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Iteration and Identification of the Appropriate ARIMA Models for Forecasting Groundnut Area, Production, and Yield in Telangana and India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Groundnut cultivation plays a crucial role in India's agricultural landscape, but there has been a declining trend in acreage in the past two decades. At the state level, despite groundnut productivity in Telangana being higher than the national average, it was not among the major groundnut-producing states for its only rabi cultivation and low acreage. Under such conditions, forecasting area, production and yield beforehand the prices is necessary to address dynamics at the supply end. This study aims to forecast groundnut cultivation, production, and yield in India and Telangana using ARIMA modelling. The annual time series data were sourced from the Directorate of Economics and Statistics, Government of India from 1990-91 to 2021-22. ARIMA. SPSS

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software was employed for the analysis and modelling tasks. By analysing the model fit and residual statistics ARIMA (2,1,3) ARIMA (0,0,0), and ARIMA (3,1,3) were performed as the best-fit models for groundnut area, production, and yield forecasts in India. For Telangana, ARIMA (0,1,0) ARIMA (1,1,6), and ARIMA (14,1,14) were found better. The forecasts of groundnut at the country level indicated stagnation in production, declination in area and inclination in yield, which was found fluctuating. Proactive planning is necessary to address these challenges and ensure sustainable production at the country level. In Telangana, there is a positive trend in groundnut production and the increasing trend in cultivation but may decline in the long run, if proper planning and marketing strategies are not followed consistently. Accurate forecasting of groundnut metrics is crucial for stakeholders to make informed decisions, bridge supply-demand gaps, and promote a resilient groundnut industry.

Keywords: Groundnut; ARIMA forecasting; India and Telangana.

1. INTRODUCTION

Groundnut cultivation plays a vital role in India's agricultural landscape due to its economic significance and nutritional value. India is the second largest producer and consumer of groundnuts globally [1]. The crop not only provides income and employment opportunities for farmers but also contributes to food security and the domestic oilseed industry.

However, despite the increasing yield and production of groundnuts in recent years, there has been a concerning trend of decreasing cultivation [2,3]. Several factors contribute to this phenomenon, However, one of the primary reasons is the changing cropping patterns and the shift towards more profitable or less labor-intensive crops. Farmers often choose alternative crops that offer higher returns or require less manual labor, leading to a decline in groundnut cultivation.

Another factor is the availability of hybrid and high-yielding varieties of groundnuts. These varieties have significantly increased productivity, resulting in higher yields and production. As a result, farmers can meet the demand with a lesser land area dedicated to groundnut cultivation, which inadvertently contributes to the decrease in overall cultivation.

Despite the decline, groundnut cultivation remains essential in countries like India due to its strategic importance in the current oil-demand supply lag [4]. Groundnut oil is widely consumed in the Indian culinary culture and is a significant component of various traditional dishes. The domestic demand for groundnut oil remains high, and the country heavily relies on imports to bridge the supply gap.

Telangana is highly productive in groundnut cultivation with an average yield of 2.29 tonnes/ ha. after Tamil Nadu. Among the oilseeds cultivated, groundnut occupies the second position in terms of area share (37.87%) after Soybean. It registered the highest productivity among oilseeds cultivated in the state (Directorate of Economics and Statistics, Govt, of Telangana) but does not remain among the top-producing states of the country.

So, forecasting the groundnut cultivation, its production, and yield in India and Telangana becomes crucial under such circumstances. The fluctuation in prices of any commodity can be observed due to the imbalance in the supply and demand of the commodity. Forecasting the area, production, and yield beforehand the prices is necessary as they are basic dictatives in determining the supply of the commodity. By forecasting these variables in advance, policymakers, agricultural authorities, and farmers can make informed decisions and develop strategies [5] to address the decline in cultivation while ensuring a stable supply of groundnut oil. Forecasting also aids in planning crop rotations, optimizing resource allocation, promoting sustainable practices, and identifying interventions to encourage groundnut cultivation.

Under this context, the study formulated an objective to forecast the area, production, and yield of groundnut in India and Telangana using ARIMA methodology. The study aims to compare various ARIMA models for each variable and select the most suitable model based on the comprehensive evaluation of model and residual statistics. By achieving these objectives, the study intends to provide accurate and reliable forecasts for the variables considered, enabling better decision-making and planning for groundnut cultivation both at national and regional level.

2. MATERIALS AND METHODS

2.1 Methodology

The study employed ARIMA modelling as the forecasting approach. Box and Jenkins (1968) were the first to extensively use this model in forecasting. ARIMA (Auto Regressive Moving Average) models are commonly used for time series analysis and forecasting [6,7,8].

The equation for the simplest ARIMA model is as follows [9,10]:

$$Y_t = \delta_0 + \delta_1 Y_{t-1} + \delta_2 Y_{t-2} + \cdots + \delta_p Y_{t-p} + \varepsilon_t + \varphi_1 \varepsilon_{t-1} + \varphi_2 \varepsilon_{t-2} + \cdots + \varphi_q \varepsilon_{t-q}$$

Here, Y_t stands for area, production and yield of groundnut value with reference to time.
It combines three components: autoregressive (AR), differencing (I), and moving average (MA).

Autoregressive (AR) Component: This component models the relationship between the current observation and a certain number of lagged observations. It assumes that the current value of a variable depends on its past values. The order of the autoregressive component (denoted as p) determines the number of lagged observations considered in the model and is shown in the equation as follows.

$$Y_t = \delta_0 + \delta_1 Y_{t-1} + \delta_2 Y_{t-2} + \cdots + \delta_p Y_{t-p} + \varepsilon_t$$

Differencing (I) Component: This is used to make the time series stationary. If the time series exhibits trends or seasonality, differencing can be applied to remove them. The order of differencing (denoted as d) represents the number of times differencing is performed to achieve stationarity

No difference (d=0): $y_t = Y_t$
First difference (d=1): $y_t = Y_t - Y_{t-1}$
Second difference (d=2): $y_t = (Y_t - Y_{t-1}) - (Y_t - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2}$

Here, denotes the original series and y_t denotes the differenced series.

Moving Average (MA) Component: The moving average component models the dependency between the current observation and a linear combination of past error terms. It captures the short-term dynamics and random shocks in the data. The order of the moving average component (denoted as q) determines the number of lagged error terms and are included in the model as follows.

$$Y_t = \delta_0 + \varepsilon_t + \varphi_1 \varepsilon_{t-1} + \varphi_2 \varepsilon_{t-2} + \cdots + \varphi_q \varepsilon_{t-q}$$

The methodology for implementing an ARIMA

model is illustrated in the Chart 1.

2.2 Data Sources

The data sets of Area, Production, and Yield of India and Telangana utilized for forecasting were sourced from the Directorate of Economics and Statistics, Ministry of Agriculture and farmer welfare, Government of India, which are accessed at (https://eands.dacnet.nic.in/). The data sets cover the period from 1990-91 to 2021-22, providing a comprehensive and extensive time series for analysis.

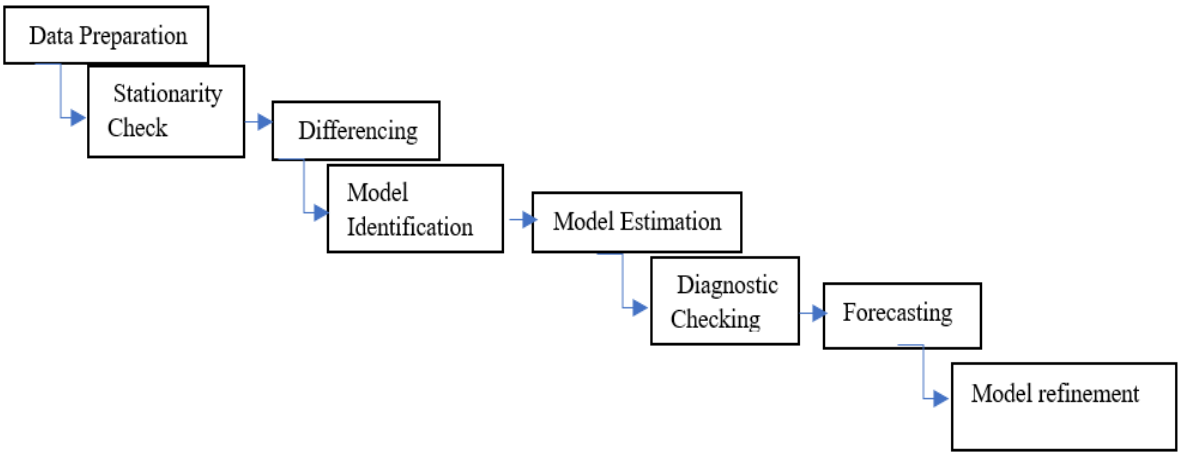


Chart 1. Procedure flow chart of ARIMA modelling and forecast
(Source: Author's own compilation)

2.3 Data Analysis

The time-series data for groundnut area, production and yield were pre-processed and transformed to ensure compatibility with the SPSS software. The missing values or outliers, were handled before performing the analysis. To examine the time series and determine the stationarity, the stationarity check is performed using statistical tests like the ADF Augmented Dickey-Fuller (ADF) Test, Phillips-Peron (PP), and KPSS tests or visual inspection of plots like the autocorrelation function (ACF) and partial autocorrelation function (PACF). If the time series is not stationary, the series were differenced to make it stationary. The differencing is performed by taking the difference between consecutive observations, or higher-order differencing if needed.

The appropriate orders (p, d, q) for the ARIMA model were identified by analyzing the ACF and PACF plots. The model with the lowest values of AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) [11,12], RMSE (Root Mean Square Error), MAE (Mean Absolute Error), Mean Absolute Percentage Error (MAPE) were also used for model selection. The parameters were estimated for the ARIMA model using maximum likelihood estimation or other appropriate estimation techniques [13,14].

For the diagnostic checking, the model residuals were assessed to ensure the assumptions of the ARIMA model are met [15]. The absence of autocorrelation and heteroscedasticity in the residuals were checked using Ljung -Box statistic [16,17] and Residual plots of ACF and PACF. The Ljung -Box statistic test and its decision criteria are used to assess the presence of autocorrelation in a time series dataset based on the calculated Q statistic and associated p-value. If the p-value is less than a chosen significance level (e.g., 0.05 or 0.01), we reject the null hypothesis of no autocorrelation and conclude that there is significant autocorrelation in the data. If the p-value is greater than the chosen significance level, we fail to reject the null hypothesis and conclude that there is no significant evidence of autocorrelation in the data. If the ACF of the residuals is well within the significant bounds, it indicates the absence of the residuals of the model.

The estimated ARIMA models are used to generate forecasts (out of sample) for future time periods. The forecast accuracy is validated by comparing the predicted values (in sample values) with actual values [18]. The sample period of 2015 to 2021 is used as testing data set for validation. The predictions accurate to the original values are considered as a good model for forecasting. If the model did not perform well, it was iterated again by adjusting the model orders or incorporating additional components (e.g., seasonal ARIMA).

Using the ARIMA modelling technique, the study predicted future trends in groundnut area, production, and yield for India and Telangana. By fitting various ARIMA models to the historical data, the iterative process involved evaluating different model configurations to identify the best-performing model for accurate forecasting.

2.4 Software and Tools

The Statistical Product and Service Solutions (IBM SPSS) [19] software was employed for the analysis and modelling tasks. SPSS facilitated data manipulation, transformation, model fitting, and generating forecast results.

3. RESULTS AND DISCUSSION

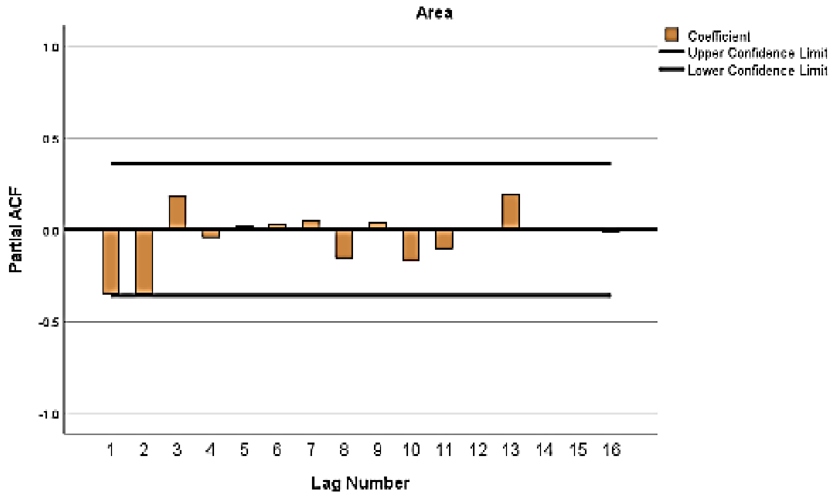
3.1 Forecast Analysis of Groundnut Area, Production, and Yield in India using ARIMA model

Area: The non-stationarity of the groundnut area is confirmed through the unit root tests (Table 1). ACF and PACF plots in the (Fig. 2) revealed differencing of the original series is necessary and tentative values for p (1,2) and q (1,3) were obtained. Based on the model fit and residual statistics highlighted in Table 2. suggested ARIMA (2,1,3) for area forecasting. However, the model is relatively better considering the other tentative models and is validated through the comparisons made from training data set values with predicted values as presented in Table 3. The Mean Absolute Percent Error (MAPE) that denotes the deviation was found low (2.24%) for the considered years. The forecasts indicated that the area coverage under groundnut could decline in the further years which is visually presented in the graph (Fig. 3) Wankhade & Kale [20] also forecasted the decreasing trend in area using ARIMA (1,1,1) model.

Table 1. Unit root test results of groundnut area in India

Groundnut	Level form I (0) with constant and trend			1st diff form I (1) with constant and trend		
	ADF	PP	KPSS	ADF	PP	KPSS
Area	-2.630 ns	-2.591 ns	0.164 ns	-6.772 s	-8.494 s	0.08 s

Critical values for ADF and PP test at 1%, 5% and 10% level of significance are -4.309, -3.574, -3.221; Critical values for KPSS test are 0.216, 0.146 and 0.119; ns= non stationary, s = stationary.



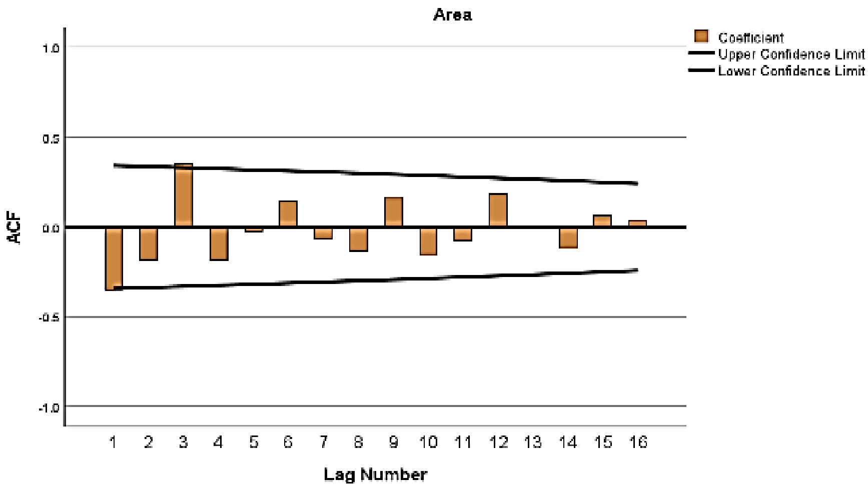


Fig 1. ACF and PACF plots of first differenced data of groundnut area in India

Table 2. Selection of appropriate ARIMA model from residual analysis and model fit statistics of all tentative ARIMA models

ARIMA Model (p d q)	Stationary R^2	Adj R^2	Normalized BIC	RMSE	MAE	MAPE	Ljung -box p-value
111	0.364	0.87	12.63	443.51	354.37	6.034	0.591
011	0.350	0.87	12.51	440.52	354.79	6.038	0.255
110	0.182	0.83	12.74	493.99	382.39	6.507	0.274
210	0.346	0.86	12.66	449.95	334.96	5.560	0.898
211	0.353	0.86	12.80	456.11	321.06	19.703	0.842
013	0.387	0.87	12.75	443.89	330.58	16.119	0.815
113	0.412	0.88	12.85	443.21	306.04	5.057	0.720
213	0.474	0.89	13.93	427.98	299.28	4.976	0.379

BIC = Bayesian Information Criteria, RMSE= Root Mean Square Error, MAE = Mean Absolute Error, Mean Absolute Percentage Error

Table 3. Validation of predicted values of the fitted ARIMA (2,1,3) model with the actual values and forecasts from 2022 to 2029

Year	Actual Values Y	Predicted Values Ŷ	Error (Y - Ŷ)	Absolute Percent Error	Forecasts of Groundnut Area ('000 ha)	
2015	4769	5421	-652	-13.672	2022	5931
2016	4597	4685	-88	-1.914	2023	5621
2017	5338	4513	825	15.455	2024	5537
2018	4888	5254	-366	-7.488	2025	5453
2019	4731	4804	-73	-1.543	2026	5369
2020	4825	4647	178	3.689	2027	5285
2021	6015	4741	1274	21.180	2028	5201
Mean Absolute Percent Error				2.244	2029	5033

Production: The unit root tests (Table 4) confirmed the stationarity of the series and suggested no first differencing. From the ACF and PACF plots (Fig. 4) the number of lags out of standard error limits was found zero. The only considerable model for the situation is ARIMA (0,0,0). The expert modeller of SPSS had also suggested ARIMA (0,0,0) as the best-fit model for the current scenario. The model fit and residual statistics in Table 5. were found low and with such lower error measures can be considered as a good fit [21]. The ARIMA (0,0,0) model contains only constant; hence the predictions and the forecasts have shown at constant value of 7514.97. The ARIMA (0,0,0)-model selected by the expert system software Forecast Pro outperformed the other models in the study conducted by Crone [22]. Fig. 5 implies that groundnut production stagnated over the years and shows the same trend in the forecasts. The stagnation in groundnut production can be attributed to a continuous decline in the area under cultivation, despite an increase in yield.

Yield: The non-stationarity in the ground nut yield data is illustrated as the series is trending upwards and was confirmed through the three-unit root tests presented in Table 7. p (1,3), d (1), and q (1,2,3) were taken from the ACF and PACF plots (Fig. 6). Through the iterative process, various tentative models are fitted for the yield data. The majority criteria of the model fit and residual statistics were satisfied by the ARIMA (3,1,3) model as highlighted in Table 8. The cross-validation of the predicted values of the model with actual data was found with low Mean Absolute Percent Error (3.802%) indicating the robustness of the fitted model (Table 9). The forecasts of the groundnut yield in India conclude that 1805 (Kgs/Ha) and 1689 for the years 2022 and 2025, respectively. The forecasts implied increasing trends in yield with fluctuations which can be visually observed in the graph. (Fig. 7). The trend analysis on yield showed a positive trend for groundnut in the study conducted by Gayathri [23].

3.2 Forecast Analysis of Groundnut Area Production and Yield in Telangana Using ARIMA Model

Area: The unit root test from Table 10 reveals the non-stationarity of the groundnut area in Telangana. The tentative models through iterations were fitted based on the obtained p, d, q values from ACF and PACF plots (Fig. 8). From ARIMA (0,1,0) model had the highest R^2, lowest RMSE (26.53), MAE (20.32) MAPE (9.70%), and Normalized BIC (6.85). Ljung -box probability value of 0.883 was insignificant confirming the non-dependence of the residuals (Table 11). The cross-validation from Table 12. reveals the nearest accuracy of the model. The ARIMA (0,1,0) model forecasts that the groundnut area in Telangana will be increasing in the coming years and later the downfall. The significant increase in groundnut cultivation can be attributed to the proactive promotion of the state government in promoting groundnut as a prominent Rabi crop. ARIMA (0,1,0) model was used to forecast the groundnut prices in Bikaner district of Rajasthan by Bannor and Sharma, [24].

Production: Neither graphical analysis nor unit root results (Table 13) confirmed the stationarity of groundnut production. From the correlogram analysis (Fig. 9) the parameter values were identified as (p=1; d=1; q=1,6). The ARIMA (1,1,6) model showed high R^2, low RMSE, MAE, and MAPE. The insignificant Ljung-Box probability (0.719) confirmed the independency of residuals. Cross-validation indicated good accuracy (Table 15.) The forecast predicts increasing groundnut production in Telangana. The production was predicted 328 thousand tonnes in 2022 to 378 thousand tonnes in 2025. The increase in groundnut production in Telangana can be attributed to the increase in productivity in the future years.

Yield: The non-stationarity of groundnut yield is predicted from unit root results (Table 16) and necessitates the first differencing of the series. Parameter values (p=1 and q =1,2) were identified from the correlogram analysis (Fig. 12). The model fit statistics with the lowest RMSE (182.48), MAE (139.15), and MAPE (11.31%) and highest R^2 values relatively suggest ARIMA (0,1,1) as a better fit. The insignificant Ljung-Box probability (0.822) confirmed independent residuals as observed in Table 17. While comparing the models, ARIMA (0,1,0) model was found better fit in the study conducted by Celik [25]. The yield was found from 2049 kg/ha in 2022 to 2707 Kg/ ha in 2025 and reached 3285.24. Kg/ha by 2029. The groundnut yield was found to be continuously increasing for the forecasted years which was pictographically represented in Fig. 12.

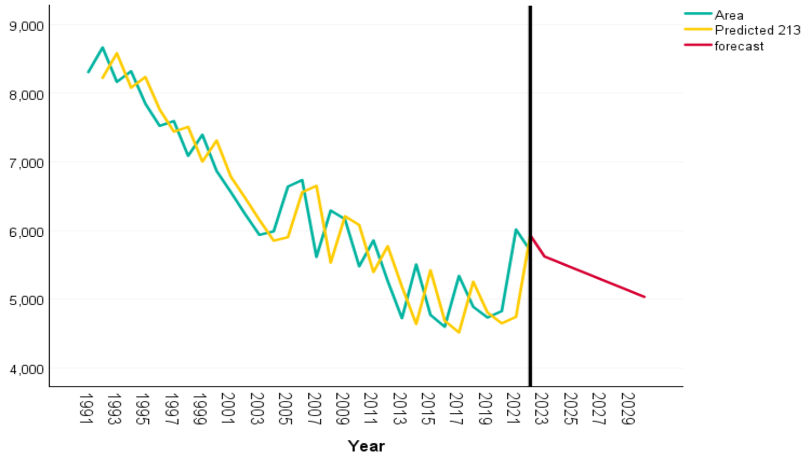
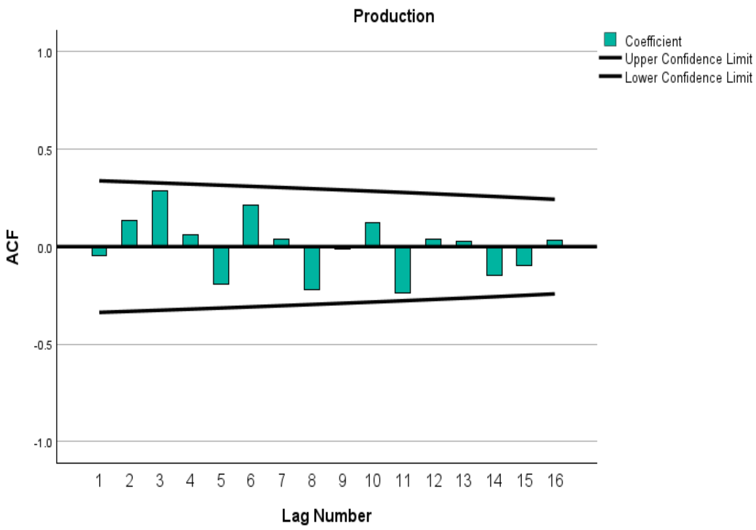


Fig. 2. Forecasting groundnut area in India using ARIMA (2,1,3)

Table 4. Unit root test results of groundnut production in India

Groundnut	Level form I (0) with constant and trend		
	ADF	PP	KPSS
Production	-2.09 ns	-8.236 s	0.080 s

Critical values for ADF and PP test at 1%, 5% and 10% level of significance are -4.309, -3.574, -3.221; Critical values for KPSS test are 0.216, 0.146 and 0.119; ns= non stationary, s = stationary.



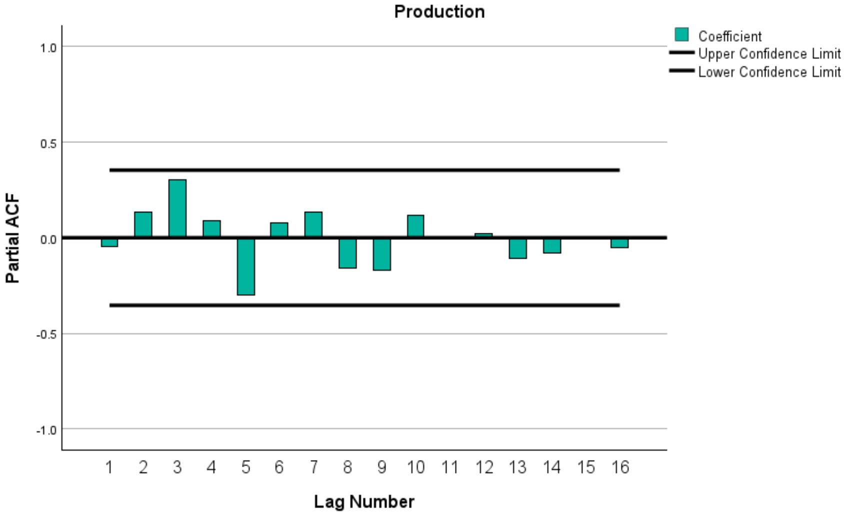


Fig. 3. ACF and PACF plots of level data of groundnut production in India

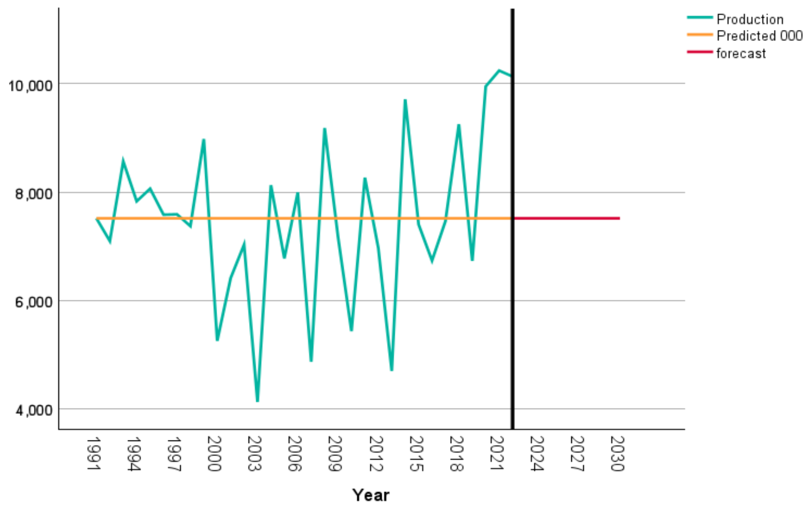
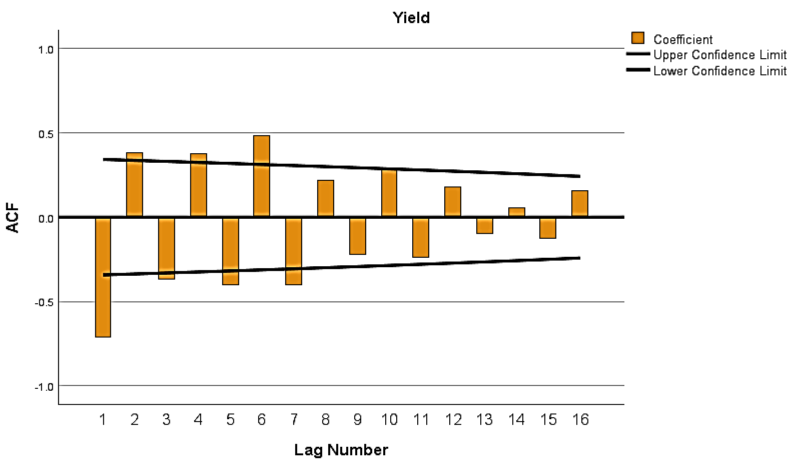


Fig. 4. Forecasting groundnut Production in India using ARIMA (0,0,0)



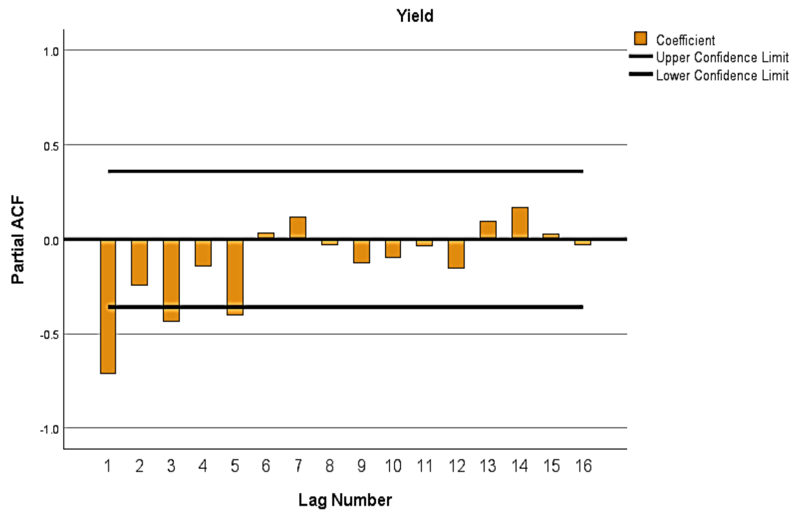


Fig. 5. ACF and PACF plots of first differenced data of groundnut yield in India

Table 5. Selection of appropriate ARIMA model from residual analysis and model fit statistics of all tentative ARIMA models

ARIMA Model (p d q)	Stationary R^2	Adj R^2	Normalized BIC	RMSE	MAE	MAPE	Ljung -box p value
000	000	000	14.815	1561.39	1171.78	17.50	0.358

BIC = Bayesian Information Criteria, RMSE= Root Mean Square Error, MAE = Mean Absolute Error, Mean Absolute Percentage Error

Table 6. Validation of predicted values of the Fitted ARIMA (000) model with the actual values and forecasts from 2022 to 2029

Year	Actual Values Y	Predicted Values Ŷ	Error (Y - Ŷ)	Absolute Percent Error	Forecasts of Groundnut Production ('000 tonnes)	
2015	7402	7515	113.0	1.527	2022	7514.97
2016	6733	7515	782.0	11.614	2023	7514.97
2017	7462	7515	53.0	0.710	2024	7514.97
2018	9253	7515	-1738.0	-18.783	2025	7514.97
2019	6727	7515	788.0	11.714	2026	7514.97
2020	9952	7515	-2437.0	-24.488	2027	7514.97
2021	10244	7515	-2729.0	-26.640	2028	7514.97
Mean Absolute Percent Error				-6.335	2029	7514.97

Table 7. Unit root test results of groundnut yield in India

Groundnut	Level form I (0) with constant and trend			1st diff form I (1) with constant and trend		
	ADF	PP	KPSS	ADF	PP	KPSS
Yield	0.921 ns	-3.517 ns	0.165 ns	-5.112s	-34.73s	0.06 s

Critical values for ADF and PP test at 1%, 5% and 10% level of significance are -4.309, -3.574, -3.221; Critical values for KPSS test are 0.216, 0.146 and 0.119; ns= non stationary, s = stationary

Table 8. Selection of appropriate ARIMA model from residual analysis and model fit statistics of all tentative ARIMA models

ARIMA Model (p d q)	Stationary R^2	Adj R^2	Normalized BIC	RMSE	MAE	MAPE	Ljung -box p value
011	0.594	0.581	11.17	238.84	175.09	15.201	0.021
111	0.632	0.620	11.22	231.26	166.15	14.486	0.536
110	0.503	0.487	11.38	264.20	209.67	17.292	0.206
012	0.626	0.614	11.24	233.28	171.77	15.354	0.270
013	0.633	0.622	11.36	235.12	169.56	14.971	0.305
313	0.685	0.675	11.66	231.01	160.06	14.307	0.589
312	0.677	0.666	11.53	229.41	165.15	14.725	0.554
311	0.655	0.644	11.45	232.51	166.02	14.383	0.577

BIC= Bayesian Information Criteria, RMSE= Root Mean Square Error, MAE = Mean Absolute Error, Mean Absolute Percentage Error

Table 9. Validation of predicted values of the fitted ARIMA (3,1,3) model with the actual values

Year	Actual Values Y	Predicted Values Ŷ	Error (Y - Ŷ)	Absolute Percent Error	Forecasts of Groundnut Yield (Kg./ha)	
2015	1552	1351	201	12.951	2022	1805.00
2016	1465	1633	-168	-11.468	2023	1622.32
2017	1398	1436	-38	-2.718	2024	1911.17
2018	1893	1702	191	10.090	2025	1689.21
2019	1422	1512	-90	-6.329	2026	1945.39
2020	2063	1725	338	16.384	2027	1773.66
2021	1703	1571	132	7.751	2028	1986.97
Mean Absolute Percent Error				3.802	2029	1849.29

Table 10. Unit root test results of groundnut area in Telangana

Groundnut	Level form I (0) with constant and trend			1st diff form I (1) with constant and trend		
	ADF	PP	KPSS	ADF	PP	KPSS
Area	-3.031ns	-1.540 ns	0.182 ns	-5.178 s	-7.294 s	0.0337

Critical values for ADF and PP test at 1%, 5% and 10% level of significance are -4.309, -3.574, -3.221; Critical values for KPSS test are 0.216, 0.146 and 0.119; ns= non stationary, s = stationary.

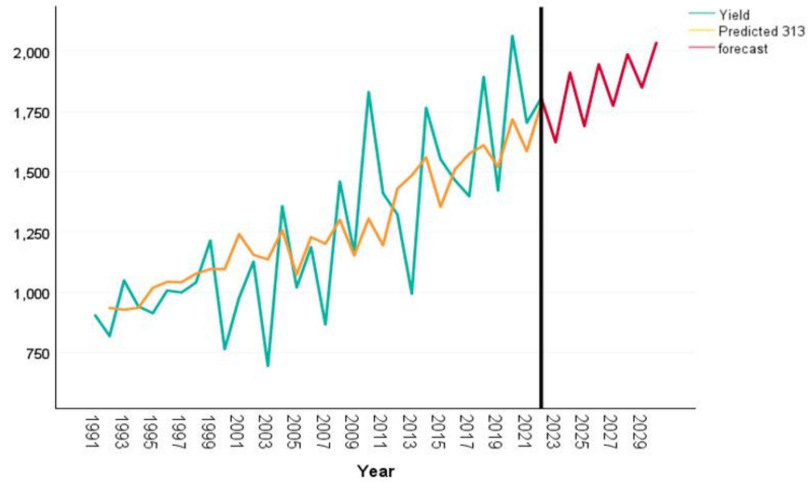


Fig. 6. Forecasting groundnut Yield in India using ARIMA (3 ,1, 3)

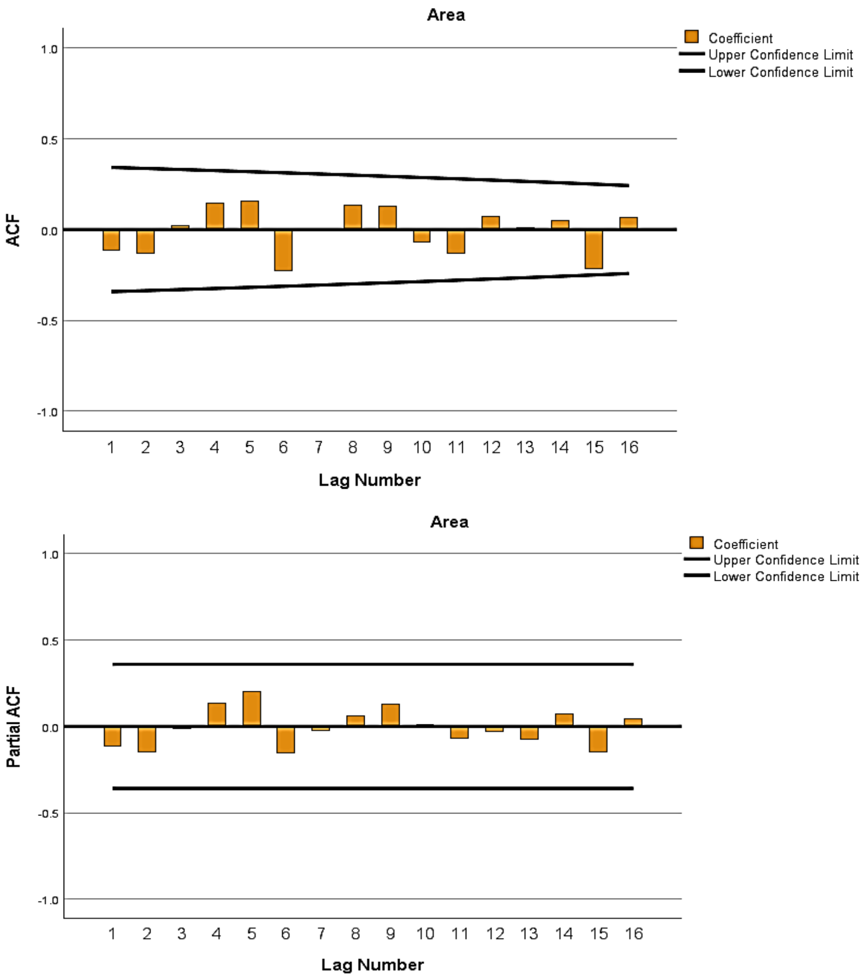


Fig. 7. ACF and PACF plots of first differenced data of groundnut area in Telangana

Table 11. Selection of appropriate ARIMA model from residual analysis and model fit statistics of all tentative ARIMA models

ARIMA Model (p d q)	Stationary R^2	Adj R^2	Normalized BIC	RMSE	MAE	MAPE	Ljung -box p-value
010	0.22	0.916	6.85	26.53	20.32	9.702	0.883
111	0.25	0.937	7.00	29.08	23.12	11.01	0.826
020	0.08	0.765	7.78	43.82	33.62	15.65	0.659

Table 12. Validation of predicted values of the fitted ARIMA (0, 1, 0) model with the actual values

Year	Actual Values Z	Forecasted Values $\hat{Z}$	Error($Z-\hat{Z}$)	Absolute Percent Error	Forecasted values of Groundnut Area ('000 ha)	
2015	154.79	199.26	-44	-28.73	2022	116.47
2016	127.79	143.97	-16	-12.66	2023	143.79
2017	167.09	116.98	50	29.99	2024	132.98
2018	167.05	156.27	11	6.45	2025	122.17
2019	126.50	156.24	-30	-23.50	2026	111.36
2020	110.92	115.69	-5	-4.30	2027	100.54
2021	127.28	100.12	27	21.35	2028	89.73
Mean Absolute Percent Error				-1.63	2029	68.10

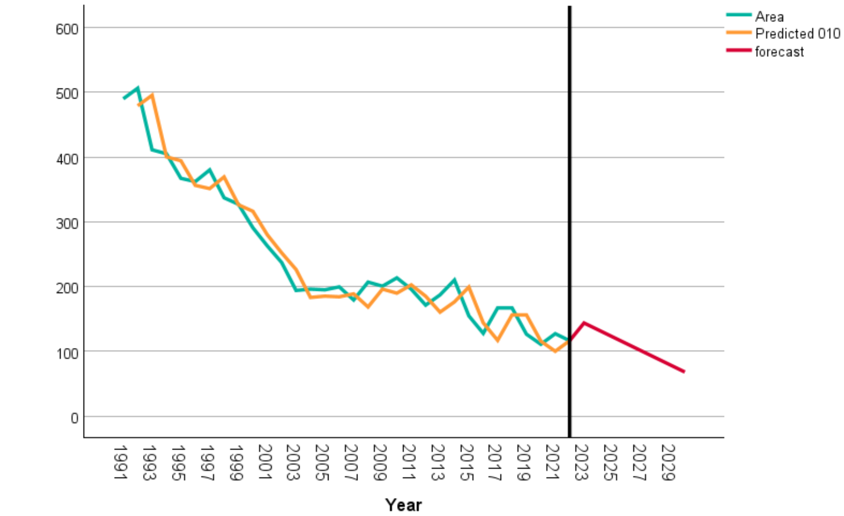


Fig. 8. Forecasting groundnut area in Telangana using ARIMA (0, 1, 0)

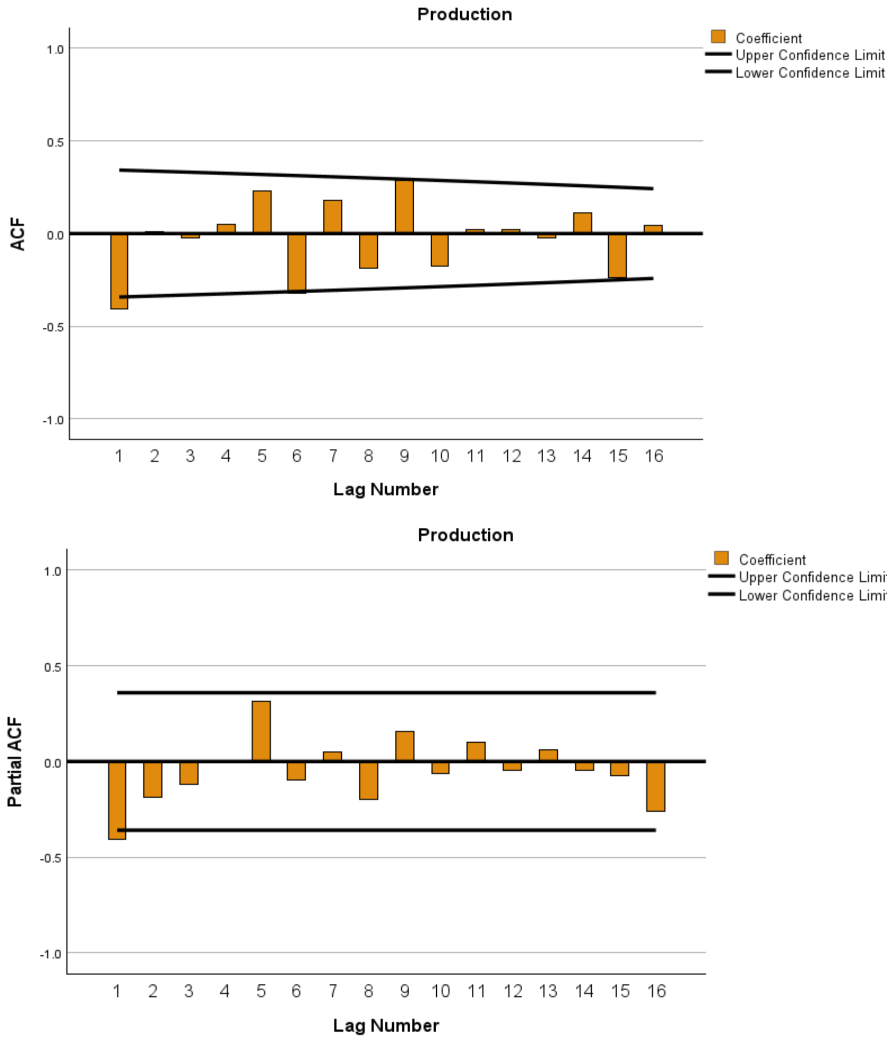


Fig 9. ACF and PACF plots of level data of groundnut production in Telangana

Table 13. Unit root test results of groundnut production in Telangana

Groundnut	Level form I (0) with constant and trend			1st diff form I (1) with constant and trend		
	ADF	PP	KPSS	ADF	PP	KPSS
Production	-4.945 ns	-4.904 ns	0.251 ns	-8.447 s	-18.57 s	0.005 s

Critical values for ADF and PP test at 1%, 5% and 10% level of significance are -4.309, -3.574, -3.221; Critical values for KPSS test are 0.216, 0.146 and 0.119; ns= non stationary, s = stationary

Table 14. Selection of appropriate ARIMA model from residual analysis and model fit statistics of all tentative ARIMA models

ARIMA Model (p d q)	Stationary R^2	Adj R^2	Normalized BIC	RMSE	MAE	MAPE	Ljung -box
111	0.307	0.095	8.809	65.567	51.78	18.43	0.656
011	0.307	0.235	8.662	64.388	51.83	18.45	0.590
110	0.226	-0.01	8.772	68.026	54.32	19.43	0.381
116	0.451	0.284	9.334	64.620	43.63	14.90	0.719

Table 15. Validation of predicted values of the Fitted ARIMA (1, 1, 6) model with the actual values

Year	Actual Values Z	Forecasted Values $\hat{Z}$	Error(Z-$\hat{Z}$)	Absolute Percent Error	Forecasts of Groundnut Production ('000 tons)	
2015	338.33	284.76	54	15.834	2022	328.42
2016	329.09	272.17	57	17.299	2023	350.03
2017	292.00	284.73	7	2.490	2024	365.36
2018	318.70	357.37	-39	-12.138	2025	378.32
2019	347.89	346.14	2	0.502	2026	443.23
2020	346.88	338.06	9	2.544	2027	481.73
2021	329.36	329.50	0	-0.043	2028	520.09
Mean Absolute Percent Error				3.784	2029	547.79

Fig. 10. Forecasting groundnut production in Telangana using ARIMA (1, 1, 6)

Table 16. Unit root test results of Groundnut yield in Telangana

Groundnut	Level form I (0) with constant and trend			1st diff form I (1) with constant and trend		
	ADF	PP	KPSS	ADF	PP	KPSS
Yield	-2.479 ns	-2.34ns	0.167ns	-10.031 s	-14.892 s	0.070

Critical values for ADF and PP test at 1%, 5% and 10% level of significance are -4.309, -3.574, -3.221; Critical values for KPSS test are 0.216, 0.146 and 0.119; ns= non stationary, s = stationary.

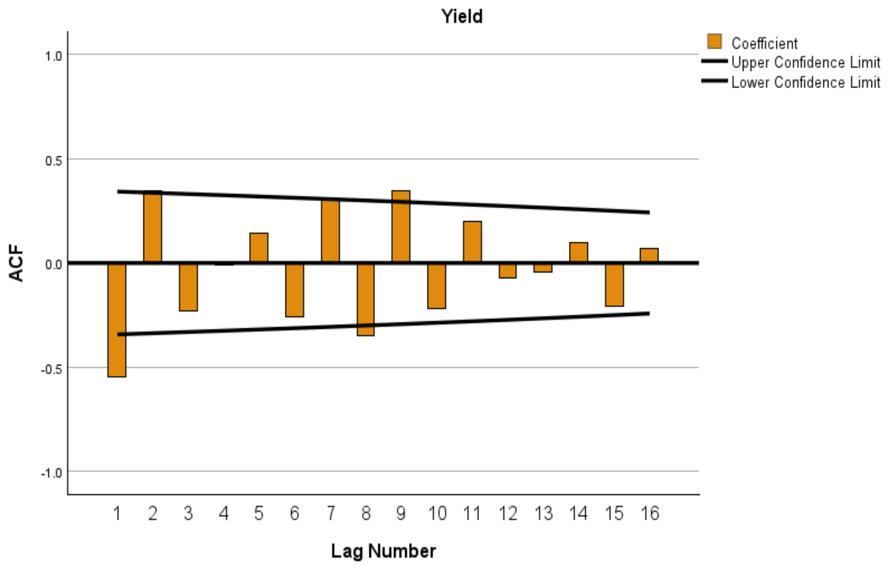
Table 17. Selection of appropriate ARIMA model from residual analysis and model fit statistics of all tentative ARIMA models

ARIMA Model (p d q)	Stationary R^2	Adj R^2	Normalized BIC	RMSE	MAE	MAPE	Ljung -box
111	0.331	0.888	10.983	194.41	145.75	11.482	0.567
110	0.219	0.869	10.699	199.21	162.80	12.586	0.700
011	0.388	0.898	10.746	182.48	139.15	11.305	0.822
012	0.371	0.897	10.889	185.50	140.71	11.343	0.682
112	0.384	0.897	11.048	190.03	140.65	11.544	0.696

AIC = Akaike Information Criteria SBIC =Schwarz-Bayesian Information Criteria, RMSE= Root Mean Square Error, MAE = Mean Absolute Error, Mean Absolute Percentage Error

Table 18. Validation of predicted values of the fitted ARIMA (0, 1, 1)) model with the actual values

Year	Actual Values Z	Predicted Values Ẑ	Error(Z-Ẑ)	Absolute Percent Error	Forecasts of Groundnut Yield (Kg per ha)	
2015	1907.33	1865.40	42	2.19	2022	2048.84
2016	1611.28	1948.85	-338	-20.95	2023	2505.04
2017	2046.66	2020.71	26	1.27	2024	2600.61
2018	2229.90	2109.61	120	5.39	2025	2707.03
2019	2491.02	2204.92	286	11.48	2026	2816.53
2020	2392.29	2308.88	83	3.48	2027	2929.11
2021	2283.07	2408.85	-126	-5.51	2028	3044.77
Mean Absolute Percent Error				0.38	2029	3285.24



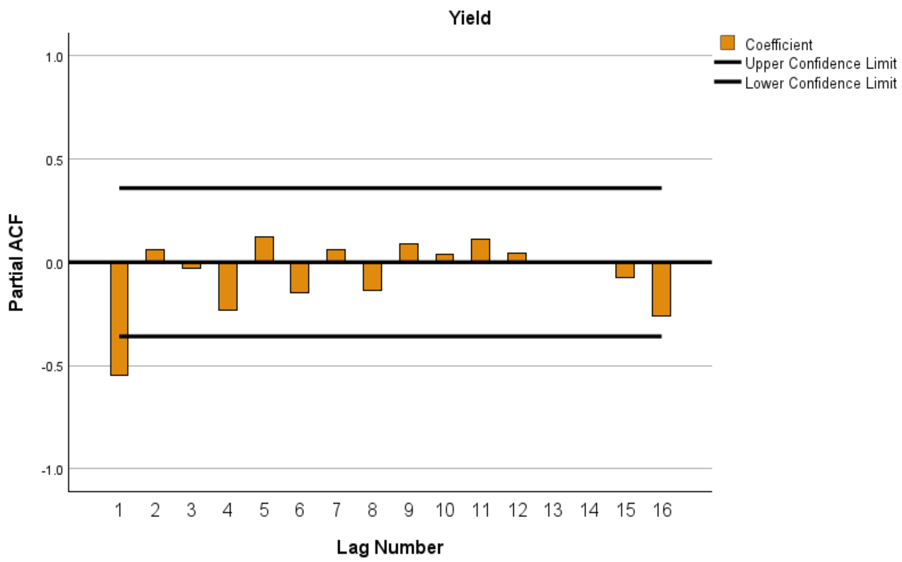


Fig. 11. ACF and PACF plots of first differenced data of groundnut yield in Telangana

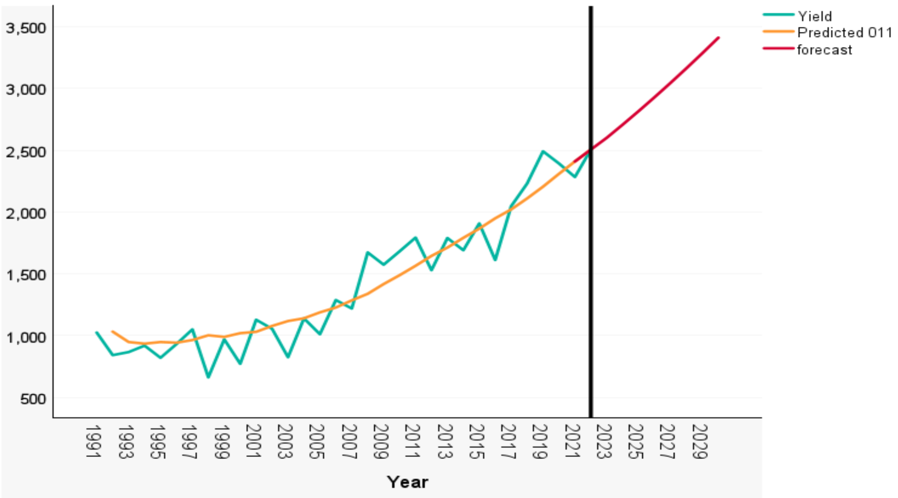


Fig. 12. Forecasting groundnut yield in Telangana using ARIMA (011)

4. CONCLUSION AND RECOMMENDATION

The forecasts for groundnut production in India are predicted to be stagnated with the declining area under cultivation and increasing, yet fluctuating yield levels. This decline in area, stagnated production and fluctuating yield levels need to be addressed. It is crucial to address the decline in cultivation area, stagnant production, and fluctuations in yield to ensure sustainable and consistent groundnut production. The forecasts for Telangana indicate a positive trend of increasing groundnut production and productivity. However, without proactive planning regarding sowings and marketing strategies, the sustained increase in area acreage may eventually decline in the long run. Accurate forecasting of groundnut Area, Production, and Yield is essential for stakeholders to anticipate future trends, address supply-demand imbalances, and optimize production processes. By doing so, the groundnut industry can achieve sustainability and resilience in the face of evolving market dynamics. Groundnut cultivation holds significant economic, nutritional, and cultural value in India. Despite cultivation challenges, accurate forecasting plays a vital role in supporting decision-making, bridging supply-demand gaps, and fostering a thriving groundnut sector in the country.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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