*Original Research Article*

# The Box-Jenkins approach: forecasting oforganic sorghumproductionin Chhattisgarh, India


## 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 was conducted on forecasting of sorghum crops in Chhattisgarh India using historical data on currently cultivated area, production and yield of sorghum crops. The time series data was collected from 2001 to 2023, and analysis of the studywas carried out using path analysis and Box JenkinsARIMA 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

## 1. Introduction

Agriculture is the most important livelihood strategies in India, with two thirds of the county's workforce depend 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 (Krishna *et al.*, 2023). Sorghum is the major staple food of millions of rural poor in arid and semi-arid regions of the world. It is the second cheapest source of energy and micronutrients after pearl millet, and majority of population in the central India depends on sorghum for their dietary and energy requirements (Rao *et al.*, 2006). Because of its drought adaptation capability, sorghum is a preferred crop in tropical, warmer and semi-arid regions of the world with high temperature and water-stress conditions. In India, the crop is grown in both rainy (June–October) and post-rainy (November–February) seasons. In spite of its multiple uses as food, feed, fodder and bio-fuel, the area under grain sorghum has drastically declined (Mishra et al., 2017). Sorghum is second larger millet crops, when compared with other crops in respect to the source of energy which is sorghum has pearl millet (361 Kcal/100 g), (349 Kcal/100 g), and maize with (325 Kcal/100 g). Sorghum has carbohydrate content of 67.5 g/100 g; with 56 to 65% starch content, 20 to 22% of amylase, 2.6-2.8% sucrose andfiber (1.2 g/100 g). It is a good source of vitamin and minerals (Pearl Millet News, 2018; Saravand et al., 2022).

Time series forecasting is an important statistical analysis technique used as a basis for manual and automatic planning in many application domains (Gooijer and Hyndman, 2006). Forecasts are calculated using mathematical models that capture a parameterized relationship between past and future values to express behaviour and characteristics of a historic time series. The parameters of these forecast models are estimated on a training data set to fit the specifics of the time series by minimizing the forecast error. Timeseries data collected in many situations are hierarchical in structure. These datasets generally contain information in clusters which can be combined into another series of interest. Here, the time series are aggregated along the hierarchy based on dimensional attributes such as location (Hyndman *et al.*, 2011; Athanasopoulos *et al.* 2009).

India shares around 20% of the world's sorghum area and is the fourth largest producer of this cereal crop. The cultivation area of sorghum in India was more than 16 million ha in 1981, but has gradually decreased to 6.3 million ha in 2012. Production of this cereal has also faced a decline from 12 million tonnes to 6 million tonnes during this period. But marvellous, yield of sorghum, on the contrary, has climbed up from 7.3 tonnes/ha to only 9.5 tonnes/ha in the same tenure (Pal and Paul, 2016).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 (IIMR, 2023; DES, 2023).

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. Butit's mostly cultivated area inSurguja division- Balarampur, Koriya, Surajpur, Jashpur and Sarguja (Ambikapur) district, Bastar division-Sukma, Bijapur, Bastar (Jagdalpur), Kanker, Kondagaon and Narayanpurdistrict, Raipur division-Gariyaband, Dhamtari and Mahasamunddistrict, Durg division- Rajnadgaonv,Kabirdham, Balodand 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 (Babu et al., 2023). 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. (Saravand et al., 2022) was conducted Pearl millet crop in Gujarat and India with the use of historical data on an area, production and yield of Pearl millet crop. The data was collected for 20 years from the year 1999-2000 to 2018-2019, and analysis was carried out using 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.(Lama et al., 2020) was studies of price index of Ragi and used structural break analysis. The volatile ragi price index series were modelled and forecasted used of GARCH model and its asymmetric extensions. The results indicated improvement in modelling and forecasting performance of the models after incorporation of the policy interventions.(Bellundagi et al., 2016) conducted research on ragi production in Karnataka, and different linear and nonlinear growth models were explored. The forecasting results showed that, even though there was a deceleration in area, the production of ragi was increasing due to increase in productivity in the future time. (Vijay and Mishra, 2018) Studies was pearl millet production in Karnataka, and used ARIMA and ANN models, and ARIMA (0, 1, 1) model was selected for forecasting of the future value from 2011 to 2014. Thus, following researchers was conducted research onmillet production, i.e. (Tripathi el al., 2013) was research on pearl millet production and productivity, (Prabhu et al., 2022) was conducted research on forecasting minor millet in India, (Sathish el al., 2022) was studies on trend analysis of minor millet in India, (Sankar and Pushpa, 2023) was studies on forecasting of millets production in India. (Nireesha et al., 2016) was conducted research on pearl millet production in Andhra Pradesh, India, and also some of the investigated works were i.e., Kour et al., 2017; Das et al., 2019; Dharamraja et al., 2019; Patra and Mahapatra, 2020; Chandra, 2023; Gandhi et al., 2023; and Chandra, 2024.

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; andno study has been found regarding sorghum production in Chhattisgarh.Thus, it's a gap and motivated us to undertake 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 2001to2023for the research study, time series data was compiledof 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 select the best fitted ARIMA model, several statistical tools are being applied, viz., AIC (Akaike, 1974; Priya et al., 2015; Chandra, 2023; Chandra, 2024), BIC/SIC (Schwarz, 1978), MAPE (Lewis, 1982; Armstrong and Collopy, 1992; Goodwin and Lawton, 1999;Ren and Glasure, 2009;Moreno et al., 2013),Ljung-Box test (Box and Jenkins; 1978; Saravand et al., 2022),RMSE(Draxler, 2014),and MAE(Reddy, 2000; Gujarati et al. 2015; Tofallis, 2015; Chandra and Brahme,2023; Chandra et al. 2023), and thus, the formulation of the models are given bellow:

AIC written as follow:

*AIC*= {n (1+ log 2□) + n log $\sigma^2$ + 2m} …...…. (1)

AIC = (-2log L + 2m); where: m= p + q, L = Likelihood function and -2log L = approximately equal to {n (1+ log 2□) + n log $\sigma^2$}, where: $\sigma^2$ = 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.

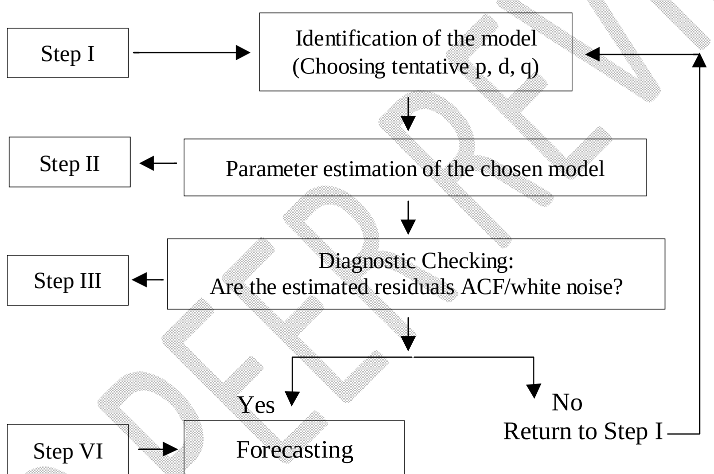
### 3.3. The Box-Jenkins Approach

**Step I-** In the first step of the study, the time series data selected for the study was collected from a reliable source, 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 at the first difference. After the series has stationary, the correlogram has seen, with the help of which the model has selected

(Gujarati et al. 2015; Chandra et al. 2023; Chandra, 2023, Chandra, 2024). Figure 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 (Gujarati et al. 2015; Chandra, 2023, Chandra, 2024).

**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 (Gujarati et al. 2015; Chandra et al. 2023; Ashoka et al., 2014; Chandra, 2023, Chandra, 2024).




**Source:** (Gujarati et al., 2015; Chandra, 2023; Chandra, 2024)

**Figure 1** shows the Box-Jenkins methodology consist of following four steps.

**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 (Hellin, 2013). 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 (Gujarati et al.,2015; Chandra et al. 2023; Chandra, 2023; Chandra, 2024).

### 3.4. Equation for ARIMA Models

ARIMA is a linear regression model for time series predicting, and it uses its own lags as predictors. Any 'non-seasonal' time series that exhibits patterns and is not a random white noise can be modelled with ARIMA models. An ARIMA model is characterised by 3 terms: *p*, *d*, *q* (Box and Jenkins, 1978; Gujarati et al. 2015; Chandra, 2023; Chandra and Brahme, 2023; Chandra et al. 2023; Chandra, 2024).

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 (Chandra et al. 2023; Chandra, 2024):

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

Where: $\theta$ = constant, $\alpha$ = coefficient of AR terms, $\beta$ = coefficient of MA terms, $u$ = white noise error terms

### 3.5. Model Identification for Sorghum cultivationarea, production and yield

In generally, a non-stationary series is made stationary after differencing '*d times*', and is said to be integrated of order '*d*', denoted by *I (d)*. If, the original series is stationary *d=0*,and then the ARIMA model transform into an ARMA model. The time series data used for the present study, i.e., SA, SP, and SY. The series SA, SP, and SYwere become stationary after the 1st order differencing. Since, there is no need for further differencing the series, and it is necessary to adopt *d=1* (first difference) for ARIMA (*p, d, q*) model. We have checked the correlogram after first difference, and the level in time series (given figure 5). Since, there was no significant spikes of ACF and PACF residuals of the selected ARIMA and ARMA models, to get the appropriate numbers for '*p*' (in AR) and '*q*' (in MA) in the models, and thereafter we were checked white noise in the correlogram after first difference in time series (given figure5). Since, there was no significant spikes of ACF and PACF residuals of the selected ARIMA and ARMA models, and therefore there was no need for further consideration of any more 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 provides the estimation results of different parameters of AR(*p*) and MA(*q*) of ARIMA model for area, production and yield. Using these values, the best-fit ARIMA (*p, d, q*), models for predicting time series DSA, DSP and DSY were identified. Therefore, the prediction equations for the models can be written as follows. The equations for SCA(8), SP(9), and SY(10) respectively(Chandra, 2023, Chandra, 2024).

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

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

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

## 4. Result Analysis

### 4.1. Stationary test (ADF test)

The results of Argument Dickey-Fuller (Dickey-Fuller, 1979) unit root test at level and 1st order difference given in table 1. Before differencingthe time series SCA, SP and SY we performed thestationary test at the level,butthe p-valuesat the level were insignificant. Therefore, seriesSA,SP and SYwere 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 wasrespectively = 5.814, 8.122 and 6.787 and p-value were respectively = 0.0006, 0.0000, and 0.0001which was smaller than critical values at 1%, 5% and 10% level of significance. Hence, we fail to accept the null hypothesis for unit root. It means that the series DSCA, DSP and DSYwas not containing the unit root, and thus it is stationary. Figure 4 part (a), part (b), and part (c) represent the plot of correlogram (ACF and PACF) of the stationary series DSCA, DSP and DSY for lags 1 to 12 at the 1st order difference.Figure 2(a) Scatter plot and (b) Quantiles graphs of Sorghum Area, production and yield in Chhattisgarh. Figure 3Representation of time series plot of (a) Original and (b) Stationary series.

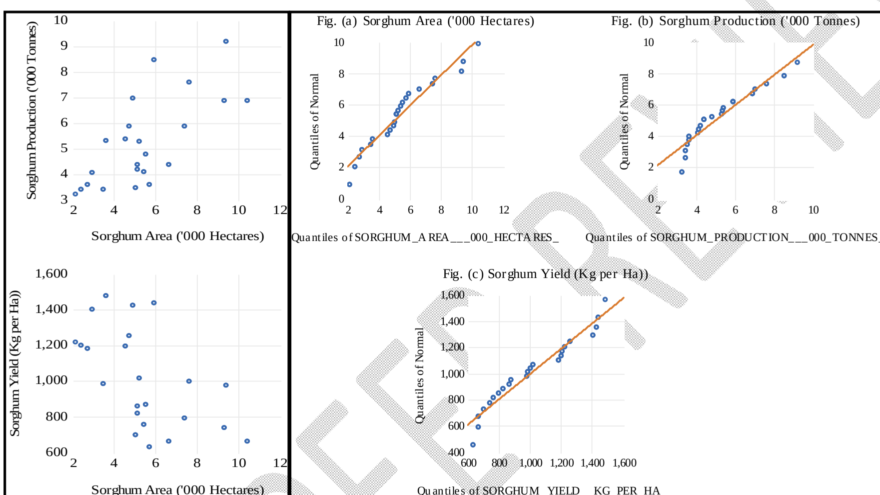



Fig. (a) Fig. (b)

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

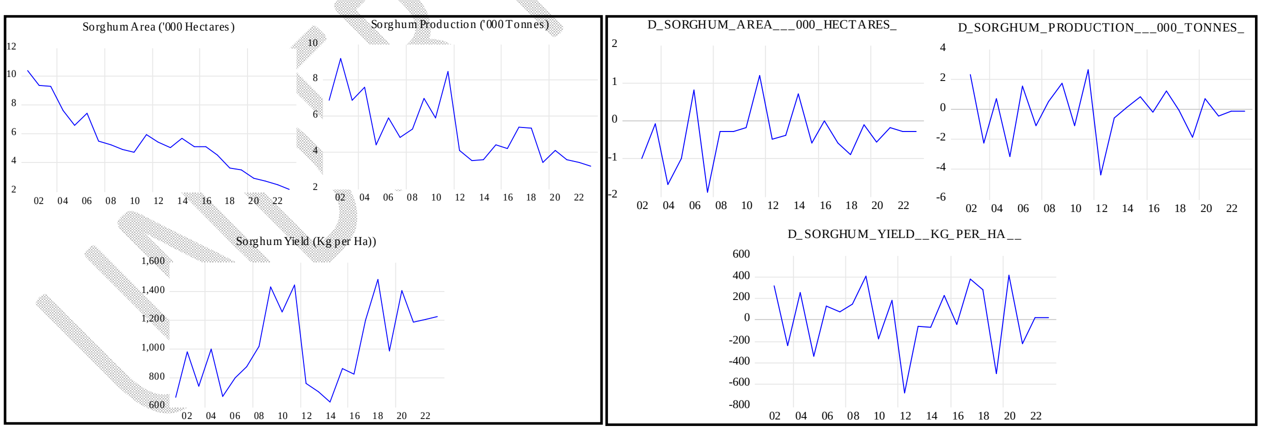



Fig. (a) Fig. (b)

**Figure 3** Representation of time series plot of Original and Stationary series

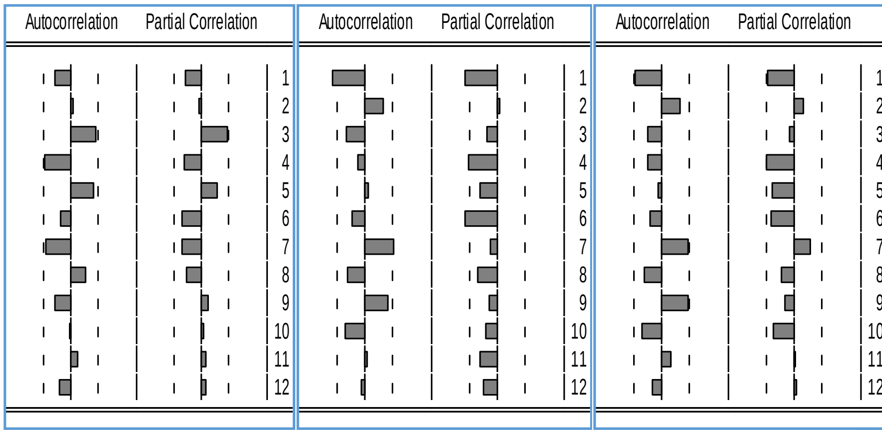



Fig. (a) Fig. (b) Fig. (c)

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

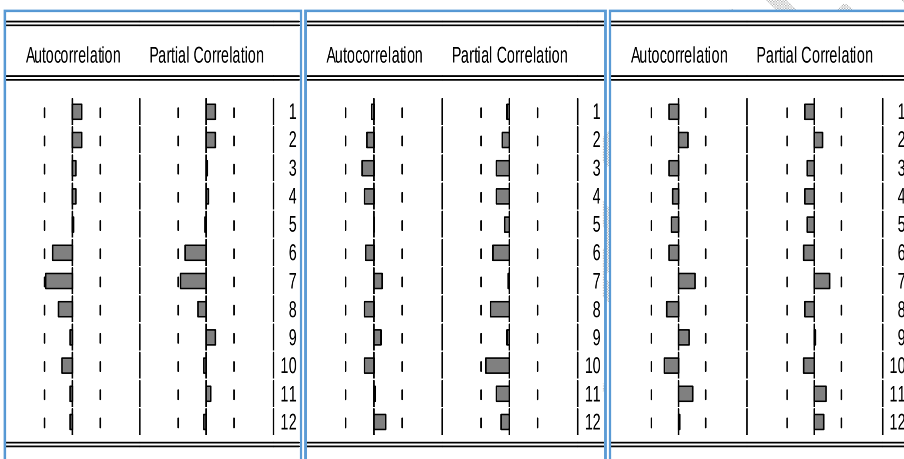



Fig. (a) Fig. (b) Fig. (c)

**Figure 5** ACF & PACF of Residuals for time series sorghum in Chhattisgarh

### 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 criterionshave 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 ($\sigma^2$ 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 (Chandra, 2023; Chandra, 2024). 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 figure 5(a), figure 5(b), and figure5(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 figure 5). Thereafter, we go out for forecasting the above models (Forecasting result given in table 5).

**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** | **$\sigma^2$** | **$R^2$** | **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** |
|---|---|---|---|---|---|---|---|---|---|---|
| **hum** | (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 | - | |
| | (P) | **C** | **-0.1720** | **0.840** | **-0.187** | **-0.496** | **-2.924** | **2.924** | **-0.999** | -28.369 |
| | | Std. Error | 0.0069 | 0.495 | 0.508 | 0.323 | 52.465 | 58.543 | 38.412 | |
| | | 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

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)-

  $Y_t = -0.1720 + 0.840Y_{t-1} - 0.187Y_{t-2} - 0.496Y_{t-3} - 2.924u_{t-1} + 2.924u_{t-2} - 0.999u_{t-3} + u_t$

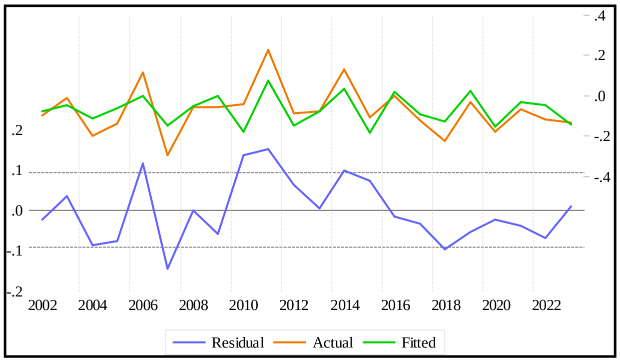
- Model for Sorghum Yield (SY)-

  $Y_t = 6.8737 + 0.828Y_{t-1} - 0.446Y_{t-2} - 0.436u_{t-1} + 0.999u_{t-2} + u_t$

### 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 2030was forecasted amount of sorghum cultivationarea (SCA), production, and yield. In table 5shows 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 yieldrespectively; and we have estimated that the yearly amount of SPA, SP and SY achieved in the year 2023-24 from 2.1593 (cultivationarea 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 (figure 7).Figure 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.



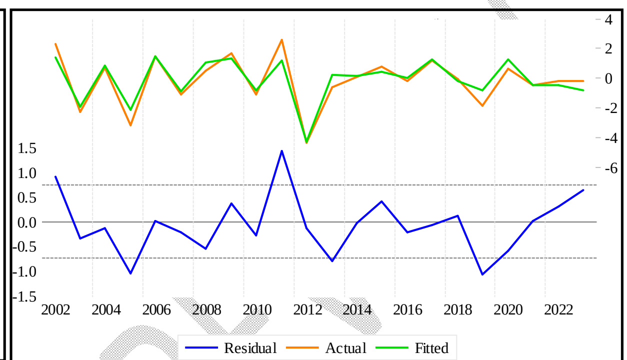




Fig. (a) AreaFig. (b) Production

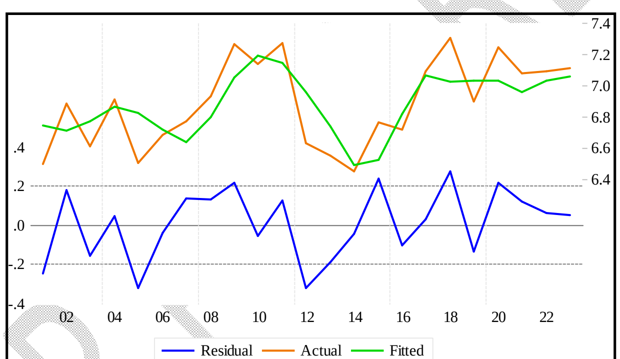



Fig.(c) Yield

**Figure 6** Representation of Residual, Actual and fitted graphs of sorghum

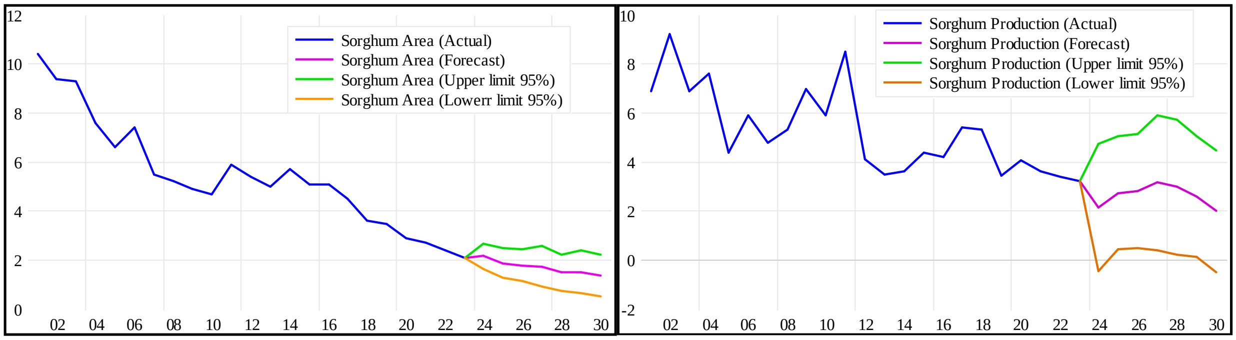



Fig. (a) AreaFig. (b) Production

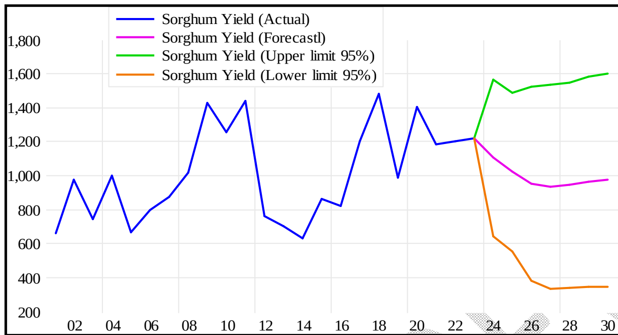



Fig. (c) Yield

**Figure 7** Forecast graphs of time series sorghum cultivation area, production and yield in Chhattisgarh

**Table 5 Forecast Value of Sorghum Area, Production, 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

## 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 wasfound 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 respectively1.3592 (‘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.Butmarvellous, sorghum production, and yield has shown stochastic and increasing trend in the forecasting period.

**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/.

**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

## References


1. Akaike H. (1974). A New look at the Statistical model Identification, *IEEE Transactions on Automatic Control*, 19(6): 716-723. https://doi.org/10.1109/TAC.1974.1100705
2. Armstrong J. S., and Collopy F. (1992). Error measures for generalizing about forecasting methods: Empirical comparisons, *International Journal of Forecasting*, 8: 69-80.
3. Ashoka N., Naik B. K., and Kulkarni V. S. (2014). Behavior of arabica coffee prices in international and Indian markets, *Green Farming*, 2014; 5 (6): 1-5.
4. Athanasopoulos G., Ahmed R. A. and Hyndman R. J. (2009). Hierarchical forecasts for Australian domestic tourism, *International Journal of Forecasting*, 25(1): 146–66.
5. Babu S., Tandon S. and Pandey S. N. (2023). Magic of Millets in Chhattisgarh: Status, Opportunity, and Challenges, *Indian Farming*, 73(12): 03-07; December.
6. Bellundagi V., Umesh K. B. and Ravi S. C., (2016). Growth dynamics and forecasting of finger millet (Ragi) production in Karnataka, *Economic Affairs*, 61(2): 195-201 June.
7. Box G. P. E., and Jenkins G. M. *Time Series Analysis: Forecasting and Control*, Revised edition, Holden Day, San Francisco. 1978.
8. Chandra R. P., (2023). Econometric Modeling for High Impact Sustainable Organic Tea Production: The Box-Jenkins Approach, *Asian Journal of Economics, Business and Accounting*. 23(24): 141–154. DOI:https://doi.org/10.9734/ajeba/2023/v23i241193
9. Chandra R. P., and Brahme R., (2023). Econometric modelling and forecasting of groundnut Production and Productivity in India using ARIMA model, *The Indian Economic Journal* (*Journal of the Indian economic association*). Special issue- Dec. (7): 01-14.
10. Chandra R. P., Brahme R., and Patel S. K., (2023). Stochastic models for Coffee Production and Productivity Forecasting in India, *The Indian Economic Journal* (*Journal of the Indian economic association*). Special issue- Dec. (7): 158-171.
11. Chandra, R. P. (2024). Econometric Modeling and Forecasting of Arabica and Robusta Coffee Production for Sustainable Agriculture Development. *Asian Journal of Economics, Business and Accounting*, 24(5), 154–170. DOI: https://doi.org/10.9734/ajeba/2024/v24i51300

12. Das B., Satyapriya, Singh P., Sangeetha V., Bhowmik A. and Poulami R. (2019). Growth and Instability in Area, Production, Productivity and Consumption of Millets in India: An Analysis, *Indian Journal of Extension Education*, 55(4): 158-161.

13. Dharmaraja S., Jain V., Anjoy P., and Chandra H. (2020). Empirical Analysis for Crop Yield Forecasting in India, *Agric Res.* 9(1): 132–138. https://doi.org/10.1007/s40003-019-00413-x

14. Dickey D. A., and Fuller W. A. (1979). 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*, 2012. DOI: https

15. Directorate of Economics and Statistics, DA&FW, Government of India, website:https://desagri.gov.in/statistics-type/normal-estimates/

16. Draxler T. C. (2014). Root Mean Square Error (RMSE) or Mean Absolute Error (MAE)? – Argument against avoiding RMSE in the Literature, Geoscientific Model Development. 7(3): 1247-1250.

17. Gandhi T., Saravanakumar V., Chandrakumar M., Divya K. and Senthilnathan S., (2023). Forecasting pearl millet production and prices in Rajasthan, India: An ARIMA approach, *International Journal of Statistics and Applied Mathematics, SP*-8(5): 307-314.

18. Goodwin P., and Lawton R. (1999). On the asymmetry of the symmetric MAPE, *International Journal of Forecasting*, 15: 405-408.

19. Gooijer J. G. D., and Hyndman R. J. (2006). 25 years of time series forecasting. *International Journal of Forecasting* 22(3): 443–73.

20. Gujarati D. N., Porter D. C., and Gunsekar S. *Basic Econometrics*, Revised edition, McGraw Hill Education, New Delhi. 2015.

21. Hellin M., (2013). Gauss-Markow theorem in Statistics, Encyclopaedia of Environmetrics. January 15, John Wiley & Sons Ltd. DOI: https://doi.org/10.1002/9780470057339.vnn102

22. Hyndman R. J., Ahmed R. A., Athanasopoulos G. and Shang H. L., (2011). Optimal combination forecasts for hierarchical time series. *Computational Statistics and Data Analysis,* 55(9): 2 579–89.

23. Indian Institute of Millet Research (IIMR), website: https://www.milletstats.com/sorghum-jowar/

24. Kour S., Pradhan U. K., Paul R. K. and Vaishnav P. R., (2017). Forecasting of Pearl millet productivity in Gujarat under time series framework, *Economic Affairs,* 62(1), pp. 121-127, March.

25. Krishna N., Bhute A., Sahai S., Dwivedi T. and Ghosh M., (2023). Socio- economic impact of organic farming in reference to Chhattisgarh, India. *Eur. Chem. Bull.* 12(5), 659-668.

26. Lama A., Singh K. N., Shekhawat R. S., Sarkar K. P. and Gurung B., (2020). Forecasting price index of finger millet (Eleusine coracana) in India under policy interventions, *Indian Journal of Agricultural Sciences*, 90(5): 885–9, May.

27. Lewis C. D. Industrial and business forecasting methods, London: Butterworths, p. 40. 1982.
28. Mishra JS., Kumar Rakesh, Ravikumar S, Kumar Ravikant, Prakash Ved, Rao KK and Bhatt BP (2017). Production potential of improved grain sorghum cultivars (Sorghum bicolor) under staggered plantings in non-traditional areas of Eastern India. *Indian Journal of Agronomy*, 62 (1): 74-80.
29. Moreno J. J. M., Pol A. P., Abad A. S., and Blasco B. C. (2013). Using the R-MAPE index as a resistant measure of forecast accuracy, *Psicothema*, 25(4): 500-506. DOI: https://doi.org/10.7334/psicothema2013.23
30. Nireesha V., Rao V. S., Rao D.V.S. and Reddy D. G. R. (2016). A study on forecasting of area, production and productivity of pearl millet in Andhra Pradesh, *J. Res. Angrau*, 44:(3&4), 119-126.
31. Pal S. and Paul R. K. (2016). Modelling and forecasting sorghum (Sorghum bicolor) production in India using hierarchical time-series models. *Indian Journal of Agricultural Sciences* 86 (6): 803–808.
32. Patra C. and Mahapatra S. K. (2020). Forecasting of Ragi Production in Koraput Districts of Odisha, India, *Int. J. Curr. Microbiol. App. Sci.* 9(7): 1923-1929.
33. Pearl Millet News. ICAR- All India Coordinated Research Project on Pearl Millet; 2018. www.aicpmip.res.in
34. Prabhu R., Gowri MU, Gayatri R, Govindaraj M, Manikandan G., (2022). Growth dynamics and forecasting of minor millets in India: A time series analysis, *Journal of Applied and Natural Science*, 14 (SI), 145 - 150. https://doi.org/10.31018/jans.v14iSI.3600
35. Priya S. R. K., Bajpai P. K., and Suresh K. K. (2015). Stochastic models for sugarcane yield forecasting, *Indian Journal of Sugarcane Technology*, 30(01): 1-5.
36. Rao Parthasarathy P., Birthal B. S., Reddy B. V. S., Rai K. N. and Ramesh S., (2006). Diagnostics of sorghum and pearl millet grains-based nutrition in India. *International Sorghum and Millets Newsletter* 47: 93–96.
37. Reddy C. V. (2000). Modelling and Forecasting: NCDEX AGRIDEX, *SCMS Journal of Indian Management*, 114-130.
38. Ren L., and Glasure Y. (2009). 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*, 15:409-420.
39. Sankar T. J. and Pushpa P., (2023). Stochastic ARIMA Model for Pennisetum glaucum Production in India, *Int. J. Agricult. Stat. Sci.* 19:(1), pp. 373-379. https://doi.org/10.59467/IJASS.2023.19.373
40. Saravand M. J., Revappa M. R., Relekar S. P. and Thakar K. P. (2022). Forecasting of pearl millet production in North Gujarat by using ARIMA model, *The Pharma Innovation Journal*, *SP*-11(11): 672-677.

41. Sathish M. K., Lad Y. A., and Mehera A. B., (2022). Trend Analysis of Area, Production and Productivity of Minor Millets in India, *Biological Forum - An International Journal,* 14(2): 14-18.

42. Schwarz G. (1978). Estimating the Dimension of a Model, *Ann. Statist.* 6 (2) 461 - 464, March, 1978. https://doi.org/10.1214/aos/1176344136, First available in Project Euclid: 12 April 2007.

43. Tofallis C. A. (2015). Better Measure of Relative Prediction Accuracy for Model Selection and Model Estimation, *Journal of Operations Research Society*. 66(8): 1352-1362.

44. Tripathi S., Mishra P., and Sahu P. K., (2013). Past Trends and Forecasting in Area, Production and Yield of Pearl Millet in India Using ARIMA Model, *Environment & Ecology* 31(4): 1701-1708, October-December.

45. Vijay N. and Mishra G. C., (2018). 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*, 7(12): 880-889.