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Timeseries analysis of consumption and production of wheat in India using ARIMA models

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Abstract
Wheat is one of the most important staple food grains of human for centuries. It has a special place in the Indian economy because of its significance in food security, trade and industry. This study made an attempt to model and forecast the production and consumption of wheat in India by using annual time series data from 1959–2019 based on the ARIMA models. The best fitted model was selected based on the performance of the goodness of fit criteria *viz.* of Root Mean Square Error, Normalized Bayesian Information Criterion, Akaike Information Criterion. The study found ARIMA (0,1,1) with drift is the best model for consumption and production of wheat. According to the ARIMA prediction, consumption and production are expected to increase during the next eight years i.e., consumption in 2026-27 will be 1,10,960.03 thousand MT and production will be 1,13,909.70 thousand MT.

Keywords: ARIMA, box and Jenkins, Consumption, production, trend, wheat

Introduction

Agriculture plays vital role in Indian economy and employment. In 2019, percentage share of agriculture was about 15.96% of total Gross Domestic Product (GDP) of Indian economy and 43.21% in employment. Wheat is the most important cereal crop and prime well spring of energy and nutrition in human eating routine (Mishra *et al*., 2015) [10]. Around 66% of global wheat production is utilized for human food and 16.6percentis utilized as food for animals. It grew on an area of 218 million hectares, producing 605.99 million tons in the world during 2019 (ICAR – Vision 2020). India was the second largest producer of wheat near China, with a production of 103.6 million tons in 2019. Wheat is a main food for about 33.3% of population and main supplement in the human diet that contains protein, niacin and thiamine (Malik *et al*., 2010) [8]. In the domain of food crops in the world; wheat (Triticum spp.) possesses the main position (Chand *et al*., 2009) [4]. India is one of the major wheat producing and consuming countries in the world. Its ranking in Indian agriculture is second to rice only. Wheat flour-based products, for example, chapatti, is important for the staple eating regimen in many areas in India -especially in northern India. Wheat straw is likewise utilized for feeding cattle. The Green Revolution, which was started in the last part of the 1960s, had a decisive effect in increasing wheat production in India. Uttar Pradesh, Punjab and Haryana are the three major wheat producing states with a share of almost 70% of the total wheat produced in India. Better water system in these states is liable for better yield. In Haryana, 98% of the territory area under wheat is irrigated and in Punjab it is 96%. Wheat crop contributes significantly to the national food security by giving over half of the calories to the individuals who predominantly rely upon it (Mishra *et al*., 2015) [10].

World population, especially in the developing countries, is expanding at a disturbing rate. To take care of this consistently expanding human population, stays a provoking assignment to the policy makers of each country and furthermore the world bodies (Singh *et al*., 1990) [16]. The policy makers should know the potential population behaviour of the countries under evolving situation. Simultaneously, they ought to have ideas about the potential demand for food and other goods. Accordingly, forecasting production behaviours of the major crops plays an important role for policy makers to ensure food and nutrition security. The policy makers should have ideas about potential production scenarios of the major crops (Mishra *et al*., 2021) [9].

Forecasts have been made using parametric univariate time series models, known as Autoregressive Integrated Moving Average (ARIMA) model popularized by Box and Jenkins

(1976) [2]. These approaches have been employed extensively for forecasting economics time series, inventory and sales modelling (Brown, 1959) [3]. Ljung and Box (1978) [7] and Pindyck and Rubinfeld (1981) [12] have also discussed the use of univariate time series in forecasting. Rachana *et al*. (2010) [13], used ARIMA models to forecast pigeon pea production in India. Badmus and Ariyo (2011) [1], forecasted area of cultivation and production of maize in Nigeria using ARIMA model. They estimated ARIMA (1, 1, 1) and ARIMA (2, 1, 2) for cultivation area and production respectively. The ARIMA methodology have been used extensively by a number of researchers to forecast demands in terms of internal consumption, imports and exports to adopt appropriate solutions (Muhammed *et al*., 1992; Shabur and Haque, 1993; Sohail *et al*., 1994) [11, 14, 17]. Thus, in this study, we modelled and forecasted the consumption and production of wheat in India using ARIMA methodology. This would help predict future values of consumption and production in the country.

Materials and Methods

The present study was based on secondary data of Wheat in India and it was collected from different publications of United States Department of Agriculture, Foreign Agricultural Service. Auto Regressive Integrated Moving Average (ARIMA) Model was applied for consumption and production data of Wheat.

Auto Regressive Integrated Moving Average (ARIMA) Model

Box and Jenkins, 1976 [2] suggested a method for identifying, estimating, and checking models for a specific time series dataset popularly known as ARIMA (p, d, q) model. A non-seasonal ARIMA model is classified as an "ARIMA (p, d, q)" model, whereas ‘p’ is the number of autoregressive terms, ‘d’ is the number of non-seasonal differences needed for stationarity, and ‘q’ is the number of lagged forecast errors in the prediction equation. The lags of the stationary series in the forecasting equation are called autoregressive (AR) terms, lags of the forecast errors are called moving average (MA) terms, and a time series which needs to be differenced to be made stationary is said to be an "integrated" version of a stationary series (Sharma *et al*., 2018) [15].

The basic formulation of ARIMA (p, d, q) could be described as

$$Y_t = \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \cdots + \varphi_p Y_{t-p} + \mu - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} + \varepsilon_t$$

Where, Y_t is Area or Production at year t; Y_{t-1}, Y_{t-2}..., Y_{t-p} are response variable at time lags t-1, t-2..., t-p respectively; μ is constant mean; ε_{t-1}, ε_{t-2}…, ε_{t-q} are errors in the previous time periods; φ_s are coefficients to be estimated in AR process; θ_s are coefficients to be estimated in MA process; ε_t is the forecast error.

Model specification and Parameter estimation: Model specification involves the use of the techniques to determine the values of p, q and d. The values are determined by using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). For any ARIMA (p, d, q) process, the theoretical PACF has non-zero partial autocorrelations at lags 1, 2,.., p and has zero partial autocorrelations at all lags, while the theoretical ACF has non zero autocorrelation at lags 1, 2, …, q and zero autocorrelations at all lags. The non-zero lags of the sample PACF and ACF are tentatively accepted as the p and q parameters. For a non-stationary series, the data is differenced to make the series stationary. The number of times the series is differenced determines the order of d. Thus, for a stationary data d = 0 and ARIMA (p, d, q) can be written as ARMA (p, q). Estimating the model parameters for the tentatively selected models have been performed after model specification.

Diagnostic checking: The estimated model must be to Verified to check its adequacy to represents the series. The best model was selected based on the minimum values of Root Mean Square Error (RMSE), Normalized Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC) (Dasyam *et al*., 2015) [5]. Diagnostic checks are performed on the residuals to see if they are not auto correlated and normally distributed. Shapiro-wilk test and Box-Ljung Tests were utilized for checking normality and autocorrelation of residuals respectively.

Forecasting: After the assessment of the predicting capacity of fitted ARIMA model, forecast for future years along with 95% confidence intervals have been performed.

Results and Discussion

The consumption and production of wheat in India has increased over the years from 1,42,18,000 MT and 1,03,20,000 MT in the year 1958-59 to 10,22,17,000 MT and 10,78,60,000 MT, respectively in the year 2018-19. The descriptive statistics of consumption and production of wheat in India is presented in Table 1.

Table 1: Summary statistics of consumption and production of wheat in India

Consumption		Production	
Mean	53031.03	Mean	52397.64
Standard Error	3383.45	Standard Error	3685.10
Median	53377	Median	54110
Standard Deviation	26425.62	Standard Deviation	28781.53
Kurtosis	-1.20	Kurtosis	-1.14
Skewness	0.13	Skewness	0.10
Range	88324	Range	98006
Minimum	13893	Minimum	9854
Maximum	102217	Maximum	107860
Sum	3234893	Sum	3196256
Count	61	Count	61

The time series plot (Fig. 1) of consumption and production showed that the series was not stationary. The data was differenced to make it stationary. The first difference was enough to make the data stationary. The rapid decay in the autocorrelation function and the partial autocorrelation function of the differenced series for consumption and production (Fig. 2) indicates that the series was stationary. To identify the orders of the ARIMA (p, d, q) model for production and consumption, the autocorrelation functions and partial autocorrelation functions were examined. The Augmented Dickey-Fuller test (Consumption: ADF statistic = -5.161, p-value = 0.01; Production: Dickey-Fuller = -5.706, p-value = 0.01) for the first differenced series shows that both the consumption and the production series were integrated of order one.

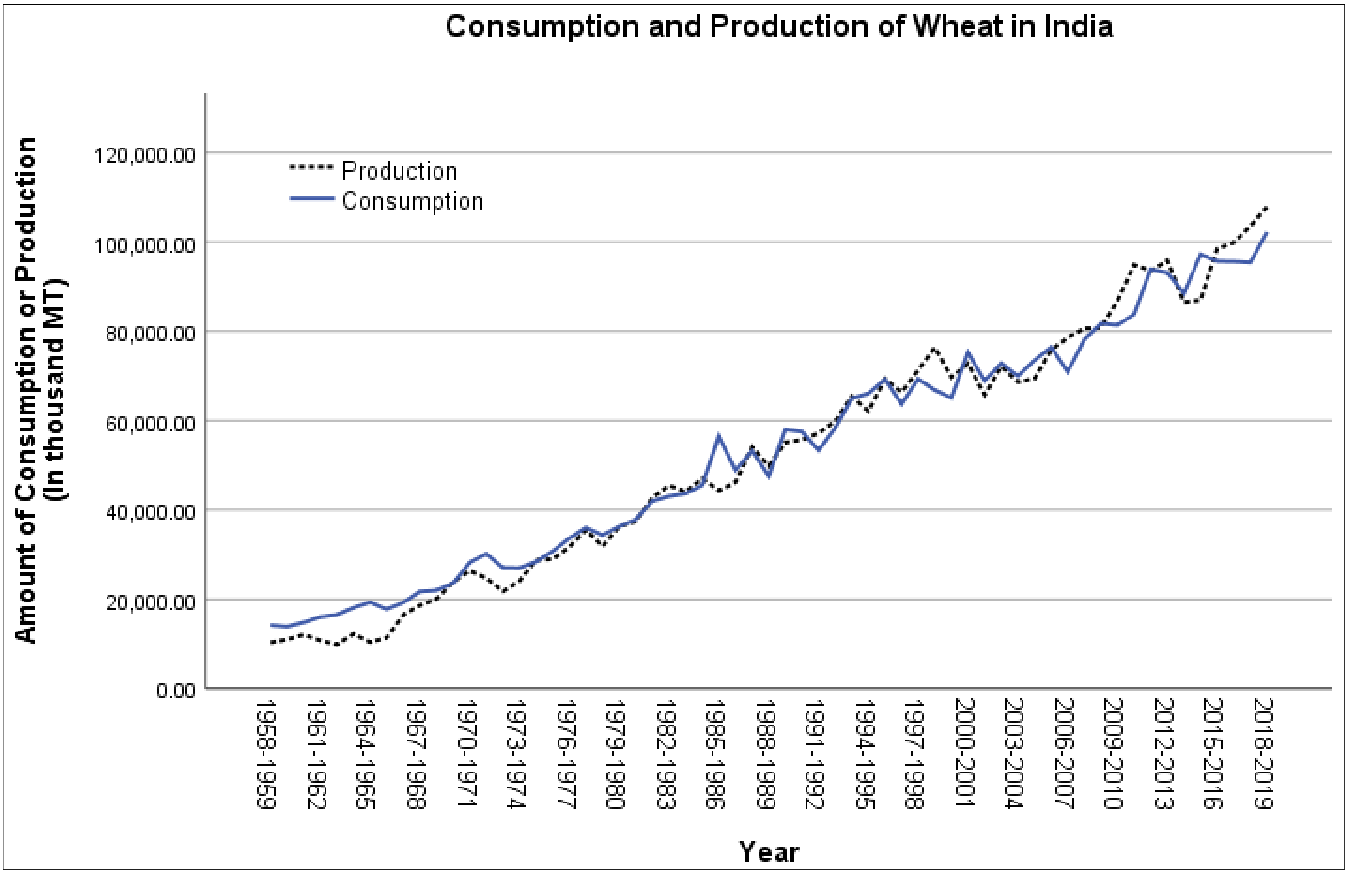

Fig 1: Timeseries plot of consumption and production of wheat in India

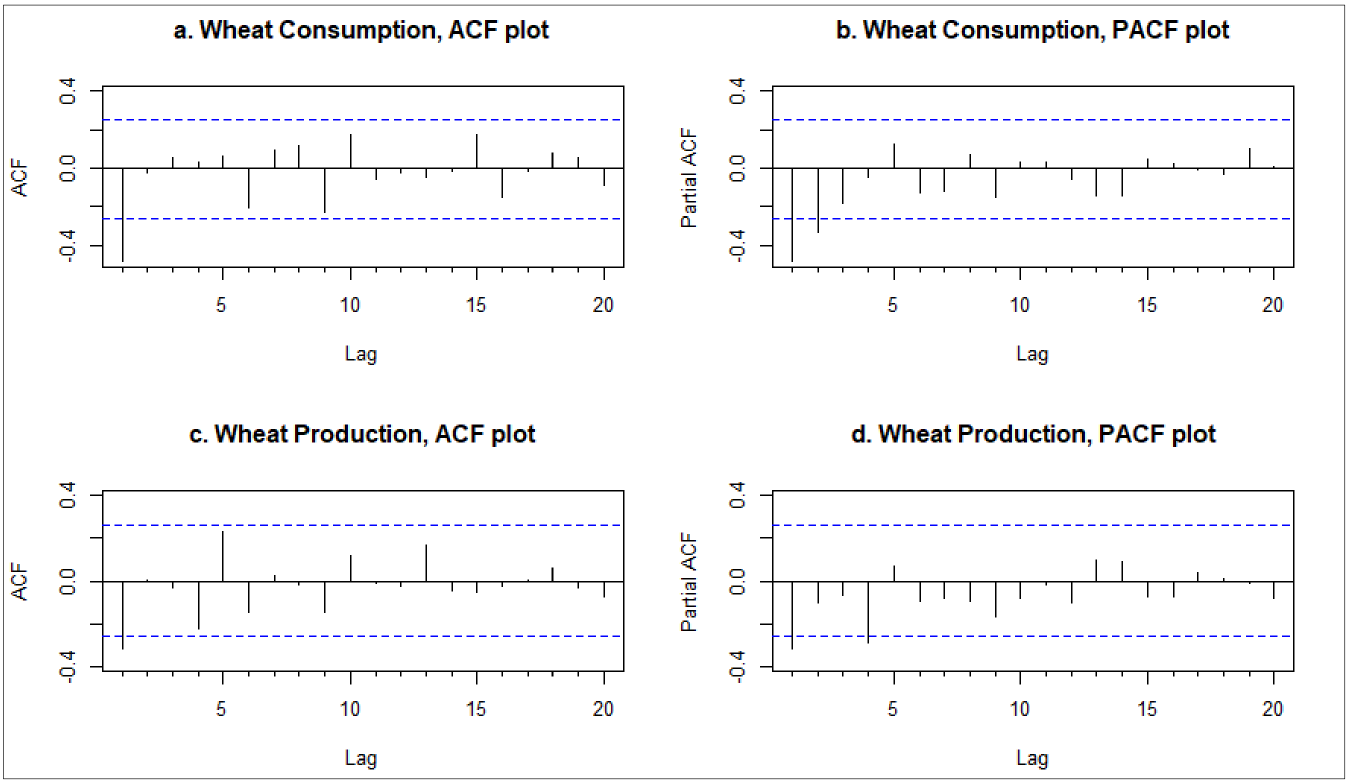

Fig 2: Auto correlation function and Partial autocorrelation function plots for first order differenced series of consumption and production

Autocorrelation function and the partial correlation function were examined and different ARIMA models were fitted using various significant values of p and q. ARIMA (0, 1, 1) with drift was selected as the best model for production and consumption based on the minimum values of RMSE, BIC and AIC value as shown in Table 2 & 3. The estimates of the ARIMA (0, 1, 1) with drift model parameters for both the production and consumption were highly significant and they were presented in the Table 4.

Table 2: Suggested models for Consumption

Model	AIC	BIC	RMSE	Variance
ARIMA (0,1,0)	1138.547	1140.607	4317.060	4354.117
ARIMA (0,1,2)	1134.402	1140.583	4015.491	4121.645
ARIMA (0,1,1) with drift	1112.980	1119.162	3328.413	3416.404
ARIMA (1,1,1)	1136.190	1142.371	4083.069	4191.010
ARIMA (1,1,0) with drift	1121.115	1127.297	3580.908	3675.574

Table 3: Suggested models for Production

Model	AIC	BIC	RMSE	Variance
ARIMA (0,1,0)	1135.079	1137.140	4189.925	4225.891
ARIMA (0,1,2)	1136.919	1143.100	4110.494	4219.160
ARIMA (0,1,1) with drift	1123.282	1129.464	3650.233	3746.732
ARIMA (1,1,2)	1138.918	1147.160	4110.496	4257.345
ARIMA (1,1,1)	1137.750	1143.931	4141.350	4250.831
ARIMA (1,1,0) with drift	1124.807	1130.988	3701.646	3799.504

Table 4: Model parameter estimates for consumption and production

	Type	Estimate	Standard error	z value	Pr(>|z|)
Consumption	MA1	-0.673	0.1025	-6.5627	0.00
	drift	1450.125	149.723	9.6854	0.00
Production	MA1	-0.424	0.157	-2.6975	0.00
	drift	1534.372	281.880	5.4434	0.00

The residuals of the fitted ARIMA models were diagnosed to confirm the adequacy of the models. Shapiro-wilk statistics of the fitted models were 0.966 (p-value = 0.10) and 0.985 (p-value = 0.70) for consumption and production respectively. Box-Ljung test (Chi square statistic) of the fitted models were 0.101 (0.75) and 0.114 (0.73) for consumption and production respectively. Non-significant results of Shapiro-wilk test and Box-Ljung test indicates no autocorrelation and normality of fitted ARIMA model residuals. Similar kinds of results have been observed for Suleman and Sarpong (2012). Hence, the diagnostic test indicates that ARIMA (0, 1, 1) with drift model was appropriate for both the production and consumption.

Finally, on the basis of best fitted ARIMA models, eight years ahead forecast was made for consumption as well as production and it was presented in the Table 5. The consumption forecast for the year 2026-2027 was 110960.03 thousand MT with a 95% lower and confidence limits of 1,01,577.99 and 1,20,342.07 thousand MT respectively. In the same year the production forecast was 1,13,909.70 thousand MT with a 95% lower and upper confidence limits of 99,255.94 and 1,28,563.46 thousand MT respectively.

Table 5: Forecast for Consumption and Production of Wheat up to 2026-2027

Year	Consumption (in 1000 MT)	Production (in 1000 MT)
2019-2020	100809.16 ± 7377.92	103169.10 ± 9468.96
2020-2021	102259.28 ± 7696.23	104703.50 ± 10369.63
2021-2022	103709.41 ± 8001.91	106237.80 ± 11197.99
2022-2023	105159.53 ± 8296.32	107772.20 ± 11969.25
2023-2024	106609.66 ± 8580.64	109306.60 ± 12693.74
2024-2025	108059.78 ± 8855.83	110841.00 ± 13379.06
2025-2026	109509.91 ± 9122.73	112375.30 ± 14030.84
2026-2027	110960.03+9382.04	113909.70+14653.76

Conclusion
In the present study, the ARIMA approach was used to model and forecast consumption and production of wheat in India. According to the prediction, Consumption and production are expected to increase during the next eight years. Despite the increase in production, government must continue to invest money in wheat production, motivate wheat farmers, and implement good policies for better land tenure systems for wheat cultivation in order to ensure that production always surpasses consumption to avoid importation of wheat into the country. This is necessary since importation could lead to high wheat prices and more inflation rate, hence affecting the country's economy.

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