Original Research Article

Time series modeling and forecasting of finger millet cultivation area, production and productivity in Chhattisgarh, India: The Box Jenkins methodology

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 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 fluctuatingtrend was observed in finger millet cultivationarea and production over the forecast period.Whereasincreasing 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

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). 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 (Rao et al., 2006;Bellundagi et al., 2016; Patra and Mahapatra, 2020; Mahapatra et al., 2024). 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. 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).

In year 2000-01 finger milletscultivation area, production and yieldin 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 (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

(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. (Lama et al., 2020) 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. (Saravand et al., 2022) 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. (Vijay and Mishra, 2018) 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 researchon millet production, i.e. (Tripathi et al., 2013) was research on pearl millet production and productivity, (Prabhu et al., 2022) conducted was research on forecasting minor millet in India, (Sathish et 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., Pal and Paul, 2016; Kour et al., 2017; Das et al., 2019; Dharamraja et al., 2019; Gandhi et al., 2023; Chandra, 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 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) 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 Methods

To select the best fitted ARIMA model, several statistical tools are being applied (Chandra, 2023; Chandra, 2024), viz. AIC (Akaike, 1974), BIC/SIC (Schwarz, 1978), Ljung-Box test (Box and Jenkins, 1978), MAPE (Moreno et al., 2013), RMSE (Draxler, 2014) and MAE(Lewis, 1982; Armstrong and Collopy, 1992; Goodwin and Lawton, 1999; Reddy, 2000; Ren and Glasure, 2009;Tofallis, 2015; Priya et al., 2015).Thus, the formulation of the models is given bellow:

AIC written as follow:
$AIC = \{n\,(1+\log 2\pi) + n \log \sigma^2 + 2m\}$ …...…. (1)

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

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

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \overline{X}_i\right)^2}{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$MAE = \sum_{i=1}^{n}\left|\frac{X_i - \overline{X}_i}{X_i}\right| \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$Q = n\left(n+2\right)\sum_{i=1}^{k}\frac{r_i^{\,2}}{n-i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

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 (Box and Jenkins, 1978; Gujarati et al. 2015; Chandra, 2023; Chandra and Brahme, 2023; Chandra et al. 2023; Chandra, 2024). 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 (Chandra et al. 2023; Chandra, 2024). Thus,Y follows an ARMA (3, 4) process,therefore it can be written as:

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

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

3.4. Model Identification

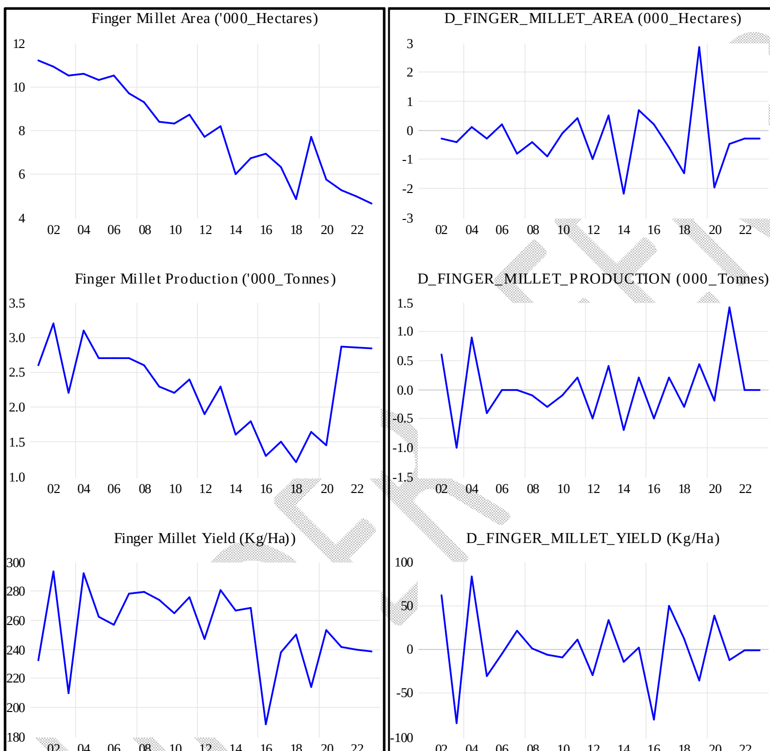
In generally, a non-stationary series is made stationary after differencing '*d times*', and is said to be integrated of order '*d*' denoted by *I (d)*. If, the original series is stationary $d=0$,and then the ARIMA model transform into an ARMA model. The time series data used for the present study, i.e., FMCA, FMP, and FMY. The series FMCA and FMPwere 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 figure 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 figure 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.

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

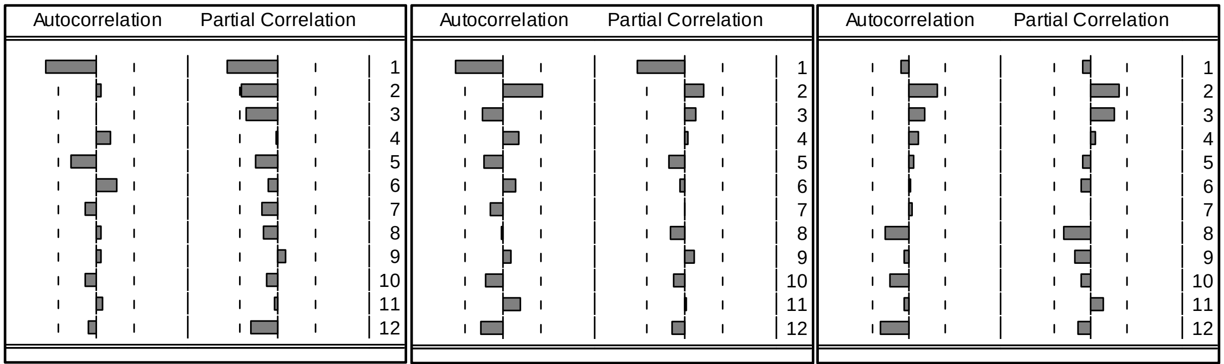
$$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 Y_{t-3} + \beta_1 u_{t-1} + u_t \quad \ldots\ldots\ldots \quad (9)$$

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



(a) (b)

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



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

Figure 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 (Dickey-Fuller, 1979) unit root test at 1st order difference and level given in table 1. The time series FMCA andFMP at level p-value were insignificant. Thus, seriesFMCA and FMP was statically not significant, so it is not stationary.After that we go through 1storder difference, and 1st order difference series DFMA and DFMP calculated t–statistics value was respectively = -4.477 and- 9.295and p-value are respectively = 0.0111 and 0.0000which 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 andFMP 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. Figure 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 figure 2 shows not containing the unit root.So, it is stationary.

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

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 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)-

  $Y_t = 2.2951 + 1.1518Y_{t-1} + 0.3645Y_{t-2} – 0.6568Y_{t-3} – 0.9999u_{t-1} + u_t$

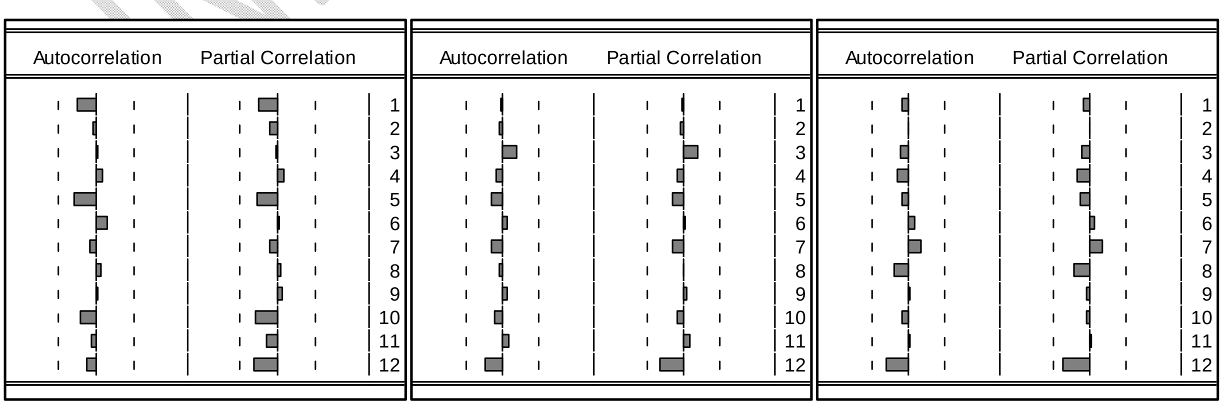
- Model for Finger Millet Yield (FMY)-

  $Y_t = 254.75 + 1.915Y_{t-1} – 0.999Y_{t-2} – 2.981u_{t-1} + 3.089u_{t-2} – 1.165u_{t-3} – 0.057u_{t-4} + u_t$

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 MilletCultivation Area(b) Finger MilletProduction (c) Finger MilletYield

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

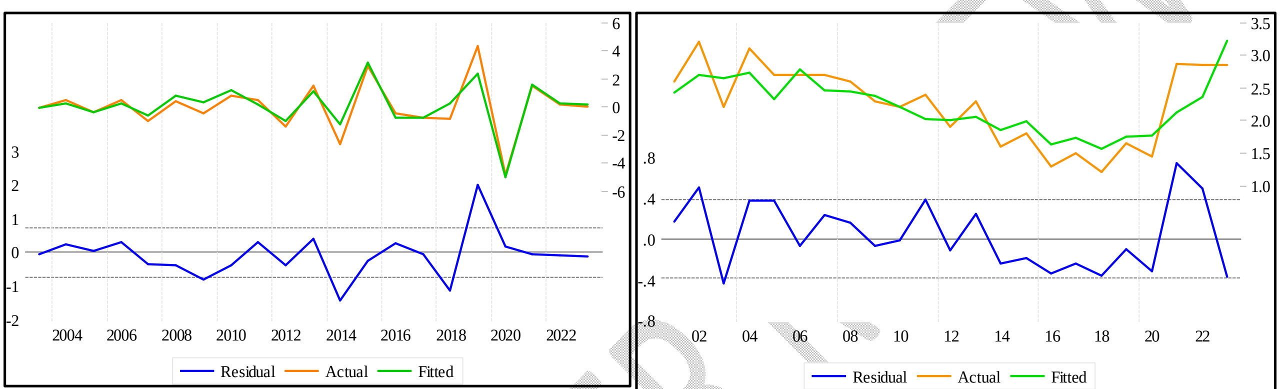
4.2. Diagnostic Checking

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:

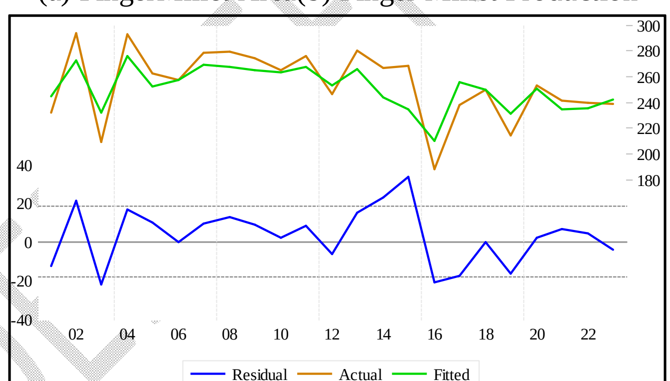
- The lowest values of the AIC criterions have chosen as the best fitted model for the above selected models (given in table 2), and the lowest values of the SIC/BIC criterions has chosen as the best fitted model for the above selected models (given in table 2).
- ARIMA model parameters, viz., MAPE, 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 (figure 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 figure 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 figure 3). So, we were going out for forecasting the above models (forecasting results given in table 5).

4.3. Forecastingresultsof the Finger Millet

This research study is based on annual amount of the finger milletcultivation 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 milletcultivation 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 milletcultivation 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 milletcultivation 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) and2.5233 (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 andFMP continuous decreasing throughout the forecast period of 2023-24 to 2029-30, but series FMYwill 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 (figure 5).

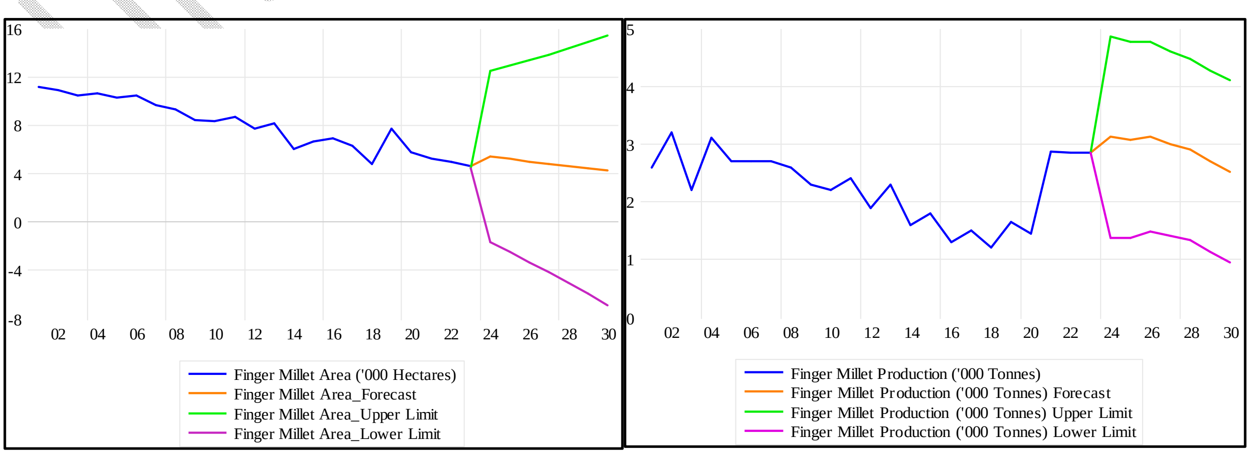


(a) FingerMillet Area(b) Finger Millet Production

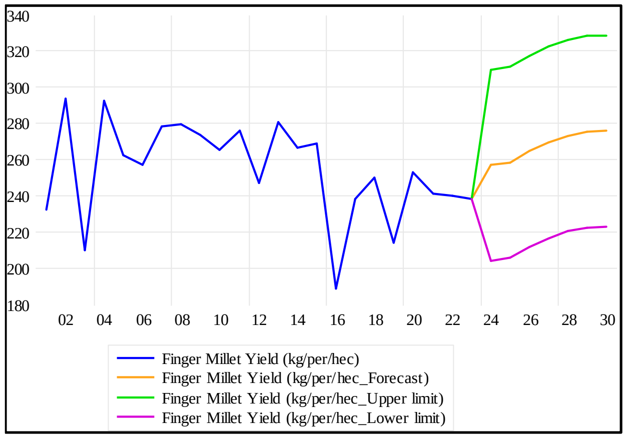


(c) Finger Millet Productivity

Figure 4 Representation of Residual, Actual and Fitted graphs



(a) Finger Millet Area (b) Finger Millet Production



(c) Finger Millet Productivity;

(**Figure 5** Representation of Forecast graphs of Finger Millet)

Table 5 Forecast Value of Finger MilletCultivation 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 calculationusing 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 (Chandra, 2024). Forecasts of agricultural productions are useful to the farmers, policymakers and agribusiness industries. In the present studyARIMA (0, 1, 2), (3, 1, 1) and (2, 0, 4) models for figure milletcultivation 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 andFMP achieved in the year 2023-24 respectively5.4109 ('000 hectare) and 3.1182 ('000 tonnes)to which will decrease in the year 2029-30 respectively4.2827 ('000 hectare), 2.5233 ('000 tonnes), andbut 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 productionshow the decreasingand 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.

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/.

Disclaimer (Artificial intelligence)

Option 1:

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.

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Details of the AI usage are given below:

1. No use of AI

2.

3.

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. Athanasopoulos G., Ahmed R. A. and Hyndman R. J. (2009). Hierarchical forecasts for Australian domestic tourism, *International Journal of Forecasting*, 25(1): 146–66.
4. 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.
5. 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.

6. Box G. P. E., and Jenkins G. M. *Time Series Analysis: Forecasting and Control*, Revised edition, Holden Day, San Francisco. 1978.
7. 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
8. Chandra R. P., and Brahme R., (2023). Econometric modelling 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.
9. 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.
10. 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
11. 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.
12. 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
13. 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://doi.org/10.1080/01621459.1979.10482531
14. Directorate of Economics and Statistics, DA&FW, Government of India https://desagri.gov.in/statistics-type/normal-estimates/
15. 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.
16. 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.
17. Goodwin P., and Lawton R. (1999). On the asymmetry of the symmetric MAPE, *International Journal of Forecasting*, 15: 405-408.
18. Gooijer J. G. D., and Hyndman R. J. (2006). 25 years of time series forecasting. *International Journal of Forecasting* 22(3): 443–73.
19. Gujarati D. N., Porter D. C., and Gunsekar S. *Basic Econometrics*, Revised edition, McGraw Hill Education, New Delhi. 2015.

20. 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.

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

22. 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.

23. 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.

24. 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.

25. Lewis C. D. Industrial and business forecasting methods, London: Butterworths, p. 40. 1982.

26. 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

27. 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.

28. 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.

29. Patra C. and Mahapatra S. K. (2020). Forecasting of Ragi Production in Koraput Districts of Odisha, India, *International Journal of Current Microbiology and Applied Sciences*, 9(07): 1923-1929. https://doi.org/10.20546/ijcmas.2020.907.219

30. 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

31. 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.

32. 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.

33. Reddy C. V. (2000). Modelling and Forecasting: NCDEX AGRIDEX, *SCMS Journal of Indian Management*, 114-130.

34. 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.

35. 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

36. 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.

37. 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.

38. 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.

39. 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.

40. 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.

41. 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.

42. Mahapatra S. K., Dhakre D. S., Bhattacharya D., and Sarkar K. A., (2024). Forecasting of finger millet production in Odisha by ARIMA & ANN model: A comparative study, *International Journal of Statistics and Applied Mathematics,* SP-9(1): 276-281.

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