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Radhika Thakur
Department of Basic Sciences
Dr. Y. S. Parmar University of Horticulture and Forestry Nauni- Solan, Himachal Pradesh, India

RK Gupta
Department of Basic Sciences
Dr. Y. S. Parmar University of Horticulture and Forestry Nauni- Solan, Himachal Pradesh, India

Corresponding Author:
Radhika Thakur
Department of Basic Sciences
Dr. Y. S. Parmar University of Horticulture and Forestry Nauni- Solan, Himachal Pradesh, India

Prediction of milk yield using ARIMA

Radhika Thakur and RK Gupta

Abstract

Monthly milk yield data of Jersey and Holstein Friesian crossbred cows which were collected from Dairy Farm of Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni from 1978 - 2014 to find out the most suitable forecasting method for milk production for sustainable future production and policy implications. ARIMA time- series (p, d, q) was applied to predict monthly milk yield over the years. The common approach modelling univariate time series is the autoregressive AR model. Autoregressive model is a linear regression of the current value of the series against one or more prior values of the series AR (p). The value of p is known as the order of the AR model. AR model has the straightforward interpretation. Another common approach for modelling univariate time series models is the moving average. A moving average is primarily a lagging indicator which makes it one of the most popular tools for technical analysis. Thirty seven years data on milk yield was used for modeling purpose. Moving Average ARIMA (6, 0, 2) was found the best fitted model for prediction of monthly milk yield.

Keywords: Monthly milk yield, jersey cross, holstein friesian cross, ARIMA

Introduction

Milk is the second largest agricultural commodity (155.5 million tonnes) in our country next only to rice. Holstein and Jersey are the most important dairy breeds of cattle known for their high milk yield and quality. Holstein and Jersey breeds are intensively used in India for crossbreeding purpose. In dairy industry, milk production provides a great contribution to economy of country and people nourishment throughout the world. In the milk manufacturing process, one of the most important aspects of dairy production is the modeling of the milk yield and quality (Beever *et al*., 1991) [1]. Time series analysis models plays a vital role in prediction of monthly milk yield of crossbred cows, thereafter an effort is made to build and standardized the models for prediction of monthly milk yield of crossbred cows. The empirical model of milk yields is the time series model. The time series model makes use of all available data on milk yield. The forecast yield for tomorrow is an optimally weighted average of the yield today and on recent days. Predictions should be reasonably precise, so relatively small deviations below the prediction could in principle be detected. The time series model is suitable for relatively short- term forecasting, it adapts to long-term trends in yield (Lark *et al.*, 1999) [7]. Dairy industry in India is growing at the rate of 10 per cent per annum. Considering this, it is essential to know the future production to improve the sustain the growth and development in this sector. The aim of the study is to find the most suitable forecasting method for milk production for sustainable future and policy implications.

Materials and Methods

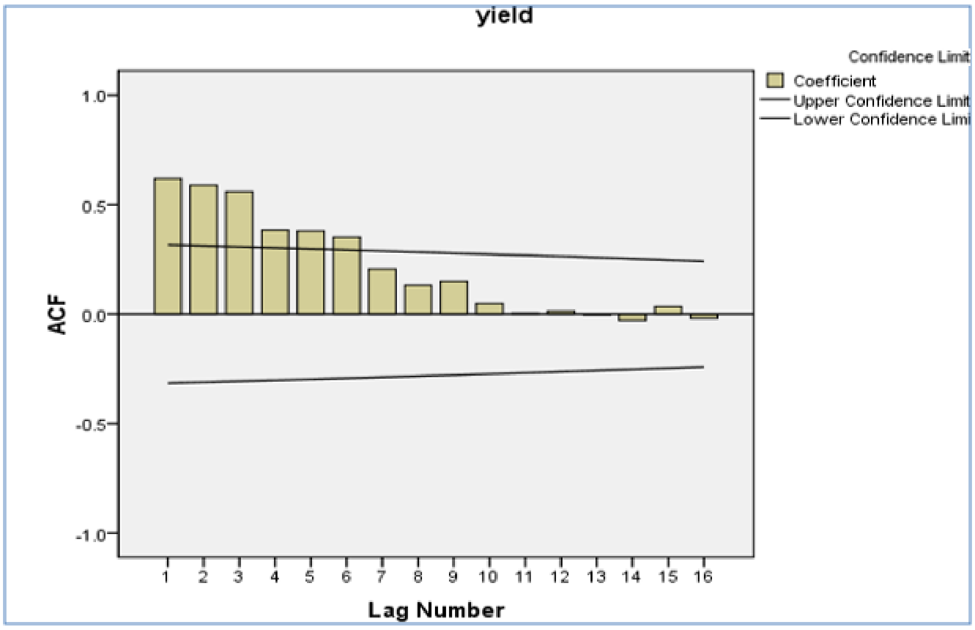
In the present study, secondary data on monthly milk yield for thirty seven years from 1978-2014 for the Jersey and Holstein Friesian crossbred cows were taken from dairy farm of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. ARIMA (p, d, q) was applied to predict milk yield over the years. ARIMA time-series models was traditionally applied to expressed as ARIMA (p, d, q) combine as many as 3 types of processes, *viz.* auto regression (AR) of order p; differencing d times to make a series stationary and moving average (MA) of order q.

Results and Discussion

In view of globalization, it is imperative to study the trend of yield and production of different commodities by employing sound statistical modeling techniques that, in turn will be beneficial to the planners in formulating suitable policies to face the challenges ahead.

Fluctuations in production are interrelated as larger area gives greater production. The production of milk yield fluctuates over years due to variations in many parameters like weather condition, technological changes, etc. Thus modeling and forecasting the yield over the years is of much practical importance. ARIMA (p, d, q) was applied to predict monthly milk yield over the years. ARIMA time-series models traditionally expressed as ARIMA (p, d, q) combine as many as 3 types of processes, *viz.* auto regression (AR) of order p; differencing d times to make a series stationary and moving average (MA) of order q. Thirty seven years data i.e. from 1978 to 2014 on monthly milk yield was used for modeling purpose.

A good starting point for time series analysis is a graphical plot of the data. It helps to identify the presence of trends. Before estimating the parameter (p, q) of model, the data were examined to decide about the model which best explains the data. This is done by examining the sample ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) of differenced series. Figure 1 shows the autocorrelation function and partial autocorrelation function of the historical observations of the monthly milk yield. From the area correlogram two facts are evident. First, the ACF declines very slowly. ACF up to 15 lags positive (and thereafter negative up to 16 lags) and are individually statistically different from zero. Secondly, after the first lag the PACF drops dramatically and all PACFs are statistically non - significant. The autocorrelations not drop out quickly for higher lags and time plot of the given series shows an increasing trend, indicating it to be a non -stationary series.



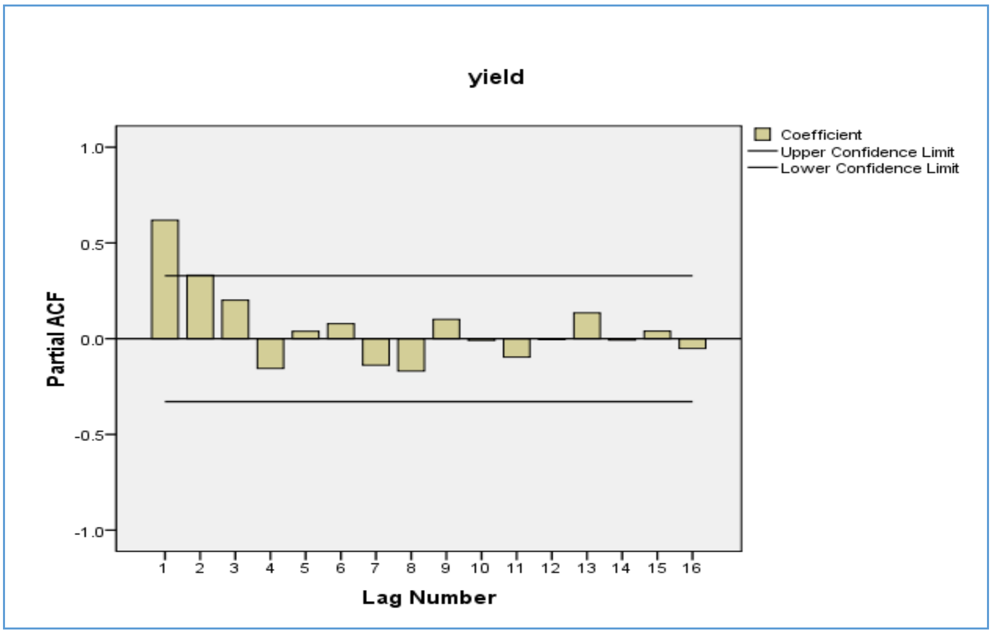


Fig 1: ACF and PACF and correlogram of monthly milk yield (litres)

The PACF of the univariate time series data of has the 1st and 2nd spike significant and the others are nonsignificant while in case of production data. Observing the nature of ACF and PACF plots of the series and their theoretical properties, the order of auto-regression and moving average process of monthly milk yield series were selected by estimating the ARIMA models at different p, d, q values.

Table 1: Estimates of parameters of best fitted models for milk yield (litres)

Model	Parameters	Estimates	R^2	Ljung-Box Q (18)
Arima (6,0,2)	Constant	-6075	0.826	13.716
	AR(1)	-.133		
	AR(2)	-.663		
	AR(3)	.371		
	AR(4)	-.259		
	AR(5)	.230		
	AR(6)	.049		
	MA(1)	-.297		
	MA(2)	-.998		
ARIMA (5,0,2)	Constant	-6107	0.826	13.778
	AR(1)	-.139		
	AR(2)	-.677		
	AR(3)	.380		
	AR(4)	-.283		
	AR(5)	.220		
	MA(1)	-.303		
	MA(2)	-.997		
Arima (4,0,2)	Constant	-6076	0.821	17.422
	AR(1)	-.319		
	AR(2)	-.599		
	AR(3)	.304		
	AR(4)	-.234		
	MA(1)	-.444		
	MA(2)	-.996		
Arima (3,0,2)	Constant	-6075	0.817	14.126
	AR(1)	-.488		
	AR(2)	-.573		
	AR(3)	.380		
	MA(1)	-.615		
	MA(2)	-.999		

In Table 1, different models were selected by comparing maximum values of Stationary R^2 and $\bar{R}^2$. Further, the value of Ljung - Box Q (18) was compared to critical values from chi-square distribution. If model is correctly specified, residuals should be uncorrelated and Q should be small. A significant value indicated that the chosen model does not fit well.

Table 2: Trend values of various predicted functions for monthly milk yield (litres) through ARIMA

Year	Milk Yield (litres)	Predicted values (6,0,2)	Predicted values (5,0,2)	Predicted values (5,1,2)	Predicted values (4,0,2)	Predicted values (3,0,2)
1978	103.86	132.80	132.49		132.77	132.83
1979	138.78	138.16	137.91	106.68	138.39	136.80
1980	141.34	141.26	140.79	126.03	140.91	138.51
1981	138.62	128.97	129.01	123.71	130.71	130.98
1982	144.02	155.88	156.35	151.78	156.06	152.73
1983	158.40	147.52	147.33	143.98	151.71	153.03
1984	143.48	142.73	143.21	143.41	141.74	142.80
1985	157.63	158.32	158.09	159.57	157.27	157.00
1986	156.27	166.65	166.19	166.74	166.64	165.88
1987	150.84	149.87	149.71	148.27	151.05	152.21
1988	162.20	163.87	164.22	162.62	162.65	162.53
1989	198.13	171.96	171.44	171.03	172.50	172.23
1990	205.54	170.23	170.25	174.07	169.11	167.24
1991	209.04	182.34	182.47	194.14	182.67	182.35
1992	186.19	195.91	195.91	213.27	196.37	199.73
1993	183.71	179.82	179.21	194.04	177.87	184.02
1994	189.79	179.87	179.07	192.52	172.21	177.09
1995	158.70	192.82	190.91	205.17	188.75	191.42
1996	199.14	196.42	195.27	195.86	195.84	192.71
1997	182.15	184.86	185.28	182.63	181.32	180.34
1998	189.23	181.49	181.41	179.89	186.34	191.45
1999	210.16	218.61	218.97	217.97	218.25	211.83
2000	169.88	196.82	196.44	196.76	195.74	193.01
2001	181.37	187.51	188.63	180.24	190.33	196.51
2002	211.03	209.97	210.45	204.04	212.16	212.14
2003	215.29	204.40	203.68	201.03	203.32	196.62

2004	191.08	217.87	218.53	215.07	215.74	211.89
2005	205.15	220.79	221.67	214.19	229.47	232.75
2006	195.72	202.14	203.49	195.09	205.77	205.88
2007	215.90	208.77	208.84	203.38	204.15	202.47
2008	245.82	243.13	242.77	239.43	241.80	238.93
2009	246.34	229.08	229.51	226.65	236.85	232.68
2010	208.38	225.59	227.62	227.62	228.04	226.14
2011	253.19	242.88	243.21	245.15	242.57	248.69
2012	252.97	238.62	238.25	244.49	235.58	237.71
2013	211.72	234.10	233.64	241.84	234.45	230.40
2014	293.51	265.41	265.76	265.39	265.12	262.86

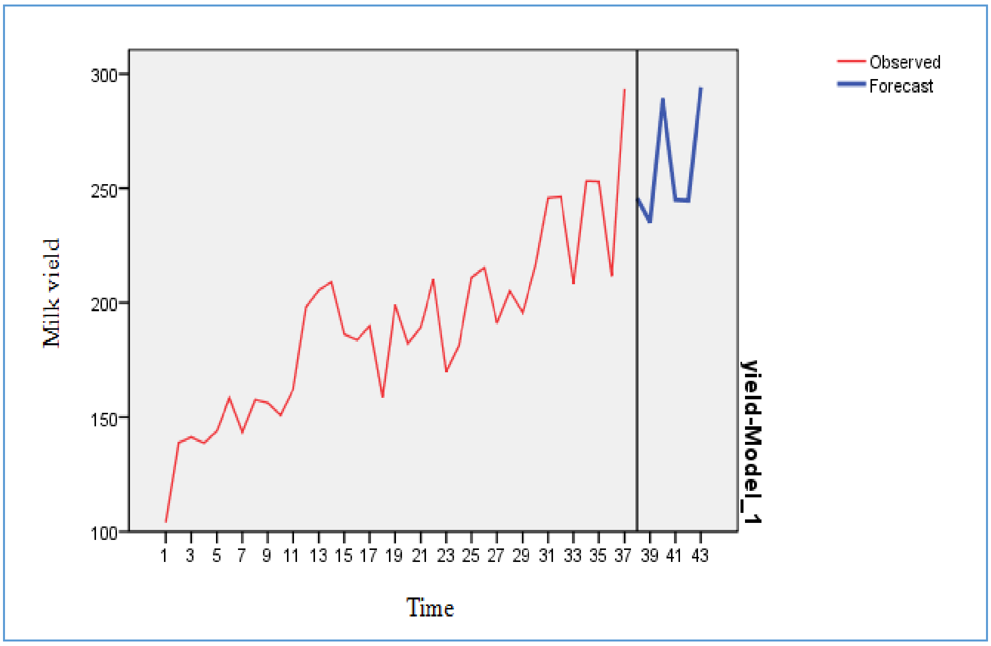


Fig 2: Monthly Milk Yield (litres) prediction through ARIMA

Table 3: Monthly Milk Yield (litres) prediction for the period of 2015-16 to 2019-2020

Year	Milk Yield
2015-16	245.74
2016-17	235.14
2017-18	289.22
2018-19	245.04
2019-20	244.68

The selected models for monthly milk yield were ARIMA (6,0,2), ARIMA (5,0,2), ARIMA (5,1,2), ARIMA (4,0,2) and ARIMA (3,0,2).

All these criteria (R^2, Ljung-Box Q (18), half splitting technique) revealed that ARIMA (6, 0, 2) was the best fitted models for prediction of monthly milk yield. In Table 2, Trends of all prediction functions for the monthly milk yield from 1978 to 2014 are presented.

Whereas in figure 2 observed the prediction of milk yield by Autoregressive integrated moving average. In Table 3, the forecasted values of monthly milk yield are presented.

Results in the present study in close consistency with the earlier findings of Deluyker *et al.* (1990) [4], Pal *et al.* (2007) [9], Cole *et al.* (2009) [3], Chaudhari and Tingre (2013) [2] and Deshmukh and Paramasivam (2016) [5].

Summary and Conclusions

37 years secondary data on monthly milk yield of Jersey and Holstein Friesian crossbred cows were collected from 1978-2014. The year to year fluctuations in the monthly milk yield of all crossbred are quite common. These fluctuations were due to climatic factors and weather conditions during the lactations. These fluctuations adversely affect the monthly milk yield. The record on cows monthly milk yield for 37 years of all crossbred showed that data increase during certain years and also decrease during some other years. In the present study an attempt has been made to develop and standardize the prediction models to estimate the monthly milk yield of crossbred cows. Different orders of auto-regression and moving average process of monthly milk yield were selected by estimating the ARIMA models at different p, d, q values whereas ARIMA (6, 0, 2) was found the best fitted model for prediction of monthly milk yield.

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