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Forecasting area, production and productivity of rice in Tamil Nadu using time series model

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Abstract

For proper planning and policy making in the agriculture sector of the country crop yield forecasting and crop acreage estimation are the two important crucial components. This research is a study model of forecasting area, production and productivity of rice and sugarcane in Tamil Nadu. Data for the period of 2000-01 to 2022-23 were analysed by time series methods. Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) were calculated for the data. Appropriate Box- Jenkins Auto Regressive Integrated Moving Average (ARIMA) model was fitted. Validity of the model was tested using standard statistical techniques. For forecasting area, production and productivity ARIMA (0, 1, 1) model respectively were used to forecast five leading years. The forecasts for the next five years were made. We also correlated climate data *viz.*, Temperature and Rainfall with Production. The results showed the area forecast for the year 2023 to be about 1906086.73 hectare with lower and upper limit 1507149.18 and 2305024.28 hectares respectively, production forecast to be about 6115107.56 tonnes with lower and upper limit 3498028.08 and 8732187.05 tonnes respectively and productivity forecast to be about 3.336 tonnes per ha with lower and upper limit 2.413549 and 4.258816 tonnes per ha respectively. Temperature was negatively correlated with production whereas Rainfall was positively correlated with production.

Keywords: ARIMA, ACF, PACF, SBI, AIC

Introduction

The Required food production is necessary to be enhanced to provide food and nutritional security for the growing population. To make proper planning and policy making in the agriculture sector crop yield forecasting is necessary. The Gross Cropped Area in Tamil Nadu is around 58.43 lakh hectares of which the Gross Irrigated Area is 33.09 lakh hectares which is 57% and the balance 43% of the area are under rainfed cultivation. Out of these, Tamil Nadu has achieved a record coverage of paddy in financial year (2022-23) as the total area stands at 22.05 lakh hectares. D. Balanagammal *et al.* (2000) ^[2] utilised the ARIMA model to forecast the cultivable area, production, and productivity of several crops in the Indian state of Tamil Nadu based on data from 1956 to 1994 for the following years. Zahra N. *et al.* used the linear model, quadratic model and the exponential model to analyze the trends in rice area and yield in Punjab, Pakistan. Forecast of area, production and productivity of rice in Thanjavur, Tamil Nadu also done by M. Hemavathi *et al.* (2018) ^[5] with ARIMA model by analyzing the time series data

Tamil Nadu secured third position in rice productivity in India and from total gross cropped area (58.97 La ha) of the state, paddy alone cultivated in 22.05 L ha (37%) and it ranks first in area and production among other cereal crop cultivated in Tamil Nadu state (source: Policy Note 2022-23, Govt of TN), because it is the main staple food of the state with regard to human nutrition and caloric intake.

Tamil Nadu is the biggest producer of rice in the country now. It is also the staple food of the state and has also played a pivotal role in the politics of the state. Tamil Nadu ranks sixth in the production of rice among the states of India. In fact, Tamil Nadu ranks first in the country in productivity of rice. Triennium average productivity of rice in Tamil Nadu is 3,494 kg/ha, which is 79% higher than triennium average productivity (1,947 kg/ha) of the country.

The main objective of the study is

1. To predict and forecast the area, production, productivity of Paddy along with rainfall data
2. To make time series analysis using data from the past 20 years and provide forecast for the next four years 2023-2027.

Materials and Methods

The secondary data of rice area, production and productivity was collected for the period from 2001 to 2022 from various sources like Directorate of Economics and Statistics, Season and Crop report and Tamil Nadu state website. ARIMA Time series model was used in the study. The accuracy of ARIMA model is measured using Mean square error (MSE) and Mean absolute percentage error (MAPE) (Markidakis and Hibbon, 1979) [4].

Results and Discussion

Time series Data for rice crop cultivated area, production and yield for the period 2000-01 to 2022-23 has been employed in the Auto Regressive Integrated Moving Average (ARIMA) model in Gretl software.

Model identification

ARIMA model estimates only stationary series, so it is important to check the stationary. In stationary series, the values vary over time only around a constant mean and constant variance. The common method used to check stationarity is through examining the graph or time plot of the data. From the Fig 1, 2 and 3, it is showed that the data are stationary. The next step is to identify the values of p and q. For this, The Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) from Fig 4, 5 and 6 showed that the order of p and q can at most be 0.5. We entertained eight tentative ARIMA models and chose that model which has minimum AIC (Akaike Information Criterion) and SBC (Schwartz Bayesian Criterion). The models and corresponding AIC and SBC values are given in Table 1. So, the most suitable model is ARIMA (0, 1, 1) for rice area, ARIMA (0, 1, 1) for rice production and ARIMA (0, 1, 1) for rice productivity has the lowest AIC and SBC values.

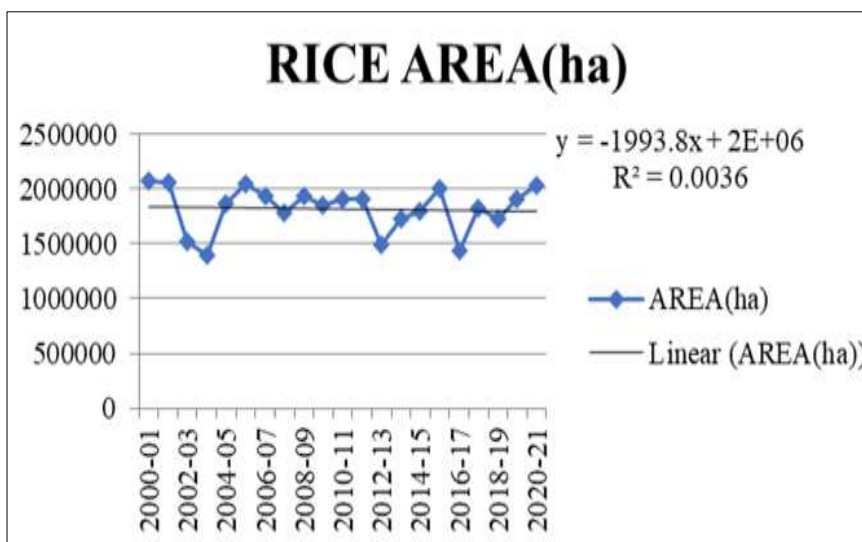


Fig 1: Time series plot for rice area

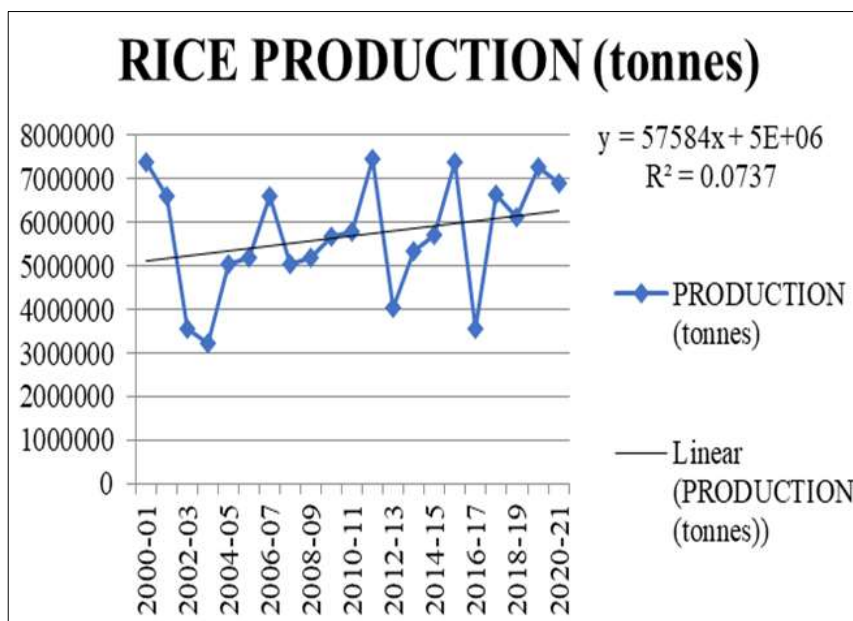


Fig 2: Time series plot for rice production

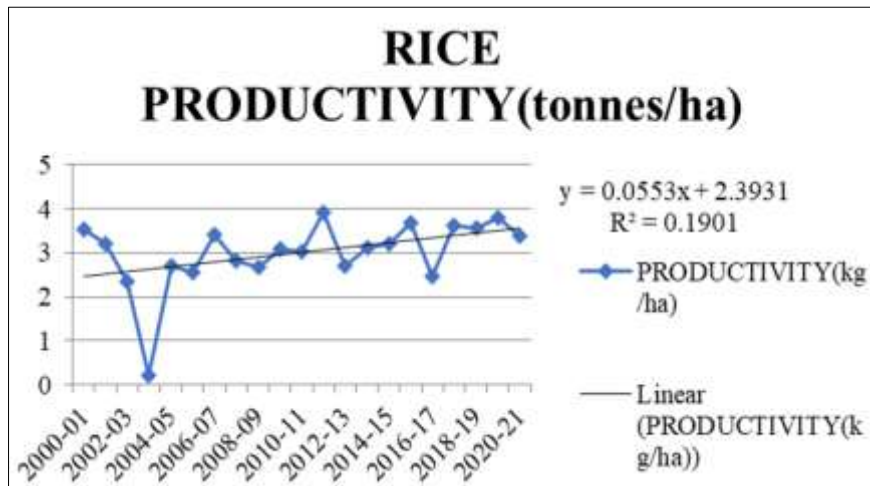


Fig 3: Time series plot for rice productivity

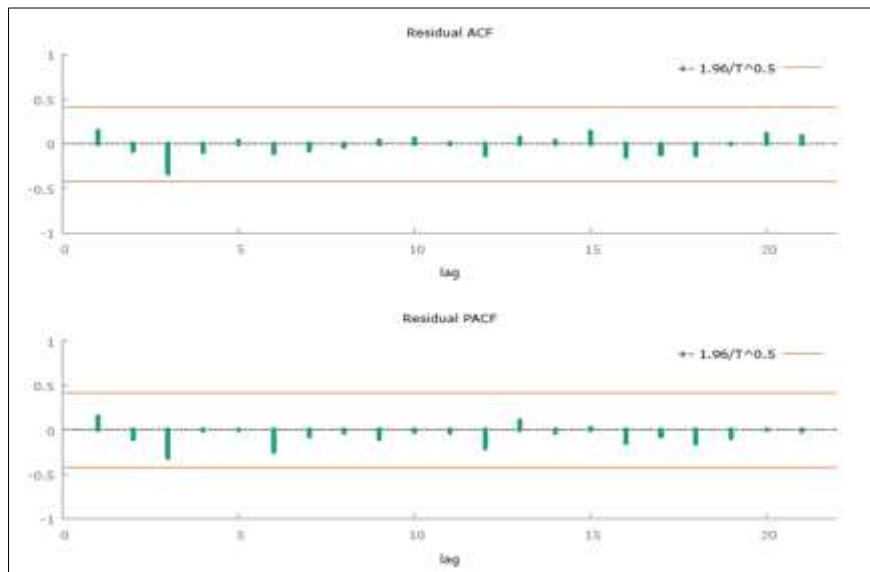


Fig 4: Auto correlations and partial auto correlations for rice area

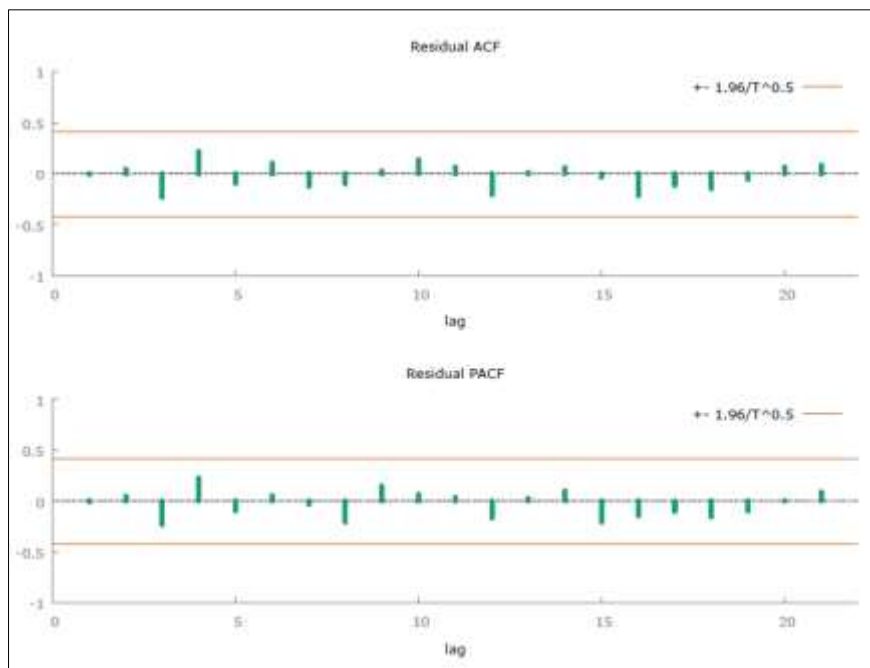


Fig 5: Auto correlations and partial auto correlations for rice production

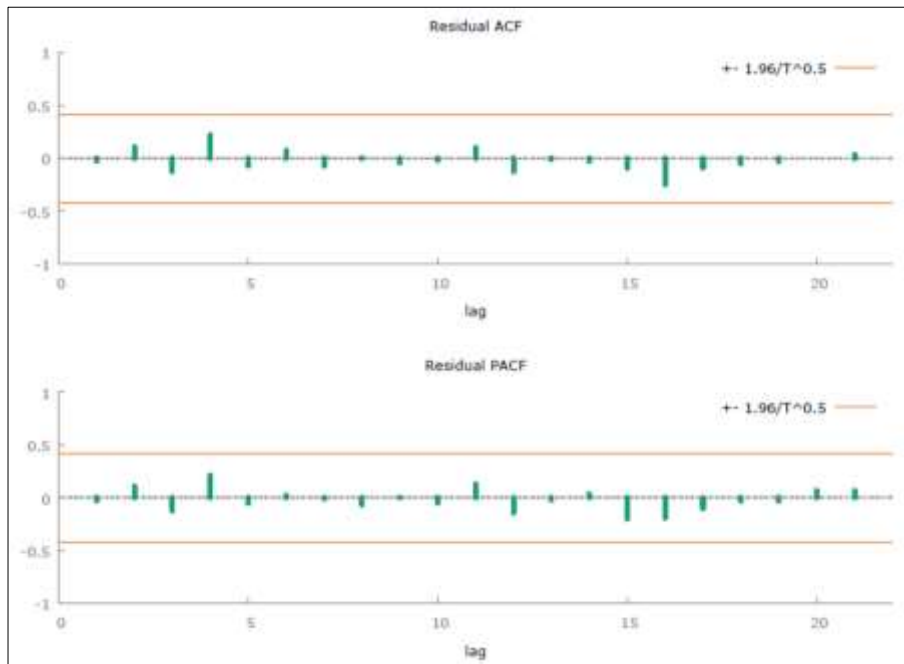


Fig 6: Auto correlations and partial auto correlations for rice productivity

Table 1: AIC and SBC values for tentative ARI MA models for Area, Production and Productivity of Rice

	011		110		111		012		210		112		211		212	
	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC
Area	584.08	587.21	608.33	612.69	584.97	589.14	584.59	588.77	589.28	593.46	586.59	591.81	585.51	590.73	592.38	586.12
Production	659.33	662.47	664.46	667.59	661.33	665.51	661.33	665.51	666.30	670.48	662.92	668.14	663.05	668.28	664.58	670.85
Productivity	33.29	36.42	42.29	39.16	35.04	39.22	33.24	37.42	448.83	40.66	36.73	41.95	36.73	41.95	38.64	44.91

Forecasting and verification

Rice cultivated area, production and productivity with upper and lower confidence level are forecasted using SPSS package. Results of estimation are reported in the Table 2. The results showed the area forecast for the year 2023 to be about 1906086.73 hectare with lower and upper limit 1507149.18 and 2305024.28 hectares respectively, production forecast to be about 6115107.56 tonnes with lower and upper limit 3498028.08 and 8732187.05 tonnes respectively and productivity forecast to be about 3.336 tonnes per ha with

lower and upper limit 2.413549 and 4.258816 tonnes per ha respectively. The graphs of predicted domains Fig 7,8and 9 shows that as the year goes on, there is continuous decreasing trend in rice area due to which production and yield both resulted in decreasing trend. The Mean Absolute Percentage Error (MAPE) for rice cultivated area, production and productivity is found to be 10.78, 15.38 and 12.6 respectively. This measure indicates that the forecasting inaccuracy is low.

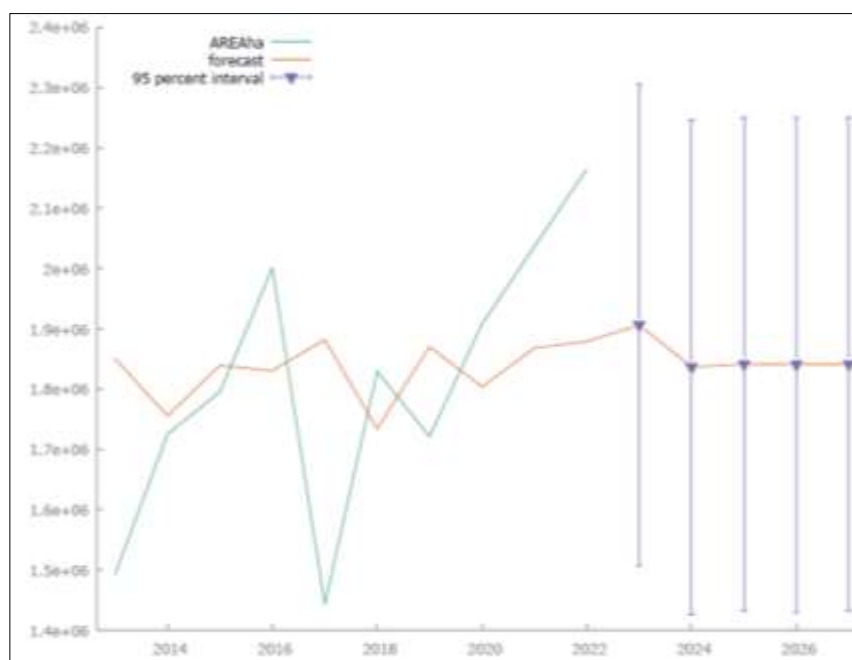


Fig 7: Forecasted values of rice cultivated area with 95% Confidence Level (CL)

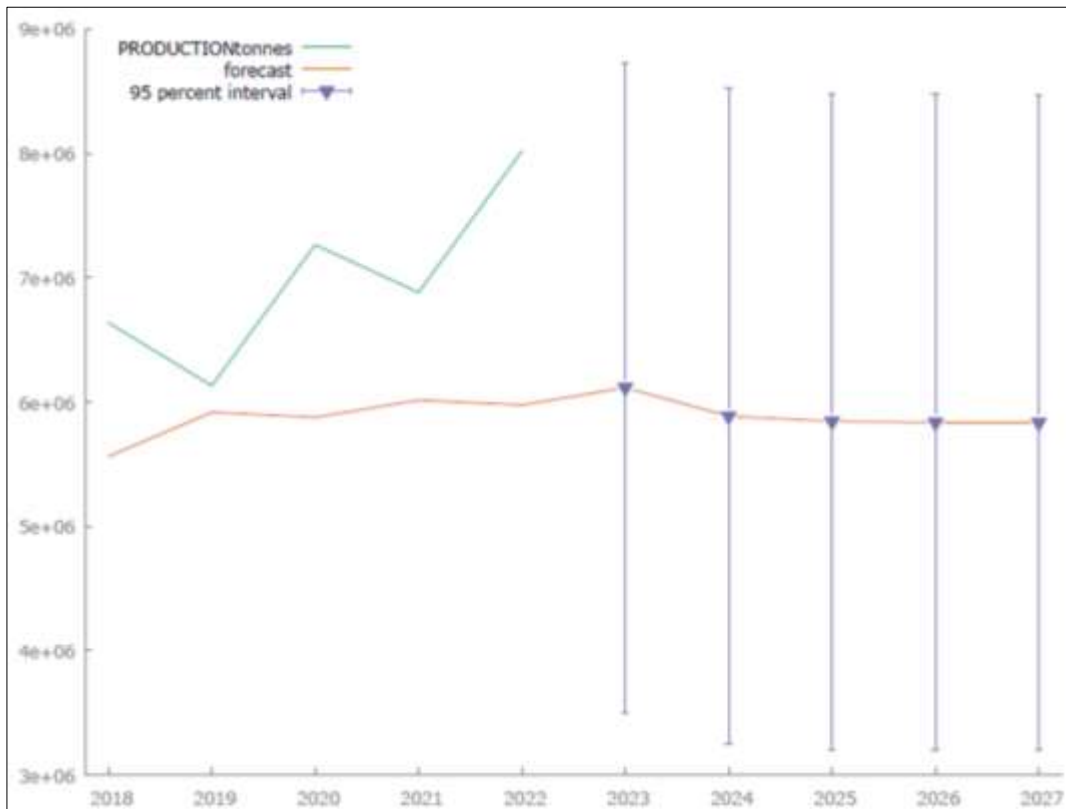


Fig 8: Forecasted values of rice production with 95% Confidence Level (CL)

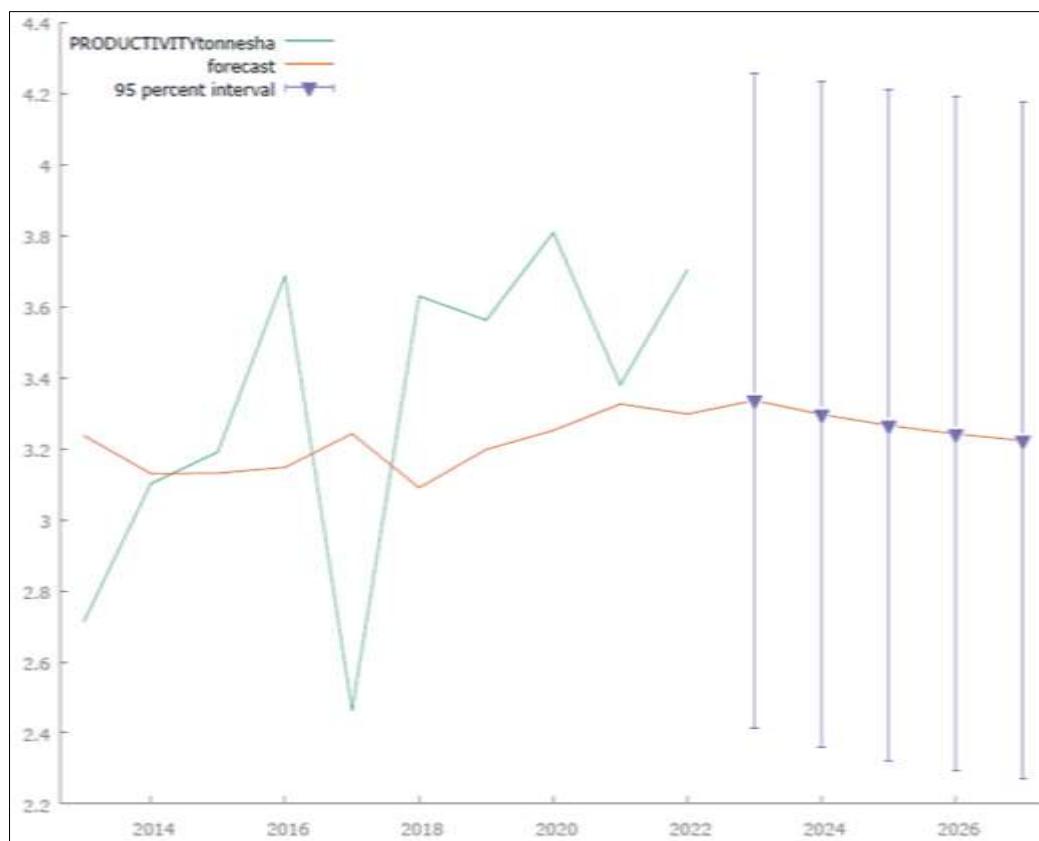


Fig 9: Forecasted values of rice productivity with 95% Confidence Level (CL)

Table 2: Forecasted values of rice cultivated Area, Production and Productivity in Tamil Nadu

Year	Area (Ha)	Production (Tonnes)	Productivity (Tonnes/ha)
2023	1906086.73	6115107.56	3.3361
2024	1836366.34	5886437.84	3.296
2025	1840873.33	5843835.25	3.625
2026	1840581.98	5835898.12	3.241
2027	184060.81	5834419.39	3.229

Conclusion

Time series Data for rice crop cultivated area, production and yield for the period 2000-01 to 2022-23 has been employed in the Auto Regressive Integrated Moving Average (ARIMA) model in Gretl software. As we have earlier stated that development of ARIMA model for any variable involves four steps: Identification, Estimation, Verification and Forecasting. The results showed the area forecast for the year 2023 to be about 1906086.73 hectare with lower and upper limit 1507149.18 and 2305024.28 hectares respectively, production forecast to be about 6115107.56 tonnes with lower and upper limit 3498028.08 and 8732187.05 tonnes respectively and productivity forecast to be about 3.336 tonnes per ha with lower and upper limit 2.413549 and 4.258816 tonnes per ha respectively.

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