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Trend Modelling and Forecasting of Mustard & Rapeseed in India Using Time Series Analysis

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ABSTRACT

Mustard & Rapeseed are among India's most important *rabi* oilseed crops, contributing substantially to domestic edible oil supply. This study analyzes long-term trends and forecasts area, production and yield of mustard and rapeseed in India using time-series data from 1950-51 to 2021-22. Compound growth rate, the Cuddy–Della Valle instability index and additive decomposition analysis were used to assess growth patterns and sources of change in production, while linear, logarithmic, quadratic and cubic trend models were compared using R^2, RMSE and MAPE to identify the best-fitting model for forecasting. The results show that compound growth rate was found highest for production (3.82% per year), followed by yield (2.09% per year) and area (1.69% per year), while decomposition analysis revealed that yield effect (59.45%) was the major contributor to the growth in production. On the basis of the cubic model, area is likely to decline from 6.41 to 5.74 million hectares, while production and yield are likely to increase from 9.75 to 11.43 million tonnes and from 1457.77 to 1673.62 kg/ha, respectively, during 2023-2032. These findings indicate that future growth in mustard and rapeseed production in India will depend largely on continued yield improvement through better varieties and farm management, rather than area expansion.

Keywords Mustard and rapeseed crop, Compound growth rate, Instability index, Decomposition analysis, Trend modelling, Forecasting.

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INTRODUCTION

Mustard & rapeseed (*Brassica* spp.) are vital oilseed crops in India, contributing significantly to the country's edible oil production and rural economy. Grown mainly during the *rabi* season, these crops are well-suited to India's semi-arid regions and play a key role in ensuring nutritional and economic security. India is the third-largest producer of rapeseed-mustard

in the world. Among all oilseed crops cultivated in the country rapeseed-mustard stands out covering an area of approximately 8.06 million hectares, with a total production of 11.75 million tons and an average yield of 1,458 kg per hectare (DES 2022).

Several researchers have studied related to time series analysis of mustard & rapeseed. An illustration Mahal *et al.* (2013) analyzed the growth and instability of oilseed production in Punjab based on secondary data from 1960-61 to 2009-10. Snehdeep *et al.* (2017) examined trend and growth rates of area, production and productivity of rapeseed and mustard pertaining to the period 1980-81 to 2010-11 in Uttar Pradesh. Kolar *et al.* (2020) investigated the growth and instability of major edible oilseeds production across major states in India using secondary time series data on area, production and productivity of soybean, rapeseed, mustard and groundnut from the period 1995-96 to 2017-18. Singh and Bansal (2020) examined the trends, variability and decomposition analysis of rapeseed and mustard crop in major growing states as well as in the India from 1992-93 to 2017-18. Kumar *et al.* (2022) evaluated the performance of rapeseed-mustard in India using time series data from 1967-68 to 2019-20. The total period was divided into periods I, II and III to analyze the trends, compound annual growth rate (CAGR), decomposition analysis, instability analysis and impact of technological change in production of rapeseed-mustard. Sharma *et al.* (2022) examined the growth rate and instability of rapeseed and mustard in Rajasthan using time series data on area, production and productivity separated into two decadal periods i.e. Period I (1997-98 to 2007-08), Period II (2008-09 to 2017-18), and Overall Period (1997-98 to 2017- 18). Yadav *et al.* (2023) analyzed seventy years of nutri-cereals data in India using multiple regression models. Among linear, logarithmic, quadratic, power and exponential forms, the cubic regression model emerged as best fit, with R^2 values of 0.969 for area and 0.870 for production. Forecasts indicated that by 2030, nutri-cereal area may reach 27.14 million hectares and production 62.09 million tonnes, confirming cubic regression as a high-accuracy tool for agricultural forecasting. Khan *et al.* (2024) analyzed instability in area, yield and production of oilseed crops in Pakistan using time series data spanning from 1971-72 to 2021-22. Pal *et al.* (2025) conducted a comprehensive analysis of maize production in Uttar Pradesh using time-series data from 1950-2022, and reported that the area effect was the dominant contributor to production changes, while the cubic model provided the most accurate fit for forecasting area, yield, and production. Kumar *et al.* (2025) analyzed *kharif* crop diversification in Chhattisgarh using 19 years of area data (2000-2019), and reported that rice and soybean areas expanded steadily, while small millets and urd declined, highlighting structural shifts in cropping patterns across the state. Some other significant work related to time series analysis of crops, other than mustard & rapeseed has been made by Kumar *et al.* (2024), Mishra *et al.* (2025), Mehta (2014), Monika *et al.* (2014), Pooja *et al.* (2023), Yadav *et al.* (2023) Singh and Kumar (2025), Sharma *et al.* (2013), Sharma *et al.* (2014) and Singh *et al.* (2025). Although several studies have examined growth and instability of mustard and rapeseed, limited work has integrated trend analysis with forecasting at the national level. Therefore, the present study analyzes long-term changes in area, production and yield of mustard and rapeseed in India and provides forecasts for future behavior.

MATERIALS AND METHODS

Source of data

In the present paper the secondary time series data on area (million hectare), production (million tonnes) and yield (kg / hectare) of mustard & rapeseed in India has been collected from the Ministry of Agriculture & Farmers Welfare, Government of India, specifically from the Directorate of Economics and Statistics and the "*Agricultural Statistics at a Glance* 2022" Agricultural-Statistics-at-a-Glance-2022.pdf. report covering data from 1950-51 to 2021-22.

Analytical framework

To examine the long-term performance, structural changes and temporal behavior of mustard and rapeseed production in India, a combination of growth analysis, instability analysis, decomposition analysis, trend modelling and forecasting techniques was used. The analytical procedures adopted in the study are described below.

Estimation of Growth Rates

Compound growth rates were estimated for area, production and yield to assess the growth pattern over the study period. The functional form used for estimation is given by :

$$Y_t = a\,(1 + r)^t$$

Where,

Y_t = value of the variable in year t

a = constant = Compound growth rate

t = time in years

Instability analysis

Instability in area, production and yield was measured using the Cuddy–Della Valle instability index, which adjusts the coefficient of variation for trend effects. The index is given as:

$$I = CV\sqrt{(1 - R^2)}$$

Where,

CV = coefficient of variation

R^2 = coefficient of determination from the time trend regression

Decomposition of output change

To identify the sources of change in production, an additive decomposition approach was used to separate the contribution of area effect, yield effect and their interaction. The total change in production (ΔP) is expressed as:

$$\Delta P = A_o\,(Y_n - Y_o) + Y_o\,(A_n - A_o) + \Delta A \Delta Y$$

Where,

A_o = base year area

Y_o = base year yield

A_n = current year area

Y_n = current year yield

ΔA and ΔY= change in area and yield respectively

Trend modelling

To study the long-term trend in area, production and yield of mustard and rapeseed, different trend models were fitted to the time-series data. The models used in the study are given below.

Linear model

$$Y_t = a + bt + \varepsilon$$

Quadratic model

$$Y_t = a + bt + ct^2 + \varepsilon$$

Cubic model

$$Y_t = a + bt + ct^2 + dt^3 + \varepsilon$$

Logarithmic model

$$Y_t = a + b\ln(t) + \varepsilon$$

Where,

Y_t = value of the variable (area, production or yield) in year t

T = time in years, a = Intercept

b, c, d = regression coefficients

ε = random error term

Model evaluation criteria

The performance of the fitted models was evaluated using the following statistical measures.

Coefficient of determination

$$R^2 = 1 - \frac{\Sigma\,(Y_i - \hat{Y}_t)^2}{\Sigma\,(Y_i - \bar{Y})^2}$$

Mean absolute percentage error

$$MAPE \frac{100}{n} \Sigma \left| \frac{Y_i - \hat{Y}_t}{Y_i} \right|$$

Root mean square error

$$RMSE = \sqrt{\frac{\Sigma (Y_i - \hat{Y}_t)^2}{n}}$$

Where,

Y_i = actual value

$\hat{Y}_t$ = estimated value

n = number of observations

These criteria were used to select the best-fitting model among the competing trend functions.

Forecasting

After selecting the best-fitting model based on the evaluation criteria, the model was used to generate forecasts of area, production and yield. Forecasting was carried out under the assumption that the historical trend pattern continues in the future.

RESULTS AND DISCUSSION

Growth, instability and decomposition analysis

Table 1 shows that the compound growth rate (CGR) was found highest for production (3.82% per year) followed by yield (2.09% per year) and area (1.69% per year). Production also showed the highest variability with a coefficient of variation of 71.07% and an instability index of 24.57%, indicating large fluctuations over time. In contrast yield and area recorded relatively lower instability indices of 13.51% and 14.39% respectively. Decomposition analysis further revealed that yield effect (59.45%) was the major contributor to the growth in production during the study period while area effect (20.54%) and interaction effect (20.01%) contributed relatively smaller shares.

Temporal trend analysis of area, production and yield

Fig. 1 shows the temporal trends in area, production and yield of rapeseed and mustard in India during 1951–2022. Area, production and yield increased over the study period with noticeable year-to-year fluctuations. The 5-years moving average smoothed these short-run variations and highlighted the long-term rising trend in all three variables. Since the smoothing was used only for visualization, the subsequent trend modelling was carried out using the original (unsmoothed) data series.

Trend model fitting and model comparison

To assess the long-term trends in area, production and yield four deterministic trend models linear, logarithmic, quadratic and cubic were fitted to the time-series data for the period 1951–2022. The performance of the models was evaluated using the coefficient of determination (R^2), root mean squared error (RMSE) and mean absolute percentage error (MAPE).

Trend model fitting for mustard and rapeseed area in India

Four deterministic trend models, namely linear, logarithmic, quadratic and cubic, were fitted to the area data for the period 1951–2022. The performance

Table 1. Growth, instability and decomposition analysis of rapeseed and mustard in India (1951–2022).

Variable	CGR (%)	Instability index		Decomposition		
		CV (%)	I	Area effect (%)	Interaction effect (%)	Yield effect (%)
Area	1.69	35.59	14.39	–	–	–
Production	3.82	71.07	24.57	20.54	59.45	20.01
Yield	**2.09**	**43.79**	**13.51**	–	–	–

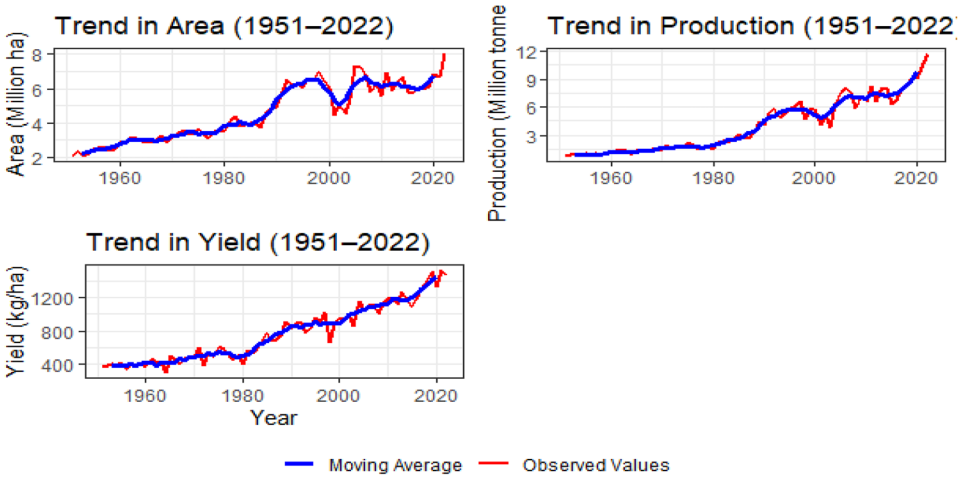

Fig. 1. Temporal trends in area, production and yield of rapeseed & mustard in India during 1951–2022 with 5-year moving average smoothing.

of the models was evaluated using R^2, RMSE and MAPE values.

As shown in Table 2 among the four models the cubic trend model provided the best fit for area as it showed the highest R^2 (0.8558) and the lowest RMSE (0.6203) and MAPE (9.77).

Estimated Cubic Trend Equation

The estimated cubic trend equation for area was obtained as:

$$\hat{Y}_{Area} = 235028.1 - 355.54t + 0.179t^2 - 0.000030\ 1t^3$$

Table 2. Goodness-of-fit statistics of trend models fitted to mustard & rapeseed area.

Model	R^2	RMSE	MAPE (%)
Linear	0.8346	0.6607	10.26
Logarithmic	0.8368	0.6599	10.29
Quadratic	0.8390	0.6555	10.85
Cubic	**0.8558**	**0.6203**	**9.77**

Table 4. Goodness-of-fit statistics of trend models fitted to mustard & rapeseed production.

Model	R^2	RMSE	MAPE (%)
Linear	0.8804	0.9850	35.0
Logarithmic	0.8785	0.9925	35.0
Quadratic	0.9225	0.7930	16.0
Cubic	**0.9239**	**0.7855**	**15.0**

Where $\hat{Y}_{Area}$ denotes area (million ha) in year t.

Forecasting of mustard & rapeseed area in India

On the basis of the best-fitted cubic model, future area was projected for the period 2023–2032. The forecasted values are shown in Table 3.

The forecasts indicate a marginal decline in area during the next decade, from 6.41 million ha in 2023 to 5.74 million ha in 2032. The observed and forecasted trends are presented in Fig. 2. The observed series fluctuated from year to year, whereas the forecasted series followed a smooth trend, indicating a gradual

Table 3. Forecasted mustard and rapeseed area in India (2023–2032).

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Forecasted Area	6.41	6.37	6.32	6.26	6.19	6.12	6.04	5.95	5.85	5.74

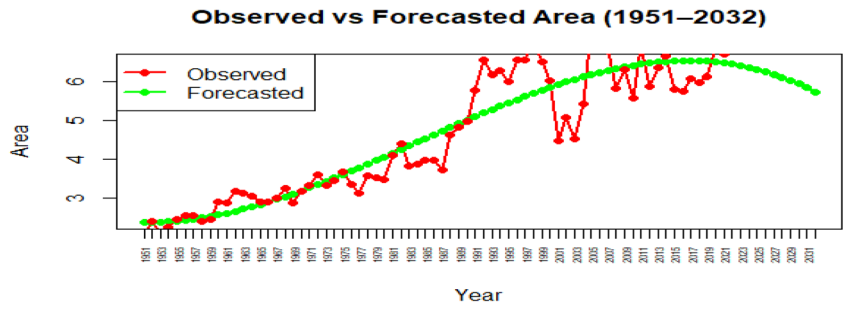

Fig. 2. Observed and forecasted mustard & rapeseed area during 1951–2032.

decline in area over time.

Trend model fitting for mustard and rapeseed production in India

Four deterministic trend models, namely linear, logarithmic, quadratic and cubic, were fitted to the production data for the period 1951–2022. The performance of the models was evaluated using R^2, RMSE and MAPE values.

As shown in Table 4, among the fitted models

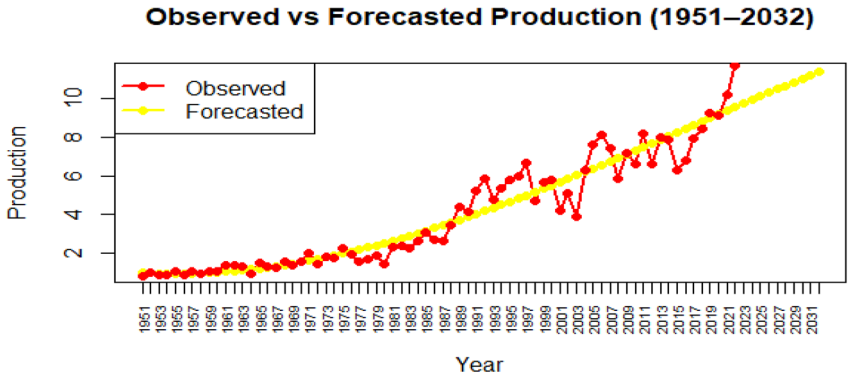

Fig. 3. Observed and forecasted mustard & rapeseed production during 1951–2032 using the cubic trend model.

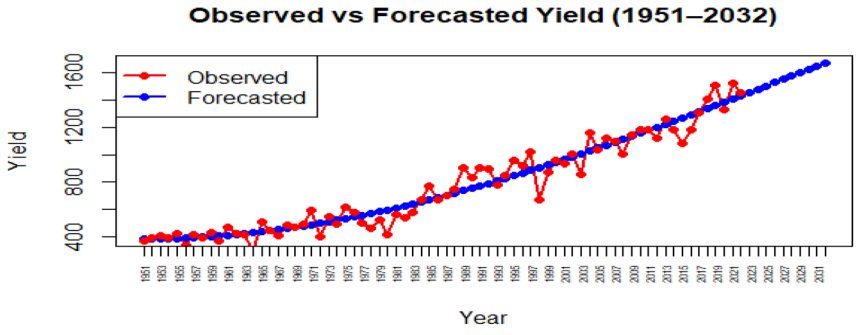

Fig. 4. Observed and forecasted mustard yield (kg/ha) during 1951–2032.

Table 5. Forecasted mustard and rapeseed production in India (2023–2032).

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Forecasted Production	9.75	9.94	10.13	10.32	10.50	10.69	10.88	11.06	11.25	11.43

Table 6. Goodness-of-fit statistics of trend models fitted to mustard & rapeseed yield.

Model	R^2	RMSE	MAPE (%)
Linear	0.9049	103.76	13.40
Logarithmic	0.9031	104.71	13.53
Quadratic	0.9327	80.50	9.11
Cubic	**0.9434**	**80.02**	**8.87**

the cubic model provided the best fit for production with the highest R^2 (0.9239) and the lowest RMSE (0.7855) and MAPE (15.36).

Estimated cubic trend equation for production

$$\hat{Y}_{Production} = 1.269\times10^{5} - 188.9t + 0.0937t^{2} - 1.546\times10^{-5}\, t^{3}$$

Where, $\hat{Y}_{Production}$ denotes production (million tonnes) in year t.

Forecasting of mustard & rapeseed production in India

Based on the best-fitted cubic model, production was forecasted for the period 2023–2032. The results are presented in Table 5.

The forecasts show a continued increase in mustard production over the next decade rising from 9.75 million tonnes in 2023 to 11.43 million tonnes in 2032. The observed and forecasted trends are depicted in Fig. 3. The observed production values exhibited yearly fluctuations whereas the forecasted values followed a smooth increasing cubic trend. The projections indicate a continued rise in production over the forecast horizon.

Trend model fitting for mustard & rapeseed yield in India

Similar to area and production, four deterministic trend models were fitted to the yield data for the period 1951–2022. The adequacy of each model was evaluated based on R^2, RMSE and MAPE values.

As shown in Table 6, the cubic model provided the best fit for yield as it recorded the highest R^2 (0.9434) along with the lowest RMSE (80.02) and MAPE (8.87) among the four models.

Estimated cubic trend equation for yield

The estimated cubic trend equation for yield was obtained as:

$$\hat{Y}_{Yield} = 1.036\times10^{7} - 15340t + 7.562t^{2} - 1.241\times10^{-3}\, t^{3}$$

Where, $\hat{Y}_{Yield}$ denotes yield in year t.

Forecasting of mustard & rapeseed yield in India

Based on the best-fitted cubic model yield was forecasted for the period 2023–2032 and the values are presented in Table 7.

The forecasts indicate a steady increase in mustard yield from 1457.77 kg/ha in 2023 to 1673.62 kg/ha in 2032. The observed and forecasted trends

Table 7. Forecasted mustard and rapeseed yield in India (2023–2032).

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Forecasted Yield	1457.77	1481.59	1505.46	1529.38	1553.35	1577.36	1601.40	1625.46	1649.54	1673.62

are depicted in Fig. 4. The observed yield values exhibited short-run fluctuations, while the forecasted values followed a smooth upward cubic trend. The projections suggest a continued improvement in yield over the forecast horizon.

DISCUSSION

The results show that in India the production and yield of mustard and rapeseed have increased over time while the area under cultivation has decreased. This means that farmers are now growing the crop on less land but getting higher output due to better yield. The instability analysis shows that yield changed more from year to year than area which indicates that yield is more affected by weather and farming practices. The decomposition results confirmed that most of the improvement in production came from higher yield while the role of area was very small or negative. Among the fitted models, the cubic model gave better accuracy based on fit statistics. The forecasting results also show that yield and production will continue to increase in future years while the cultivated area may continue to decline.

CONCLUSION

This study concludes that the increase in mustard and rapeseed production in India is mainly due to improvements in yield even though the area under cultivation has decreased. Future production growth is also expected to come from better yield rather than expanding the cultivated land. Therefore, better varieties, improved farming practices and good management will be important for sustaining production in the coming years.

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Contributions

Amit Kumar Yadav: Conceptualization, investigation, methodology, data analysis, writing original draft, editing, and visualization.

Vishal Mehta: Supervision, review and editing.

Abhishek Pal: Data collection, data preprocessing.

Sandeep Kumar: Technical support, validation of results and manuscript review.

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