



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; 7(12): 535-543

Received: 25-09-2024

Accepted: 30-10-2024

S Harshitha Nayak

Research Scholar, Division of
Agricultural Economics, ICAR-
IARI, New Delhi, India

Mathikere Shivaraju Apoorva

Research Scholar, Environment
Science, ICAR-IARI, New Delhi,
India

Dinesh Sindhu

Research Scholar, Division of
Genetics, ICAR-IARI, New Delhi,
India

Rakesh N

Scientist, Agricultural Economics,
ICAR-MGIFRI, Motihari Bihar,
India

Corresponding Author:

S Harshitha Nayak

Research Scholar, Division of
Agricultural Economics, ICAR-
IARI, New Delhi, India

Economic and predictive analysis of millet cultivation in India

S Harshitha Nayak, Mathikere Shivaraju Apoorva, Dinesh Sindhu and Rakesh N

DOI: <https://doi.org/10.33545/2618060X.2024.v7.i12g.2207>

Abstract

Background: The aim of the current study was to forecast the area, production, and productivity of millet in India up to 2023. And also examining the growth patterns and instability of millet crop cultivation in India. The main objective of this study is to provide policymakers with data on millet cultivation in India up to 2030. This information will help them to make decisions about future food distribution, import and export regulations, pricing schemes, and administrative procedures related to the marketing and storage of nutri-cereals.

Methods: For the present research study, annual time series data from 1970-71 to 2022-23 on area, production, and productivity of millet in India (Agriculture Statistics at a Glance 2022) ^[1] were used in the analysis. The study used the compound annual growth rate (CAGR) and the Caddy Della Valle instability index to find out the growth patterns and instability of millet crop cultivation in India, respectively. In order to forecast future values of millet production, Box-Jenkins ARIMA model was employed.

Results: Decadal analysis of millet cultivation in India reveals a consistent decline in cultivation area and production of sorghum in the years 2011-2023 with -4.811 and -2.997, respectively, and productivity in 2001-2010 was 3.052. The productivity trends of Bajra, Ragi, and small millets in 2011-2023 are 1.99, -0.67, and 3.72, respectively. Caddy-Della Valle Instability Index results show that, compared to rice and wheat, millets such as sorghum, bajra, ragi and small millets show more variability in area, production, and yield. The sorghum area's forecast values demonstrated a declining pattern, from 3535.02 thousand hectares in 2022-2023 to 2416.12 thousand hectares in 2029-2030. Similarly, in 2029-2030, sorghum production dropped from 3814.34 thousand tons to 3259.34 thousand tons. From 2022-2023 to 2029-2030, productivity increases from 1149.24 kg/ha to 1308.64 kg/ha. Similar forecasts have been made for the area under cultivation, production, and productivity of finger millet, small millets, and pearl millet up to 2030. Thus, high-yielding varieties, timely application of inputs, and governmental measures like policy support, the public distribution system, subsidization, and awareness-raising through propaganda and demonstration can all help to increase the output of these nutri-cereals.

Keywords: Growth rate, instability, arima model, millets

Introduction

Millets are small-seeded grasses that can grow in arid and semi-arid regions. They are also referred to as dryland cereals or nutri-cereals. In rainfed farming, millets are resilient to stress and drought and a good source of minerals and nutrients. Millets can survive in a wide range of natural situations. Based on the size of the grain, millets are categorized as Major Millets and Minor Millets such as Sorghum (Jowar), Pearl Millet (Bajra), and small millets such as Kodo Millet (Kodon), Proso Millet (Cheena), Little Millet (Kutki), Finger Millet (Ragi), and Foxtail Millet (Kakun) (Gowri, U.M. *et al.*, 2020) ^[4]. They are a good source of phytochemicals, minerals, and protein and high in dietary fibre. Millets have a composition of 7-12% protein, 2-4% fat, 65-75% carbohydrates, and 15-20% dietary fibre (Saravand *et al.*, 2022) ^[16]. Compared to rice, wheat flour, and maize, which provide 64-68 grams of carbohydrates per gram, millets have 60-70 grams.

From the perspective of sustainable development, millets have shown to be supportive in reducing the effects of SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 3: Good Health and Well-Being, SDG 5: Gender Equality, SDG 8: Decent Work and Economic Growth, SDG 12:

Responsible Consumption and Production, and SDG 13: Climate Action (Kumari. P. *et al.*, 2023) ^[11]. India stands as the leading global producer of millets, with 19% of the global production share in 2022. In 2022-23, the cultivated area of millets in India was 12.45 million hectares, with a production of 15.53 million metric tons and an average yield of around 1,247 kg per hectare (Agriculture Statistics at a Glance 2022) ^[1]. Rajasthan has the highest area under millets cultivation (29.05%) followed by Maharashtra (20.67%), Karnataka (13.46%). In India, per capita millet consumption has decreased significantly from 30.94 kg per year in 1960 to 3.87 kg per year in 2022-2023 (FAO, USDA 2023). After the introduction of the National Year of Millets the export value reached from US\$ 59 million to US\$ 75 million between 2019-20 and 2022-23. During 2022-2023 India experienced a 29.56% increase in export quantity over the previous year (WITS 2023). According to APDA's 2023 report, the UAE ranked first among the top five export destinations in terms of value, with USD 13.33 Mn (17.76%), followed by Saudi Arabia with USD 10.39 Mn (13.67%), Nepal with USD 5.57 Mn (7.35%), Bangladesh with USD 3.69 Mn (4.92%), and Japan with USD 3.37 Mn (4.43%).

The year 2018 was designated as the National Year of Millets in an effort to increase promotion and demand. Millets were renamed "Nutri Cereals" in April 2018. On March 5, 2021, the United Nations adopted a resolution designating the year 2023 as the International Year of Millets, with support from 72 nations. (PIB.gov.in.2023) The potential of millets to improve food and nutritional security is not being fully realized, and their cultivation and consumption are decreasing in many countries. With growing emphasis on the consumption of nutritious food on the consumption side, sustainability on the supply-side production, there is a need to highlight the nutritional and environmental benefits of millet to producers, consumers, and decision-makers (Joshi, P.K. *et al.*, 2005) ^[9].

Analyzing growth trends is important for ensuring a stable supply of millets, evaluating the economic impact on farmers, safeguarding food security, and developing effective agricultural policies (Umagowri *et al.*, 2020) ^[18]. The instability index addresses challenges related to fluctuating yields and helps to build strength against climatic variations, supporting agricultural diversification and food security initiatives (Jainuddin S. M. *et al.*, 2019) ^[8]. In India, where the economy heavily relies on agricultural production, making timely and reliable forecasts is essential for stakeholders to make informed decisions (Bellundagi *et al.*, 2016) ^[2]. Hence, forecasting crop production and productivity is crucial for India's agriculture commodities, as it aids in planning and policy making for future food distribution, export and import decisions, pricing, and administrative measures for storage and marketing of agriculture commodities. The autoregressive integrated moving average (ARIMA) (Paswan *et al.*, 2022) ^[14] model is widely used for forecasting agricultural produce and prices, which gives accurate and unbiased forecasts. Therefore, the present study was conducted with the following objectives:

1. To assess the growth trends and instability of the millets area, production and productivity in India.
2. To forecast the area, production and productivity of millet in India up to 2023.

Methodology

The data on production were taken from Agriculture Statistics at a Glance 2022 ^[1] and examined for the period from 1971-72 to 2021-2022. Over the years, India's millet cultivation has faced a significant challenge characterized by declining cultivation area.

The study used the compound annual growth rate (CAGR) and the Cuddy Della Valle instability index of millet cultivation in India.

Trend analysis: The exponential growth function was used to estimate the growth rates of the selected economic variables and the model is

$$Y_t = ab^t u_t \quad (1)$$

Y_t : Dependent variable for which growth rate of increase/decrease is estimated (area, production, and yield)

A: Intercept (constant)

B: Regression coefficient

T: Years which take values, 1, 2, ..., n

U_t : Disturbance term for the year t

The equation $Y_t = ab^t u_t$ was transformed into log linear form for estimation purpose and was estimated using the Ordinary Least Square (OLS) technique. The compound growth rate (g) in percentage was then computed from the relationship,

$$g = (\text{Antilog of } \ln b - 1) * 100$$

The significance of the regression coefficient was tested by using the 't' test

Instability analysis

In order to study the variability in the area, production and yield of millets, an instability index suggested by Cuddy and Della (1978) was used: The CDVI shows trends and the exact direction of the instability.

Cuddy-Della Valle Index (CDVI) Formula: $I = CV * \sqrt{1 - AdR^2}$

- **I:** instability index (in percent)
- **CV:** Coefficient of Variation (in percent) $CV = \text{Standard Deviation} / \text{Mean} * 100$

Adjusted R²: Coefficient of determination.

The ranges of CDVI are given as: Low instability = between 0 and 15; Medium instability = greater than 15 and lower than 30; High instability = greater than 30.

In order to anticipate the series under consideration, Box-Jenkins ARIMA Modeling was employed.

ARIMA model: The ARIMA model was first introduced by Box and Jenkins in 1976; as a result, this approach is commonly referred to as the Box-Jenkins method in academic literature. The analysis and forecasting of univariate time series data utilizing the ARIMA model are most frequently used. It makes a prediction in response to the linear combination of the values from its own historical time series.

Time series models are typically considered to be stationary, meaning that the series mean, variance, and covariance are all constant throughout time. It can be concluded that ARMA (p, q) is used if the time series is stationary. If the series is not stationary, it can be made stationary by differencing it "d" times, in which case the model is known as ARIMA (p,d,q).

Auto-Regressive (AR) Model

The AR model expresses the current value of a time series as a linear combination of its past values (response variable at time

lags). The equation for an AR(p) process is:

$$AR(p): Y_t = \mu + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \dots + \varphi_p Y_{t-p} + \varepsilon_t \quad (1)$$

- Y_t is the value of the variable (production in '000 tonnes) at time
- μ is constant mean
- $\varphi_1, \varphi_2, \dots, \varphi_p$ are the autoregressive coefficients to be estimated for lags 1 to p.
- $Y_{t-1}, Y_{t-2}, \dots, Y_{t-p}$ are the response variable values at the respective time lags.
- ε_t represents a predicted error at time t.

Moving Average (MA) Model:

The MA model models the current value of a time series as a linear combination of past forecast errors. The equation for an MA(q) process is:

$$MA(q): Y_t = \mu + \varepsilon_t + \delta_1 \varepsilon_{t-1} + \delta_2 \varepsilon_{t-2} + \dots + \delta_q \varepsilon_{t-q} \quad (2)$$

- $\delta_1, \delta_2, \dots, \delta_q$ are the moving average coefficients to be estimated for lags 1 to q.
- $\varepsilon_{t-1}, \varepsilon_{t-2}, \dots, \varepsilon_{t-q}$ are the error terms from the previous time periods.

ARIMA Model

ARIMA combines both AR and MA models with an integration (I) component to handle non-stationarity. The ARIMA model equation is:

$$Y_t = \mu + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \dots + \varphi_p Y_{t-p} + \varepsilon_t + \delta_1 \varepsilon_{t-1} + \delta_2 \varepsilon_{t-2} + \dots + \delta_q \varepsilon_{t-q} \quad (3)$$

- The letters 'p' stands for the number of autoregressive terms,
- 'q' stands for the number of lagged forecast errors and
- d represents the order of difference or the degree of time series differencing.

A model should be extended with seasonal parameters known as the seasonal ARMA (in the case of stationary time series) or SARIMA (in the case of non-stationary time series) if the model has a seasonality component. SARIMA (p, d, q) (P, D, Q) is an abbreviation for them, where P denotes seasonal autoregressive order, D denotes seasonal differencing number, and Q denotes seasonal moving average order.

Time-series data can be fitted to an ARIMA model using the procedures listed below: (Kathayat & Dixit, 2021) ^[10].

Identification: Since only stationary data series can be used for estimation, this is the initial step in determining the stationarity of the data series. The arrangement of autocorrelation and partial correlation coefficients gives insights into whether stationarity is present. If the analysis indicates that the model lacks stationarity, the data series can be made stationary through differencing.

1. **Model identification:** To find the values of p and q, analyze the autocorrelation function (ACF) and partial autocorrelation function (PACF). Then, from the set of models, using Akaike's information criterion (AIC) with

correction (AICc), choose the optimal ARIMA model.

2. **Diagnostic checking:** Diagnostic checking is necessary to confirm that the identified ARIMA model is the best model after estimating its parameters. The residuals in this ACF and PCF are examined to rule out white noise. Plotting the ACF and the PACF from the best model will allow you to examine the residuals. If the plotted ACF and PACF do not resemble white noise, try altering the model.
3. **Forecasting:** For the short term in particular, the forecasts calculated by ARIMA are more accurate than those obtained from conventional econometric modeling.

Verifying the Model's Adequacy Based on the minimum root mean square error (RMSE), minimum mean absolute percentage error (MAPE), minimum mean squared error (MSE), minimum mean absolute error (MAE), and minimum Akaike information creation (AIC), AICc, and Bayesian information criterion (BIC), which are statistical measures that assess the effectiveness of the fit of the forecasting, the best Box-Jenkins model was selected from the competing models. Any model that highly satisfied those requirements was chosen. (Mishra *et al.*, 2021) ^[13].

The statistical software tool R was used to conduct the statistical analysis for the present study. The ideal ARIMA model was chosen using R's `auto.Arima()` function. The unit root test and AICc minimization are used in this function to create an ARIMA model using the Hyndman-Khandakar algorithm (Hyndman & Khandakar, 2008) ^[6]. The Hyndman-Khandakar method only uses the first two stages described above, thus we carried out the other steps on our own. In addition, we tested further models based on the ACF and PACF graphs using the R software.

Results and Discussion

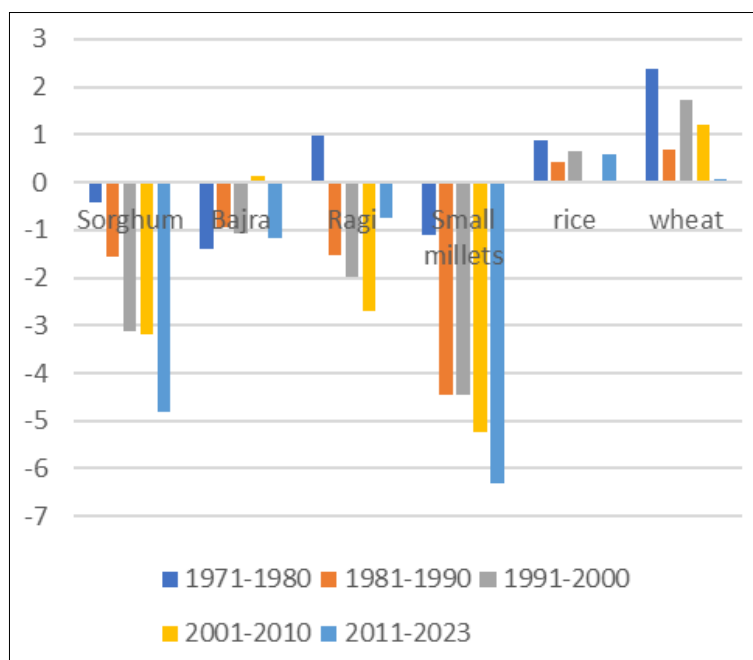
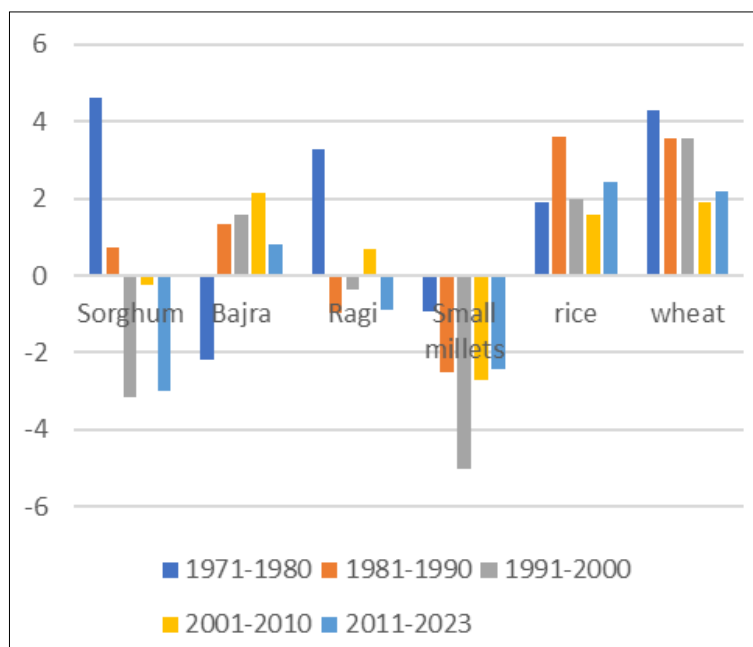
Trends in area, production and productivity of millets.

Decadal analysis of millet cultivation in India reveals distinct patterns. Sorghum experienced a consistent decline in cultivation area and production, with a noteworthy negative growth rate during 2011-2023 area (-4.811) and production (-2.997). However, productivity showed a positive trajectory from 2001-2010 (3.052), highlighting adaptability to improved practices. Bajra displayed positive productivity trends with a growth rate of 2.673 in 1991-2000, and the introduction of improved varieties of ragi in the 2000s has led to a favourable upward trajectory in production with a growth rate of 0.696 as shown in table 1. Small millets faced persistent negative growth in cultivation area and production, but a positive trend in productivity (table 2) from 2011-2023 (3.72) signifies advancements in yield improvement despite challenges in cultivation area.

As seen in Figs. 1, 2, and 3, the millets when compared to rice and wheat, millets continuously showed declining output and cultivated area growth, while rice and wheat showed increasing trends. Despite government efforts to promote millet cultivation for nutritional value, negative growth in millet cultivation area may be attributed to changing farmer cropping patterns and the millets' lesser significance in consumption practices. It is found that the studies conducted by (Sharma *et al.*, 2022) ^[17] and (Kumar *et al.*, 2022) ^[12] also had comparable findings.

Table 1: Compound annual growth rate (CAGR) of millet cultivation area and production in India.

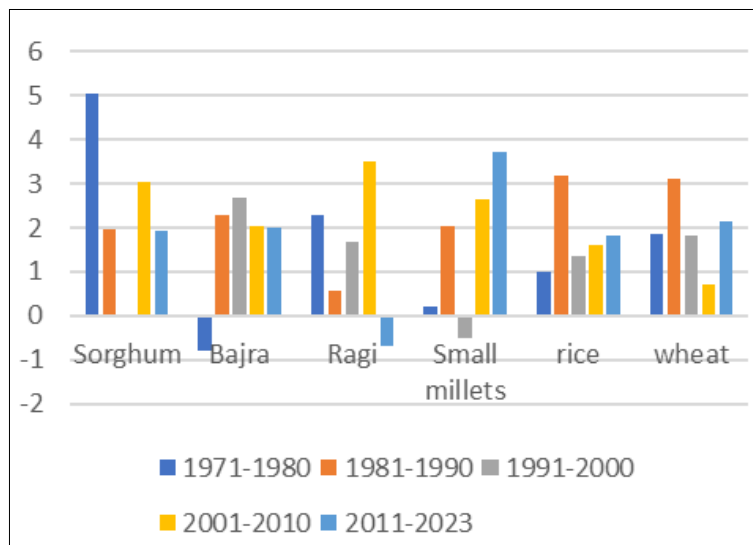
Year	Area						Production					
	Sorghum	Bajra	Ragi	Small millets	rice	wheat	Sorghum	Bajra	Ragi	Small millets	rice	wheat
1971-1980	-0.409	-1.398	0.970	-1.113	0.876	2.394	4.618	-2.184	3.279	-0.920	1.901	4.311
1981-1990	-1.571	-0.925	-1.512	-4.465	0.413	0.692	0.715	1.348	-0.953	-2.508	3.615	3.575
1991-2000	-3.106	-1.064	-1.993	-4.453	0.651	1.715	-3.139	1.580	-0.354	-5.036	2.007	3.569
2001-2010	-3.194	0.118	-2.709	-5.220	-0.02	1.197	-0.239	2.144	0.696	-2.722	1.585	1.898
2011-2023	-4.811	-1.152	-0.753	-6.324	0.593	0.067	-2.997	0.817	-0.894	-2.407	2.423	2.205

**Fig 1:** Decadal growth rate of area of millets in India**Fig 2:** Decadal growth rate of production of millets in India**Table 2:** Compound annual growth rate (CAGR) of millet cultivation yield in India

	Productivity					
	Sorghum	Bajra	Ragi	Small millets	rice	Wheat
1971-1980	5.04	-0.79	2.28	0.19	1.01	1.87
1981-1990	1.94	2.29	0.56	2.04	3.19	3.10
1991-2000	-0.03	2.67	1.67	-0.52	1.33	1.82
2001-2010	3.05	2.02	3.50	2.63	1.60	0.69
2011-2023	1.90	1.99	-0.67	3.72	1.82	2.12

Table 3: CDVI Instability of Area, Production and Yield of millets, rice and wheat in India.

Crop	Area	Production	Productivity
Sorghum	6.858	10.613	11.468
Bajra	5.786	8.288	4.735
Ragi	9.016	15.046	11.085
Small millets	5.988	7.544	6.120
Rice	1.623	2.918	2.271
wheat	2.426	3.918	4.872

**Fig 3:** Decadal growth rate of yield of millets in India

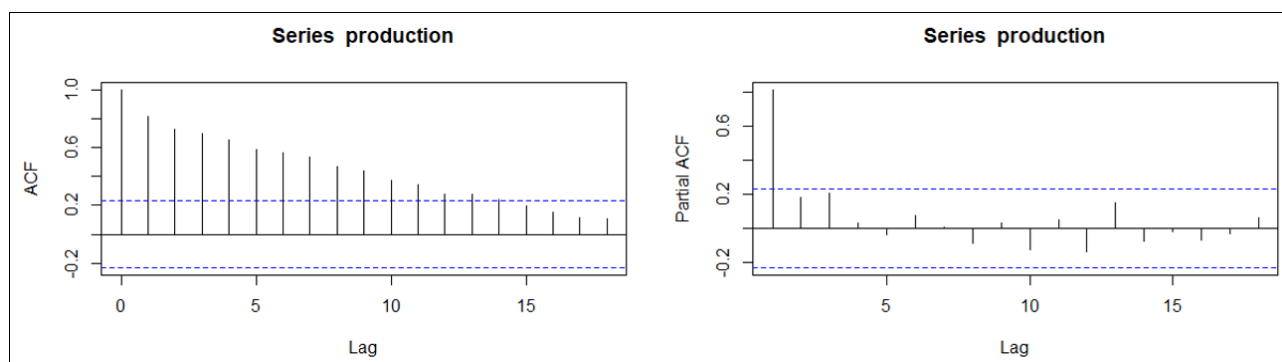
CDVI Instability Index

According to the study, compared to rice and wheat, millets such as ragi, sorghum, small millets, and bajra show more variability in area, production, and yield. More instability is seen in area of cultivation of ragi (9.016) and the sorghum (6.858), followed by small millets (5.988) and bajra (5.786) presented in Table 3. Production instability in sorghum (10.613) and ragi (15.04) is almost three times higher than in rice and wheat. Unlike other cereals, this instability is mostly related to decreased growing area and inadequate adoption of improved varieties. Additionally, the yield instability of millet (11.0) is twice as large as that of major cereals (~4), highlighting the technological and variety advances in major cereals compared to millets. The results align with the research conducted by (Gowda *et al.*, 2019) [3] and (Kumar *et al.*, 2023) [11].

ARIMA model: The data has been analyzed and graphically plotted using the R program. Box-Jenkins ARIMA Modeling was used to predict the series under investigation.

Verification of the stationarity of the data

The ACF (autocorrelation function) and PACF (partial autocorrelation function) graphs are used to determine whether the data is stationary. The graphs below show how the data is related to its previous values at various time lags. Figure 4 shows that the ACF plot is gradually diminishing, implying that the data's correlation with its previous values decreases as time goes on. This decline suggests that the mean value of the data is changing over time, indicating that the time series data is not stationary.

**Fig 4:** The correlogram of millet production of (ACF) and (PACF) before differencing

The Augmented Dickey-Fuller (ADF) test is used to check if a time series is stationary. The null hypothesis (H0) assumes that the time series is non-stationary, while the alternative hypothesis (Ha) assumes that the time series is stationary.

In Figure 5, the ADF test results show that when the p-value is

higher than 5%, we can accept the null hypothesis, indicating that the time series is non-stationary. However, to determine if the data is actually stationary, the first difference in the data is calculated. After calculating the first difference, the p-value of the ADF test falls below 5% as shown in Figure 6. As a result,

we reject the null hypothesis, implying that the data is stationary. (Haerani & Nugraha, 2022) ^[5]. Figure 7 shows the production series becomes stable after the first difference.

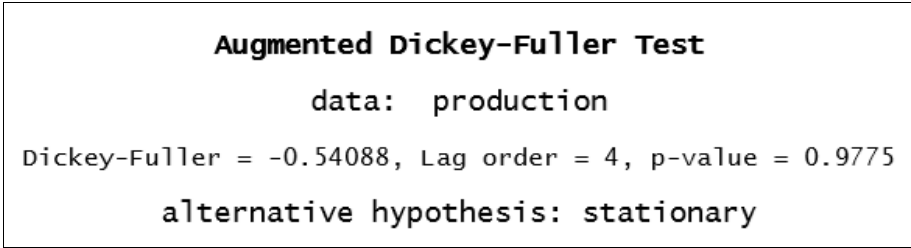


Fig 5: The results of the ADF test before differencing.

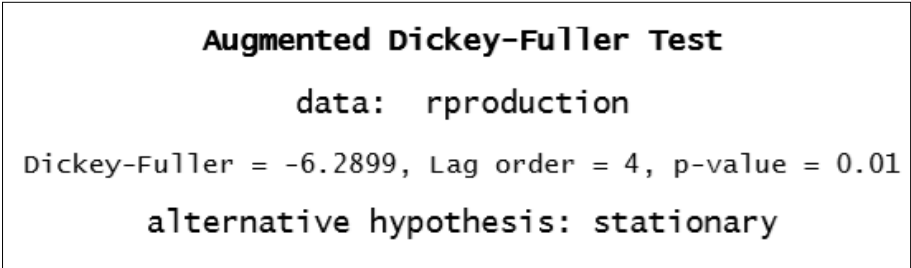


Fig 6: The result of ADF test after differencing

Figure 7 shows how the production series becomes stable after the first difference.

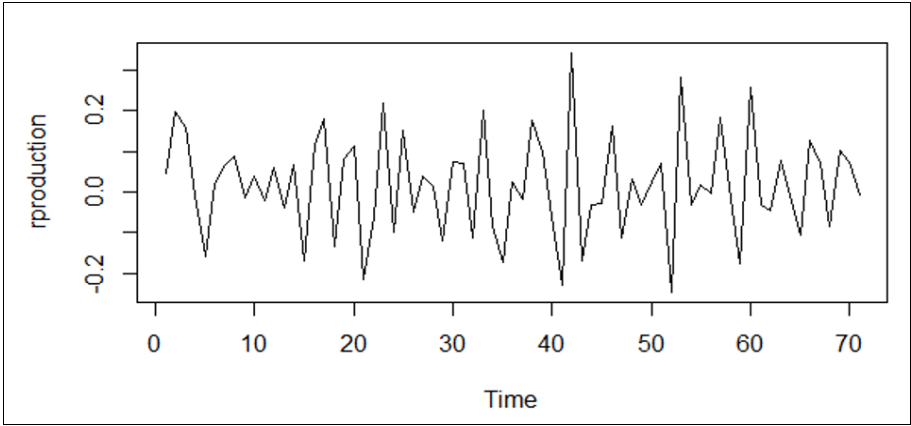


Fig 7: Time series plot the after differentiation

Identification (finding p, d, and q) and fitting the model to the study
The autocorrelation and partial correlation functions were examined, and multiple ARIMA models were fitted with various significant values of p and q, such as (2,1,2), (0,1,0), (1,1,0), (0,1,0), (1,1,1), (0,1,2), (1,1,2), and (0,1,1).

ARIMA (0, 1, 1) with drift was chosen as the optimal model for production ('000 tonnes) based on the RMSE, BIC, and AIC minimum values as given in Tables 4 and 5. Table 6 shows the highly significant estimates of the ARIMA (0, 1, 1) with drift model parameters for production.

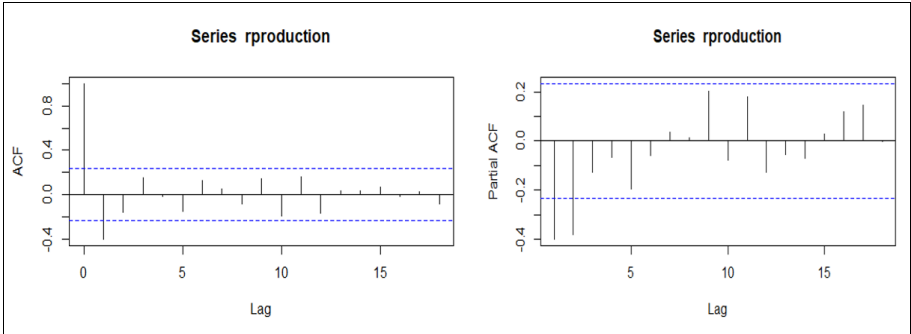


Fig 8: The correlogram of millet production of (ACF) and (PACF) after differencing.

Table 4: Suggested model for millet production

	(2,1,2)	(0,1,0)	(1,1,0)	(0,1,1)	(0,1,0)	(1,1,1)	(0,1,2)	(1,1,2)	(0,1,1)
AIC	-113.125	-90.944	-101.149	-116.306	-91.6415	-114.445	-114.529	-113.891	-107.697
BIC	-99.54	-86.419	-94.6318	-109.52	-86.419	-105.394	-105.478	-102.577	-103.171

Table 5: Estimates from the fitted ARIMA model for millet production in India.

ME	RMSE	MAE	Variance	AIC	AIC _c	BIC	Log likelihood
0.0048670	0.1009626	0.0803743	0.01064	-116.31	-115.95	-109.52	61.15

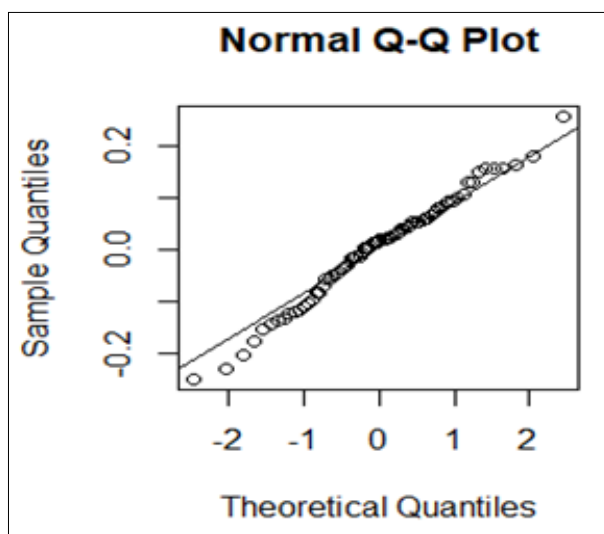
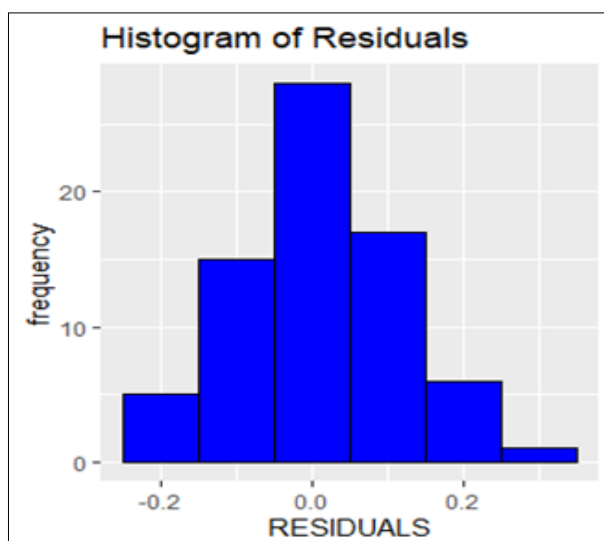
Table 6: Estimated model parameters for millet production in India

	Type	Estimate	Standard error
Production	MA ₁	-0.7477	0.0807
	Drift	0.0141	0.0033

Test for diagnosis (residual analysis)

The Box-Pierce or Ljung-Box test used to assess the residuals' autocorrelation. Figure 9 depicts the Normal Q-Q plot of the (0,1,1) model, and Figure 10 depicts the residual histogram of the (0,1,1) model. A normal QQ plot (Quantile-Quantile plot) is used to assess whether the residuals of the model follow a normal distribution. The points on the QQ plot approximately form a straight line, it suggests that the residuals are normally

distributed. Deviations from a straight line may indicate non-normality, which can impact the validity of statistical inferences made using the model. The histogram is used to assess whether the residuals exhibit a normal distribution. A bell-shaped curve in the histogram suggests that the residuals are approximately normally distributed. Departures from a normal distribution may indicate issues with the model assumptions or suggest opportunities for improvement.

**Fig 9:** Normal Q-Q plot of (0,1,1) model**Fig 10:** The residual histogram of the (0,1,1) model

Residual Autocorrelation Analysis using ACF and PACF Plots and the White Noise Test:

There is no lag in the ACF and PACF residual plots that exceeds

the Bartlett line, indicating that the residuals from our model do not exhibit any significant autocorrelation as shown in the figure 11.

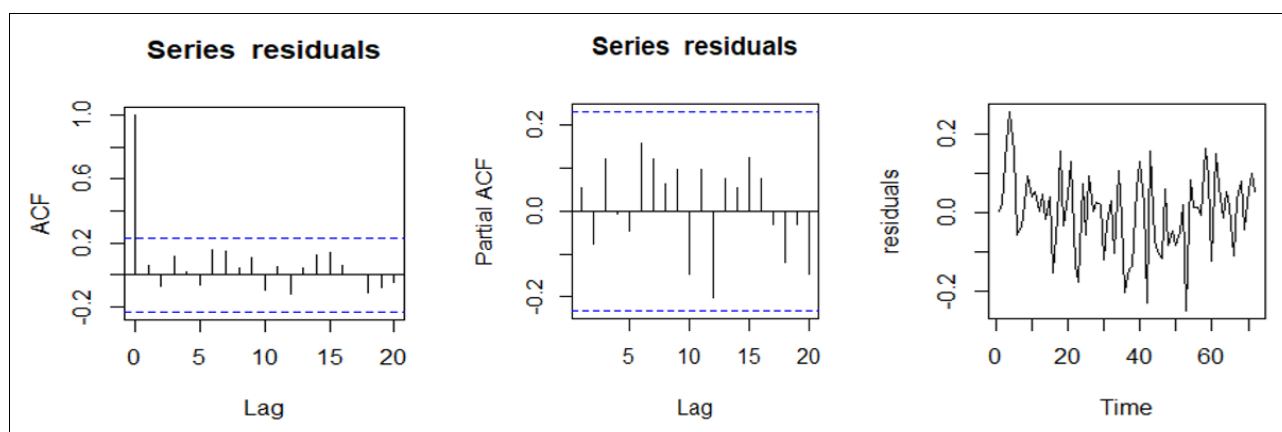


Fig 11: The correlogram of millet production of (ACF) and (PACF) of the (0, 1, 1) model's residual and time series plot of residuals

Process of White Noise: The purpose of white noise assumptions is to determine whether there is any correlation between the residuals produced by ARIMA models.

The Ljung-Box test was conducted under the following hypothesis:

H0: The residuals have white noise (There is no correlation

between the residuals).

H1: The residuals do not contain white noise (the residuals are correlated). Figure 12 shows the findings of the Ljung-Box tests. These results demonstrate that the p-value actually exceeds the level of significance ($\alpha = 5\%$), demonstrating that H0 is satisfied.

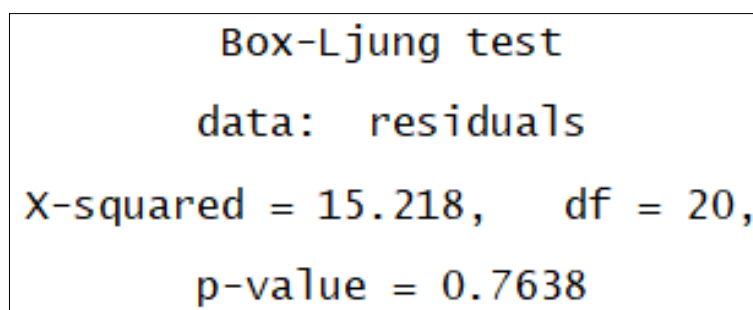


Fig 12: Result of Ljung-Box test for (0,1,1) model

Forecasting

The millet production determined by the ARIMA (0,1,1) model

and the outcome of the forecasting for the next 6 years is given in table 7.

Table 7: Model validation and forecasting of area, production and yield of sorghum in India up to 2029-2030

Year	Area ('000 ha)		Production ('000 tonnes)		Yield (kg/ha)	
	Observed	Predicted	Observed	Predicted	Observed	Predicted
2015-16	6,077.03	6,089.36	4,238.02	4,349.37	697.38	712.39
2016-17	5,624.42	5,698.34	4,567.90	4,463.25	812.15	883.64
2017-18	5,024.45	5,012.69	4,803.38	4,849.39	956.00	946.32
2018-19	4,092.87	4,102.61	3,475.09	3,369.34	849.06	902.34
2019-20	4,823.76	4,842.37	4,772.20	4,812.42	989.29	1,012.45
2020-21	4,381.24	4,416.25	4,814.98	4,892.78	1,099.00	1,186.2
2021-22	3,812.20	3,892.51	4,231.54	4,345.29	1,110.00	1,126.49
2022-23	-	3535.02	-	3814.34	-	1149.24
2023-24	-	4100.00	-	4400.46	-	1186.36
2024-25	-	3034.41	-	4044.02	-	1205.5
2025-26	-	2873.80	-	4049.43	-	1260.70
2026-27	-	2721.70	-	4020.31	-	1287.43
2027-28	-	2577.65	-	3929.29	-	1292.49
2028-29	-	2403.99	-	3319.03	-	1293.61
2029-30	-	2416.12	-	3259.34	-	1308.64

In the agricultural landscape of 2021-22, sorghum cultivation area was 3,812.20 thousand hectares, slightly below the earlier forecast of 3,892.51 thousand hectares. Looking ahead to 2029-

30, the anticipated sorghum cultivation area was projected to be 2,416.12 thousand hectares. Despite these variations, the actual sorghum production for 2021-22 amounted to 4,231.54 thousand

metric tons, compared to the projected 4,345.29 thousand metric tons. Forecasts for 2029-30 suggest an expected production of 3,259.34 thousand metric tons. Examining the yield per hectare, the sorghum yield in 2021-22 stood at 1,110.0 kg/ha, slightly

lower than the predicted 1,126.49 kg/ha. Projections for 2029-30 indicated an expected yield of 1,308.64 kg/ha. These figures highlight the dynamic nature of sorghum cultivation in the future.

Table 8: Projected cultivation of millets area, production, and productivity of millets in India up to 2030.

Year	Pearl Millet (Bajra)			Finger millet (ragi)			Minor Millets		
	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)
2022-23	7699.3	9255.4	1399.5	1204.6	1125.6	1269.3	374.3	340.8	834.9
2023-24	7692.4	9404.6	1407.6	1200.1	1478.2	1335.4	353.3	332.2	843.3
2024-25	7443.5	9392.2	1412.7	1185.9	1472.8	1461.6	333.5	323.9	850.5
2025-26	73839	9440.8	1423.0	1179.2	1179.1	1464.3	314.8	315.8	856.5
2026-27	7112.7	9435.0	1468.5	1174.0	1293.0	1667.0	297.1	307.9	861.7
2027-28	6816.0	9409.0	1474.4	1165.8	1295.6	1869.1	280.4	300.2	866.0
2028-29	6709.2	9420.9	1507.6	1157.6	1380.4	1882.5	264.7	342.3	869.6
2029-30	6782.3	9329.4	1564.3	1206.4	1402.6	1932.5	283.6	312.6	890.3

Similarly, as given in table 8 projections for the future cultivation area, production, and productivity of pearl millet, finger millet, and small millets have been forecasted up to 2030. The selection of optimal ARIMA models was determined through an analysis of autocorrelation and partial autocorrelation functions at various lags. The forecasting accuracy of these models was assessed based on minimum AIC, RMSE, MAE, MAPE, and maximum R values. the future trends in cultivation area, production, and yield for all millets in India have been predicted with a 95 percent accuracy level.

Conclusion

Utilizing the ARIMA approach, the study forecasts a decline in millet cultivation area while anticipating an increase in production and productivity over the next eight years. Despite this projected rise, sustained government investment, farmer encouragement, and effective policies are crucial to securing favourable land tenure systems for millet cultivation. This proactive approach aims to ensure consistent production surpassing consumption, mitigating the need for wheat imports, and preventing potential economic repercussions such as heightened millet prices and increased inflation. Additionally, it sheds light on the concerning negative trends in millet cultivation, emphasizing the necessity for targeted interventions to address instability and sustain farming systems.

References

- Government of India, Department of Agricultural, Cooperation and Farmers Welfare, Ministry of Agricultural and Farmers Welfare. Agricultural Statistics at a Glance 2022.
- Bellundagi V, Umesh KB, Ravi SC. Growth dynamics and forecasting of finger millet (Ragi) production in Karnataka. *Economic Affairs*. 2016;61:195.
- Gowda HR, Amrutha T, Raghavendra KJ, Kumar S. Millet's production and prospects in India: An economic overview. *Green Farming*. 2019;10:300-305.
- Gowri UM, Shivakumar KM. Millets - miracle grains: growth trends and cost effectiveness in India. *Agricultural Research Journal*. 2020;57:805-812.
- Haerani SLS, Nugraha ES. ARIMA Model in predicting Jakarta Composite Index. *Journal of Actuarial, Finance*. 2022;27-35.
- Hyndman RJ, Khandakar Y. Automatic time series forecasting: The forecast package for R. *Journal of Statistical Software*. 2008;27:1-22.
- <https://doi.org/10.18637/jss.v027.i03>
- Indian Institute of Millets Research (IIMR). Vision 2050. Hyderabad: IIMR; 2015.
- Jainuddin SM, Seema, Suhasini K, Lavanya. Determinants of growth and instability of groundnut in Karnataka: Evidence from Hazel's decomposition model. *Economic Affairs*. 2019;65:649-661.
- Joshi PK, Singh NP, Singh NN, Gerpacio RV, Pingali PL. Maize in India: Production Systems, Constraints, and Research Priorities. Mexico, D.F.: CIMMYT; 2005.
- Kathayat B, Dixit A. Paddy price forecasting in India using ARIMA model. *Journal of Crop and Weed*. 2021;17:48-55. <https://doi.org/10.22271/09746315.2021.v17.i1.1405>
- Kumar P, Sonnad JS, Yeledhalli RA. A study on trend in area and production of major millets in India. *Journal of Farm Sciences*. 2023;36:290-294. <https://doi.org/10.61475/JFS.2023.v36i3.13>
- Kumar S, Lad YA, Mahera AB. Trend analysis of area, production, and productivity of minor millets in India. *Biological Forum-An International Journal*. 2022;14:14-18.
- Mishra P, Yonar A, Yonar H, Kumari B, Abotaleb M, Das SS, Patil SG. State of the art in total pulse production in major states of India using ARIMA techniques. *Current Research in Nutrition and Food Science*. 2021;4:800-806. <https://doi.org/10.1016/j.crfs.2021.10.009>
- Paswan S, Paul A, Paul A, Noel AS. Time series prediction for sugarcane production in Bihar using ARIMA & ANN model. *The Pharma Innovation Journal*. 2022;11:1947-1956.
- Sankar TJ, Pushpa P. Stochastic ARIMA Model for *Pennisetum glaucum* production in India. *International Journal of Agricultural and Statistical Sciences*. 2023;19:373. <https://doi.org/10.59467/ijass.2023.19.373>
- Saravand MJ, Rebasiddanavar RM, Relekar SP, Thakar KP. Forecasting of pearl millet production in North Gujarat by using ARIMA model. *The Pharma Innovation Journal*. 2022;11:672-677.
- Sharma S, Meena L, Sharma LG, Singh H, Chaudhary R. Growth and instability in area, production and yield of major millets in Rajasthan. *The Pharma Innovation Journal*. 2022;11:1536-1543.
- Umagowri M, Shivakumar KM. Millet scenario in India. *Economic Affairs*. 2020;65:363-370.