Economic Affairs, Vol. **71**(01), pp. 65-74, March 2026
DOI: 10.46852/0424-2513.1.2026.10

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RESEARCH PAPER

Forecasting of Area, Production and Productivity of Total Pulses in Madhya Pradesh and its Yield Sustainability

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Received: 7-November-2025 **Revised:** 21-February-2026 **Accepted:** 10-March-2026

ABSTRACT

The present study was conducted to analyze the pulse area, production and output in India and Madhya Pradesh from 1950 to 2022, employing descriptive statistics, trends and Sustainability index. The result revealed that the area under pulses in India and Madhya Pradesh has expanded by 67.01% and 146.05% respectively, with output growth of 215.00% and 826.16% during the study period. Pulses yields in India and Madhya Pradesh have shown a slight improvement, with yields increasing by two and ten times from 1950 to 2020. In the case of trend analysis quadratic trends are found in the area, yield, and production of pulses in India, while in Madhya Pradesh, trends are quadratic in area and production, and exponential in yield. The Box-Jenkins methodology was used for forecasting up to 2030. The best-fitted ARIMA models were selected based on ACF and PACF at various lags. Forecasting performances of this model were selected based on their minimum AIC, RMSE,MAE, MAPE, and maximum R^2 values. Model parameters were estimated by using the Gretl software. Empirical results showed that ARIMA (1,1,5) and (1,1,4) are found to be the best for area under pulses in India and Madhya Pradesh, respectively. The ARIMA (0,1,1) and ARIMA (1,1,5) models are the best for yield under pulses in India and Madhya Pradesh, respectively. Furthermore, according to the sustainability index of pulses production in India and Madhya Pradesh indicating that both regions are highly sustainable in pulses production during period III (2001-2022). Moreover, this study provided valuable insights into the trends and sustainability of pulses production in India and Madhya Pradesh, which can inform policy decisions and future planning for the agricultural sector.

HIGHLIGHTS

- Both India and Madhya Pradesh have witnessed a substantial expansion in the acreage and production of pulses.
- Despite some fluctuations, the positive skewness and kurtosis values suggest overall upward trends in pulse output.
- Sustainability indices affirm the high sustainability of pulses production in India and Madhya Pradesh, during 2001-2022.
- ARIMA models predict a continued upward trajectory in pulse area, production, and yield in both India and Madhya Pradesh.

Keywords: ARIMA, Sustainability, Forecasting, Production

How to cite this article: Dhakad, N., Mishra, P., Singh, U., Ray, S., Chouhan, S.S., Jain, V. and Das, S.S. (2026). Forecasting of Area, Production and Productivity of Total Pulses in Madhya Pradesh and its Yield Sustainability. *Econ. Aff.*, **71**(01): 65-74.

Source of Support: None; **Conflict of Interest:** None

Given that pulses, also known as edible legumes, have been produced for millennia and are a fundamental component of Indian cuisine, they have traditionally been seen as the sole protein source accessible to the disadvantaged. Pulses, together with cereals and oilseeds, provide a substantial portion of the dietary intake on the Indian subcontinent. Dal, which refers to the separated grains of pulses, is an excellent source of essential amino and fatty acids, fiber, minerals, and vitamins, as well as high-quality protein. Common varieties of legumes, including lentils, peas, moong beans, black beans, chickpeas, and pigeon peas, are cultivated. Pulses have a substantial protein content (20-25% by weight) in comparison to the protein content found in wheat and rice. The crops improve soil health by augmenting the soil's nitrogen status, long-term fertility, and the sustainability of cropping systems. It acquires around 80% of the nitrogen it requires by symbiotic nitrogen fixation from the atmosphere, and it deposits a substantial quantity of organic matter and residual nitrogen for subsequent crop utilization.

Given the significance of pulses, forecasting their production in the future is crucial for developing a solid plan for sustainable commodities. The process of making future projections based on historical and current data is known as forecasting, and it is most frequently used to trend analysis. There are numerous uses for forecasting in the realm of agriculture. A time series model was developed by many authors in order to assess the forecasting behaviour in various agricultural commodities. Goyal *et al.* (2022) conducted a study to examine the productivity, production, and area growth of Punjab's primary oilseed crop. The objective was to discover potential avenues for the state to enhance its competitiveness against other major oilseed-producing states in the country. Kumar *et al.* (2022) employed the ARIMA model to forecast the spatial extent, efficiency, and output of the wheat crop in Madhya Pradesh and India. The model fitting and predictions were based on annual data spanning from 1960 to 2020, with projections extending until 2026. Srivastava *et al.* (2021) conducted an examination of the ARIMA model for forecasting the area, display, and yield of wheat in Uttar Pradesh. The selection of ARIMA models was based on the analysis of the autocorrelation and partial autocorrelation functions at various lags. Mishra *et al.* (2021) utilized the autoregressive integrated moving average (ARIMA) technique to provide a concise overview of the pattern in the total output of pulses in India. Stochastic trend estimation was conducted using yearly data from 1961 to 2019. The ARIMA model is chosen as the most suitable representation of the pulse production trend, based on the outcomes of various goodness of model fit criteria.

Crop production estimates facilitate government planning and policy ramifications. Trend analysis is an essential tool for visualizing the overall pattern of the event being studied in time series research. Uncertainty The growth and long-term viability of agriculture rely on the combination of crop productivity and land area, which are ultimately influenced by the extent to which enhanced farming techniques are embraced, the condition of infrastructure such as irrigation and agro-processing facilities, and the demand for agricultural products in both local and international markets. Given the aforementioned data, we conducted an analysis of the attributes pertaining to pulse production in Madhya Pradesh, specifically focusing on the factors of land area, yield, and efficiency.

MATERIALS AND METHODOLOGY

The pulses area, production and productivity data series of Madhya Pradesh and whole India were collected from the official website of Directorate of Pulses Development Govt. of India, Ministry of Agriculture and Farmer welfare, and mpkishi.mp.gov.in from the study period of 1970 to 2022.

Statistical methodology: Summary statistics, different parametric models, sustainability index and Box-Jenkins ARIMA models were used as statistical methodology in this study.

Descriptive statistics: To examine the nature of each series, various statistics have been obtained Descriptive statistics are used to describe patterns and general trends in data sets It is a numerical and graphical procedure for summarizing a set of data in a clear and understandable manner.

Trend Analysis: For the best trend model on the bases of maximum R^2 (Coefficient of determination)

Linear Model: $Y_t = b_0 + (b_1 * t)$

Quadratic Model: $Y_t = b_0 + (b_1{*}t) + (b_2{*}t^2)$. The Quadratic Model can be used to model a series which "takes off" or a series which dampens.

Compound Model: $Y_t = b_0{*}\ (b_1^{\,t})$ Or $ln\ (Y_t) = ln(b_0) + t\ ln(b_1)$

Cubic Model: $Y_t = b_0 + (b_1{*}t) + (b_2{*}t^2) + (b_2{*}t^3)$

Exponential Model: $Y_t = b_0{*}e^{(b1{*}t)}$ Or $ln(Y_t) = ln(b_0) + (b_1{*}t)$

Logarithmic Model: $Y_t = b_0 + b_1\, ln(t)$

Growth Model: $ln\ (Y_t) = b_0 + b_1{*}t$

Where Y_t is value of the series in time t and b_0, b_1, b_2, b_3 are the parameters.

Sustainability Index (SI): For sustainability index will divide the data into three period.

- Period -1 (1950-1975)
- Period -2 (1976-2000)
- Period -3 (2001-2022)

1. Singh *et al.* (1990) has given the following measures of sustainability. Sustainability Index (SI) = $\frac{\bar{y} - s}{y_{\max}}$, where $\bar{y}$ is the average yield of a treatment, s is the standard deviation of yields over the years and $y_{\max}$ is the maximum yield of a treatment in any year. Higher the value of the index, higher is the sustainability status.
2. Sahu *et al.* (2005) $SI = \frac{Y_{\max} - \bar{Y}}{\bar{Y}}$ a sustainability index value closer to zero is the most desirable value.
3. Pal and Sahu (2007) $SI = \frac{s_i}{\bar{y}_i} . \frac{1}{s_{\max}}$ lower the value of the sustainability index higher is the sustainability.

Forecasting

After analyzing the trend of each and every series, our next task is to forecast the series for the year to come. For the purpose we adopted the Box –Jenkins methodology.

Box-Jenkins Methodology (ARIMA model)

For using the ARIMA model will be divide two parts:

1. The training data 1972 to 2016.
2. Testing data 2017 to 2022 and Forecasting will be made for 2030.

Autoregressive model: ARIMA models which for Autoregressive Integrated Moving Average models. Integrated means the trends have removed; if the series has no important trend, the models are known as ARMA models (Supriya *et al.* 2023).

The notation AR(p) refers to the autoregressive model of order p. The AR (p) model is formulated as—

$$X_t = c + \sum_{i=1}^{P} \alpha_i X_t + \mu_t$$

Where are the parameters of the model, c is a constant and is it noise is Sometimes the constant term is omitted for simplicity.

Moving Average model: The symbol MA (q) corresponds to a moving average model with order q:

$$X_t = \mu + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \varepsilon_t$$

In this expression $\theta 1, ..., \theta q$ are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and the is an e error term.

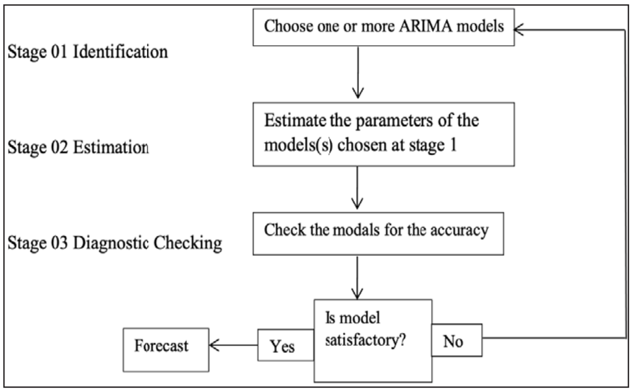

Fig. 1: Flowchart of ARIMA model

Checking for Model Adequacy

The optimal Box- Jenkins model was chosen from candidate models, considering the highest R^2, minimum root means square error (RMSE), Mean absolute error (MAE) minimum mean absolute percentage error (MAPE), and minimum Akaike information creation (AIC).

RESULTS AND DISCUSSION

Summary Information

In India, where they are the most important food crop in terms of profits, pulses rank among the most important crops worldwide. Among the main pulses farmed are chickpeas, pigeon peas, moong beans, black beans, lentils, peas, and a range of other legumes. India produces the majority of the world's pulses, making up 25% of total production. Additionally, it consumes the most amount of pulses (27% of global consumption). Thus, the success of the pulse crop is closely related to India and the food security of the state. Descriptive statistics like maximum, minimum, mean, median, skewness, and kurtosis are used in this part to explain the pattern of the series and produce a consensus that is looked at in Table 1.

Table 1: Summary statistics of Pulses data series.

	Area	Production	Yield
India			
Mean	23519.07	13624.60	565.99
Standard Error	23156	12310	539
Median	285.28	501.85	13.72
Standard Deviation	2437.46	4287.77	117.24
Kurtosis	2.38	2.10	0.82
Skewness	1.37	1.62	1.05
Minimum	18775.00	8347.00	377.00
Maximum	31357.00	26325.00	892.00
Madhya Pradesh			
Mean	4577.70	2935.40	666.97
Standard Error	4622.00	2488.00	544.00
Median	95.19	190.00	51.55
Standard Deviation	813.28	1623.39	440.48
Kurtosis	1.57	2.12	20.48
Skewness	0.75	1.53	4.20
Minimum	3040.00	873.00	289.00
Maximum	7480.00	8111.58	2993.00

The area cultivated with pulses in India and Madhya Pradesh has expanded by roughly 67.01 and 146.05 percent per year, from 19091.00 and 3040.00 thousand hectares in 1950 to 30156 and 5478.01 thousand hectares in 2022. The Platykurtic structure of the data, combined with the skewness (1.37), implies that the area under pulses in India has been steadily shifting over time.

An expansion inside a certain region is the main driver of this increase in output, with a marginal increase in yield coming in second. The output of pulses in Madhya Pradesh and India grew during the research period, from 8411.00 and 1241.00 thousand tonnes in 1950 to 26325.00 and 8111.58 thousand tonnes in 2022, or roughly 215.00 and 826.16 percent more. India and Madhya Pradesh produce an average of 13624.60 and 2935.40 thousand tonnes of pulses annually, respectively. According to the kurtosis and positive skewness ratings (1.62 and 2.12), output rose at the beginning of the study and remained essentially unchanged throughout the course of the inquiry. The kurtosis and positive skewness (1.62 and 2.12) values indicate that output rose at the start of the study and stayed rather stable over the course of the investigation. The positive skewness requirement is supported by the measure of central tendency, which is mean > median > mode, suggesting that the data are asymmetrical.

The pulse crop yields in India and Madhya Pradesh have shown a slight improvement, increasing by two and ten times from 405.00 kg/ha and 408.00 kg/ha in 1950 to 892.00 kg/ha and 2993.00 kg/ha in 2020. This represents an annual yield growth of approximately 120% and 633% respectively. The mean pulses yield is 565.99 and 666.97 kg/ha, and the presence of Platykurtic distribution suggests a deliberate attempt to enhance the output of pulses per hectare. The positive skewness score (1.05 and 4.20) suggests a constant upward trend in pulse yields since the start of the investigation. According to the evaluation of pulses' area, production, and yield, there has been advancement in all aspects.

Trend Analysis

Using a parametric trend model, the entire performance path of the series movement was tracked to parametric trend. A range of parametric models such as linear, exponential, logarithmic, quadratic, cubic, compound, and growth models were employed to determine the trend in area output and yield in India and Madhya Pradesh. Based on the largest R^2 value, model significance, and coefficients, the model found to be most appropriate is picked from the set of competing models. The next section contains the results of these exercises (Tables 2, 3, 4).

Table 2: Trend analysis of area data series

AREA ('000 ha) India					
Model Summary and Parameter Estimates					
Equation	**Model summary**		**Parameter estimates**		
	R²	**Sig.**	**Constant (b)**	**b1**	**b2**
Linear	0.3080	0.000	21160	63.76	
Exponential	0.3032	0.000	0.000	0.0026	
Logarithmic	0.2301	0.000	19247	1281.8	
Quadratic	0.7321	0.000	19868	412.11	13.768
Cubic	0.7315	0.000	19662	464.74	16.918
Compound	0.3032	0.000	0.000	0.0026	
Growth	0.3032	0.000	0.000	0.0026	
AREA ('000 ha) Madhya Pradesh					
Model Summary and Parameter Estimates					
Equation	**Model summary**		**Parameter estimates**		
	R Square	**Sig.**	**Constant (b)**	**b1**	**b2**
Linear	0.5941	0.000	3484.5	29.545	
Exponential	0.6216	0.000	0.0000	0.0065	
Logarithmic	0.5627	0.000	2348.8	668.84	
Quadratic	0.6896	0.000	3144.5	35.122	2.6547
Cubic	0.6693	0.000	2748.1	136.08	3.3876
Compound	0.6216	0.000	0.000	0.0065	
Growth	0.6216	0.000	0.0000	0.0065	

Table 3: Trend analysis of production data series

PRODUCTION ('000' tons) India					
Model Summary and Parameter Estimates					
Equation	**Model summary**		**Parameter estimates**		
	R²	**Sig.**	**Constant (b)**	**b1**	**b2**
Linear	0.609	0.000	7787.300	157.760	
Exponential	0.662	0.000	0.000	0.011	
Logarithmic	0.363	0.000	4185.400	2832.000	
Quadratic	0.896	0.000	9695.400	91.177	91.170
Cubic	0.890	0.000	8621.900	364.600	364.600
Compound	0.662	0.000	0.000	0.011	
Growth	0.662	0.000	0.000	0.011	
PRODUCTION ('000' tons) Madhya Pradesh					
Model Summary and Parameter Estimates					
Equation	**Model summary**		**Parameter estimates**		
	R²	**Sig.**	**Constant (b)**	**b1**	**b2**
Linear	0.6849	0.000	592.500	63.321	
Exponential	0.7604	0.000	0.000	0.020	
Logarithmic	0.4305	0.000	955.990	1167.700	
Quadratic	0.8496	0.000	1416.700	18.158	4.101
Cubic	0.8412	0.000	908.950	111.170	3.639
Compound	0.7604	0.000	0.000	0.020	
Growth	0.7604	0.000	0.000	0.020	

Table 4: Trend analysis of productivity data series

YIELD (Kg/ha) India					
Model Summary and Parameter Estimates					
Equation	**Model summary**		**Parameter estimates**		
	R²	**Sig.**	**Constant (b)**	**b1**	**b2**
Linear	0.7175	0.000	392.81	4.6804	
Exponential	0.7354	0.000	0.0079	414.45	
Logarithmic	0.447	0.000	279.63	85.931	
Quadratic	0.8662	0.000	459.49	0.0882	0.107
Cubic	0.8646	0.000	443.3	4.2142	0.14
Compound	0.662	0.000	0.000	0.011	
Growth	0.662	0.000	0.000	0.011	
YIELD (Kg/ha) Madhya Pradesh					
Model Summary and Parameter Estimates					
Equation	**Model summary**		**Parameter estimates**		
	R²	**Sig.**	**Constant (b)**	**b1**	**b2**
Linear	0.3794	0.000	193.850	12.787	
Exponential	0.6746	0.000	0.000	0.016	
Logarithmic	0.2079	0.000	66.721	220.16	
Quadratic	0.5405	0.000	464.070	14.460	1.192
Cubic	0.5333	0.000	336.610	18.005	0.751
Compound	0.6746	0.000	0.000	0.016	
Growth	0.6746	0.000	0.000	0.016	

From the trend analysis that distinct quadratic trends can be seen in the area, yield and production of pulses in India but in Madhya Pradesh the trends are showed quadratic in area and production while in yield exponential, this suggested that in the recent past most likely series have reached maximum values and then either remained constant or decreased, which is cause for concern. As depicted in the figure area of pulses has been elevated during the year in India but in Madhya Pradesh after 2017 it starts declining throughout the year with some fluctuation. The impact of the expansion of region can be seen in the pulse production scenario, which has increased from 1978 to 2022 with some fluctuation 8572 thousand tonnes in 1978 to 14905 thousand tonnes in 2002, after that it start increasing throughout the year in India. However, in Madhya

Pradesh, pulses exhibited some variation from 1960 to 1998. Then, it began to rise from 1999 (3780.50 thousand tonnes) to 2018 (7812 thousand tonnes) with some variation, but after 2018, it began to decrease until 2020, at which point it began to rise once more throughout the year.

The pulses yield trend in India and Madhya Pradesh showed a modest increase, with trend yields of 377 kg/ha and 413 kg/ha in 1967, then a major fluctuation in trend was 635 kg/ha to 759 kg/ha in 2004, then start increasing from 2005 to 2022 with fluctuation in India, but in Madhya Pradesh the yield of pulse take a huge hype in 2018 and 2019 then start declining throughout the year. As a consequence of the research, it is obvious that changes in area, per hectare yield, management, and other practices have influenced the production process in question.

The positive nature of the *b*2 coefficient indicates that the area and yield of pulses in India and Madhya Pradesh have increased in recent years. Farmers' interest in pulses production is increasing, as shown by the rising trend. Throughout the study period, overall production in India and Madhya Pradesh increased, possibly due to the adoption of new technology such as hybrid crop, fertilizer usage, and so on. Table 5 indicates the best trend model equation of the data series.

Table 5: Trend model equation of the data series

India
Area
$y = 0.0004x^4 + 0.1075x^3 - 13.768x^2 + 412.11x + 19868$
$R^2 = 0.7321$
Production
$y = 0.0023x^4 - 0.1736x^3 + 2.3779x^2 + 91.177x + 9695.4$
$R^2 = 0.8957$
Productivity
$y = 3E{-}05x^4 - 0.003x^3 + 0.1071x^2 + 0.0882x + 459.49$
$R^2 = 0.8662$
Madhya Pradesh
Area
$y = 0.0009x^4 - 0.0971x^3 + 2.6547x^2 + 35.122x + 3144.5$
$R^2 = 0.6896$
Production
$y = 0.0011x^4 - 0.1168x^3 + 4.101x^2 - 18.158x + 1416.7$
$R^2 = 0.8496$
Productivity
$y = 331.4e^{0.016x}$
$R^2 = 0.4404$

SUSTAINABILITY ANALYSIS

Sustainability in productivities of pulses in India and Madhya Pradesh has been evaluated-based on sustainability indices as described in material and method section and has been displayed in Table 6. From the table, it is clearly depicted that the whole India and Madhya Pradesh is highly sustainable in yield of pulses in period III (2001-2022) as per indices given by SI-1 (Singh *et al.* 1990), SI-2 (Sahu *et al.* 2005) and SI-3 (Pal and Sahu, 2007) as measured by various formulas for accuracy, all of which produced the same result, clearly demonstrating that we can meet our own needs without compromising the ability of future generations.

Modelling and Forecasting

Our subsequent objective is to forecast the series for the upcoming year after evaluating the trend of each individual series. As mentioned in the material and technique section, we used the Box-Jenkins methodology for this. Data from 1950 to 2014 were used to build the model, while data from 2015 to 2022 were used to validate it. The models that best fit the data are used to predict future series. The ACF and PACF graphs from the original series clearly show that none of them are stable in nature, and first order differencing is sufficient to make them so. The analysis then estimates ARIMA equations for all parameters using the differenced series and data from 1950 to 2022. It then generates forecasts

Table 6: Sustainability pulses yield measurement

Sustainability Index	Period 1 (1950-1975)		Period 2 (1976-2000)		Period 3 (2001-2022)	
	India	Madhya Pradesh	India	Madhya Pradesh	India	Madhya Pradesh
SI 1	0.675138928	0.132869883	0.766771258	0.59506286	0.796170876	0.710267684
SI 2	0.250309225	1.858076695	0.166164696	0.355368391	0.139593292	0.227671209
SI 3	0.001432198	0.00095492	0.000972319	0.000297863	0.000851678	0.000197104

through 2030 using Gretl software. The models with the lowest RMSE, MAE, MAPE, AIC, and R^2 values are chosen as the best models among the competing models after testing. Nevertheless, ACF and PACF graphs are also used to perform diagnostic checks on residuals. The graph unequivocally shows that Madhya Pradesh and India's pulse acreage, yield, and output are predicted to rise in the next years. None of the production and yield data series are stationary in the pulses area. Therefore, all of the series become stationary—that is, have a constant mean and variance—by first differencing with the original data..

Fig. 1 displays the ACF and PACF plot of the first difference, or the area under pulses in Madhya Pradesh and India. It indicates that p = 1 and q = 5 for Madhya Pradesh and p = 1 and q = 4 for India would be a reasonable range for area under pulses. Consequently, it was demonstrated that the optimal ARIMA models for area under pulses in

Table 7: Different ARIMA Model for area, under pulses in India and Madhya Pradesh

ARIMA	R^2	RMSE	MAPE	MAE	AIC
			India		
ARIMA (1,1,2)	0.7055	1297.1000	4.3266	1024.6000	1246.6770
ARIMA (1,1,3)	0.7075	1294.2000	4.3040	1019.3000	1248.3580
ARIMA (1,1,4)	0.7104	1286.2000	4.2749	1009.9000	1249.5130
ARIMA (1,1,5)	0.7184	1267.5000	4.0915	965.2300	1249.6270
			Madhya Pradesh		
ARIMA (1,1,1)	0.75343	404.56000	5.68500	265.63000	1076.95800
ARIMA (1,1,2)	0.75312	404.52000	5.69060	266.09000	1078.94400
ARIMA (1,1,3)	0.77194	381.68000	5.43910	235.50000	1075.26100
ARIMA (1,1,4)	0.77407	380.03000	5.42200	253.07000	1075.11700
ARIMA (1,1,5)	0.77403	380.03100	5.42140	253.00000	1078.29200

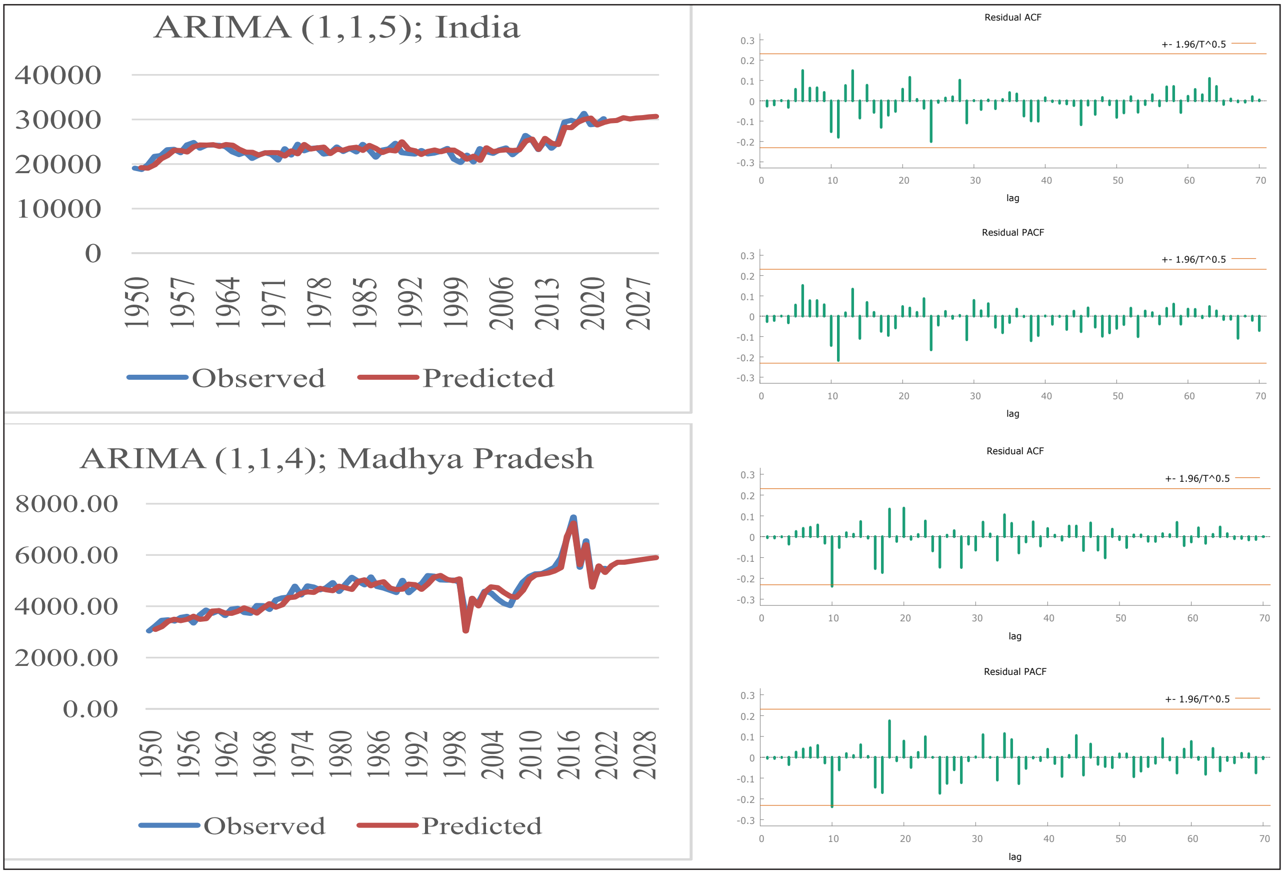

Fig. 1: (Observed-forecasting) and ACF-PACF plot of Area under pulses in India and Madhya Pradesh

Madhya Pradesh and India were ARIMA (1,1,5) and ARIMA (1,1,4). Additionally, Table 7 demonstrates that while Madhya Pradesh has the lowest RMSE value and greatest R^2 value, the ARIMA (1,1,5) and ARIMA (1,1,4) areas under pulses have the highest R^2 value and the lowest RMSE, MAPE, and MAE values in India.. So the best-fitting models in India and Madhya Pradesh is (1,1,5) and (1,1,4). In 2022-2023, the area of pulses in India and Madhya Pradesh was 30156 thousand hectares and 5478.01 thousand hectares, respectively, compared to 29314.33 thousand hectares and 5320.39 thousand hectares predicted. For the years 2030-2031, India is expected to have 30692.68 thousand hectares and Madhya Pradesh will have 5898.06 thousand hectares, respectively.

The autocorrelation (ACF) and partial autocorrelation (PACF) plots were generated for first difference, the value of production under pulses in India and Madhya Pradesh, is shown in Fig. 2, which suggests that the tentative value of p and q that would be suitable for area under pulses is p = 1 and q = 4

Table 8: Different ARIMA Model for Production under pulses in India and Madhya Pradesh

ARIMA	R^2	RMSE	MAPE	MAE	AIC
			India		
ARIMA (1,1,1)	0.8644	1589.5000	9.1268	1181.9000	1274.1480
ARIMA (1,1,2)	0.8754	1499.6000	9.0400	1149.3000	1268.9610
ARIMA (1,1,3)	0.8771	1490.4000	9.0947	1154.4000	1270.2890
ARIMA(1,1,4)	0.8779	1486.0000	9.0030	1142.9000	1272.0450
ARIMA (1,1,5)	0.8769	1503.4000	9.3483	1204.4000	1275.8555
			Madhya Pradesh		
ARIMA (1,1,1)	0.83433	655.69000	16.95800	411.25000	1146.52300
ARIMA (1,1,2)	0.83529	653.78000	16.92400	410.01000	1148.11500
ARIMA (1,1,3)	0.83975	646.92000	17.01400	408.03000	1148.68500
ARIMA(1,1,4)	0.83975	646.43000	17.06700	408.38000	1150.59000
ARIMA (1,1,5)	0.84075	644.12000	17.21500	407.44000	1152.16400

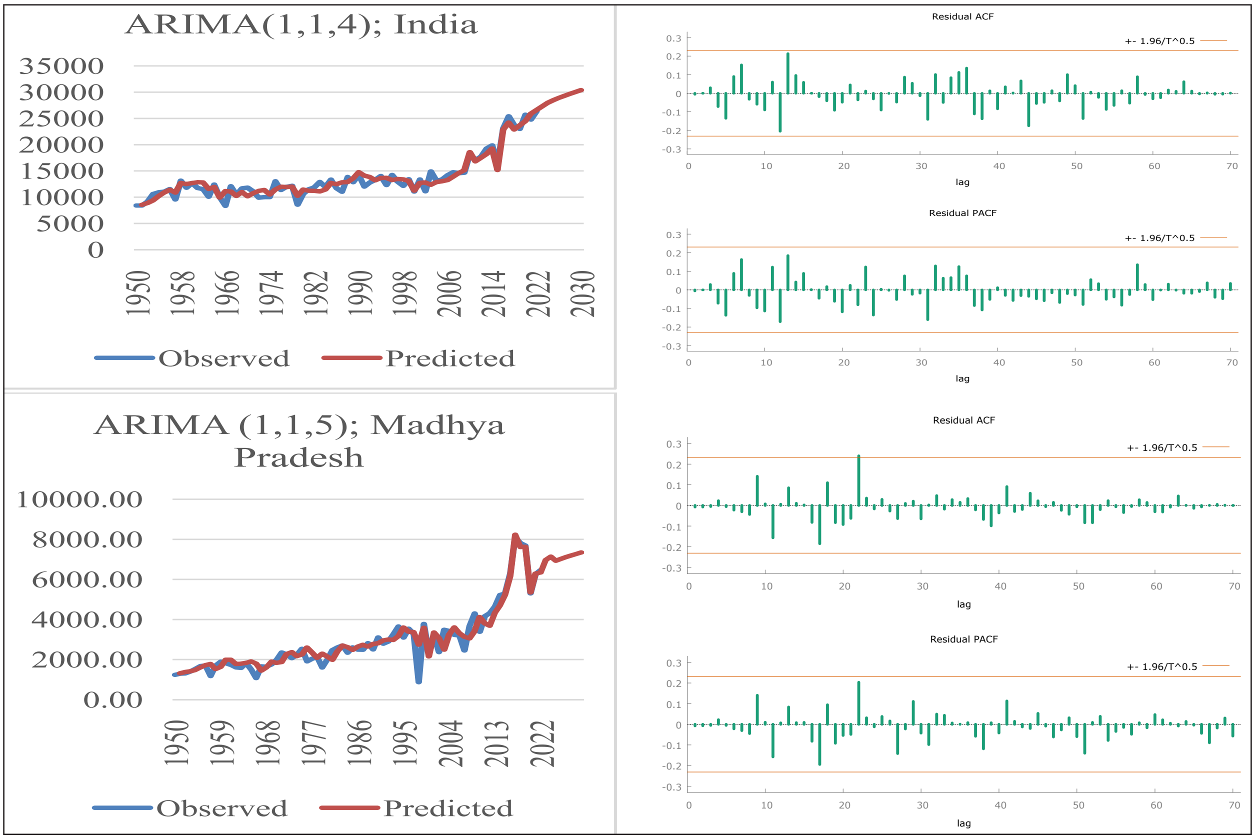

Fig. 2: (Observed-forecasting) and ACF-PACF plot of production under pulses in India and Madhya Pradesh

for India and $p = 1$ and $q = 5$ for Madhya Pradesh. Thus, the ARIMA model that found suitable for Production under pulses is ARIMA (1,1,4) and ARIMA (1,1,5). And, look at Table 8 reveal that the ARIMA (1,1,4) and ARIMA (1,1,5) production under pulses has highest R^2 value as well as lowest RMSE, MAPE, and MAE value in India but in Madhya Pradesh pulses has highest R^2 value as well as lowest RMSE and MAE value. So (1,1,4) and (1,1,5) is the best-fitting model in India and Madhya Pradesh. In 2022-2023, pulses production in India and Madhya Pradesh was 26325 thousand tones and 6458.77 thousand tones, respectively, compared to the expected 26606.01 thousand tones and 6345.50 thousand tones. India is expected to produce 30394.42 thousand tonnes in 2030-31, while Madhya Pradesh will produce 7344.50 thousand tonnes.

The autocorrelation (ACF) and partial autocorrelation (PACF) plots were generated for first difference, value of yield under pulses in India and Madhya Pradesh showed in Fig. 3 which suggest the possible value of p and q that would be suitable for yield

Table 9: Different ARIMA Model for Productivity under pulses in India and Madhya Pradesh

India					
ARIMA(0,1,0)	0.7392	60.2710	8.7600	48.3330	798.5621
ARIMA(0,1,1)	0.8274	48.8000	7.0118	38.0310	770.7304
ARIMA(0,1,2)	0.8287	48.5590	7.0532	38.2750	772.0606
ARIMA(0,1,3)	0.8294	48.4370	7.1479	38.6420	773.7479
Madhya Pradesh					
ARIMA(1,1,1)	0.570	289.490	13.948	110.780	1031.575
ARIMA(1,1,2)	0.707	238.390	15.597	116.880	1007.910
ARIMA(1,1,3)	0.729	228.990	16.199	121.000	1006.991
ARIMA(1,1,4)	0.731	228.660	15.915	119.810	1008.869
ARIMA(1,1,5)	0.744	224.140	16.190	120.100	1010.657

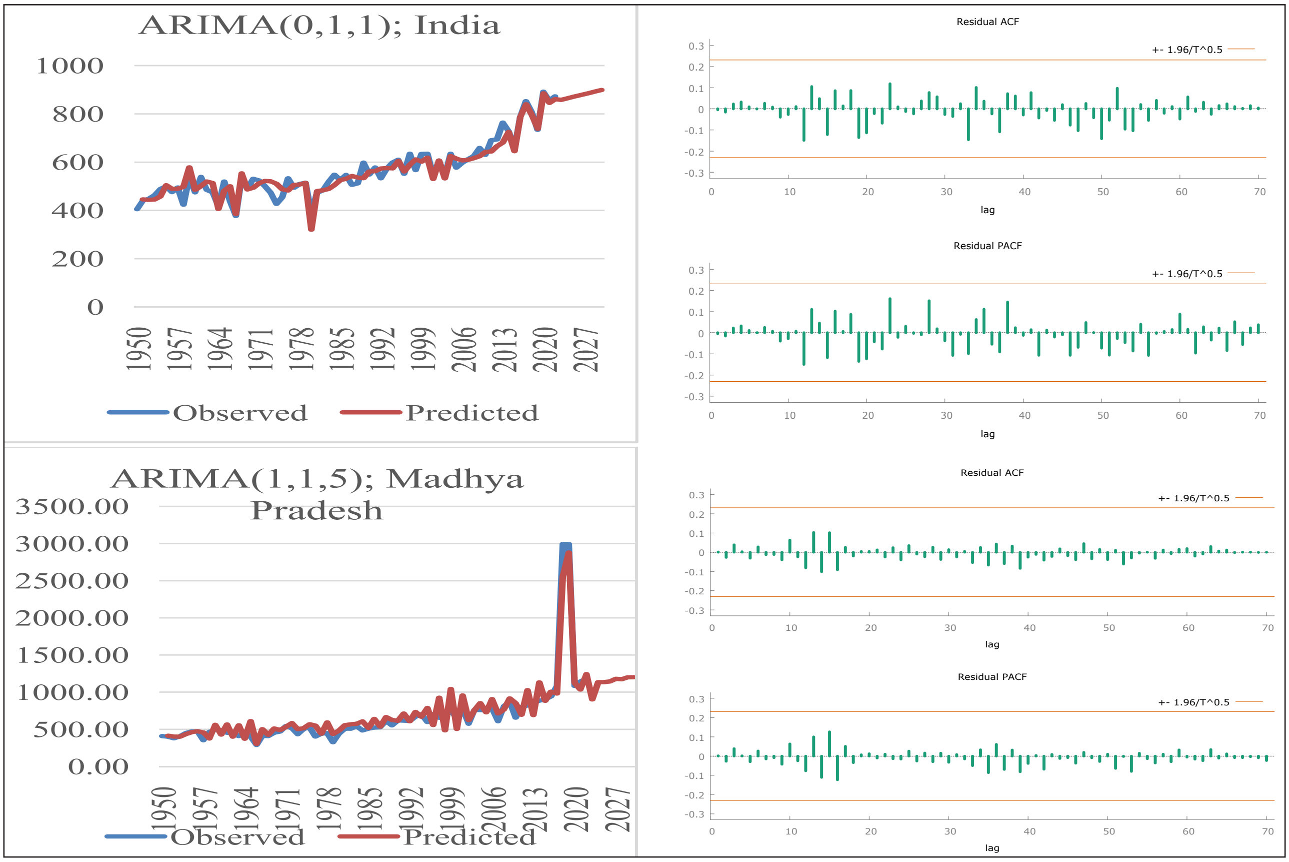

Fig. 3: (Observed-forecasting) and ACF-PACF plot of productivity under pulses in India and Madhya Pradesh

under pulses is p = 0 and q = 1 for India and p = 1 and q = 5 for Madhya Pradesh. Thus the ARIMA model that found suitable for yield under pulses in India and Madhya Pradesh is ARIMA (0,1,1) and ARIMA (1,1,5). And, the review of the Table 9 revealed that the ARIMA (0,1,1) and ARIMA (1,1,5) yield under pulses lowest MAPE, MAE and AIC value in India but in Madhya Pradesh maximum R^2 value and minimum RMSE value. As a result, ARIMA is the most appropriate model in India and Madhya Pradesh is (0,1,1) and (1,1,5). Pulses yields in 2022-2023 were 873 kg/ha and 1179.04 kg/ha, respectively, against the predicated 861.36 kg/ha and 1243.3 kg/ha. In India, 899.11 Kg/ha is expected in 2030-31, while in Madhya Pradesh, 1201.82 Kg/ha is expected.

CONCLUSION

The study utilized univariate time series data for the analysis. Each data series is described using a performance visualization. The central tendency and variability of the data are utilized to characterize the series. To investigate whether the time series data contained an inherent trend component, instability analysis was developed. The coefficient of variation around trend (CVt) is employed for sustainability analysis. In this work, the CVt values for various series are computed by utilizing the coefficient of determination obtained from the best fitted models and considering the nonlinearity in trend models. The primary goal is to assess the predicting skills of each series following the use of the Box-Jenkins technique to analyze its trend. The Autoregressive Integrated Moving Average (ARIMA) was implemented to construct a model, and the resulting model's output is utilized to predict the series for the upcoming year. The model's fitting performance was assessed through the highest R^2 value, lowest RMSE value, MAPE, MAE, and AIC. This research study has effectively highlighted the importance of time series analysis in agricultural commodities. The study would undoubtedly benefit farmers, politicians, and other stakeholders by providing them with dependable forecast data for Madhya Pradesh and India. Moreover, this research will contribute to the extensive and rapidly growing body of literature on the application of time series analysis in the field of agriculture.

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