Time Series Modeling and Forecasting of Finger Millet Cultivation Area, Production and Productivity in Chhattisgarh, India: The Box Jenkins Methodology

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Authors' contributions

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

Original Research Article

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 present study was conducted on time series modelling

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and forecasting of finger millet crops in Chhattisgarh India using Box Jenkins methodology and used historical data on currently cultivated area, production and yield of finger millet crops. The time series data was collected from 2001 to 2023, and analysis of the study was carried out using path analysis and Box Jenkins ARIMA model; and among various 20 models the best and suitable ARIMA (0, 1, 2), (3, 1, 1) and (2, 0, 4) model was selected based on AIC, BIC, MAPE, RMSE, MAE. With the help of the selected appropriate model, the cultivation area, production and yield of finger millet cultivation in Chhattisgarh was forecasted for the year 2024 to 2030. But marvellous, diminishing and fluctuating trend was observed in finger millet cultivation area and production over the forecast period. Whereas increasing and stochastic trend was observed in finger millet yield over the forecast period.

Keywords: Finger millet; forecasting; ARIMA; AIC; ACF; MAPE.

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

ABBREVIATION

ACF	*: Autocorrelation Function*
AIC	*: Akaike Information Criterion*
ANN	*: Artificial Natural Network*
AR	*: Autoregressive*
ARIMA	*: Autoregressive Integrated Moving Average*
ARMA	*: Autoregressive Moving Average*
BIC/SIC	*: Bayesian Information Criterion/ Schwarz Information Criterion*
FMCA	*: Finger Millet Cultivation Area*
FMCAPY	*: Finger Millet Cultivation Area, production and yield*
FMP	*: Finger Millet Production*
FMY	*: Finger Millet Yield*
GARCH	*: Generalised Autoregressive Conditional Heteroscedastic*
IIMR	*: Indian Institute of Millet Research*
JB	*: Jarque:Bera*
MA	*: Moving Average*
MAE	*: Mean Absolute Error*
MAPE	*: Mean Absolute Percentage Error*
PACF	*: Partial Autocorrelation Function*
RMSE	*: Root Mean Square Error*
SER	*: Standard Error of Regression*

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 [1]. Finger millet (Ragi) is the major staple food of millions of rural poor in arid and semi-arid regions of the world. Finger millet is an important cereal crop in Chhattisgarh, it is the richest source of calcium, iron, and protein which makes it more important for health. It's considered jointly of the foremost nutritious cereals. Finger millet could be a millet crop and their current use is restricted relative to their economic potential [2,3,4,5]. Time series forecasting is an important statistical analysis

technique used as a basis for manual and automatic planning in many application domains [6]. 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. 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 [7,8].

In year 2000-01 finger millets cultivation area, production and yield in Chhattisgarh was respectively 11.20 ('000 hectare), 2.60 ('000

tonnes) and 232.14 (per/hectare). Whereas in year 2019-20 finger millet cultivation area, production in Chhattisgarh respectively 5.25 ('000 hectare), 2.87 ('000 tonnes) and 241.23 (per/hectare) has been increases but cultivation area was continuing decrease into the last ten decades. In this present study researcher's focus on forecasting of the finger millet cultivation area, production and yield (FMCAPY) in Chhattisgarh State. Finger millet is cultivated in almost all the areas of Chhattisgarh state. But it's mostly cultivated area in Surguja division- Surajpur and Jashpur district, Bastar division- Sukma, Bijapur, Bastar (Jagdalpur), Kanker, Kondagaon and Narayanpur district, Raipur division- Gariyaband and Dhamtari district, and in Durg division- Rajnadgaonv and Balod district of the state. There is immense potential for increase in the production of finger millet (ragi) 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 [9]. 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

[3] 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 [10]. researchers' studies was 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 [11]. conducted was 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. [12] Studies was pearl millet production in Karnataka, and used ARIMA and ANN models, and ARIMA (0, 1, 1) mode selected for forecasted of the future value from 2011 to 2014. Thus, following researchers were conducted research on millet production, i.e. [13] was research on pearl millet production and productivity, [14] conducted was research on forecasting minor millet in India, [15] was studies on trend analysis of minor millet in India, [16] was studies on forecasting of millets production in India. [17] was conducted research on pearl millet production in Andhra Pradesh, India, and also some of the investigated works were i.e., [18,19,20,21,22,23,24] 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 finger millet, pearl millet production, millet (Ragi) prices, minor millet production, tea production, groundnut production and coffee production, and moreover study related to Karnataka, Gujarat, Odisha, Andhra Pradesh and India. Hence there is no study available of finger millet production related to Chhattisgarh. Thus, it is a gap, and motivated us to undertake study on time series modeling and forecasting of finger millet in Chhattisgarh, India.

3. METHODS AND METHODOLOGY

3.1 Data Collection

We were 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) [25] 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/ [26].

3.2 Econometric Methods

To select the best fitted ARIMA model, several statistical tools are being applied [27,24], viz. AIC [28], BIC/SIC [29], Ljung-Box test [30], MAPE [31], RMSE [32] and MAE [33,34,35,36,37,38,39]. Thus, the formulation of the models is given bellow:

AIC written as follow:

$$AIC = \{n (1+ \log 2\pi) + n \log \sigma^2 + 2m\} \ \ldots\ldots (1)$$

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.

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

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,

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

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

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

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

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

3.3 Equation for ARIMA Model

ARIMA is a linear regression model for time series predicting, and its uses 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 [30,40,41,27,23,24]. An ARIMA model is characterised by 3 terms: *p, d, q*.

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 an ARMA model [23,24]. Thus, *Y* follows an ARMA (3, 4) process, therefore it can be written as:

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

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

3.4 Model Identification

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., FMCA, FMP, and FMY. The series FMCA and FMP were 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. Series FMY were become stationary at level. Since, there is no need for further differencing the series, and it is necessary to adopt *d=0* (at level) for ARIMA (*p, d, q*) model. We were checked the correlogram after first difference order and the level in time series (given Fig. 2). 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 Fig. 2). Since, there was no significant spikes of ACF and PACF residuals of the selected ARIMA and ARMA models, and thus 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 (0, 1, 2), (3, 1, 1) and (2, 0, 4) have been considered to be the best predictive models that have been used to forecast future values of time series, such as DFMCA, DFMP and FMY. Table 2 shows that the best-fitting ARIMA model with parameters has selected, and Table 3 shows the estimation results of different parameters of AR (*p*) and MA (*q*) of ARIMA model for finger millet cultivation area, production and yield (FMCAPY). Using these values, the best-fit ARIMA (*p, d, q*) models for predicting time series DFMCA, DFMP and FMY were identified. Therefore, the prediction equations for the models can be written as follows.

Equations for FMCA (Eq. 8), FMP (Eq. 9), and FMY (Eq. 10) respectively.

$Y_t = \theta + \beta_1 u_{t-1} + \beta_2 u_{t-2} + u_t$ …..………… (8)

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

$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \beta_2 u_{t-3} + \beta_3 u_{t-4} + u_t$ …………………… (10)
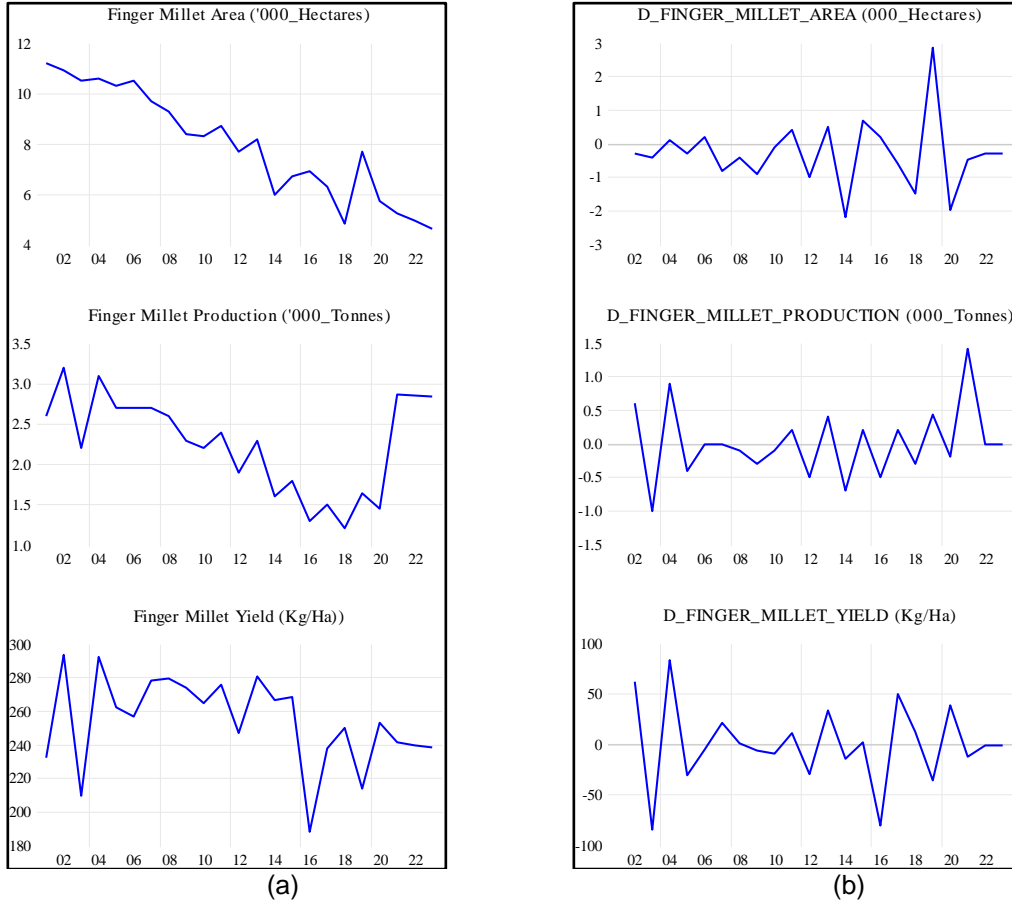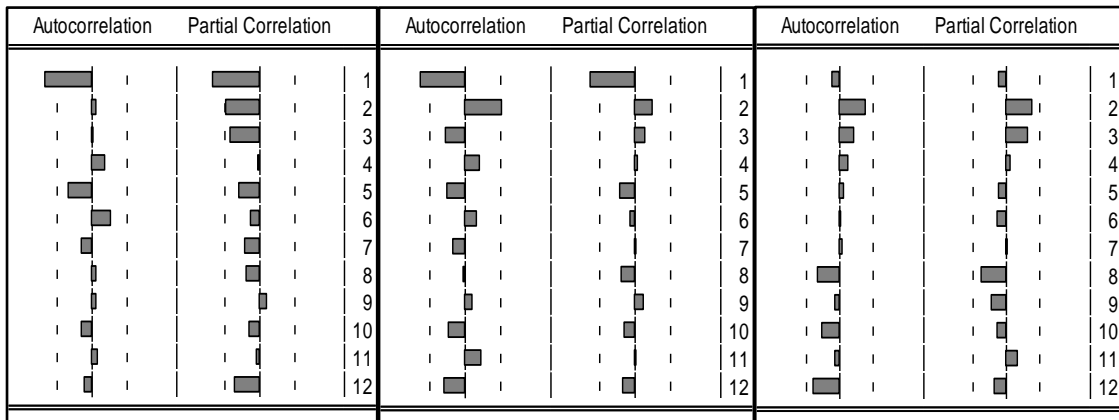

Fig. 1. Represent of (a) Original Series and (b) Zero Mean Series of the Finger Millet

(a) Finger millet cultivation area   (b) Finger millet production   (c) Finger millet yield*

Fig. 2. Correlogram of the Finger Millet (at 1 order difference and level*)

4. RESULT ANALYSIS

4.1 Stationarity test (ADF)

The results of Argument Dickey-Fuller [42] unit root test at 1st order difference and level given in Table 1. The time series FMCA and FMP at level p-value were insignificant. Thus, series FMCA and FMP was statically not significant, so it is not stationary. After that we go through 1st order difference, and 1st order difference series DFMA and DFMP calculated t–statistics value was respectively = - 4.477 and - 9.295 and p-value are respectively = 0.0111 and 0.0000 which was smaller than critical values at 1%, 5% and 10% levels of significance. Hence, we fail to accept the null hypothesis for unit root. It means the series FMCA and FMP was not containing the unit root and thus it was stationary. But time series FMY was statically significant at the level and calculated t-statistics value was - 6.277 and p-value 0.0002 which was smaller than critical values at 1%, 5% and 10% levels of significance, and thus it was stationary. Fig. 2 part (a), part (b), and part (c) represent the plot of correlogram (ACF and PACF) of the stationary series FMCA, FMP and FMY for lags 1 to 12 at the 1st order difference and level; and Fig. 2 shows not containing the unit root. So, it is stationary.

Table 2 shows calculation result of appropriately selected models and parameter value for finger millet cultivation area, production and yield, and Table 3 presented the calculation result of estimated parameters of AR and MA terms. Based on the estimation results of ARIMA (0, 1, 2), (3, 1, 1), and (2, 0, 4) 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 Finger Millet Cultivation Area (FMCA)-
  $Y_t = 0.0044 - 1.9764u_{t-1} + 0.9999u_{t-2} + u_t$
- Model for Finger Millet Production (FMP)-
  $Y_t = 2.2951 + 1.1518Y_{t-1} + 0.3645Y_{t-2} - 0.6568Y_{t-3} - 0.9999u_{t-1} + u_t$
- Model for Finger Millet Yield (FMY)-
  $Y_t = 254.75 + 1.915Y_{t-1} - 0.999Y_{t-2} - 2.981u_{t-1} + 3.089u_{t-2} - 1.165u_{t-3} - 0.057u_{t-4} + u_t$

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. But 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 in 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 in Table 2). The Ljung-Box test result for finger millet cultivation area (FMCA), finger millet production (FMP) and finger millet yield (FMY) respectively ARIMA (0, 1, 2) and (3, 1, 1), and (2, 0, 4) has shown insignificant at 1%, 5% and 10% level of significance (given in Table 4). The JB test result for FMCA, FMP, and FMY has shown the selected time series model followed the normality test (given in 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. 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 (Fig. 3 a, b & c). Therefore, we can be summarised that the residuals are 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. 3(a), Fig. 3(b), and Fig. 3(c) represents the ACF & PACF of the residual for models (0, 1, 2), (3, 1, 1), and (2, 0, 4) respectively. Here, the goodness of fit of the ARIMA (0, 1, 2), (3, 1, 1) and (2, 0, 4) models can be checked through correlogram of residuals. Normally, a flat correlogram with insignificant spikes was most ideal (given in Fig. 3). So, we were going out for forecasting the above models (forecasting results given in Table 5).

4.3 Forecasting Results of the Finger Millet

This research study is based on annual amount of the finger millet cultivation area, production and productivity, and covering the period of 2001 to 2030 (30 observations); of which 23 observations ranging from 2001 to 2023 were historical data and 12 observations ranging the period of 2024 to 2030 was forecasted amount of finger millet cultivation area, production and yield. In Table 5 exhibits the forecasting results of ARIMA (0, 1, 2), (3, 1, 1) and (2, 0, 4) for finger millet cultivation area, production and yield. ARIMA (0, 1, 2), (3, 1, 1) and (2, 0, 4) models for FMCA, FMP and FMY which was observed as the best suitable model for predicting the future amount of finger millet cultivation area, finger millet production and

finger millet yield respectively; and we were estimated that the yearly amount of FMCA, FMP and FMY achieved in the year 2023-24 from 5.4109 (cultivation area '000 hectare), 3.1182 (production '000 tonnes) and 256.842 (yield kg/hectare) respectively to 4.2827 (cultivation area '000 hectare) and 2.5233 (production '000 tonnes) respectively in the year 2029-30 will decrease. But 275.793 (yield kg/hectare) will continuously increase. Thus, the forecasting data series line of FMCA and FMP continuous decreasing throughout the forecast period of 2023-24 to 2029-30, but series FMY will continuously increasing in same period (given in Table 5). Hence, we summarise that finger millet cultivation area, production amount will decrease in the future, but finger millet yield volume will stochastically increase in the future (Fig. 5).

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

Augmented Dickey-Fuller Test					
Variable		**t-Statistics**	**Prob.**	**Difference**	**Result**
FM	Area	- 4.477	0.0111	1st difference	Series Stationarity
	Production	- 9.295	0.0000	1st difference	Series Stationarity
	Yield	- 6.277	0.0002	Level	Series Stationarity

Source: Authors calculation using EViews 12

Table 2. Appropriate model selection for finger millet cultivation area, production and yield

Variables		ARIMA	σ^2	Adj. R^2	SER	AIC	BIC	MAPE	RMSE	MAE
FM	(A)	(0, 1, 2)	0.434	0.845	0.733	2.795	2.994	9.976	0.7817	0.627
	(P)	(3, 1, 1)	0.108	0.593	0.382	1.332	1.628	32.250	0.6627	0.581
	(Y)	(2, 0, 4)	213.39	0.542	18.08	9.498	9.893	8.432	24.899	20.265

Source: Authors calculation using EViews 12
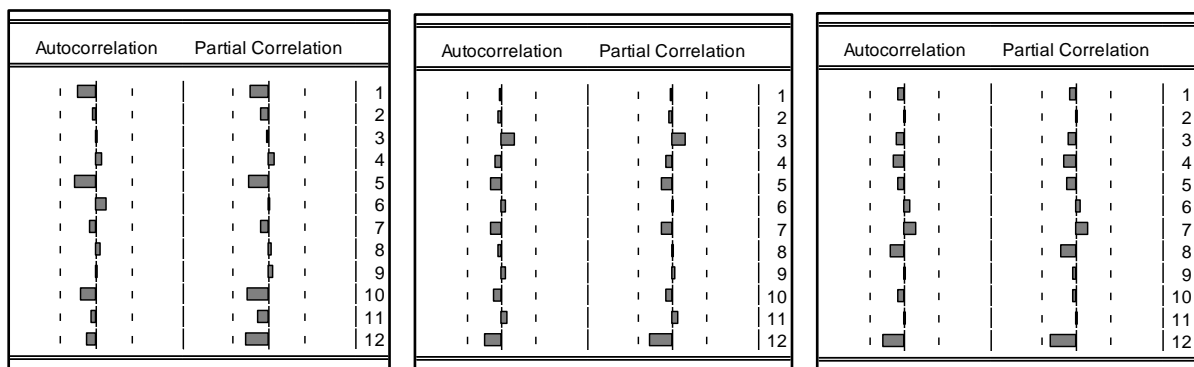
(a) Finger Millet Cultivation Area (b) Finger Millet Production (c) Finger Millet Yield

Fig. 3. Representation of Correlogram (Autocorrelation test- ACF & PACF)

**Table 3. Estimation parameters of finger millet cultivation area, production and yield**

Variable			Parameter	Intercept	AR (1)	AR (2)	AR (3)	MA (1)	MA (2)	MA (3)	MA (4)	Log Like
Finger Millet	Area (A)		**C**	**0.0044**	**-**	**-**	**-**	**-1.9764**	**0.9999**	**-**	**-**	-25.357
			Std. Error	0.0131	-	-	-	3957.58	4004.49	-	-	
			Prob.	0.7426	-	-	-	0.9996	0.9998	-	-	
	Production (P)		**C**	**2.2951**	**1.1518**	**0.3645**	**-0.6568**	**-0.9999**	**-**	**-**	**-**	-9.326
			Std. Error	0.1454	0.1872	0.2586	0.1718	44688.5	-	-	-	
			Prob.	0.0000	0.0000	0.1767	0.0014	1.0000	-	-	-	
	Yield (Y)		**C**	**254.75**	**1.915**	**-0.999**	**-**	**-2.981**	**3.089**	**-1.165**	**-0.057**	-101.23
			Std. Error	2.467	0.019	0.002	-	1.118	1.348	1.060	0.328	
			Prob.	0.0000	0.0000	0.0000	-	0.017	0.036	0.289	0.865	

Source: Authors calculation using EViews 12

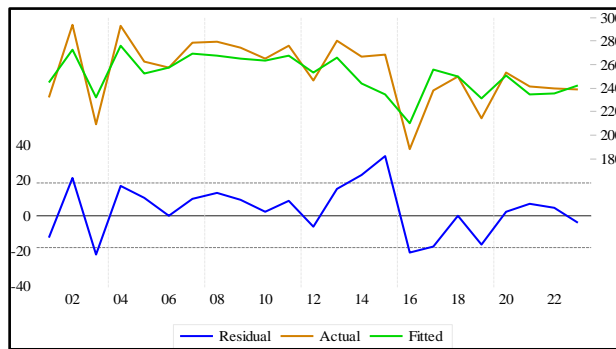**Table 4. Results of the Ljung-Box test (Q-stat.) and JB test (Normality test)**

| Variable		Models	leg	Q- Stat.	p-value	Results (Q- Stat.)	Jarque-Bera (p-value)
FM	(A)	(0, 1, 2)	12	6.3450	0.785	Insignificant	0.002
	(P)	(3, 1, 1)	12	5.0251	0.755	Insignificant	0.484
	(Y)	(2, 0, 4)	12	6.7780	0.342	Insignificant	0.876

Source: Authors calculation using EViews 12
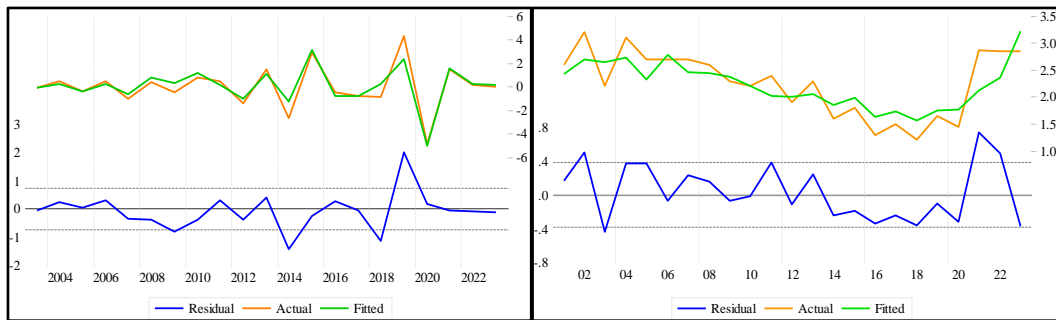
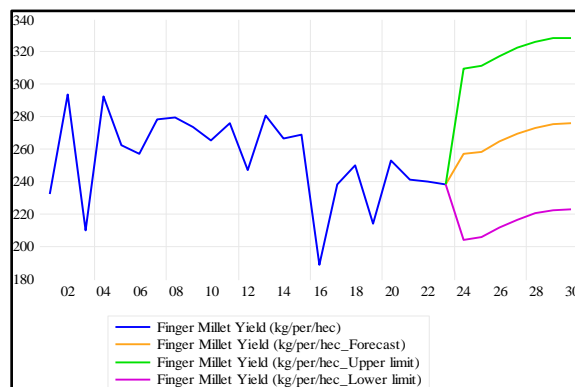(a) Finger Millet Area

(b) Finger Millet Production

(c) Finger Millet Productivity

Fig. 4. Representation of Residual, Actual and Fitted graphs
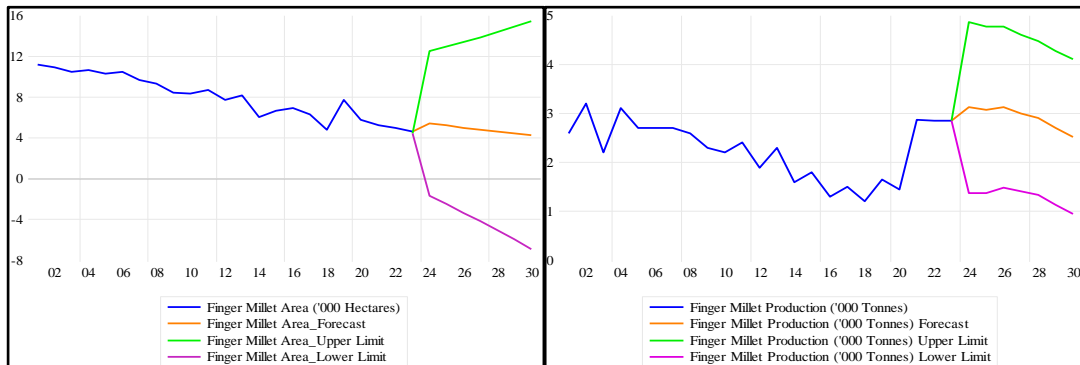
(a) Finger Millet Area

(b) Finger Millet Production

(c) Finger Millet Productivity;

Fig. 5. Representation of Forecast graphs of Finger Millet

Table 5. Forecast Value of Finger Millet Cultivation Area, Production, Yield (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/ha) Upper limit	Yield (Kg/ha) Lower limit
2023-24	**5.4109**	12.5097	- 1.6878	**3.1182**	4.8592	1.3772	**256.842**	309.740	203.943
2024-25	**5.2119**	12.9185	- 2.4946	**3.0752**	4.7690	1.3815	**258.442**	311.342	205.542
2025-26	**5.0173**	13.3593	- 3.3247	**3.1326**	4.7735	1.4916	**264.470**	317.370	211.569
2026-27	**4.8271**	13.8321	- 4.1779	**3.0035**	4.5989	1.4081	**269.451**	322.352	216.550
2027-28	**4.6412**	14.3366	- 5.0540	**2.9039**	4.4717	1.3361	**273.188**	326.089	220.286
2028-29	**4.4598**	14.8727	- 5.9530	**2.7045**	4.2678	1.1413	**275.363**	328.265	222.462
2029-30	**4.2827**	15.4403	- 6.8747	**2.5233**	4.1020	0.9447	**275.793**	328.695	222.892

Source: Authors calculation using EViews 12

5. CONCLUSION

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 [24]. Forecasts of agricultural productions are useful to the farmers, policymakers and agribusiness industries. In the present study ARIMA (0, 1, 2), (3, 1, 1) and (2, 0, 4) models for figure millet cultivation area, production and yield which was observed as the best suitable model, for predicting the future amount of figure millet cultivated area, production and yield in Chhattisgarh. Results of the study found that the yearly amount of FMCA and FMP achieved in the year 2023-24 respectively 5.4109 ('000 hectare) and 3.1182 ('000 tonnes) to which will decrease in the year 2029-30 respectively 4.2827 ('000 hectare), 2.5233 ('000 tonnes), and but FMY 256.842 (kg/hectare) to 275.793 (kg/hectare) which will increase in the year 2029-30. Finally, we can say that finger millet cultivation area and production show the decreasing and fluctuating trend in the forecasting period. But marvellous, finger millet yield has shown stochastic and increasing trend in the forecasting period. With the help of this model, to increase the production area of Ragi, production of Ragi, and the benefit to the farmers; the public investment in the agriculture sector can be encouraged, crop insurance, providing agricultural loan to farmers at low interest rates, use of agriculture mechanization and technology in modern times, and improving the quality of seeds and improving the size of the holdings as well as using suitable organic fertilizers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Used Grammarly for similarity checking.

DATA AVAILABILITY STATEMENT

The required data used in this paper has 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, Govt. of India, website https://desagri.gov.in/statistics-type/normal-estimates/.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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