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Comparative Study of Forecasting for Finger Millet (Ragi) According to their Area and Production in Different States of India through ARIMA Model

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ABSTRACT

Explains the use of time series modeling (Box-Ljung test, and ARIMA model) to predict the ragi (*Eleusine coracana*) production and area in the Indian states of Uttar Pradesh and Karnataka. It was shown that the ARIMA(Autoregressive integrated moving average) model with the best fit was (2,2,1) Furthermore, using our time series data set from 1966–1967 to 2022–2023 and the ARIMA (2,1,2) model, we attempted to ascertain as precisely as possible the future condition of Ragi (*Eleusine coracana*) for a maximum of ten years. The area of ragi in Karnataka would continue to decline between 2010 and 2015, with occasional increases, according to our examination of yearly data on the crop. For Uttar Pradesh, however, the situation of both area and production revealed.

Keywords ARIMA, Finger millet, Forecasting, Area, Production.

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INTRODUCTION

Finger millet is commonly known as Ragi in Hindi language. In India finger millet is commonly called by various names like Ragi (in Kannada, Telugu, and Hindi), also Mandua/Mangal in Hindi belts states, Kodra in Himachal Pradesh, Mandia (Oriya), Taidalu (in Telangana region), Kezhvaragu in Tamil India is the largest producer of finger millet in the world, India stands as a significant contributor to finger millet production, accounting for approximately 2.2 million tons, while Africa follows closely, producing about 2 million tons for finger millet (*Eleusine coracana*) as per ICRISAT. Ragi is widely cultivated and consumed in parts of Africa and Asia. Nutritional value: Finger millet is highly nutritious and is valued for its rich content of calcium, iron, and other minerals. It is also a good source of protein and dietary fiber. Due to its nutritional profile, finger millet is often used as a staple food, especially in regions where malnutrition is a concern. Cultivation condition for Finger millet is well adapted to various agro-climatic conditions, including regions with low rainfall and poor soil fertility. It is primarily grown in countries such as India, Uganda, Ethiopia, Kenya, and Tanzania. In India, Karnataka, Tamil Nadu, and Andhra Pradesh are among the major Finger millet producing states. Uses of Finger millet can be consumed in various forms, including whole grains, flour, porridge, and baked goods. In some regions, it is used to make traditional foods like idli, dosas, and roti. It is also used in the production of fermented beverages. Use in medical, Finger millet is considered a healthy food choice due to its high nutritional content. It is gluten-free and suitable for individuals with gluten intolerance or celiac disease. Additionally, Finger millet has a low glycemic index, making it beneficial for managing blood sugar levels. Finger millet yields can vary depending on soil fertility, rainfall, and agricultural practices. Overall, Finger millet plays a crucial role in food security and nutrition, particularly in regions where it is a staple crop. Its resilience to adverse growing conditions and nutritional benefits make it an important crop for sustainable agriculture and food security efforts. In agriculture, the classification of Ragi belongs to the Plantae kingdom, which comes under the Magnoliophyte division, class Liliopsida, order Poales family Graminae, Sub-family Chloridoideae, Genus Eleusine, Species Corocana. Ragihasa fibrous root system is shallow, branched, rooting at flower nodes. The lateral root is formed from the seminal root. Hemavathi and Prabakaran (2018) described the ARIMA model in different aspects for the period of 1990-91 to 2014-15 were analyzed by time series methods. Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) were calculated for the data. Appropriate Box- Jenkins Auto-Regressive Integrated Moving Average (ARIMA) model was fitted. The validity of the model was tested using standard statistical techniques. For forecasting area, production, and productivity ARIMA (0, 1, 2), (0, 1, 1), and (0, 1, 1) models respectively were used to forecast five leading years. Finger millet (Ragi) is considered one of the most nutritious cereals or Millet crops. Finger millet contains about 6-8% protein, 70-75% carbohydrates, 16-20% dietary fiber and 2-3% minerals. All of the cereals crop or Millet's crop Finger millet has the highest value of calcium (344mg) and potassium(410mg). Based on its nutritious value there are most benefits of Finger millet like, Finger millet is an excellent source of natural calcium which helps strengthen bones for growing children and aging people. Daily consumption of Finger millet is useful for bone health keeps diseases such as osteoporosis at bay and could reduce the risk of fracture. Chinmayee and Mahapatra (2020) used the ARIMA model for Ragi is an important cereal crop in the Koraput district of Odisha it is the richest source of calcium, iron, and protein which makes it more important for health. Forecasting of Ragi production in Koraput district. Data collected from 1985-2017-18 is used for forecasting purposes. The ARIMA model was used for trend estimation, and ACF and PACF were calculated. The result shows 52.75 tonnes of Ragi production in 2022. Different methods described and analyzed for the ARIMA methodology were employed to forecast and for diagnostics of the model MAPE, MAE, and AIC were used Govindraju *et al.* (2021). It is found that the model ARIMA(2,0,2) (1,0,1) is appropriate over the other possible models and the prices are estimated as 2327 Rs/qtl in August 2021, which is the highest during the forecast period. Lama *et al.* (2019) analyzed Ragi's price index from 2005 to 2011 and 2012 to 2017. The series was split to give an idea regarding the scenario pre-and post-implementation of the policies. It was interesting to note that Ragi's price index increased significantly from 2012 to 2017, which is post the implementation of the policies.

MATERIALS AND METHODS

Area of study

In this research paper, we study, the area and production of Finger millet (*Eleusine corcana*) in Karnataka and Uttar Pradesh states of India and also compare the present situation and forecasting of finger millet (*Eleusine coracana)* area and production.

Data collection

In this study, the secondary data were compiled on different aspects like area and production, of Finger millet (*Eleusine coracana*) for Uttar Pradesh and Karnataka's main producing states. We used the 1966-67 to 2023 data set for the studies of this research paper from the website of the IIMR.

The ARIMA model

Box and Jenkins (1976), described Auto-Regressive Integrated Moving Average (ARIMA) model, the time series variable is assumed to be a linear function of previous actual values and random shocks. In general, an ARIMA model is characterized by the notation ARIMA (P,D,Q) where P, D, and Q, denote orders of Auto Regression (AR), Integration (differencing), and Moving Average (MA), respectively. Biswas (2021) a non-seasonal series can often be represented as a process whose differences are autoregressive and moving average as prescribed by Box-Jenkins ARIMA is a parsimonious approach that can represent both stationary and non-stationary processes.

An ARIMA (*P.D.O*) process is defined by:

$$y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + ... + \phi_p y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1}\ \theta_2 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - ... - \theta_p \varepsilon_{t-p} \quad (1)$$

Where, y_t and ε_t are the actual value and random error at period *t*, respectively, $\phi_1(i\text{-}1,2....p)$ are model parameters. Since the estimate approach is only possible for a stationary series, the first step in the ARIMA modeling process is to determine if the series is stationary. If a series' statistical properties—like its mean and autocorrelation structures—remain consistent across time, it is said to be stationary. By differencing, the series' stochastic trend is eliminated. Based on an Auto-correlation function (ACF) and a partial auto-correlation function (PACF) that closely suits the data, many ARIMA models are selected. The most suitable ARIMA model is selected using the highest coefficient of determination (R^2) value and the lowest root mean square error (RMSE), mean absolute percentage error (MAPE), and Akaike Information Criterion (AIC) value. In the present study, all estimation and forecasting of the ARIMA model were performed using R-Studio Software.

Forecast evaluation methods

The forecasting ability of different models is assessed concerning with common performance measures, viz., the root mean squared error (RMSE), mean average percentage error (MAPE), mean absolute error (MAE), and percentage of forecast error. Root mean squared error (RMSE).

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} (\hat{y} - y_t)^2}{n}} \quad (2)$$

Mean absolute error

$$MAE = \frac{\sum_{t-1}^{n} |y_t - \hat{y}_t|}{n} \quad (3)$$

Mean absolute percentage error

$$MAPE = \frac{\left[\sum_{t-1}^{n} \left|\frac{y_t - \hat{y}}{y_t}\right| \times 100\right]}{n}, \quad (4)$$

Akaike Information Criterion (AIC)

$$AIC = 2k - \ln(\hat{L}) \quad (5)$$

Where,

y_t = Actual value
$\hat{y}_t$ =Predicted value
k = Number of estimated parameter
n = Number of observation
$\hat{L}$ =Maximum value for likelihood function in the model.

Ljung-Box test

Ljung-Box test can be used to check autocorrelation among the residuals. If a model fits well, the residuals should not be correlated and the correlation should be small. In this case, the null hypothesis is $H_0 : \rho_i(e) = \rho_2(e) = ... \rho_k(e) = 0$, tested with the Box-Ljung statistics $Q^* = N(N+1) \sum_{t=1}^{k} (N-k)\, \rho^2 k(e)$ (6), where *N* is the no observation used to estimate the model. The statistics Q^*approximately follows the chi-square distribution with (k–q) degree of freedom. Where, q is the number of parameters that should be estimated in the model. Q^* if is large (Significantly large from zero), it is said that the residual autocorrelation as a set is significantly different from zero, and random estimated models are probably auto-correlated.

RESULTS AND DISCUSSION

ARIMA modeling for area of Karnataka

Time series data series for the area of Karnataka region is examined for stationarity using the Dickey-Fuller unit root test. The stationarity requirement is shown to be met at difference order one with the $\rho_r(|t| \geq -46.1934) \leq 0.01$ indicating the absence of a unit root at a significance level of 5% at the first-order difference. The graphical stationarity test using ACF and PACF is shown in Fig.1.

Fig.1 clearly show that the difference in the area of the Karnataka series shows a more stable variance than the original series, whereas the original series is not stationary. That is, our different order is one to make the area of the Karnataka series stationary. Again, from the ACF and PACF, it is clear that there is no significant spike in the first-orderdifference, that is, the area of the Karnataka series is stationary

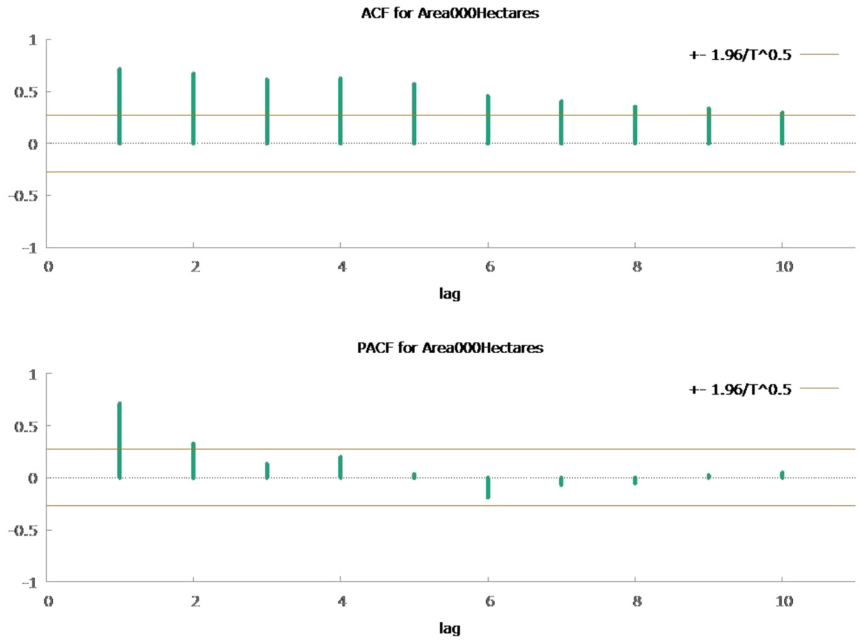

Fig. 1. ACF and PACF graphically stationary checking for the area of Karnataka.

at the first-orderdifference. From the tentative order analysis, the best selected Arima model for area of Karnataka forecasting is ARIMA (2,1,2) with *AIC* =813.8793 and *BIC* = 822.0515. The parameter estimate of the fitted ARIMA (2,1,2) is given in Table 1. The summary statistics of Table 1, show that first and second-order Auto-Regressive lag and second-order moving average lag have a statistically significant effect on the area of Karnataka at a 5% level of significance.

To check the autocorrelation assumption, the "Box-Ljung" test is used. It is found that the p_r ($|\chi^2_1| \geq 0.082$) 0.8922, which strongly suggests that we may accept that there is no autocorrelation among the residual of the fitted ARIMA (2,1,2) models at a 5% level of significance. Badmus and Ariyo (2011) found that for the cultivation of maize in Nigeria the respective values gave good results for area and production respectively ARIMA (1,1,1) and ARIMA (2,1,2). Finally all graphical and formal tests, it is clear that our fitted ARIMA (2,1,2) model is the best-selected model for forecasting the area of Karnataka in Ragi crop.

Table 1. Summary statistics of ARIMA (2,1,2) for the area of Karnataka.

Coefficient	Estimates	Standard error	*t*-value	*p* -value
AR1	1.9153	0.2801	7.3125	0.05
AR2	1.2235	0.1504	-2.125	0.0512
MA1	-1.763	0.1312	-12.712	0.0125
MA2	1.002	0.0012	9.12	0.0428

ARIMA modeling for the production of Karnataka

The augmented Dickey-fuller unit root test to check whether the production series' time sequence is stationary. It is found that the stationarity condition is satisfied at the difference order one with test statistics $t = -3.29017$ and asymptotic p -value is $p = 0.01536$, which suggests that there is no unit root in the first order difference at a 5% level of significance stationarity test using ACF and PACF is shown in Fig. 2.

Fig. 2 clearly shows that the difference in the production of the Karnataka series shows a more

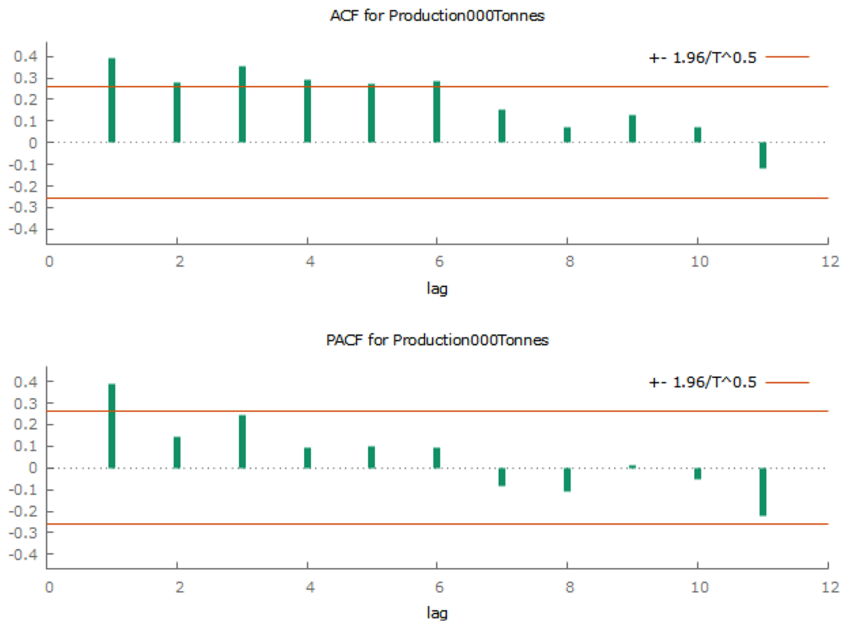

Fig. 2. ACF and PACF graphically stationary checking for the production of Karnataka.

stable variance than the original series, whereas the original series is not stationary. That is, our different order is one to make the production of the Karnataka series stationary. Again, from the ACF and PACF, it is clear that there is no significant spike in the first-order difference, that is, the production of the Karnataka series is stationary at the first-order difference. From the tentative order analysis, the best selected Arima model for the production of Karnataka forecasting is ARIMA (2,1,2) with *AIC*=815.8470 and *BIC* = 826.0623. The parameter estimate of the fitted ARIMA (2,1,2) is given in Table 2. The summary statistics of Table 2, show that first and second order Auto-Regressive lag and second-order moving average lag have a statistically significant effect on the production of Karnataka at a 5% level of significance.

Table 2. Summary statistics of ARIMA (2,1,2) for the production of Karnataka.

Coefficient	Estimates	Standard error	*t*- value	*p*- value
AR1	1.0524	0.1770	5.582	0.0028
AR2	33.024	0.1594	5.196	0.0024
MA1	1.4425	0.1234	0.1804	0.8568
MA2	1.1254	0.1965	-5.615	0.0197

To check the autocorrelation assumption, the "Box-Ljung" test is used. From the test, it is found that the $p_r(|\chi^2_1 \geq 0.094|) = 0.7922$. This suggests that we may accept that there is no autocorrelation among the residual of the fitted ARIMA (2,1,2) models at a 5% significance level. Finally all graphical and formal tests, it is clear that our fitted ARIMA (2,1,2) model is the best-selected model for forecasting the production of Karnataka in Ragi crop.

ARIMA modeling for area of Uttar Pradesh

The Augmented Dickey-Fuller unit root test to check whether the area series's time sequence is stationary. It is found that the stationarity condition is satisfied at the difference to order one with test statistics $t = -1.72154$ and the asymptotic p-value is $p = 0.4203$ which suggests that there is no unit root in the first order difference at a 5% level of significance stationarity test using ACF and PACF is shown in Fig. 3.

Fig.3 clearly shows that the difference in the area of the Uttar Pradesh series shows a more stable variance than the original series, whereas the

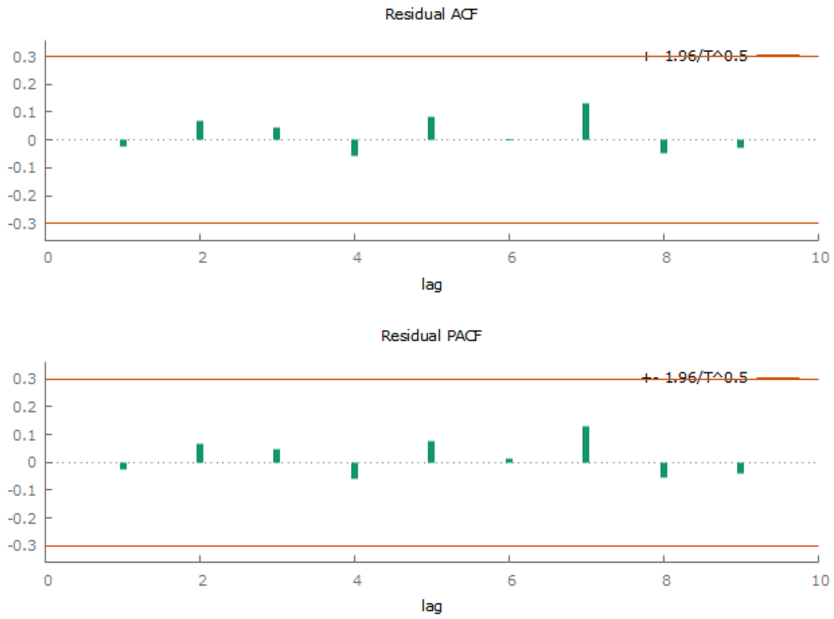

Fig. 3. ACF and PACF graphically stationary checking for the area of Uttar Pradesh.

original series is not stationary. That is, our different order is one to make the area of the Uttar Pradesh series stationary. Again, from the ACF and PACF, it is clear that there is no significant spike in the first-order difference, that is, the area of the Uttar Pradesh series is stationary at the first-order difference. From the tentative order analysis, the best selected Arima model for the area of the Uttar Pradesh forecasting is ARIMA (1,2,1) with *AIC*=388.8040 and *BIC*=395.8486. The parameter estimate of the fitted ARIMA (1,2,1) given in Table 3.The summary statistics of Table 3, show that first and second-order Auto-Regressive lag and second-order moving average lag have a statistically significant effect on the area of Uttar Pradesh at a 5% level of significance.

Table 3. Summary statistics of ARIMA (1,2,1) for the production of Karnataka.

Coefficient	Estimates	Standard error	*t*-value	*p*-value
AR1	1.524	0.2070	4.582	0.1128
AR2	36.024	0.1894	8.196	0.2324
MA1	1.7425	0.1734	1.1804	0.9568
MA2	1.3254	0.4565	-7.615	0.0297

To check the autocorrelation assumption, the “Box-Ljung” test is used. From the test, it is found that the p_r $(|\chi_1^2 \geq 0.0841|)$ =6922,s which is strongly suggests that we may accept that there is no autocorrelation among the residual of the fitted ARIMA (1,2,1) models at a 5% level of significance. Finally all graphical and formal tests, it is clear that our fitted ARIMA (1,2,1) model is the best-selected model for forecasting the production of Karnataka in Ragi Crop.

ARIMA modeling for production of Uttar Pradesh

Vijay and Mishra (2018) was used the method of Augmented Dickey Fuller tesr for the Bajra production time series under consideration is non-stationary in nature, which is further verified by results of Augmented Dickey-Fuller (ADF) unit root test and Kwiatkowsk-Phillps-Schmidit-Shin unit root test KPSS test. The Augmented Dickey-Fuller unit root test to check whether the time sequence for area series is stationary or not. It is found that the stationarity condition is satisfied at the difference order one with test statistics and asymptotic *p*-value

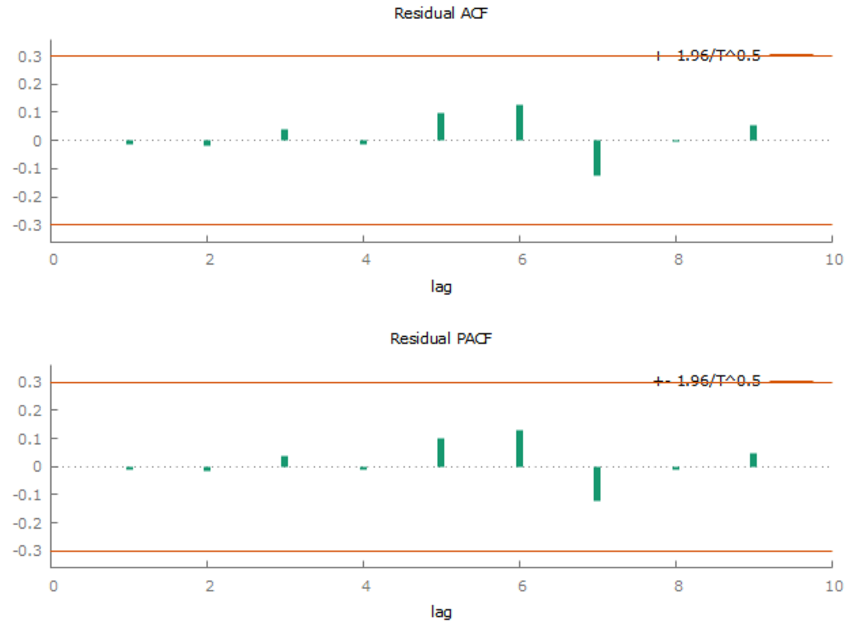

Fig. 4. ACF and PACF graphically stationary checking for the production of Uttar Pradesh.

is *p*=0.000578, which suggests that there is no unit root in the first order difference at a 5% level of significance stationarity test using ACF and PACF as shown in Fig.4.

Fig. 4. demonstrates unequivocally that the Uttar Pradesh series production variance is more stable than the original series whereas the latter is not stationary. In other words, our distinct order is to produce stationary for the Uttar Pradesh series. Once more, the ACF and PACF show that the first-order difference does not exhibit a notable spike; in other words, the Uttar Pradesh series area is stable at the first-order difference. From the tentative order analysis, the best selected Arima model for the area of the Uttar Pradesh forecasting is ARIMA (2,2,1) with *AIC* = 482.1485 and *BIC* =436.9545. The parameter estimate of the fitted ARIMA (2,2,1) given in Table 4. Best fit ARIMA model for different production of Uttar Pradesh was (2,2,1). Wider price variation has been observed for northern states than Tamil Nadu and West Bengal where forecasted prices are likely to be more stable and varying within a narrow range. Since crucial decisions with respect to production, marketing and consumption are dependent on certain price expectation, results obtained by the study might prove helpful in guiding the stakeholders involved in making timely decisions. The summary statistics of Table 4, show that first and second-order Auto-Regressive lag and second-order moving average lag have a statistically significant effect on the production of Uttar Pradesh at a 5% level of significance.

To check the autocorrelation assumption, the "Box-Ljung" test is used. From the test, it is found that the $P\ (|\ \chi_1^2| \geq 0.474)$ =0.6822, which is strongly suggests that we may accept that there is no autocorrelation among the residual of the fitted ARIMA (2,2,1) models at a 5% level of significance. Finally all graphical and formal tests, it is clear that

Table 4. Summary statistics of ARIMA (2,2,1) for the production of Karnataka.

Coefficient	Estimates	Standard error	*t* -value	*p* -value
AR1	4.4421	0.26086	0.9130	0.3612
AR2	2.9750	0.155979	2.1444	0.0321
MA1	1.000	0.155191	0.3265	0.7440
MA2	1.445	0.07390	-13.53	0.1024

Table 5. Forecasting criteria for the selected model.

Crop	Selected model	Forecasting criterion			
		ME	RMSE	MAPE	MAE
Area of Karnataka	ARIMA (2,1,2)	-11.00055	162.7135	34.71031	89.2268
Prod Karnataka	ARIMA (2,1,2)	-9.4565	178.1114	29.3214	88.2269
Area Uttar Pradesh	ARIMA (1,2,1)	-2.8881	19.3777	8.1293	13.0931
Prod Uttar Pradesh	ARIMA (2,2,1)	-3.7494	29.6822	12.3081	-3.5231

our fitted ARIMA (2,2,1) model is the best-selected model for forecasting the production of Uttar Pradesh in Ragi Crop.

Forecasting of area and production of Ragi Crop using the fitted model

After selecting the best model, now we are going to use this model to forecast the area and production of the Ragi crop. To forecast the following "Forecasting criteria" are considered which are shown in Table 5.

Forecasted value for Ragi crop

Based on the sample data, we forecast ten years forward for the area and production of Ragi (*Eleusine corcana*) in Karnataka and Uttar Pradesh State of India.

We cleary define from the Fig.5 the area of Karnataka was monitinically decling from the 2015 for Ragi crop (*Eleusine corrcana*).

Karnataka is the leading state of Finger millet but last few years we clear see from the Fig. 6. The production of finger was continously decline from the 2010-15 and showed the monotonically increasing and decreasing trend so we have to suggest Farmer to used high yielding variety of finger millet crop.

Uttar pradesh has not shown any significance in terms of finger millet crop, the area of finger millet has been continously decreasing over the last few year this can be clearly seen with the help Fig.7.

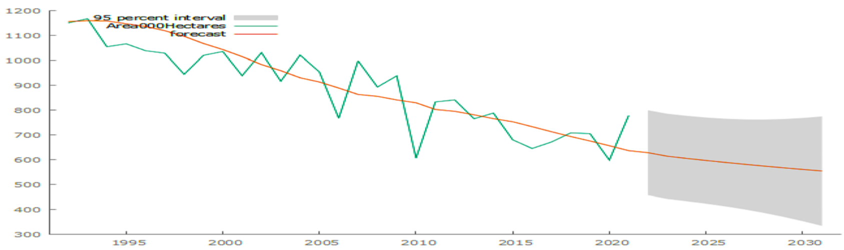

Fig. 5. Forecasting for the area of Karnataka.

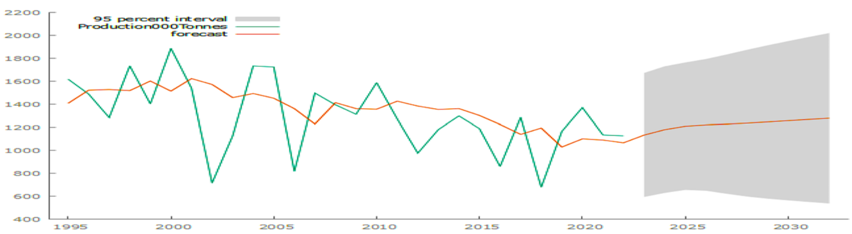

Fig. 6. Forecasting for the production of Karnataka.

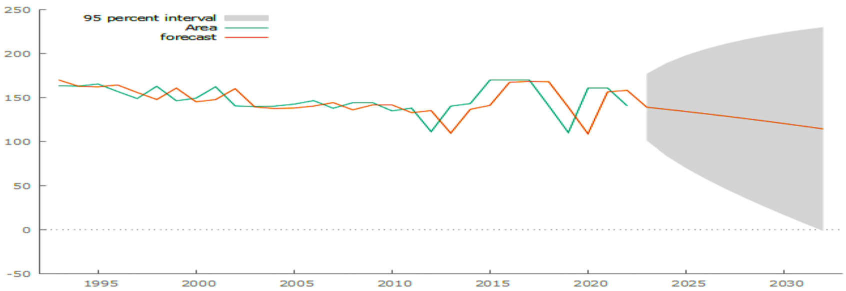

Fig. 7. Forecasting for the area of Uttar Pradesh.

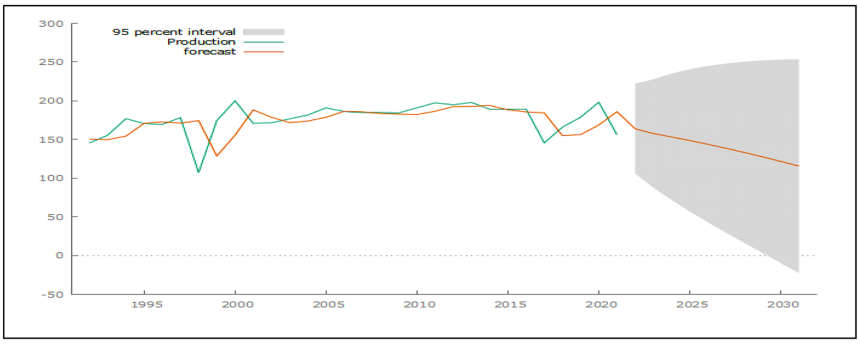

Fig. 8. Forecasting for the production of Uttar Pradesh.

Table 6. Forecasted value for Ragi crop (000ha, 000ton).

Year	Area of Karnataka	Production Karnataka	Area of UP	Production of UP
2024	604.9	1179.35	136.57	153.33
2025	596.7	1209.08	134.09	148.72
2026	588.8	1220.64	131.53	143.76
2027	581.2	1227.11	128.87	138.61
2028	574.0	1235.37	126.13	133.20
2029	567.1	1245.75	123.31	127.56
2030	560.5	1256.77	120.39	121.69
2031	554.2	1267.61	117.39	115.57
2032	560.2	1278.20	114.30	118.99
2033	566.4	1283.10	112.54	121.45

Uttar pradesh has not shown any significance in terms of Finger millet crop production. the production of finger millet has been countinously decreasing over the last few year this but from 2012 it can be declined highly negative rate this can be clearly seen with the help of Table 6.

CONCLUSION

It was shown that the ARIMA (Autoregressive integrated moving Average) model with the best fit was (2,2,1) Furthermore, using our Time series data set from 1966–1967 to 2022–2023 and the ARIMA (2,1,2) model, we attempted to ascertain as precisely as possible the future condition of Ragi (*Elusine coracana*) for a maximum of ten years. The area of Ragi in Karnataka would continue to decline between 2010 and 2015, with occasional increases, according to our examination of yearly data on the crop. For Uttar Pradesh, however, the situation of both area and production revealed. Kumar *et al.* (2021) study was to describe the growth rate study for some time series production factors of Ragi and also making of diagnostic study for detecting some influential time series production factors governing total ragi production in Karnataka and also in India during the period 1993-2017. Mahapatra *et al.* (2024). were analyzed the comparative analysis for different ARIMA and ANN model have been selected based on different parameters. The models are evaluated by using their values of RMSE and MAPE. Among all the selected model, NNAR (5,4) is selected as the best fitted model due to the low value of RMSE & MAPE. Ramesh *et al.*(2015) had find the best fitted model selected based on the performance of several goodness of fit criteria viz. Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Mean Squared Error (MSE), Akaike Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBC) and R-squared values. The assumptions of 'Independence' and 'Normality' of error terms were examined by using the 'Runtest' and 'Shapiro-Wilk test' respectively. This study found ARIMA (1,1,0) as most appropriate to model the wheat production of India. The forecasted value by using this model was obtained as 100.271 million tones (MT) by 2017-18. Vennila and Murthy (2021) was using different model and find the result the growth rate of area and production of Finger millet of Karnataka showed significant negative trend and productivity showed insignificant negative trend. Thus there is a need to take up productivity enhancing measures in finger millet like varietal improvement, improved cultural practices and irrigation facilities.

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