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Tracking the turning point: an econometric lens on oilseed growth, decomposition and instability in india

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ABSTRACT

India's oilseed sector holds a strategic position in the country's agricultural and economic framework, not only as a source of edible oil but also as a provider of employment and industrial raw materials. Despite being one of the leading producers globally, India continues to depend heavily on imports to meet its edible oil demand. This study analyzes the performance of nine major oilseed crops—castor, groundnut, linseed, nigerseed, rapeseed-mustard, safflower, sesamum, soybean, and sunflower—over the period 2010–11 to 2024–25, with a focus on growth trends, production drivers, and instability patterns. Using statistical techniques such as Compound Annual Growth Rate (CAGR), Minhas decomposition, and the Cuddy-Della Valle instability index, we dissected changes in output into area, yield, and interaction effects, while measuring variability in area, production, and yield across crops. The results reveal that most production growth in recent years has been driven by yield improvements rather than expansion in cultivated area. Crops like linseed and sunflower showed strong gains in yield despite a contraction in area, whereas groundnut and castor expanded in acreage with limited yield progress. High instability was observed in crops such as safflower, sunflower, and soybean, while mustard and castor remained relatively stable. These insights highlight the growing importance of technological advancement, varietal improvement, and sustainable agronomic practices. The study calls for crop-specific policy interventions, especially for unstable and neglected oilseeds. Strengthening research, improving market access, and promoting rainfed resilience will be critical in reducing import dependency and achieving long-term oilseed self-sufficiency in India.

Keywords: *Oilseeds, CAGR, Decomposition Analysis, Cuddy-Della Valle Index, Instability.*

Introduction

Oilseeds play a pivotal role in shaping India's agricultural economy by contributing not just to edible oil production; but also supporting livestock feed, employment generation, and industrial applications. India is among the top global producers of oilseeds, cultivating a wide range of crops including groundnut, soybean, mustard, sunflower, sesame, linseed, safflower, castor, and nigerseed. These crops together occupy nearly 15% of the country's gross cropped area and are predominantly grown under rainfed conditions. As a result, their performance is highly susceptible to climatic risks, policy interventions, and market fluctuations (Jha et al., 2012; Himani & Kumari, 2024).

Despite its prominent global standing, India continues to depend heavily on imported edible oils to meet domestic demand. Over 60% of the country's consumption is currently fulfilled through imports—a situation that has raised significant concerns about food security and economic vulnerability. The reasons behind this include stagnant yield levels, uneven regional adoption of improved practices, and inadequate crop diversification (Teja et al., 2017; Kumari & Singh, 2020). In response, the government has launched several policy initiatives, such as the National Mission on Oilseeds and Oil Palm (NMOOP) and the National Food Security Mission—Oilseeds (NFSM-Oilseeds), aimed at boosting domestic production through better seed distribution, agronomic practices, and extension services (Govindaraj et al., 2016; Akhtar & Kumawat, 2022). However, the impact of these efforts has been uneven across crops and regions. Many oilseeds still show signs of erratic growth and instability in production, leading to unpredictable income for farmers. Understanding the nature and source of these fluctuations is therefore crucial. While the Compound Annual Growth Rate (CAGR) is commonly used to track long-term trends, it does not reveal the individual contributions of acreage and productivity. To fill this gap, decomposition analysis—particularly the area-yield-interaction method developed by Minhas, Vaidyanathan, and Sinha (1974)—offers a more detailed view of what drives growth.

Equally important is the assessment of production stability. Year-to-year changes in area, yield, and output not only reflect weather conditions and market shifts but also determine the resilience of the crop sector. The Cuddy-Della Valle instability index (1978) is widely accepted in agricultural research for quantifying such variability while adjusting for underlying

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trends (Dhekale et al., 2020; Yadav & Singh, 2018). Given this context, the present study focuses on analyzing the growth dynamics and production stability of major oilseed crops in India from 2010–11 to 2024–25. By using a combination of CAGR estimates, decomposition techniques, and instability analysis, the research aims to identify crop-specific trends and provide evidence-based insights to inform future policy decisions aimed at improving India's edible oil self-reliance. The present study aims to undertake a comprehensive evaluation of the performance of major oilseed crops in India during the period 2010–11 to 2024–25, using a multi-dimensional approach. Specifically, the study analyzes:

(i) the growth patterns of area, production, and yield using CAGR;

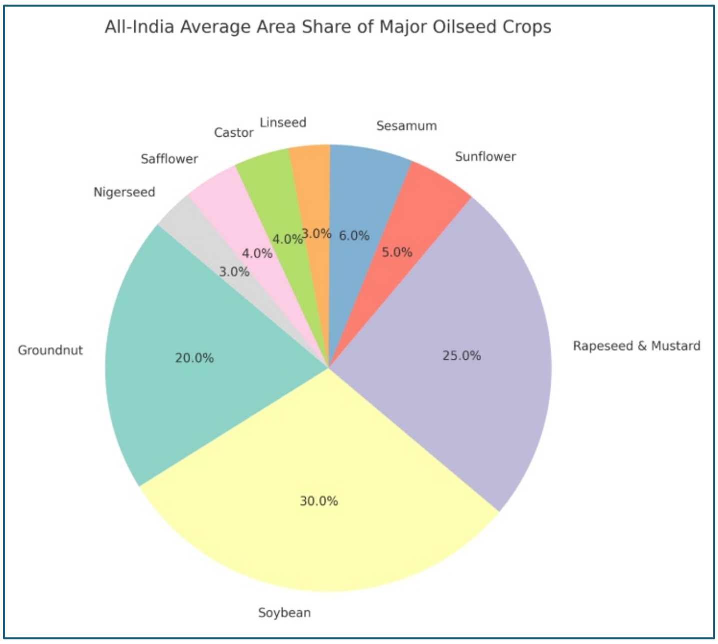
(ii) decomposes production growth into area, yield, and interaction effects; and

(iii) Assesses the temporal instability of key performance indicators using the Cuddy-Della Valle index. Such an integrated analysis is critical to formulating evidence-based policies that ensure sustainable and resilient oilseed production in the face of growing domestic demand and external uncertainties.

Methodology

- **Data Source**

The study is based on secondary data pertaining to the area (in '000 hectares), production (in '000 tonnes), and yield (kg/hectare) of nine major oilseed crops in India—groundnut, rapeseed-mustard, soybean, sunflower, sesamum, castor, linseed, nigerseed, and safflower—for the period 2010–11 to 2024–25. The data were obtained from official publications of the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers' Welfare, Government of India, and supplemented by relevant research publications and reports.



Source: Directorate of Oilseeds Development, Ministry of Agriculture & Farmers Welfare, Government of India

Analytical Tools and Techniques

Compound Annual Growth Rate (CAGR)

To assess the growth performance of area, production, and yield for each crop, the Compound Annual Growth Rate (CAGR) was computed using the formula:

$CAGR = ((Y_t / Y_0)^{(1/n)}) - 1$

Where:

- Y_0 = Value in the base year (2010–11)
- Y_t = Value in the terminal year (2024–25)
- n = Number of years

Decomposition Analysis

To determine the contribution of area, yield, and their interaction to output growth, the following additive identity was used:

$\Delta P = A_0 \cdot \Delta Y + Y_0 \cdot \Delta A + \Delta A \cdot \Delta Y$

Where:

- ΔP = Change in production
- ΔA = Change in area
- ΔY = Change in yield
- A_0 = Area in the base year
- Y_0 = Yield in the base year

Instability Analysis

To quantify variability in oilseed area, production, and yield, the Cuddy-Della Valle Instability Index (CDVI) was employed:

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

Where:

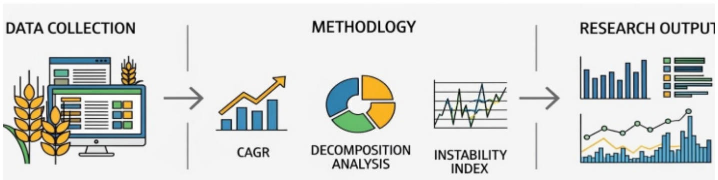
- CV = Coefficient of variation (%)
- R^2 = Coefficient of determination from linear trend regression

Statistical Tools

All calculations were carried out using Microsoft Excel 365 and R statistical software for linear regression, CAGR, decomposition tabulations, and plotting. Visual tools like scatterplots and trend lines were employed to support the interpretation of patterns.

Period of Study

The analysis covers a 15-year period from 2010–11 to 2024–25 to provide a contemporary view of oilseed dynamics in the post-reform agricultural scenario.



Results and Discussions

Trends in Area, Production, and Yield of Oilseeds (CAGR Analysis)

Table 1: Compound Annual Growth Rates (CAGR) of Area, Production, and Yield of Major Oilseed Crops in India (2010–11 to 2024–25)

Crop	Area	Production	Yield
Castor	-0.004	0.011	0.015
Groundnut	-0.005	0.021	0.027
Linseed	-0.042	-0.014	0.030
Nigerseed	-0.125	-0.127	-0.001
Rapeseed and Mustard	0.016	0.031	0.014
Safflower	-0.085	-0.074	0.012
Sesamum	-0.043	-0.047	-0.004
Soyabean	0.020	0.012	-0.008
Sunflower	-0.120	-0.094	0.029
Total Oilseeds	0.005	0.017	0.011

An analysis of the Compound Annual Growth Rate (CAGR) for area, production, and yield across major oilseed crops in India from 2010–11 to 2024–25 provides critical insights into the sector's structural evolution.

Area Trends

The area under oilseed cultivation exhibited only a marginal increase, with the total CAGR at just 0.005%, reflecting a stagnating expansion trend. Notably, rapeseed-mustard (0.016%) and soybean (0.020%) emerged as exceptions, showing a slow yet positive growth in acreage. This likely points to their relative suitability under current agronomic and market conditions. In contrast, a marked decline was observed in nigerseed (-0.125%), sunflower (-0.120%), and safflower (-0.085%), indicating a withdrawal of farmer interest. These reductions may stem from poor economic returns, policy neglect, or increasing climatic risks. Even linseed (-0.042%), despite targeted promotion in states like Chhattisgarh, saw a decline in area—likely due to lack of technological support or profitability, as also reported by Chanchal et al. (2024).

Production Trends

Production figures reflected a modest but positive trend, with an aggregate CAGR of 0.017% for total oilseeds. The strongest gains were recorded in rapeseed-mustard (0.031%) and groundnut (0.021%), which may be attributed to improved varieties, better extension services, or favorable pricing. However, production saw substantial negative growth in nigerseed (-0.127%), sunflower (-0.094%), and safflower (-0.074%), suggesting systemic production issues and declining commercial importance. Linseed (-0.014%) also showed negative growth, despite recording productivity improvements—highlighting that area shrinkage outweighed any yield progress, consistent with findings by Rambabu et al. (2014).

Yield Trends

On the productivity front, the most encouraging results were seen in linseed (0.030%), sunflower (0.029%), and groundnut (0.027%), suggesting the successful adoption of improved varieties and farming techniques in specific regions. The overall yield growth for oilseeds was recorded at 0.011%, reflecting the increasing importance of productivity as the main driver of output growth. This observation is in line with earlier findings by Krishna Teja et al. (2017), who highlighted that post-liberalization agricultural policies, including programs like the Technology Mission on Oilseeds (TMO) and the All India Coordinated Research Project (AICRP) on Oilseeds, have led to significant yield-oriented interventions. Their decomposition results indicated that over 58% of growth during 2000–2015 was yield-driven.

However, some oilseed crops—namely soybean (-0.008%), sesamum (-0.004%), and nigerseed (-0.001%)—registered stagnant or declining yield growth. These results suggest persistent challenges, such as a lack of research attention, low varietal replacement, and inadequate adaptation to changing climate conditions. These findings resonate with national trends and studies by Jha et al. (2012), who emphasized the marginalization of traditional oilseeds and the limited reach of modern technologies in rainfed regions.

Interestingly, both soybean and rapeseed-mustard seem to have maintained relatively stable trajectories across all three dimensions—area, production, and yield. This stability likely stems from favorable market conditions, minimum support prices, and wider availability of improved input packages. International agencies like FAO (2014) and Solvent Extractors' Association of India (SEAI, 2016) have also recognized these two crops as vital contributors to India's edible oil security.

Overall, the CAGR analysis reaffirms a shifting paradigm in oilseed production—from area-led expansion to yield-driven intensification. While this reflects improved technological adoption in certain crops, it also raises concerns over declining area and productivity in others, particularly those cultivated in resource-constrained and rainfed ecosystems.

Decomposition Analysis of Oilseed Production in India (2010–11 to 2024–25)

Table 2: Decomposition of Oilseed Production Growth into Acreage, Yield, and Interaction Effects (2010–11 to 2024–25)

Crop	Acerage effect	Yield effect	Interaction effect
Castor	141983.19	-33515.97	-8389.92
Groundnut	131884.96	-21308.60	-10359.82
Linseed	-289764.29	249171.43	138021.43
Nigerseed	2368.09	99031.91	-2048.94
Rapeseed and Mustard	41899.98	46879.95	11274.93
Safflower	-28190.29	107825.24	20796.12
Sesamum	10027.57	94999.56	-4871.77
Soyabean	-63312.10	184871.70	-22011.85
Sunflower	-69490.67	110296.23	59317.66
Total Oilseeds	66046.04	28643.94	5354.23

To understand the structural drivers behind changes in oilseed production over the period 2010–11 to 2024–25, we applied the Minhas decomposition framework, which disaggregates overall production growth into three components: area expansion, yield improvement, and their interaction. The findings revealed notable differences among crops in terms of what factors contributed most significantly to their production gains.

At the aggregate level, the growth in total oilseed production was primarily attributed to improvements in yield, which contributed approximately 28,643.94 tonnes. In contrast, the area effect added about 66,046.04 hectares, and the interaction effect—indicating synergy between area and yield—contributed 5,354.23 tonnes. These figures suggest that productivity gains have become the principal engine of output growth, a trend that aligns with observations made by Krishna Teja et al. (2017), who noted a shift from area-led to yield-driven growth following economic liberalization.

Among individual crops, linseed was a standout case. It experienced a significant contraction in area (- -289,764.29 ha), likely due to market disincentives or its reduced appeal under current cropping systems. Despite this, yield gains were substantial (+249,171.43 t), complemented by a strong positive interaction effect (+138,021.43 t). This points toward the successful introduction of better agronomic practices or superior varieties that helped boost production even with less land under cultivation. A comparable pattern emerged in sunflowers, where area shrank considerably, but technological interventions and improved practices resulted in strong positive yield and interaction effects.

In contrast, crops such as castor and groundnut expanded significantly in area (+141,983.19 ha and +131,884.96 ha, respectively) but reported declines in yield (-33,515.97 t and -21,308.60 t) and negative interaction effects. This imbalance suggests that while more land was brought under cultivation, productivity did not keep pace—perhaps due to the stagnation of varieties, insufficient technological adoption, or increased exposure to climatic risks. This mirrors findings by Swain (2007), who observed similar area-driven growth patterns in Rajasthan with limited yield improvement.

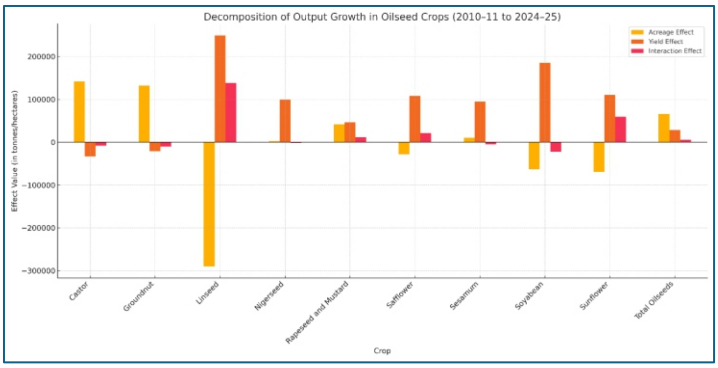
The decomposition results for soybean also revealed important trends. Although the crop saw a reduction in cultivated area (-63,312.10 ha), yield gains were robust (+184,871.70 t), indicating a favorable response to improved technology.

However, the negative interaction effect (-22,011.85 t) implies that the benefits from yield improvements were not fully realized in conjunction with area shifts—likely due to uneven regional uptake or policy inconsistencies.

Rapeseed and mustard presented a relatively balanced growth pattern, with positive contributions from area (+41,899.98 ha), yield (+46,879.95 t), and interaction (+11,274.93 t). This reflects a more sustainable and stable production trajectory, possibly supported by better market infrastructure, higher oil extraction rates, and strong policy backing under programs like NFSM-Oilseeds, as emphasized by Govindaraj et al. (2016).

Lesser-grown oilseeds such as nigerseed and sesamum contributed modestly through yield improvements (+99,031.91 t and +94,999.56 t, respectively). These crops hold relevance in traditional and niche farming systems but continue to lack widespread commercial support or geographic scalability, resulting in minimal contributions from area or interaction effects.

Taken together, the decomposition analysis underscores the increasing centrality of yield improvements in India's oilseed sector. The declining trend in cultivated area for crops like linseed, sunflower, and soybean points to a structural transformation in farmer decision-making—often driven by profitability concerns, risk perceptions, and access to better market opportunities. Therefore, future gains in oilseed production are more likely to come from targeted research, climate-resilient technologies, and optimized input use rather than expansion in land under cultivation (Chanchal et al., 2024).



Instability analysis:

The instability analysis of oilseed crops during 2010–11 to 2024–25 revealed considerable inter-crop variability, reflecting the influence of both biophysical and policy factors on oilseed cultivation in India.

Castor showed moderate fluctuations in area (16.94%) and production (16.57%), while yield instability remained low (4.25%). This pattern is indicative of consistent varietal performance and improved adoption of hybrid technology in Gujarat and Rajasthan, as noted by Choudhary et al. (2016). Groundnut experienced low area instability (9.00%) but higher variation in yield (12.60%) and production (15.03%). The crop's sensitivity to rainfall—particularly under rainfed conditions in states like Gujarat and Andhra Pradesh—has been identified as a key cause of instability by Rajeshwaran and Ramasamy (2007). Linseed recorded high instability in area (26.43%), with moderate fluctuations in yield and production (15.42% each). According to Singh et al. (2015), this is due to declining economic viability, limited market support, and poor varietal response to changing climates. Nigerseed presented moderate instability in area (9.29%) and production (11.17%), while yield variation was low (6.55%). Its cultivation remains limited to tribal belts, with minimal technological interventions, leading to low yield fluctuations despite modest shifts in area (Kumar et al., 2014). Rapeseed and mustard showed stable yield (6.40%) but moderate area (11.40%) and production (12.01%) instability. This aligns with efforts under NFSM-Oilseeds that have supported yield improvements, as supported by Meena and Meena (2014). Safflower displayed the highest instability in area (55.85%) and production (33.06%), with farmers increasingly shifting away from the crop due to lower profitability and lack of processing incentives, as highlighted by Deshmukh et al. (2017). Sesamum showed moderate instability in area (14.30%) and relatively stable yield (8.42%). The crop's dependence on monsoonal patterns, coupled with poor mechanization, has contributed to these moderate levels of variability (Yadav & Meena, 2015). Soybean, a widely cultivated kharif crop, had moderate area instability (13.20%) and high production instability (25.08%), driven largely by erratic rainfall and pest outbreaks in central India (Dwivedi & Dubey, 2015). Sunflower showed high instability in both area (23.23%) and production (25.11%), though yield instability was modest (9.52%). These trends indicate declining farmer preference and policy neglect, as previously observed by Singh and Sharma (2012).

At the aggregate level, total oilseeds showed low instability in area (5.38%) and yield (6.28%), with moderate production instability (9.06%). This is consistent with Minhas et al. (1974), who explained that inter-crop diversification and geographic spread help absorb individual crop shocks and contribute to relative output stability.

Table 3: Instability Analysis of Area, Production, and Yield of Major Oilseed Crops in India (2010–11 to 2024–25)

	Castor			Groundnut			Linseed			Nigerseed			Rapeseed and Mustard		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Mean	988.87	1715.60	1745.60	5151.80	8622.33	1673.33	253.13	138.93	565.67	203.07	62.73	311.13	6924.27	9296.20	1329.20
SD	190.80	285.09	150.40	463.48	1871.72	343.38	66.91	25.04	86.23	105.16	31.33	20.81	1187.53	2357.00	151.31
Coefficient of var (%)	19.29	16.62	8.62	9.00	21.71	20.52	26.43	18.03	15.24	51.78	49.94	6.69	17.15	25.35	11.38
R2	0.23	0.01	0.76	0.00	0.52	0.62	0.66	0.16	0.82	0.97	0.95	0.04	0.56	0.78	0.68
Instability Index	16.94	16.57	4.25	8.99	15.03	12.60	15.42	16.51	6.38	9.29	11.17	6.55	11.40	12.01	6.40
	Safflower			Sesamum			Soyabean			Sunflower			Total Oilseeds		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Mean	123.67	77.47	653.87	1655.47	754.73	457.00	11597.47	12518.87	1085.40	436.27	333.93	833.87	27333.87	33520.33	1222.40
SD	69.07	39.02	119.95	236.73	111.54	44.85	1146.88	1772.15	162.47	255.80	157.31	168.39	1862.03	4864.33	114.59
Coefficient of var (%)	55.85	50.37	18.35	14.30	14.78	9.81	9.89	14.16	14.97	58.63	47.11	20.19	6.81	14.51	9.37
R2	0.75	0.57	0.41	0.59	0.14	0.26	0.75	0.13	0.08	0.84	0.72	0.78	0.38	0.61	0.55
Instability Index	27.90	33.06	14.09	9.13	13.74	8.42	4.91	13.20	14.39	23.23	25.11	9.52	5.38	9.06	6.28

This study comprehensively analyzed the performance of major oilseed crops in India from 2010–11 to 2024–25, using a suite of statistical tools including Compound Annual Growth Rate (CAGR), Minhas decomposition, and Cuddy-Della Valle instability indices. The findings revealed that while the overall production of oilseeds has increased modestly, this growth has been primarily driven by improvements in yield rather than expansion in area. Notably, crops like linseed, sunflower, and soybean showed significant positive yield effects, suggesting the role of technological improvements, better varieties, and agronomic practices. However, negative area effects for these crops indicate declining sown areas, likely due to profitability concerns or changing farmer preferences.

Instability analysis showed that safflower, sunflower, and soybean experienced high variability in area and production, underscoring the need for policy and institutional support. In contrast, crops like rapeseed-mustard and castor demonstrated relative stability, indicating the positive influence of targeted schemes such as NFSM-Oilseeds and the effectiveness of improved varieties in those segments. The CAGR results supported these trends, with mustard and soybean showing favorable growth in both area and production, while crops such as nigerseed and safflower recorded declines, pointing to structural challenges, market neglect, and possibly climatic unsuitability. These observations highlight a dual challenge: intensifying productivity in key crops while reversing the decline in others through integrated support.

Author Contribution Statement:

The study was conceptualized by Author 1 and Author 2, who also designed the research framework and methodology. Authors 3 and 4 contributed to data collection, compilation, and preliminary organization of the dataset. Statistical analysis, interpretation of results, and visualization were performed by Author 1. The original manuscript draft was prepared by Author 1, while Author 2, Author 5, and Author 6 provided critical review, refinement, and editing of the manuscript. Overall supervision and guidance were offered by Author 6. All authors reviewed and approved the final version of the manuscript prior to submission.

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