Asian Journal of Economics, Business and Accounting

Volume 24, Issue 9, Page 31-47, 2024; Article no.AJEBA.122223
ISSN: 2456-639X

Forecasting of Organic Sorghum Production and Productivity in Chhattisgarh, India: The Box-jenkins Approach

Ram Prasad Chandra [a++*] and Bhagawat Prasad Sahu [b++]

[a] Department of Economics, Government Madan Lal Shukla Postgraduate College Seepat, (Chhattisgarh), Pin – 495555, India.
[b] Mahesh Baghel ji keshkal Dandkaranya Government College, Keshkal, (Chhattisgarh), Pin – 494331, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajeba/2024/v24i91475

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122223

Original Research Article

Received: 19/06/2024
Accepted: 21/08/2024
Published: 24/08/2024

ABSTRACT

Chhattisgarh has taken important steps towards promoting millets cultivation and improving the livelihood of farmers. To increase millets production in Chhattisgarh, the state government launched the Millet Mission in September 2021. This mission has been started with a view to make Chhattisgarh the 'millet hub of India'. The study focused on forecasting sorghum crops in Chhattisgarh, India, using historical data on the cultivated area, production, and yield of sorghum crops. The time series data was collected from 2001 to 2023, and analysis of the study was carried

[++]Assistant Professor;
**Corresponding author: E-mail: chandracgap@gmail.com;*

***Cite as:** Chandra, Ram Prasad, and Bhagawat Prasad Sahu. 2024. "Forecasting of Organic Sorghum Production and Productivity in Chhattisgarh, India: The Box-Jenkins Approach". Asian Journal of Economics, Business and Accounting 24 (9):31-47. https://doi.org/10.9734/ajeba/2024/v24i91475.*

out using path analysis and Box Jenkins ARIMA model; and among various 20 models the best and suitable ARIMA (2, 1, 2), (3, 1, 3), and (2, 1, 2) model was selected based on AIC, BIC, MAPE, RMSE, MAE. With the help of the selected appropriate model, the area, production and yield of sorghum cultivation in Chhattisgarh was forecasted for the year 2024 to 2030. But marvellous, stochastic and fluctuating trend was observed in sorghum production and yield over the forecast period.

Keywords: Econometric modeling; forecasting; SCAPY; AIC; BIC; AFC; MAPE.

JEL Code: C01, C22, C51, C52, C53.

ABBREVIATIONS

ARIMA	:	*Autoregressive Integrated Moving Average*
SCAPY	:	*Sorghum Cultivation Area, Production and yield*
IIMR	:	*Indian Institute of Millet Research*
ARMA	:	*Autoregressive Moving Average*
AR	:	*Autoregressive*
MA	:	*Moving Average*
ACF	:	*Autocorrelation Function*
PACF	:	*Partial Autocorrelation Function*
JB	:	*Jarque-Bera*
SER	:	*Standard Error of Regression*
AIC	:	*Akaike Information Criterion*
BIC	:	*Bayesian Information Criterion*
MAPE	:	*Mean Absolute Percentage Error*
RMSE	:	*Root Mean Square Error*
MAE	:	*Mean Absolute Error*
SCA	:	*Sorghum Cultivation Area*
SP	:	*Sorghum Production*
SY	:	*Sorghum Yield*
GARCH	:	*Generalised Autoregressive Conditional Heteroscedastic*
ANN	:	*Artificial Natural Network*
BJM	:	*Box-Jenkins Methodology*
BLUE	:	*Best Linear Unbiased Estimator*

1. INTRODUCTION

Agriculture is the most important livelihood strategy in India, with two-thirds of the country's workforce dependent on farming. Organic farming can be seen as an approach to agriculture, where the aim is to create integrated, environmentally and economically sustainable agricultural production systems [1]. Sorghum, a resilient and versatile grain, serves as the fundamental food source for millions of people living in arid and semi-arid regions around the globe. Widely regarded as the second most economical source of energy and essential micronutrients, sorghum plays a crucial role in meeting the dietary and energy requirements of a significant portion of the population in central India [2]. Sorghum, a resilient crop known for its ability to thrive in tropical, warmer, and semi-arid regions with high temperatures and water stress, is highly valued for its drought adaptation capability. In India, it is cultivated during the rainy season (June–October) and the post-rainy season (November–February). Despite its versatility as a source of food, feed, fodder, and biofuel, there has been a significant decline in the cultivation of grain sorghum [3]. Sorghum is second larger millet crops, when compared with other crops, sorghum has a high energy content, with pearl millet at 361 Kcal/100 g, maize at 349 Kcal/100 g, and maize at 325 Kcal/100 g. Sorghum has a carbohydrate content of 67.5 g/100 g, with 56 to 65% starch content, 20 to 22% of amylase, 2.6-2.8% sucrose, and 1.2 g/100 g fiber. It is also a good source of vitamins and minerals [4,5].

Time series forecasting is a crucial statistical analysis technique used for both manual and automatic planning in various application domains [6]. The forecasts are generated using mathematical models that capture a parameterized relationship between past and future values to represent the behaviour and characteristics of a historical time series. The parameters of these forecast models are calculated using a training dataset to match the specifics of the time series by minimizing the forecast error. Time series data collected in many situations have a hierarchical structure. These datasets typically contain information organized in clusters that can be combined into another series of interest. In this case, the time series is aggregated along the hierarchy based on dimensional attributes such as location [7,8].

India accounts for approximately 20% of the global sorghum area and ranks as the fourth largest producer of this cereal crop. The sorghum cultivation area in India exceeded 16 million hectares in 1981 but gradually decreased to 6.3 million hectares by 2012. Production of this cereal has also seen a decline from 12 million tonnes to 6 million tonnes during this period. Over the specified period, there has been a moderate improvement in the sorghum yield, with production increasing from 7.3 to 9.5 tonnes per hectare [9]. Sorghum (Jowar) production In India stood at 4803.38 thousand tonnes from the cultivated area of 5024.45 thousand hectares in the year 2017-18, and in the of 2019-20 sorghum production 4772.01 thousand tonnes from the cultivated area of 4823.76 thousand hectares. While Sorghum production in Chhattisgarh 5.32 thousand tonnes from the cultivated area of 3.59 thousand hectares in the year 2017-18, and in the of 2019-20 sorghum production 4.07 thousand tonnes from the cultivated area of 2.90 thousand hectares [10,11].

In this present study researchers' focus on forecasting of the sorghum production in Chhattisgarh State. Sorghum (Jowar) is produced in almost all the areas of Chhattisgarh state. But it's mostly cultivated area in Surguja division- Balarampur, Koriya, Surajpur, Jashpur and Sarguja (Ambikapur) district, Bastar division-Sukma, Bijapur, Bastar (Jagdalpur), Kanker, Kondagaon and Narayanpur district, Raipur division-Gariyaband, Dhamtari and Mahasamund district, Durg division- Rajnadgaonv, Kabirdham, Balod and in Bilaspur division- Korba, Bilaspur district of the state. There is immense potential for increase in the production of sorghum in Chhattisgarh. To increase millets production in Chhattisgarh, the state government launched the Millet Mission in September 2021. This mission has been started with a view to make Chhattisgarh the 'millet hub of India'. This mission has not only increased the income of farmers in forest and tribal areas, but has also increased the prominence of the state [12]. However, millet remains an important crop for the state's food security and cultural heritage. Encouraging millet cultivation and consumption in Chhattisgarh can not only provide nutritional benefits to the population, but also contribute to sustainable agricultural development and food security.

2. LITERATURE REVIEW

Many research works have been done by researchers in the past on sorghum production, the review of which is as follows [5]. A study on pearl millet crop in Gujarat and India was conducted using historical data on the area, production, and yield of the pearl millet crop. The data was collected over a 20-year period from 1999-2000 to 2018-2019. The analysis included the use of Compound Growth Rate, path analysis, and Box Jenkins' ARIMA model. The best selected ARIMA model was (0, 0, 6) and (0, 0, 5) for Gujarat and India respectively [13]. A study was conducted on the price index of Ragi, using structural break analysis. The volatile ragi price index series was modelled and forecasted using a GARCH model and its asymmetric extensions. The results showed an improvement in the modeling and forecasting performance of the models after incorporating policy interventions. Bellundagi et al., [14] conducted research on ragi production in Karnataka and explored various linear and nonlinear growth models. The forecasting results indicated that despite a deceleration in area, ragi production was increasing due to greater productivity in the future [15]. Studies was pearl millet production in Karnataka, and used ARIMA and ANN models, and ARIMA (0, 1, 1) model was selected for forecasting the future value from 2011 to 2014. Thus, following researchers was conducted research on millet production, i.e. [16] was research on pearl millet production and productivity, [17] was conducted research on forecasting minor millet in India, [18] was studies on trend analysis of minor millet in India, [19] was studies on forecasting of millets production in India. Nireesha et al., [20] was conducted research on pearl millet production in Andhra Pradesh, India, and also some of the investigated works were i.e., Kour et al., [21]; Das et al., [22]; Dharamraja et al., [23]; Patra and Mahapatra, [24]; Chandra, [25]; Gandhi et al., [26]; and Chandra, [27].

We have documented a detailed literature on time series analysis and prediction the various data series from 1950-51 to 2022-23. But researchers' carried study on forecasting of pearl millet production, millet (Ragi) prices, minor millet production, tea production, groundnut production and coffee production, and moreover study related to Karnataka, Gujarat, Odisha and Andhra Pradesh. In the above literature review, we found a research gap that no study was found on sorghum production in Chhattisgarh. Thus, this is a gap and it motivated us to conduct a study on time series modeling and forecasting of sorghum production in Chhattisgarh, India.

3. METHODS AND METHODOLOGY

3.1 Data Collection

We used time series data from 2001 to 2023 for the research study, time series data was compiled of official website of Indian Institute of Millet Research (IIMR) https://www.milletstats.com/apy-stats/, and official website of Directorate of Economics and Statistics, DA&FW, Govt. of India, website https://desagri.gov.in/statistics-type/normal-estimates/.

3.2 Econometric Models

To choose the most suitable ARIMA model, various statistical tools are being used, such as: AIC [28,29,25,27], BIC/SIC [30], MAPE [31-35], Ljung-Box test [36,5], RMSE [37], and MAE [38-42], and thus, the formulation of the models are given bellow:

AIC written as follow:

$$AIC = \{n\,(1 + \log 2\pi) + n \log \sigma^2 + 2m\} \quad \text{...... (1)}$$

AIC = (-2log L + 2m); where: m= p + q, L = Likelihood function and -2log L = approximately equal to {n (1+ log 2π) + n log σ^2}, where: σ^2 = the model MSE.

$$BIC = \log\left(\frac{rss}{n}\right) + \frac{k}{n}\log n \quad \text{.......... (2)}$$

Where, "*rss*" = the residual sum of squares; *k* = the number of coefficients estimated, i.e., *1* + *p* + *q* + P + Q; and *n* = the number of observations,

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{X_i - \overline{X_i}}{X_i}\right| \quad \text{............ (3)}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \overline{X_i}\right)^2}{n}} \quad \text{............. (4)}$$

$$MAE = \sum_{i=1}^{n}\left|\frac{X_i - \overline{X_i}}{X_i}\right| \quad \text{................ (5)}$$

$$Q = n(n+2)\sum_{i=1}^{k}\frac{r_i^{\,2}}{n-i} \quad \text{.............. (6)}$$

Where, *n* = the number of observations, r^2 = value of i th the number of observations.

3.3 The Box-Jenkins Approach

Step I- In the preliminary phase of the study, The time series data selected for the study was obtained from a reputable and well-established source, ensuring its reliability and accuracy for the research, and after which a graphical presentation of the series has seen, which shows whether the series has showed a trend or not. After this, stationarity of the series has checked at the level, and if there has not stationarity at the category level, then stationarity has checked at the first difference, and if there has no stationarity of the series at the first difference, then this process continues till this continues until the series becomes stationary. By the way, most of the series becomes stationary after the first difference. After the series has stationary, the correlogram has seen, with the help of which the model has selected [39,42,25,27]. Fig. 1 shows the Box-Jenkins methodology consist of following four steps.

Step II- In the first step, the equation of the selected model (*p*, *d*, *q*) is derived, and then the equation is created by writing the parameters of the selected model with their given values [39,25,27].

Step III- In the third step of the study, a diagnostic check of the residuals of the selected model (*p*, *d*, *q*) was carried out in the second step, in which the autocorrelation (ACF and PACF) Ljung-Box test, WNH, and JB test was done of the selected model. If all the tests after diagnostic testing of the residuals of the selected model (*p*, *d*, *q*) were found to be significant, then the forecasting process of the selected model is done, and if all the tests after diagnostic test of the residuals of were not found to be significant, then all the process is started again from the first phase of the study [39,42,43,25,27].

Step IV- In the fourth step of the study, if after diagnostic testing residuals of the model selected in the third step, all the tests are found significant, and follow the Gauss-Markov theorem [44]. Thus, the model constructed is terms the best linear unbiased estimator "BLUE". Thereafter the forecasting process of the selected model has completed, and then reporting of the model is done [39,42,25,27].

3.4 Equation for ARIMA Models

ARIMA is a linear regression model used for time series prediction. It uses lagged values of the series as predictors. Any non-seasonal time series that shows patterns and is not simply random white noise can be represented using ARIMA models. An ARIMA model is defined by three terms: p, d, q [36,39,25,41,42,27].

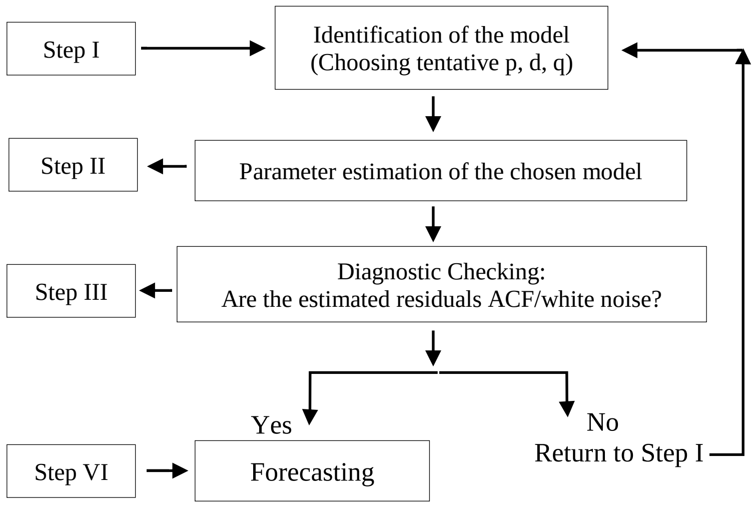

Fig. 1. Shows the Box-Jenkins methodology consist of following four steps
Source: [39,25,27]

Where: p = the order of the AR term, q = the order of the MA term, and d = order of differencing required to make the series stationary (I).

Of course, is it quite likely that Y has characteristics of both AR and MA and is therefore ARMA. Thus, if Y follows an ARMA (3, 4) process, it can be written as [42,27]:

$$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 Y_{t-3} + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \beta_3 u_{t-3} + \beta_4 u_{t-4} + u_t \ldots\ldots\ldots\ldots (7)$$

Where: θ = constant, α = coefficient of AR terms, β = coefficient of MA terms, u = white noise error terms

3.5 Model Identification for Sorghum Cultivation Area, Production and Yield

Generally, A non-stationary time series becomes stationary after differencing 'd' time and is denoted as integrated of order 'd', or I(d). If the original series is stationary (d=0), the ARIMA model becomes an ARMA model. In the present study, we used time series data for SA, SP, and SY. The series SA, SP, and SY became stationary after first-order differencing. Since no further differencing is needed, we adopted d=1 (first difference) for the ARIMA (p, d, q) model. We examined the correlogram after the first difference and observed the level in the time series as shown in Fig. 5. We didn't observe any significant spike in the ACF and PACF residuals for the selected ARIMA and ARMA models. We checked for white noise in the correlogram after the first difference in the time series (Shows in Fig. 5) and found no significant spike in the ACF and PACF residuals for the selected ARIMA and ARMA models. Therefore, there was no need to consider any additional AR (p) and MA (q). The models convince all the norms (comparatively lowest value of AIC, comparatively low values of BIC, and MAPE, MAE and RMSE). Therefore, these models have been considered to be the best predictive models that have been used to forecast future values of time series, such as DSCA, DSP and DSY. Table 2 shows that the best-fitting ARIMA model with parameters is selected, and Table 3 presents the estimation results for various parameters of AR (p) and MA (q) of the ARIMA model for area, production, and yield. With these values, we identified the best-fit ARIMA (p, d, q) models for predicting time series DSA, DSP, and DSY. Therefore, the prediction equations for the models can be written as follows. The equations for SCA (8), SP (9), and SY (10) respectively [25,27].

$$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \beta_1 u_{t-1} + \beta_2 u_{t-2} + u_t \ldots\ldots\ldots\ldots (8)$$

$$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 Y_{t-3} + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \beta_3 u_{t-3} + u_t \ldots\ldots\ldots\ldots (9)$$

$$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \beta_1 u_{t-1} + \beta_2 u_{t-2} + u_t \ldots\ldots\ldots\ldots (10)$$

4. RESULTS ANALYSIS

4.1 Stationary Test (ADF test)

The results of Argument Dickey-Fuller [45] unit root test at level and 1st order difference given in Table 1. Before differencing the time series SCA, SP and SY we performed the stationary test at the level, but the p-values at the level were insignificant. Therefore, series SA, SP and SY were statically not significant. So, it's not stationary. After that we go through 1st differenced, and 1st order difference series DSA, DSP and DSY calculated t–statistics value was respectively = 5.814, 8.122 and 6.787 and p-value were respectively = 0.0006, 0.0000, and 0.0001 which was smaller than critical values at 1%, 5% and 10% level of significance. Hence, we reject the null hypothesis for the unit root, indicating that the series DSCA, DSP, and DSY are stationary and do not contain a unit root. Fig. 4, parts (a), (b), and (c) show the plots of the correlogram (ACF and PACF) of the stationary series DSCA, DSP, and DSY for lags 1 to 12 at the 1st order difference. Fig. 2 (a) Scatter plot and (b) Quantiles graphs of Sorghum Area, production and yield in Chhattisgarh. Fig. 3 Representation of time series plot of (a) Original and (b) Stationary series.

4.2 Diagnostic Checking

We have used automatic ARIMA forecasting for model identification and parameters estimation. After that we have go out for diagnostic checking of the selected best fitted models, and which has presented in Table 2 & Table 3. However, we have performed diagnostic checking before forecasting the above selected tentative models, because it is essential to perform diagnostic checking to avoid over fitting the ARIMA models. The steps of diagnostic checking as are followed:

- The lowest values of the AIC criterions have chosen as the best fitted model for the above selected models (given in Table 2), and the lowest values of the SIC/BIC criterions has chosen as the best fitted model for the above selected models (given Table 2).
- ARIMA model parameters, viz., MAPE, RMSE, MAE, lowest value of Sigma square (σ^2 Volatility), Standard error of regression (SER), highest values of R-square criterions have chosen as the best fitted model for the above selected models (given Table 2).
- The JB test result for SA, SP, and SY has shown insignificant p-value respectively (given in Table 4). It clear that the selected time series model followed the normality test. The Ljung-Box test result for sorghum cultivation area (SCA), sorghum production (SP), and sorghum yield (SY) respectively ARIMA (2, 1, 2) and (3, 1, 3), and (2, 1, 2) has shown insignificant at 1%, 5% and 10% level of significance (given Table 4).
- After fitting the appropriate ARIMA models, the goodness of fit can be estimated by plotting the ACF of residuals of the fitted models. If most of the sample autocorrelation coefficients of the residuals lie within the limits ($\pm 1.96/\sqrt{N}$), where N = the number of observations, then the residuals have white noise indicating that the models fit is appropriate [25,27]. The null hypothesis of this test was, there is no autocorrelation in residuals, and we were found that p-values shows insignificant of all the models, which has indicated that there is no autocorrelation. Therefore, we can be summarised that the residuals have not correlated with each other or in other words, it can be said that the residuals obtained from the models are independent from each other. The following Fig. 5(a), Fig. 5(b), and Fig. 5(c) represents the ACF of the residual, for models (2, 1, 2), (3, 1, 3), and (2, 1, 2) respectively.
- Here, the goodness of fit of the ARIMA (2, 1, 2), (3, 1, 3), and (2, 1, 2) models can be checked through correlogram of residuals. Normally, a flat correlogram with insignificant spikes was most ideal (represents in Fig. 5). Thereafter, we go out for forecasting the above models (Forecasting result given in Table 5).

Based on the estimation results of ARIMA (2, 1, 2), (3, 1, 3), and (2, 1, 2) models (Intercept and coefficients given in Table 3) respectively, and the functional form of the time series forecasting models may be presented as follows (Eq. 8, 9, and 10) according to given in Table 3:

- Model for Sorghum Cultivation Area (SCA)-
  $Y_t = -0.068 - 1.493Y_{t-1} - 0.964Y_{t-2} + 1.695u_{t-1} + 1.000u_{t-2} + u_t$

- Model for Sorghum Production (SP)-
  $Y_t = -0.1720 + 0.840Y_{t-1} - 0.187Y_{t-2} - 0.496Y_{t-3} - 2.924u_{t-1} + 2.924u_{t-2} - 0.999u_{t-3} + u_t$

- Model for Sorghum Yield (SY)-
  $Y_t = 6.8737 + 0.828Y_{t-1} - 0.446Y_{t-2} - 0.436u_{t-1} + 0.999u_{t-2} + u_t$

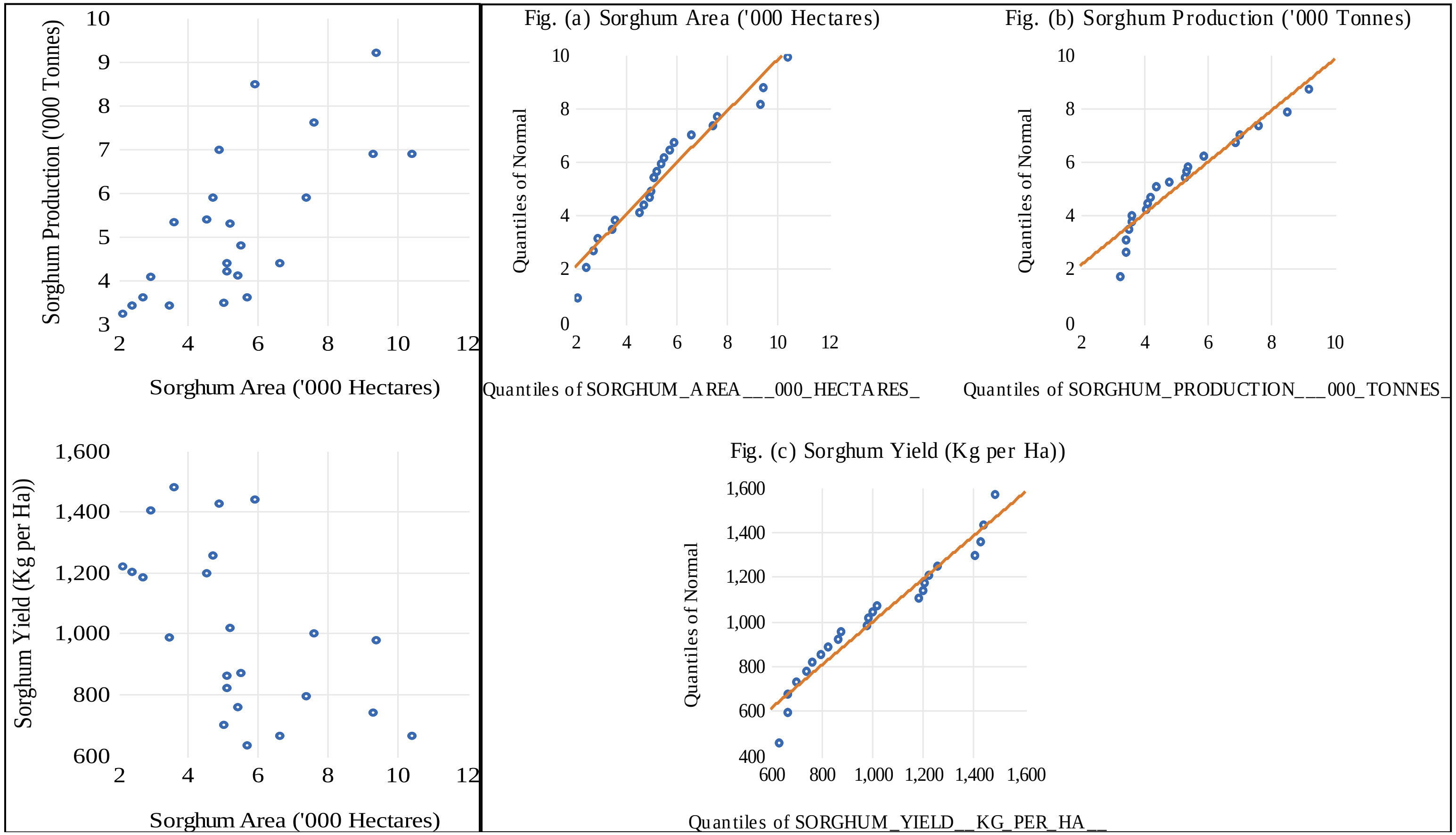

Fig. (a) **Fig. (b)**

Fig. 2. (a) Scatter plot and (b) Quantiles graphs of Sorghum Area, production and yield in Chhattisgarh

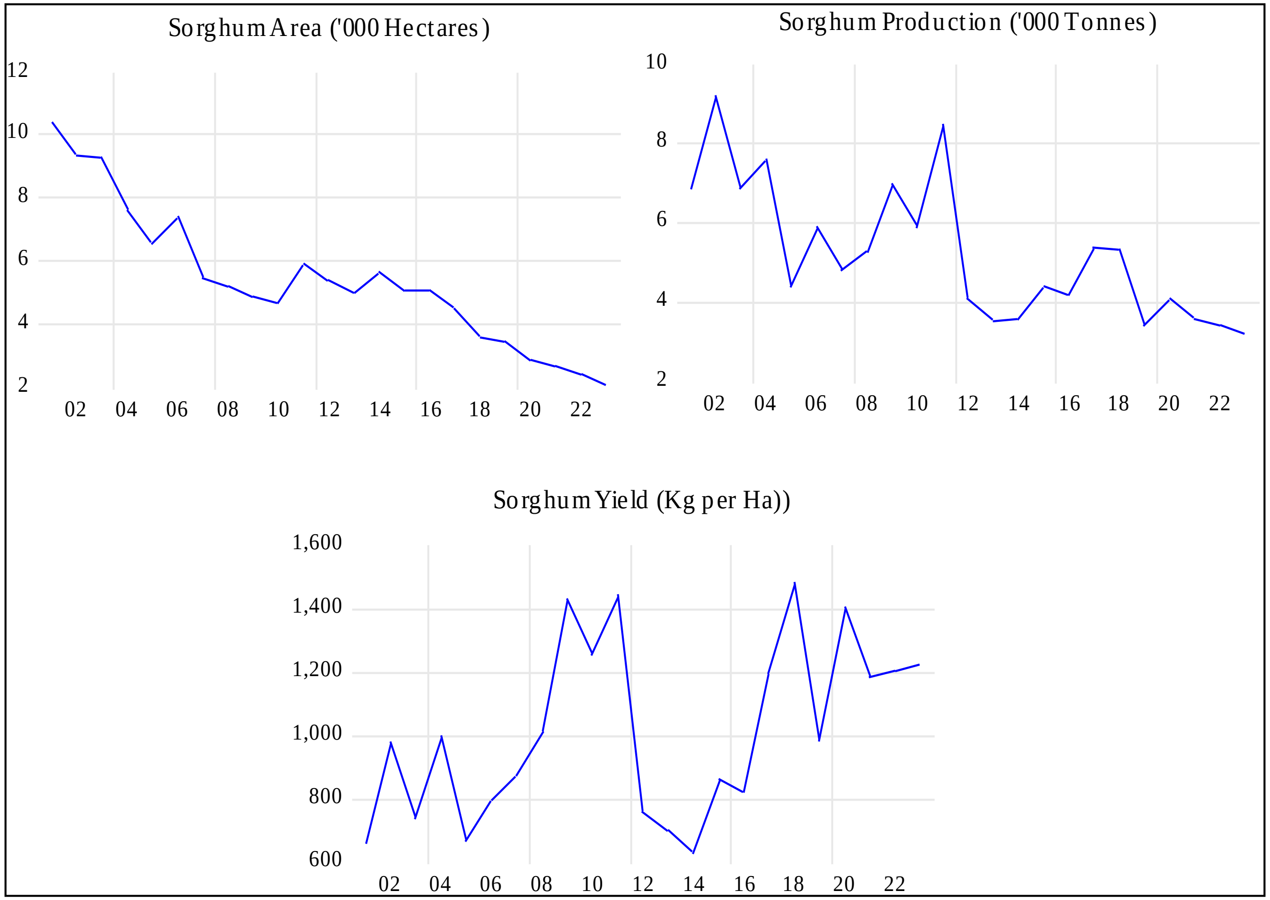
Sorghum Area ('000 Hectares)
12
10
8
6
4
2
02 04 06 08 10 12 14 16 18 20 22
Sorghum Production ('000 Tonnes)
10
8
6
4
2
02 04 06 08 10 12 14 16 18 20 22
Sorghum Yield (Kg per Ha))
1,600
1,400
1,200
1,000
800
600
02 04 06 08 10 12 14 16 18 20 22

Fig. (a)

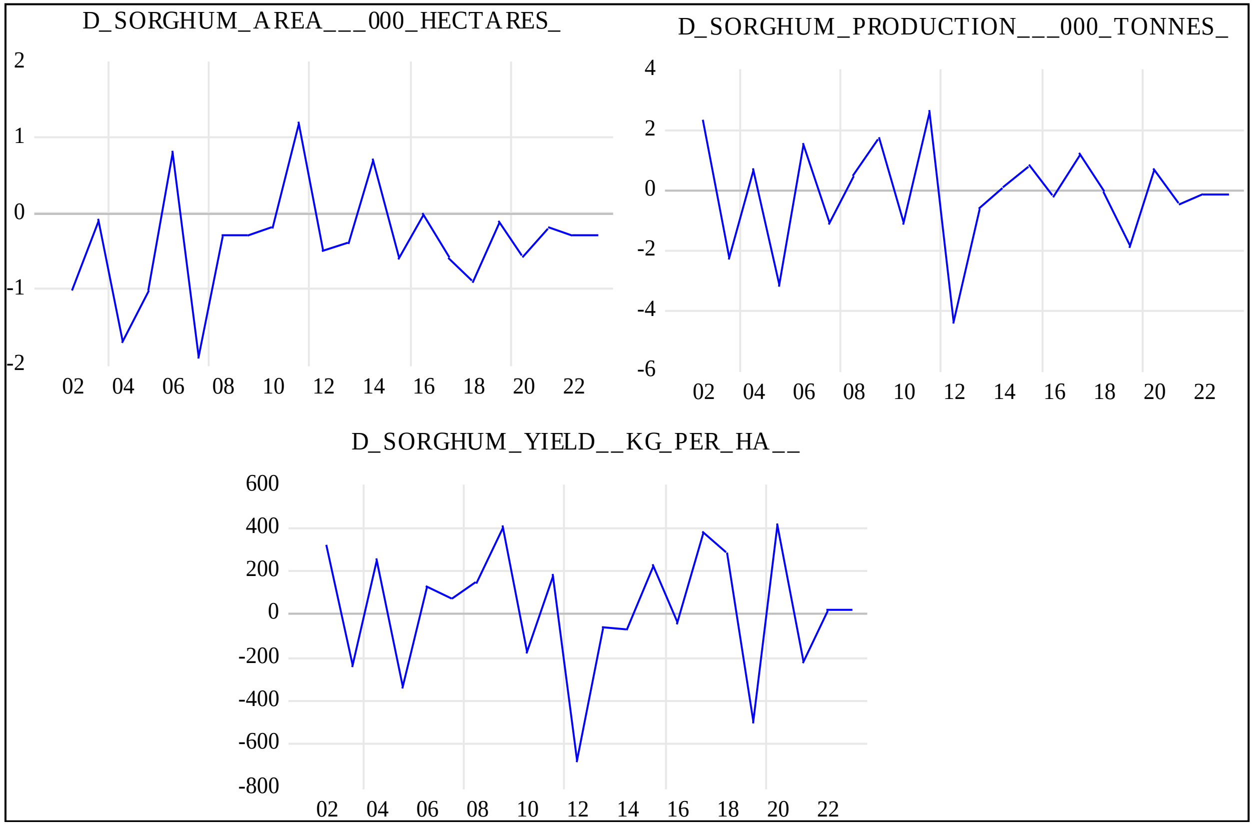

Fig. (b)

Fig. 3. Representation of time series plot of Original and Stationary series

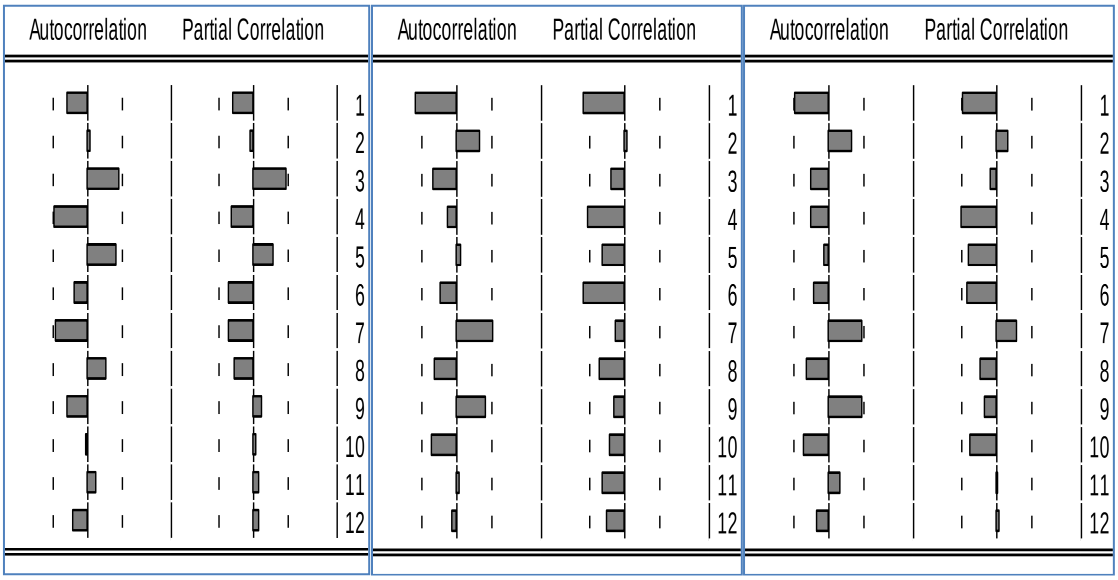

Fig. (a) **Fig. (b)** **Fig. (c)**

Fig. 4. ACF & PACF of time series for Sorghum (Jowar) area, production and yield (1st difference)

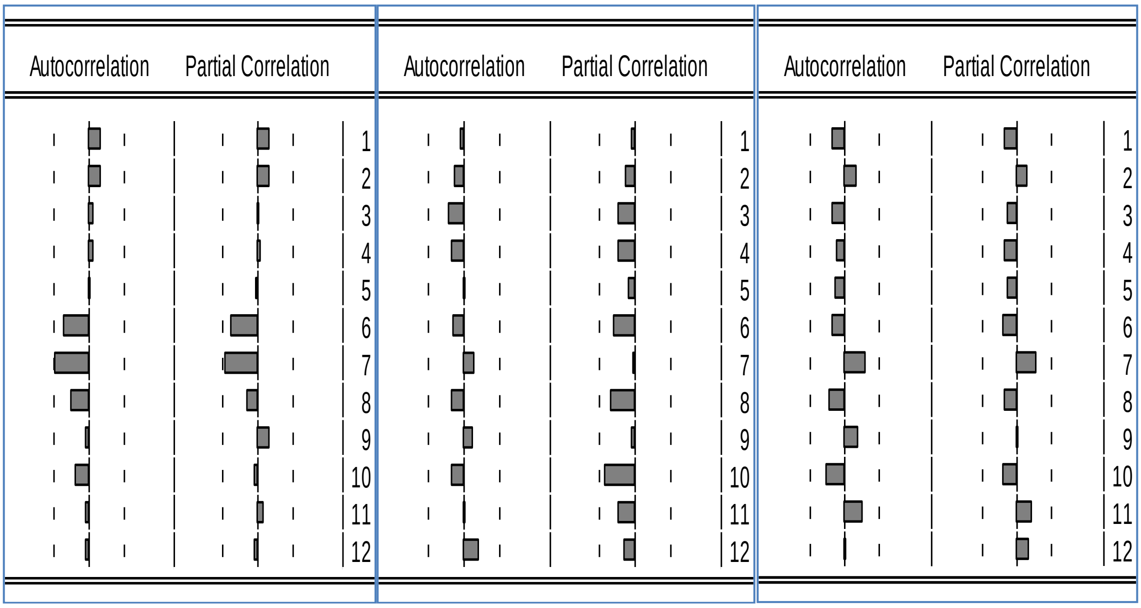

Fig. (a) **Fig. (b)** **Fig. (c)**

Fig. 5. ACF & PACF of Residuals for time series sorghum in Chhattisgarh

Table 1. Stationarity test of time series (ADF test) 1st difference

Augmented Dickey-Fuller test					
Variable		**t-Statistics**	**Prob.**	**Result**	**Difference**
Sorghum	**Area**	5.814	0.0006	Series Stationary	1st difference
	Production	8.122	0.0000	Series Stationary	1st difference
	Yield	6.787	0.0001	Series Stationary	1st difference

Source: Authors' calculation Using EView12

Table 2. Appropriate model selection for Sorghum Area, production and yield

Variables		ARIMA	σ^2	R^2	SER	AIC	BIC	MAPE	RMSE	MAE
Sorghum	(A)	(2, 1, 2)	0.0061	0.5465	0.0916	-1.708	-1.173	14.221	0.875	0.724
	(P)	(3, 1, 3)	0.3453	0.8763	0.7366	3.306	3.703	25.855	1.320	1.136
	(Y)	(2, 1, 2)	0.0303	0.5832	0.2025	0.072	0.368	24.473	286.10	247.33

Source: Authors' calculation Using EView12

Table 3. Estimation parameters of Sorghum area, production and yield (SAPY)

Variable		Parameter	Intercept	AR (1)	AR (2)	AR (3)	MA (1)	MA (2)	MA (3)	Log likelihood
Sorghum	(A)	**C**	**-0.068**	**-1.493**	**-0.964**	**-**	**1.695**	**1.000**	**-**	22.179
		Std. Error	0.022	0.080	0.100	-	3029.7	3574.2	-	
		Prob.	0.006	0.000	0.000	-	0.999	0.999	-	
		C	**-0.1720**	**0.840**	**-0.187**	**-0.496**	**-2.924**	**2.924**	**-0.999**	
	(P)	Std. Error	0.0069	0.495	0.508	0.323	52.465	58.543	38.412	-28.369
		Prob.	0.0000	0.111	0.718	0.146	0.956	0.961	0.979	
	(Y)	**C**	**6.8737**	**0.828**	**-0.446**	**-**	**-0.436**	**0.999**	**-**	5.167
		Std. Error	0.0909	0.307	0.256	-	632.03	2901.3	-	
		Prob.	0.0000	0.015	0.100	-	0.999	0.999	-	

Source: Authors' calculation Using EView12

Table 4. Results of the Ljung-Box test and JB test (Normality test)

Variable		Models	leg	Q- Stat.	P-value	Result (Ljung-Box)	Jarque-Bera (p-value)	Result (J-B test)
Sorghum	(A)	(2, 1, 2)	12	13.525	0.095	Insignificant	0.615	Accepted
	(P)	(3, 1, 3)	12	7.1537	0.307	Insignificant	0.613	Accepted
	(Y)	(2, 1, 2)	12	11.878	0.157	Insignificant	0.512	Accepted

Source: Authors' calculation Using EView12

4.3 Forecasting Result

This research study is based on annual amount of the sorghum cultivation area, production and yield, and covering the period of 2001 to 2030 (30 observations); of which 23 observations ranging from 2001 to 2023 were historical data and 7 observations ranging the period of 2024 to 2030 was forecasted amount of sorghum cultivation area (SCA), production, and yield. In Table 5 shows the forecasting results of ARIMA (2, 1, 2), (3, 1, 3), and (2, 1, 2) for sorghum produce area, production, and yield; and ARIMA (2, 1, 2), (3, 1, 3), and (2, 1, 2) models for SPA, SP and SY which was observed as the best suitable model for predicting the future amount of sorghum area, sorghum production, and sorghum yield respectively; and we have estimated that the yearly amount of SPA, SP and SY achieved in the year 2023-24 from 2.1593 (cultivation area 000' hectare), 2.1363 (production '000 Tonnes), and 1104.379 (yield kg/hectare) respectively to 1.3592 (cultivation area 000' hectare), 1.9874 (production '000 Tonnes), and 973.988 (yield kg/hectare) respectively in the year 2029-30 will decrease. The forecasting data series line of SPA, SP and SY continuous decreasing throughout the forecast period of 2023-24 to 2029-30 (given in Table 5). Hence, we have summarised that sorghum cultivation area shows the negative trend in the forecasting period. But marvellous, sorghum production, and yield has shown stochastic and increasing trend in the forecasting period (Fig. 7). Fig. 6 Representation of Residual, Actual and fitted graphs of sorghum and shows that no significant difference has found between Actual and fitted graphs of sorghum cultivation area and production. But a lot of difference has been found in the yield.

Table 5. Forecast value of Sorghum Area, production, and yield (with upper & lower limit)

Year	Area ('000 Hectare) Forecast Value	Area ('000 Hectare) Upper Limit	Area ('000 Hectare) Lower limit	Production ('000 Tonnes) Forecast Value	Production ('000 Tonnes) Upper limit	Production ('000 Tonnes) Lower limit	Yield (Kg/hectare) Forecast Value	Yield (Kg/hectare) Upper limit	Yield (Kg/hectare) Lower limit
2023-24	**2.1593**	2.6655	1.6532	**2.1363**	4.7337	-0.4611	**1104.379**	1566.083	642.676
2024-25	**1.8754**	2.4642	1.2866	**2.7415**	5.0411	0.4420	**1021.041**	1488.712	553.370
2025-26	**1.7781**	2.4237	1.1325	**2.8080**	5.1382	0.4778	**953.063**	1522.257	383.870
2026-27	**1.7421**	2.5704	0.9138	**3.1503**	5.8893	0.4113	**932.265**	1533.090	331.440
2027-28	**1.4935**	2.2294	0.7575	**2.9801**	5.7232	0.2369	**943.958**	1549.124	338.603
2028-29	**1.5141**	2.3732	0.6549	**2.5946**	5.0578	0.1314	**963.191**	1580.812	345.570
2029-30	**1.3592**	2.2250	0.4934	**1.9874**	4.4881	-0.5132	**973.988**	1599.701	348.277

Source: Authors' calculation Using EView 12

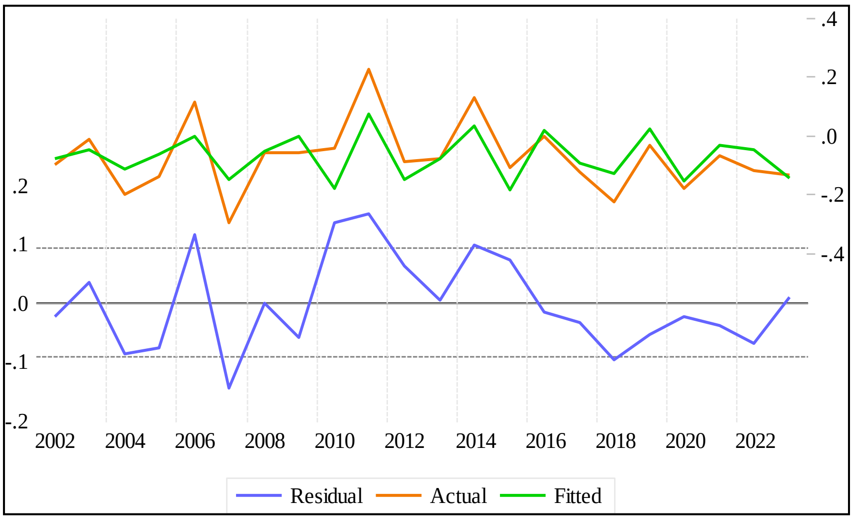

Fig. (a) Area

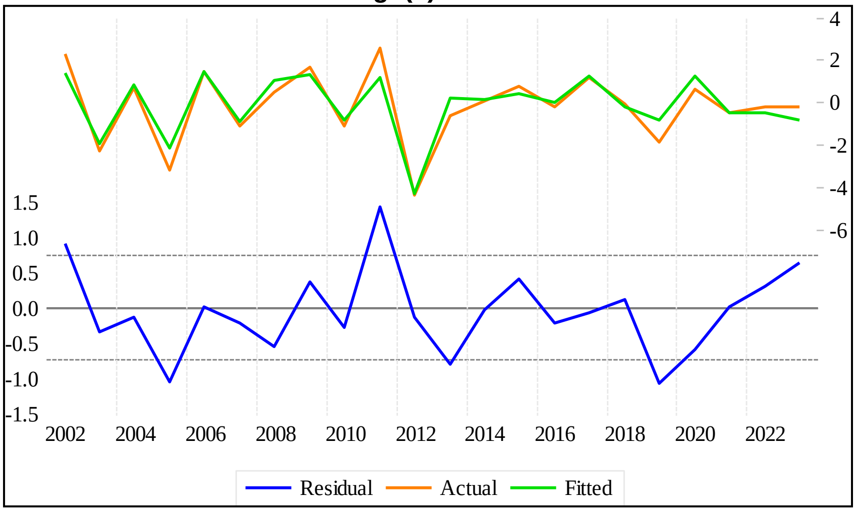

Fig. (b) Production

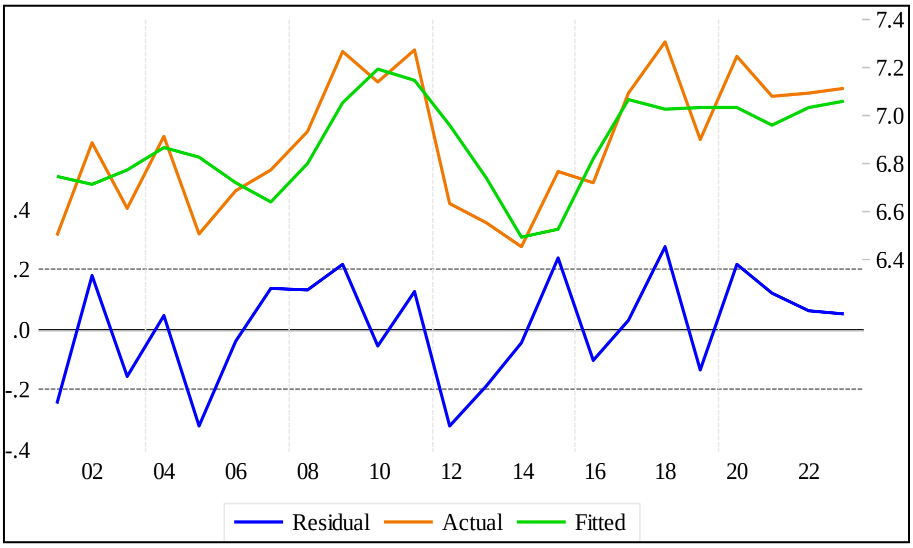

Fig. (c) Yield

Fig. 6. Representation of Residual, Actual and fitted graphs of sorghum

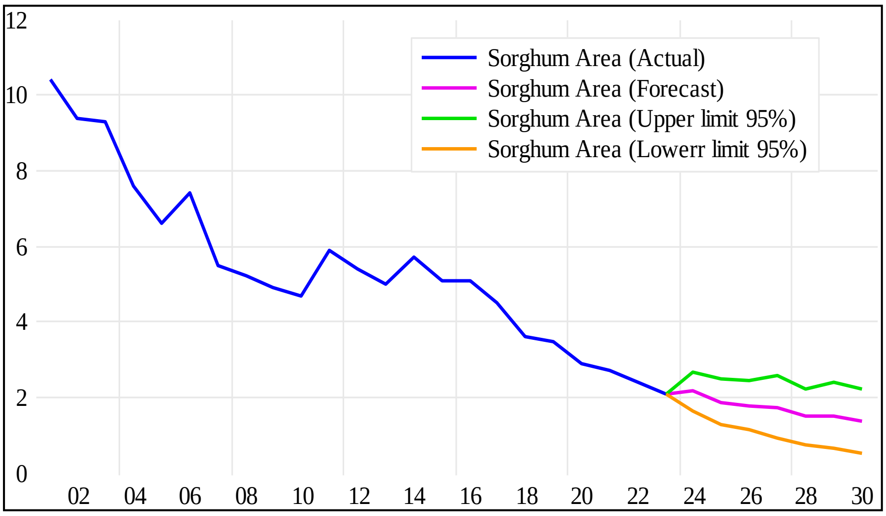

Fig. (a) Area

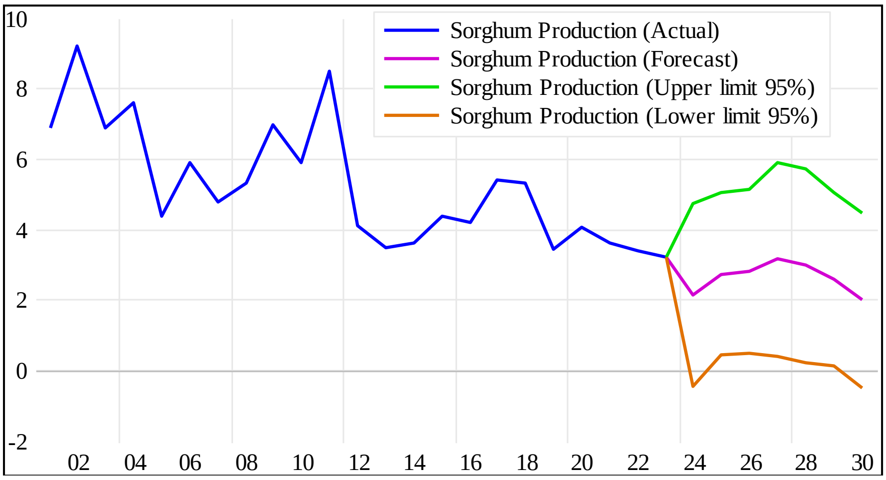

Fig. (b) Production

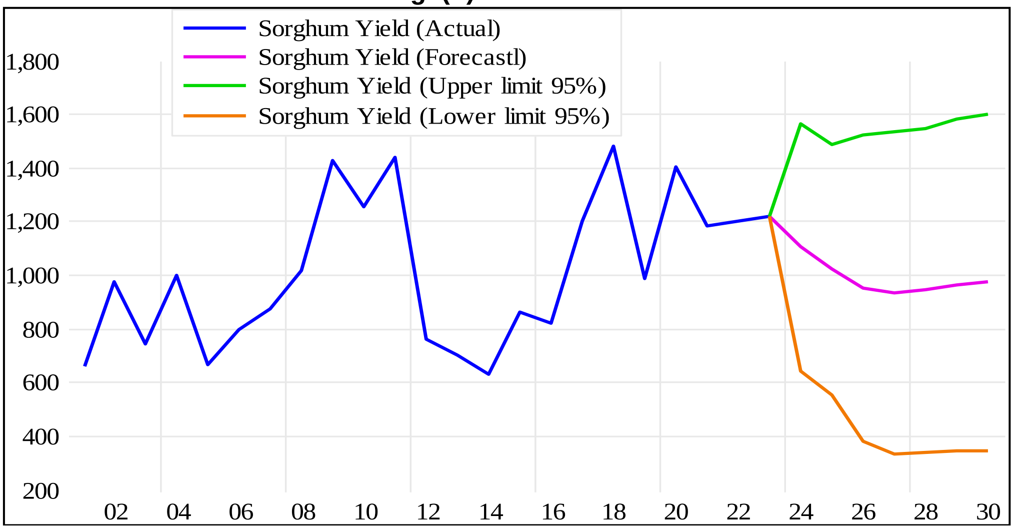

Fig. (c) Yield

Fig. 7. Forecast graphs of time series sorghum cultivation area, production and yield in Chhattisgarh

5. CONCLUSION

Agriculture is the most important livelihood strategies in India, with two thirds of the country workforce depend on farming. To increase millets production in Chhattisgarh, the state government launched the Millet Mission in September 2021.The mission has been started with a view to make Chhattisgarh the 'millet hub of India'. Forecasts of agricultural productions are useful to the farmers, policymakers and agribusiness industries. In this globalised world, there is a need for efficient and reliable production forecasting models to management of the food security in developing countries like India where agriculture is dominates. In this present study, ARIMA (2, 1, 2), (3, 1, 3), and (2, 1, 2) models for sorghum produce area, production, and yield which was observed as the best suitable model, for forecasting the future amount of sorghum cultivated area, production and yield in Chhattisgarh. Study result was found that the yearly amount of SPA, SP and SY achieved in the year 2023-24 from 2.1593 ('000 hectare), 2.1363 ('000 tonnes), and 1104.389(kg/hectare) respectively to which will decrease in the year 2029-30 respectively 1.3592 ('000 hectare), 1.9874 ('000 tonnes), and 973.988(kg/hectare). Finally, we have summarised that sorghum cultivation area shows the negative trend in the forecasting period. But marvellous, sorghum production, and yield has shown stochastic and increasing trend in the forecasting period.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

1. Used Grammarly for similarity checking.

DATA AVAILABILITY STATEMENT

The required data used in this paper are available at Indian Institute of Millet Research (IIMR) https://www.milletstats.com/apy-stats/ and Official website of Directorate of Economics and Statistics, DA & FW, Government of India, website: https://desagri.gov.in/statistics-type/normal-estimates/.

ACKNOWLEDGEMENT

Authors would like to gratitude Dr. Ravindra Brahme, Professor, School of Studies in Economics, Pt R.S.U. Raipur (C.G.) for their cooperation, supports and encourage during the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Krishna N, Bhute A, Sahai S, Dwivedi T, Ghosh M. Socio- economic impact of organic farming in reference to Chhattisgarh, India. Eur. Chem. Bull. 2023;12(5):659-668.
2. Rao Parthasarathy P, Birthal B. S, Reddy B. V. S, Rai K. N, Ramesh S. Diagnostics of sorghum and pearl millet grains-based nutrition in India. International Sorghum and Millets Newsletter. 2006 ;47:93–96.
3. Mishra JS, Kumar Rakesh, Ravikumar S, Kumar Ravikant, Prakash Ved, Rao KK, Bhatt BP. Production potential of improved grain sorghum cultivars (*Sorghum bicolor*) under staggered plantings in non-traditional areas of Eastern India. Indian Journal of Agronomy. 2017;62(1):74-80.
4. Pearl Millet News. ICAR- All India Coordinated Research Project on Pearl Millet; 2018.
   Available: www.aicpmip.res.in
5. Saravand MJ, Revappa MR, Relekar SP, Thakar KP. Forecasting of pearl millet production in North Gujarat by using ARIMA model, The Pharma Innovation Journal. 2022;SP-11(11):672-677.
6. Gooijer JGD, Hyndman RJ. 25 years of time series forecasting. International Journal of Forecasting. 2006;22(3):443–73.
7. Hyndman RJ, Ahmed RA, Athanasopoulos G, Shang HL. Optimal combination forecasts for hierarchical time series. Computational Statistics and Data Analysis. 2011;55(9):2 579–89.
8. Athanasopoulos G, Ahmed RA, Hyndman RJ. Hierarchical forecasts for Australian domestic tourism, International Journal of Forecasting. 2009;25(1):146–66.
9. Pal S, Paul RK. Modelling and forecasting sorghum (*Sorghum bicolor*) production in India using hierarchical time-series models. Indian Journal of Agricultural Sciences. 2016;86(6):803–808.
10. Indian Institute of Millet Research (IIMR).
    Available:https://www.milletstats.com/sorghum-jowar/

11. Directorate of Economics and Statistics, DA & FW, Government of India. Available: https://desagri.gov.in/statistics-type/normal-estimates/
12. Babu S, Tandon S, Pandey SN. Magic of Millets in Chhattisgarh: Status, Opportunity, Challenges, Indian Farming. December 2023;73(12):03-07.
13. Lama A, Singh KN, Shekhawat RS, Sarkar KP, Gurung B. Forecasting price index of finger millet (*Eleusine coracana*) in India under policy interventions, Indian Journal of Agricultural Sciences. May 2020;9 0(5):885–9.
14. Bellundagi V, Umesh KB, Ravi SC. Growth dynamics and forecasting of finger millet (Ragi) production in Karnataka, Economic Affairs. June 2016;61(2):195-201.
15. Vijay N, Mishra GC. Time series forecasting using ARIMA and ANN models for production of Pearl Millet (BAJRA) Crop of Karnataka, India, International Journal of Current Microbiology and Applied Sciences. 2018;7(12):880-889.
16. Tripathi S, Mishra P, Sahu PK. Past trends and forecasting in area, production and yield of Pearl Millet in India Using ARIMA Model, Environment & Ecology. October-December 2013;31(4):1701-1708.
17. Prabhu R, Gowri MU, Gayatri R, Govindaraj M, Manikandan G. Growth dynamics and forecasting of minor millets in India: A time series analysis, Journal of Applied and Natural Science. 2022;14(SI): 145-150.
Available:
https://doi.org/10.31018/jans.v14iSI.3600
18. Sathish MK, Lad YA, Mehera AB. Trend analysis of area, production and productivity of minor Millets in India, Biological Forum - An International Journal. 2022;14(2):14-18.
19. Sankar TJ, Pushpa P. Stochastic ARIMA model for *Pennisetum glaucum* production in India, Int. J. Agricult. Stat. Sci. 2023; 19:(1):373-379.
Available:https://doi.org/10.59467/IJASS.2023.19.373
20. Nireesha V, Rao VS, Rao DVS, Reddy DGR. A study on forecasting of area, production and productivity of pearl millet in Andhra Pradesh, J. Res. Angrau. 2016; 44(3&4):119-126.
21. Kour S, Pradhan UK, Paul RK, Vaishnav PR. Forecasting of Pearl millet productivity in Gujarat under time series framework, Economic Affairs. March 2017;62(1):121-127.
22. Das B, Satyapriya, Singh P, Sangeetha V, Bhowmik A, Poulami R. Growth and instability in area, production, productivity and consumption of Millets in India: An Analysis, Indian Journal of Extension Education. 2019;55(4):158-161.
23. Dharmaraja S, Jain V, Anjoy P, Chandra H. Empirical analysis for crop yield forecasting in India, Agric Res. 2020;9(1): 132–138.
Available: https://doi.org/10.1007/s40003-019-00413-x
24. Patra C, Mahapatra SK. Forecasting of Ragi production in Koraput Districts of Odisha, India, Int. J. Curr. Microbiol. App. Sci. 2020;9(7):1923-1929.
25. Chandra RP. Econometric modeling for high impact sustainable organic tea production: The Box-Jenkins Approach, Asian Journal of Economics, Business and Accounting. 2023;23(24):141–154.
DOI:https://doi.org/10.9734/ajeba/2023/v23i241193
26. Gandhi T, Saravanakumar V, Chandrakumar M, Divya K, Senthilnathan S. Forecasting pearl millet production and prices in Rajasthan, India: An ARIMA approach, International Journal of Statistics and Applied Mathematics. 2023;SP-8(5):307-314.
27. Chandra RP. Econometric modeling and forecasting of Arabica and robusta coffee production for sustainable agriculture development. Asian Journal of Economics, Business and Accounting. 2024;24(5):154–170.
DOI:https://doi.org/10.9734/ajeba/2024/v24i51300
28. Akaike H. A new look at the statistical model identification, IEEE Transactions on Automatic Control. 1974;19(6):716-723.
Available:https://doi.org/10.1109/TAC.1974.1100705
29. Priya SRK, Bajpai PK, Suresh KK. Stochastic models for sugarcane yield forecasting, Indian Journal of Sugarcane Technology. 2015;30(01):1-5.
30. Schwarz G. Estimating the Dimension of a Model, Ann. Statist. March 1978;6(2):461-464.
Available:https://doi.org/10.1214/aos/1176344136 First available in Project Euclid: 12 April 2007.

31. Lewis CD. Industrial and business forecasting methods, London: Butterworths. 1982;40.
32. Armstrong JS, Collopy F. Error measures for generalizing about forecasting methods: Empirical comparisons, International Journal of Forecasting. 1992;8:69-80.
33. Goodwin P, Lawton R. On the asymmetry of the symmetric MAPE, International Journal of Forecasting. 1999;15: 405-408.
34. Ren L, Glasure Y. Applicability of the revised mean absolute percentage errors (MAPE) approach to some popular normal and non-normal independent time series, International Advances in Economic Research. 2009;15:409-420.
35. Moreno JJM, Pol AP, Abad AS, Blasco BC. Using the R-MAPE index as a resistant measure of forecast accuracy, Psicothema. 2013;25(4):500-506. DOI:https://doi.org/10.7334/psicothema2013.23
36. Box GPE, Jenkins GM. Time Series Analysis: Forecasting and Control, Revised edition, Holden Day, San Francisco; 1978.
37. Draxler TC. Root Mean Square Error (RMSE) or Mean Absolute Error (MAE)? – Argument against avoiding RMSE in the Literature, Geoscientific Model Development. 2014;7(3):1247-1250.
38. Reddy CV. Modelling and Forecasting: NCDEX AGRIDEX, SCMS Journal of Indian Management. 2000;114-130.
39. Gujarati DN, Porter DC, Gunsekar S. Basic Econometrics, Revised edition, McGraw Hill Education, New Delhi; 2015.
40. Tofallis CA. Better measure of relative prediction accuracy for model selection and model estimation, Journal of Operations Research Society. 2015;66(8): 1352-1362.
41. Chandra RP, Brahme R. Econometric modelling and forecasting of groundnut Production and Productivity in India using ARIMA model, The Indian Economic Journal (Journal of the Indian economic association). 2023;Special issue- Dec.(7): 01-14.
42. Chandra RP, Brahme R, Patel SK. Stochastic models for Coffee Production and Productivity Forecasting in India, The Indian Economic Journal (Journal of the Indian economic association). 2023; Special issue- Dec.(7):158-171.
43. Ashoka N, Naik BK, Kulkarni VS. Behavior of arabica coffee prices in international and Indian markets, Green Farming. 2014;5(6): 1-5.
44. Hellin M. Gauss-Markow theorem in Statistics, Encyclopaedia of Environmetrics. January 15, John Wiley & Sons Ltd; 2013. DOI:https://doi.org/10.1002/9780470057339.vnn102
45. Dickey DA, Fuller WA. Distribution of the estimators for autoregressive time series with a unit root, Journal of the American Statistical Association, 74:366a, 427-431, Taylor & Francis Online Published. 1979; 2012.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122223