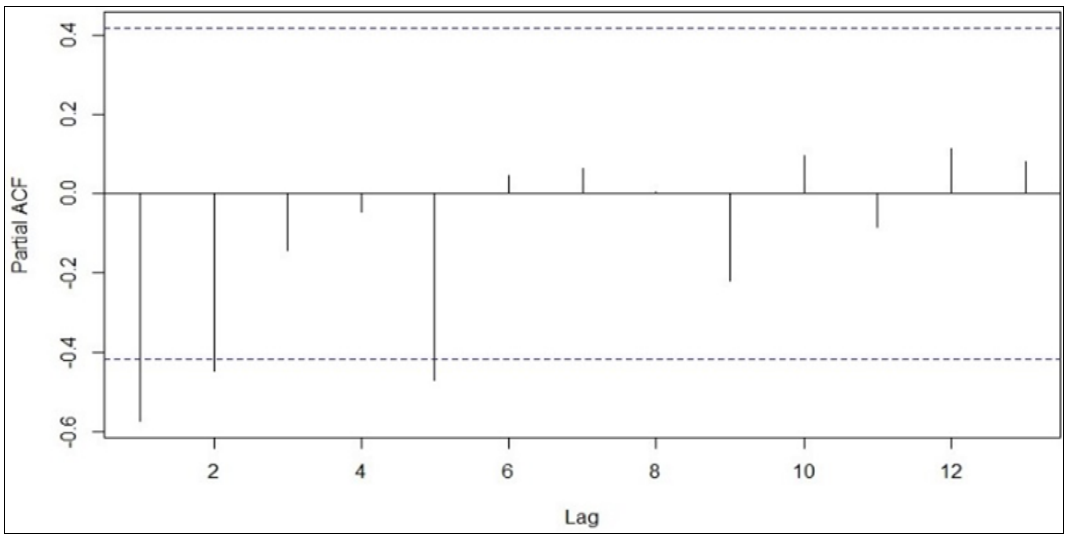

Fig 3: Correlogram of PACF

Model Estimation

The different models of milk production were fitted using different significant values of p, d and q. The minimum values of Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) were used for selecting the values of p, d and q because, it implies that the model with minimum AIC and BIC is closer to the best possible choice because they have residuals with white noise. It has been found from able 6 that ARIMA (2, 1, 0) for milk production was the best selected model based on the minimum values of AIC and BIC and is selected for the purpose of subsequent modeling and forecasting of milk production in Assam.

Table 6: Estimation of ARIMA model with AIC and BIC

ARIMA (p, d, q)	AIC	BIC
(1, 1, 0)	156.12	159.78
(2, 1, 0)	121.42	125.4
(3, 1, 0)	156.31	162.4

Source: Computed by author using R (4.0.2) software.

Diagnostic Checking

To determine the validity of the ARIMA (2, 1, 0) model, the residuals are tested for normality with the help of Shapiro Wilk test. It is a test of normality for small sample sizes (n<50). The null hypothesis for this test is that the data are normally distributed. If the chosen alpha level is 0.05 and the p-value is less than 0.05, then the null hypothesis that the data are normally distributed is rejected. If the p-value is greater than 0.05, then the null hypothesis is not rejected. From Table 7, it is clear that the data has normal distribution with W statistic of 0.96 and p value of 0.47. Ultimately, the test of the residuals for the fitted ARIMA (2, 1, 0) model suggests that there is no significant pattern in the residuals and hence, it may be concluded that the residuals are normally distributed and the model is suitable for predicting the production of milk as there is no autocorrelation among the residuals of the model.

Table 7: Test for normality of the residuals

Particulars	Value
W	0.96
p-value	0.47

Source: Computed by author using R (4.0.2) software.

Forecasting using ARIMA model

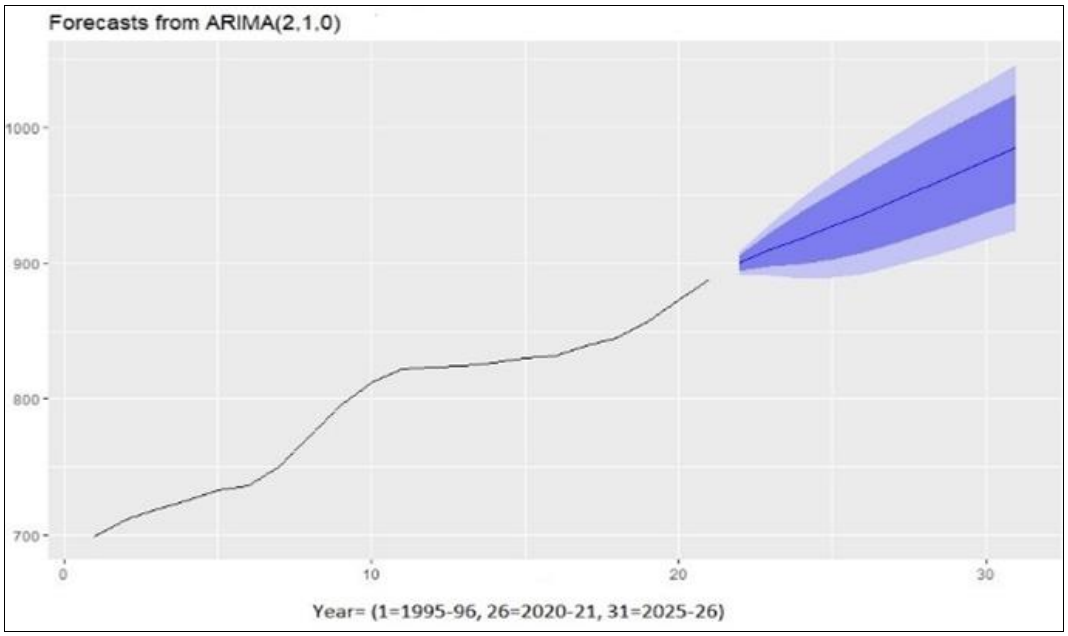

Fig 4: Forecasting of milk production in Assam with ARIMA (2, 1, 0)

ARIMA (2, 1, 0) model is used for comparing the actual and predicted values of milk production from the year 2021-22 to 2025-26 for further validation of the model. Fig. 4 depicts the forecast plot for milk production in Assam. From the plot we can see that after 2020-21, the forecast from the given data is presented with the highest and the lowest estimates at 80 and 95 percent of confidence level. The plot clearly shows an increase in the production in Assam by 2025-26. This is quite evidently depicted in Table 8 too. From the Table 8, it can be noted that most of the predicted values lie in close proximity with the actual values. We can also see that the point forecast ranges from 945.44 million litres in 2021-22 to 1024.04 million litres in 2025-26. It is also evident from the Table 8 that the highest and lowest predicted values for 2025-26 at 80 percent confidence level were 1024.73 million litres and 944.96 million litres and at 90 percent confidence level were 1045.84 million litres and 923.84 million litres, respectively. A similar trend in increasing production of milk in Tamil Nadu was reported by Balan *et al.* (2019) [1]. Mishra *et al.* (2019) [12] also revealed similar findings of increasing trend in milk production in Chhattisgarh. This is expected to encourage more and farmers to indulge in dairy farming sector in Assam in the near future.

Table 8: Forecasted milk production in Assam for the fitted ARIMA (2, 2, 1) in million litres

Year	Actual Production	Predicted Production	Lo 80	Hi 80	Lo 95	Hi 95
2016-17	904	900.17	894.69	905.74	891.66	908.68
2017-18	925	909.90	897.28	922.52	890.60	929.20
2018-19	946	918.44	899.12	937.77	888.89	948.00
2019-20	975	926.92	902.26	951.58	889.21	964.64
2020-21	1004	947.90	907.33	964.48	892.20	979.61
2021-22	-	955.44	913.95	976.92	897.29	993.59
2022-23	-	975.30	921.47	989.12	903.57	1007.02
2023-24	-	995.23	929.33	1001.14	910.32	1020.15
2024-25	-	1014.09	937.19	1013.01	917.12	1033.07
2025-26	-	1024.04	944.96	1024.73	923.84	1045.84

Source: Computed by author using R (4.0.2) software.

Conclusion

The CAGR of milk production in Assam is positive and consistent which shows that the state has seen a steady increment in terms of milk production in the recent times, but the exponential increase in population of the state has made the growth of the per capita milk availability stagnant. Hence, there is a need to scale up the production level of milk from its present level. To do this, optimal use of available dairy resources is critical and forecasting is an important exercise to determine the direction of the present action. Accordingly, the present investigation forecasts that milk production in Assam will increase in the coming years and it is expected to be 1024.04 million litres by 2025-26, which is still below the target to meet the rising demands of raw milk and derived milk products in the state. Hence, there is a need to boost the production of milk and this prediction can be beneficial for policy makers in formulating strategies for augmenting and sustaining production of milk in Assam and this can be broadly achieved by tackling supply side problems with prioritization of reducing cost of production and emphasizing on increasing the return from milk enterprises. Effort should be made to ensure the availability of good quality feed and fodder by setting up of fodder banks and community grazing centres. Feed and fodder cost should be regulated by respective authorities to make them available at reasonable prices to the dairy farmers. Setting up of dairy co-operative societies should be encouraged to restrict the milk flow through unorganized sector and regulate it through the organized sector to augment the income of dairy farmers.

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