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Model forecasting of wheat production in Bihar

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Abstract
Wheat is the most important cereal crops in Bihar. In this study data have been taken from the India Stat Bihar.com for 1950 to 2019. The most suitable ARIMA models were used for forecasting based on the diagnostic check such as AIC and BIC. The selected ARIMA (4,1,1) was the best model for the forecasting of production of wheat in the state of Bihar. The forecasted value of production of wheat crops was highest in the year of 2025 and this would be 6061.84 MT.

Keywords: Autoregression integrated moving average (ARIMA), forecasting, wheat crop

Introduction
Agriculture and cultivation have always been a part of human society, and smart farms are becoming more and more prevalent of this. Wheat (*Triticum* spp.) is the world's most widely cultivated food crop. It has high calorie, and protein intake for most of the people of India (Sahu *et al.,* 2015) [3]. There is a different type of wheat variety common wheat (*Triticum aestivum*), durum wheat (*Triticum durum*) are useful for making pasta, Emmer wheat (*Triticum dicocum*) and club wheat (*Triticum compactum*) are useful for cake, crackers, pastries, and flours, Common wheat is also known as bread wheat. According to Tripathi and Mishra (2007), wheat offer both macro - (such as carbohydrates, lipids, and protein) and micro-nutrients (such as calcium and iron). As a result, it contributes to the development of a healthy society.
In the world, China, India, and Russia are the three largest wheat producer countries. After Rice, wheat is the second principal source of food grain in India having 12% share in total world wheat production.
In India wheat cultivation alone occupies 25% of the total cropped area (H Singh *et al.*, 2007). India is the second-largest consumer or wheat in the world, 41% of world total wheat production is from India. Wheat production is necessary for the food security of India because it meets almost 61% of the protein requirement of the country (Sapkota *et al.*, 2014) [4].
Bihar is an important wheat growing state that contributes 5.7% towards national production from 8% of wheat growing area of the country. According 2022 the wheat productivity is highest in Madhepura (3,805kg/ha), and lowest in Madhubani (1939kg/ha), are the district of this state. Compared to other alternative crops like potatoes, lentil and Boro rice, wheat production is higher among all. It is mainly growing in a Rabi season along with barley, lentils, and mustard.
The supply chain for agriculture is impacted by increased global food demand, pollution, degraded soil, and other issues that affect crop quality and quantity. The production of agricultural commodities can be predicted using a variety of time-series techniques, which can assist farmers in making decisions.
The ARIMA model has frequently been used for in terms of domestic consumption and export like suitable solutions (H Sohail *et al.* 1994) [7] and which would be useful for better prediction of future data.

Material and Method
Description of data: The present study was based on secondary data of wheat production in Bihar, for the period of 69 years from 1950 to 2019 were collected from Indiastat Bihar.com.

Box-Jenkins Methodology
Box-Jenkins strategy is categorized into four steps.
1. Determining the appropriate p, d, q values. Analysis the partial autocorrelations and test autocorrelation to identify potential evidence model.

2. An estimation is made to determine the parameters of moving average and autoregressive phrases are used in the appropriate model, then the equation.
3. Diagnostic testing to see whether the selected model fits the data reasonably well, getting the residuals and using the Autocorrelation (ACF) and Partial Autocorrelation functions. The residuals are acceptable, the model white noise is what extracted from it.
4. Using forecasting to produce results based on data that has already been gathered. This method generates projections that are more precise than those from conventional econometric moiling.

Auto Regression Integrated Moving Average (ARIMA) Model

Wide range of non-stationary time-series. By differencing the initial series, the non-stationary process may be reduced to a stationary process.

An Integrated ARMA model, indicated as ARIMA (P, D, Q), is stated to be followed by a process $\{Y_t\}$, if $\nabla^d Y_t = (1-B)^d \varepsilon_t$ is ARMA (p,q). Then ARIMA model can be written as

$$\varphi(B)(1-B)^d Y_t = \theta(B)\varepsilon_t$$

WN indicating White Noise, Where $\varepsilon_t \sim WN\ (0,\ \sigma^2)$. The integration parameter d is a nonnegative integer. When d = 0, ARIMA (p, d, q) ≡ ARMA (p, q).

ACF and PACF

The ACF and PACF plot of models are analysed for patterns. For successive lags in the series, autocorrelation and Partial Autocorrelations are calculated (Panasa *et al.*). The first lag's Autocorrelation is between Yt an Yt-1, the second lag's Autocorrelation is between Yt and Yt-2, and so on. All lags are covered by the functions of ACFs and PACFs. The acquired patterns of the ACF and PACF plots are compared, and the idealised patterns of the ARIMA models are identified. The best match also indicates which size and which set of parameters (p, d, q) should be used in the model (0,1,1). Nevertheless, multiple patterns may be visible in the plots, or even the best pattern match might not be able to reduce the residuals to random error. Based on the ACF, PACF pattern a first best guess is created, and if the model does not adequately match the data, another is examined until the diagnostic procedure is successful.

Performance Evaluation Forecasting

The accuracy is checked using the lowest MAPE model, which may be calculated using the following equation.

$$M = \frac{1}{n}\sum_{i=1}^{n} \frac{A_t - F_t}{A_t}$$

Where n is the number of predicted values. Ft is the forecasted value and at is the actual value. When the deviation is calculated, statistical data that are low or almost zero are used, which suggests that the prediction will be accurate.

Result and Discussion

The data on wheat production from 1950 to 2019 was gathered and displayed on a graph, which was demonstrated an upward trend in the production of wheat in Bihar, which is shown in figure1.

The time series data with constant means and variances are related to as "stationary data". When creating a model with the Box-Jenkins method, they must be constant (Gope *et al.*). The data's stationary properties were examined using the enhanced Dickey Fuller test. According to table1, the production data show stationary after first order differencing. This time series data does not require any additional differencing; hence the fitted model was adopted with lag1 (D = 1) differencing. This is comparable to (Kumar and Baishya's outcome 2005). Fig.2 depicts the data transformation following lag1 (D = 1) differencing. Using the first order seasonal differenced series' ACF and PACF plots, the model was found using the stationary data is show in fig 3 and 4.

Finding the best-fit model

ARIMA (2,1,2), ARIMA (0,1,0), ARIMA (1,1,0), ARIMA (0,1,1), ARIMA (0,1,0), ARIMA (1,1,1), ARIMA (0,1,2), ARIMA (4,1,1), ARIMA (0,1,1) and ARIMA (0,1,2) were the tentative models used for forecasting. The MAPE and BIC values were used to choose the optimal model. Table 2 contains the model statistics and Ljung-Box Q statistic for the models that have been provisionally identified, and this table shows that the ARIMA (4,1,1) model has lower MAPE value and a lower BIC value. This was the most effective model out of those that were found.

As a result, this model was utilized to forecast the production of wheat for the market in the Bihar. Table 3 displays the predicted values with their upper and lower confidence limits. The production of wheat was accurately predicted for the period from 2020 to 2025. Fig.5 displayed a graph for the predicted values.

Table 1: ADF test statistics for production of wheat in Bihar

Sr. No	Crop	Augmented Dicky-Fuller Test		
		differencing	Statics	P-Values
01	Production	Without differencing	-2.25	0.475
02	Production	I[st] order seasonal differencing	-2.47	0.01

Table 2: MAPE, BIC and Ljung-Box Q statistic of ARIMA models for production of wheat in Bihar

Sr. No	Models	Model Statistics		Ljung-Box Q		
		MAPE	BIC	Statistics	DF	P-Value
1	ARIMA (2,1,2)	16.762	12.482	9.111	14	0.024
2	ARIMA (0,1,0)	16.622	12.294	12.816	18	0.002
3	ARIMA (1,1,0)	16.657	12.345	13.001	17	0.034
4	ARIMA (0,1,1)	17.626	12.230	11.44	17	0.076
5	ARIMA (0,1,0)	16.622	12.294	12.816	18	0.065
6	ARIMA (1,1,1)	16.677	12.241	9.244	16	0.067
7	ARIMA (0,1,2)	16.819	12.234	10.592	16	0.002
8	ARIMA (4,1,1)	15.987	12.053	9.110	14	0.001
9	ARIMA (0,1,1)	17.626	12.230	11.44	17	0.065
10	ARIMA (0,1,2)	17.626	12.230	11.44	17	0.079

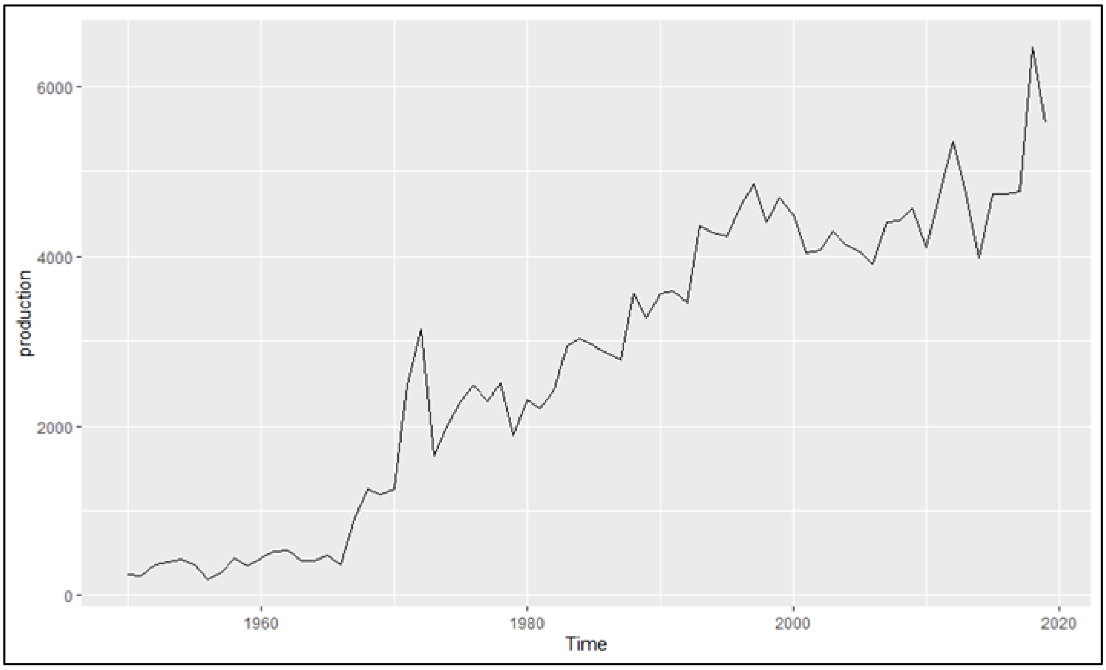

Fig 1: Yearly data of wheat production from 1950 to 2019 in Bihar state

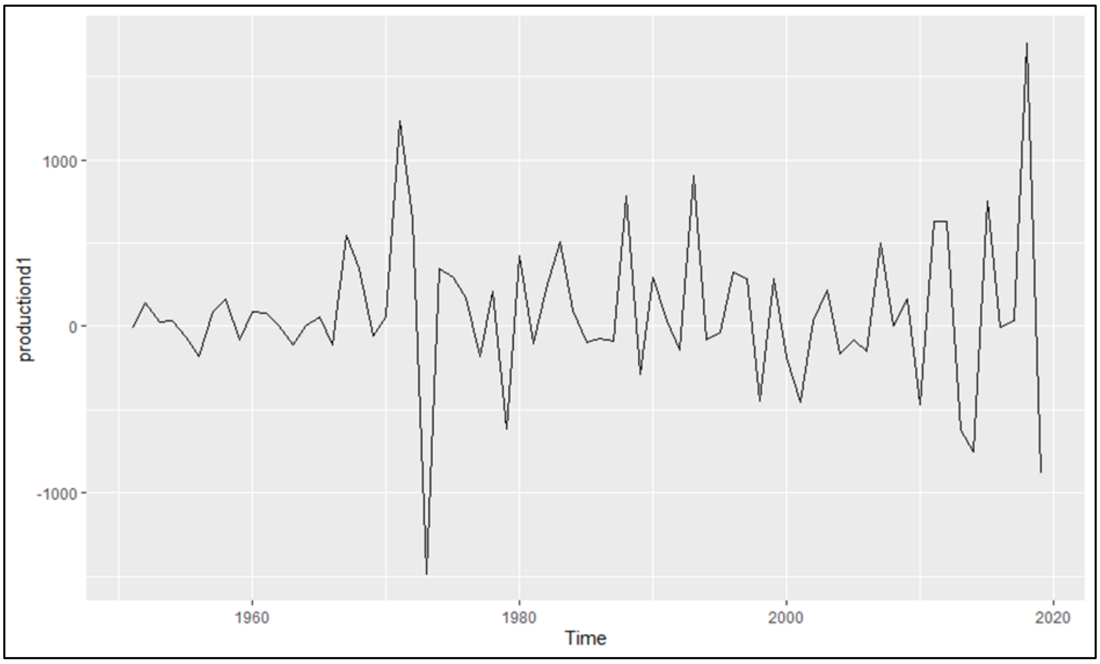

Fig 2: Transformation of data after first order differencing

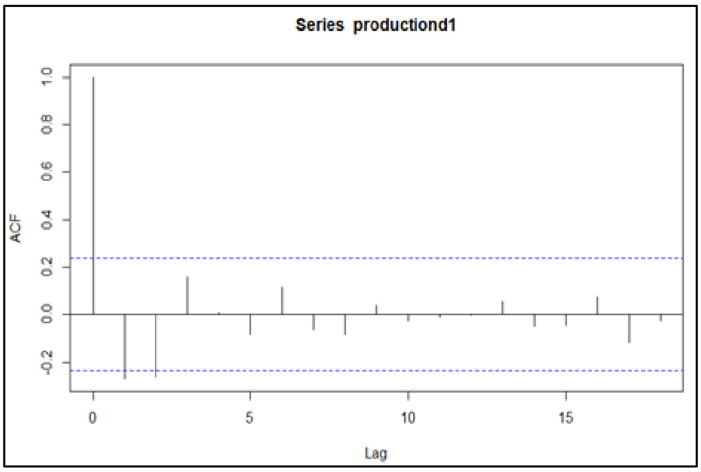

Fig 3: ACF plot

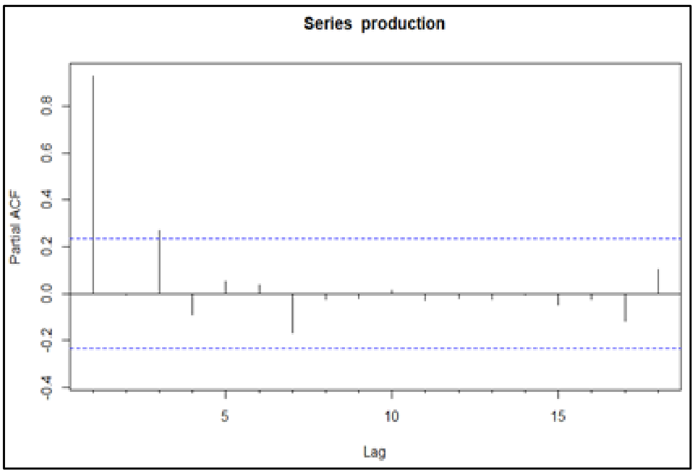

Fig 4: PACF plot

Table 3: Forecasted values by ARIMA model for production of wheat in Bihar state

Sl. No	Year	Production forecast by ARIMA (4,1,1)		
		Forecast	Lower confidence limit	Upper confidence limit
1	2020	5326.54	4487.03	6166.06
2	2021	5895.95	4887.64	6904.26
3	2022	5912.65	4851.24	6974.07
4	2023	5795.93	4605.72	6986.14
5	2024	5950.92	4632.62	7269.21
6	2025	6061.84	4657.56	7466.11

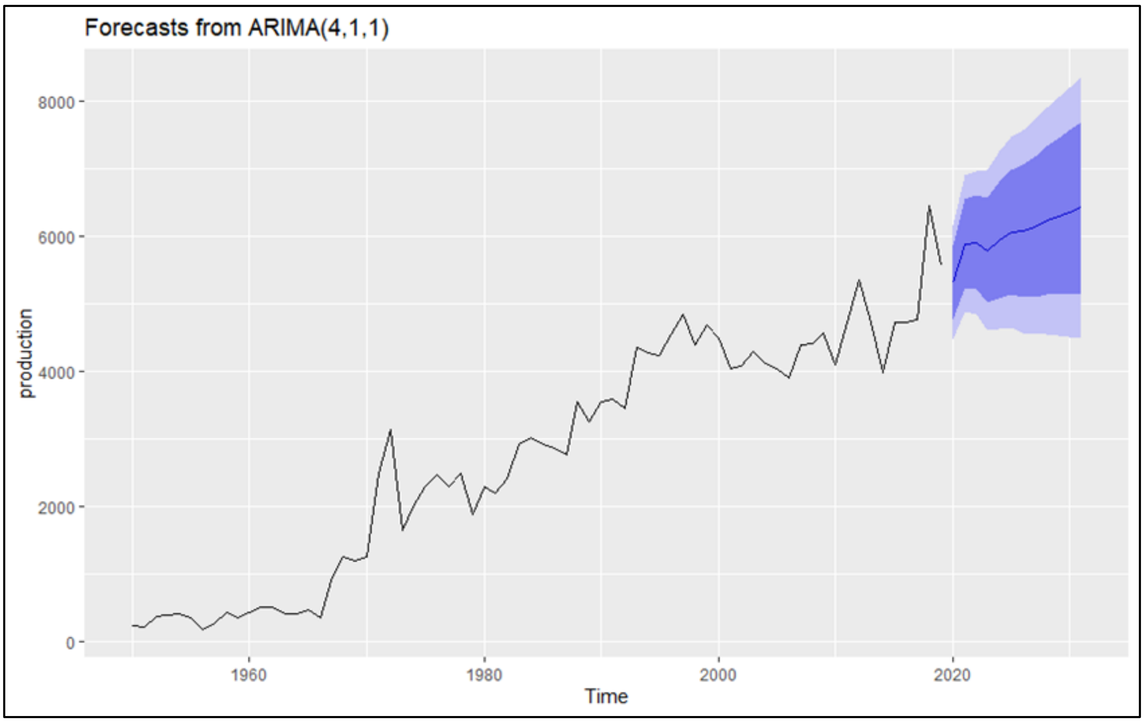

Fig 5: Forecasted values by ARIMA (4,1,1) for production of wheat in Bihar

Conclusion

Forecasting using time series is crucial in agricultural markets, a timely decision based on common sense is challenging due to the volatility of commodity products. Bihar has favourable conditions for the cultivation of the wheat crop, which is the major crop grown in this state. However, farmers in Bihar have been abandoning wheat cultivation in recent years as a result of production fluctuations. Forecasting of production of the wheat crop can be made farmer to make better decisions.

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