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Instability Analysis and Decomposition of Output of Major Oilseeds Crops in Rajasthan and India

Himani [a++*], Vikram Yogi [a#] and Vandana Kumari [a†]

[a] Department of Agricultural Economics, S.K. Rajasthan Agricultural University Bikaner-334006, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study deals with analysis of instability of area production and productivity of major oilseeds in Rajasthan and India. It also includes calculation of sources of growth of production over the period of study. Area effect, yield effect and interaction effect for crop production were calculated.
Place and Duration: The time series data of thirty years, 1990-91 to 2019-20, was analyzed. The data were further divided into Three decades, period I(1990-91 to 1999-2000), period II (2000-01 to 2009-10) and period III (2010-11 to 2019-20). Area production and productivity of major oilseed crops (*Rapeseed-mustard*, *groundnut* and *soybean*) for all three decade in Rajasthan and India were analyzed.
Methodology: This paper deals with the analysis of instability in area production and productivity of major oilseed crops in Rajasthan and India. The Cuddy Della Vella Index has been used for instability analysis. It also includes the decomposition analysis to determine factors that were

[++] *MSc Research Scholar;*
[#] *Assistant Professor;*
[†] *PhD Research Scholar;*
**Corresponding author: E-mail: 1661.himanisain@gmail.com;*

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responsible for the change in production of the crops. The additive decomposition method has been used to determine area, yield and interaction effect.

Results: Calculations revealed that the magnitude of instability in Rajasthan during period II (2000-01 to 2009-10) remained high for all the selected crops. There was instability of 32.49 percent and 34.40 percent for area and production, respectively, while 13.34 percent of variation was found in productivity. In Rajasthan, the lowest instability was observed during period III (2010-11 to 2019-20) with variation of 7.44 percent, 9.47 percent and 6.62 percent for area production and productivity of *groundnut*. In India, the highest instability was during period II. The area of *Rapeseed-mustard* has shown the highest (17.72%) instability compared to the instability of the area of other crops. Variation of production and productivity of *groundnut* was recorded at 24.79 and 21.88 percent, respectively, which is highest among the selected crops. The decomposition analysis revealed that the area effect was a major source for the growth of production of oilseed in Rajasthan as compared to the yield effect and interaction effect. During period I (1990-91 to 1999-2000), the area effect for *rapeseed mustard*, *groundnut* and *soybean* was 68.08, 87.97 and 91.35 percent. In India, both area and yield effect have a major contribution to the growth of production. During period I, the yield effect (57.50 %) was responsible for growth of *rapeseed-mustard* production, while *groundnut* and *soybean* had a high contribution of area effect with magnitudes of 70.86 percent and 84 percent. Area effects for *groundnut* and *soybean* were 118.44 percent and 58.06 percent during period II, respectively. Area effect (42.90%) and yield effect (45.76%) were equally responsible for the growth of *rapeseed-mustard*. During period III, the yield effect for *rapeseed-mustard* and *soybean* was 101.34 percent and 257.7 percent, respectively, while the area effect (52.29 %) was responsible for growth in *groundnut* production.

Conclusion: It has been found that *groundnut* was the most stable crop in term of area production and productivity. The major source for the growth of production was area effect and Yield effect while interaction effect has least impact on production of crops.

Keywords: Cuddy della vella index; instability; area effect; yield effect; interaction effect.

1. INTRODUCTION

India produces a variety of crops belonging to cereals, pulses, oilseeds and cash crops. Oilseeds are among the major crops that are grown in the country apart from cereals [1]. In India, oilseed was cultivated on 29.17 Mha of land with a production of 37.70 Mt for the year 2021–22. Rajasthan is among the leading oilseed producing states in the country, having 5.79 Mha of land under oilseed cultivation, which is around 20 percent of the total area under oilseed cultivation. The total oilseed production in Rajasthan was recorded at 8.39 Mt during 2021–22, which is 22.50 percent of all India oilseed production. *Rapeseed-mustard* (3.37 Mha), *groundnut* (0.80 Mha) and *soybean* (1.16 Mha) are the major oilseed crops that are cultivated in Rajasthan [2].

Oilseed crops play a crucial role in global agriculture and economics due to their widespread use and versatility. The edible oil industry is one of the most important industries of the agriculture sector in India. India is one of the major oilseeds growing countries. The oilseed production in India has steadily increased since 2016-17 onward after showing a fluctuating trend prior to that. The oilseed production in India has grown by almost 43 percent from 2015-16 to 2020-21 [3]. India is the world's second largest consumer and number one importer of vegetable oil. As urbanization increases in developing countries, dietary habits and traditional meal patterns are expected to shift towards processed foods that have a high content of vegetable oil. Vegetable oil consumption in India is, therefore, expected to remain high due to high population growth and consequent urbanization. The oil production in India has, however, lagged behind its consumption necessitating the import of edible oils [4].

The self-sufficiency in oilseeds attained through the "Yellow Revolution" during the early 1990s could not be sustained beyond a short period. There is a spurt in vegetable oil consumption in recent years in respect of both edible as well as industrial usages. The demand-supply gap in the edible oils has necessitated huge imports, accounting for 60 percent of the country's requirement [5]. The demand for oilseeds, edible oils and oilcake meals has been growing rapidly in the country, accelerated with the sustained growth in per capita income, increasing population and urbanization [6]. India's total

edible oil imports rose from 13.13 Mt in 2020-21 to 14.03 Mt in the 2021-22 oil year (Nov-Oct) and increased further by 30.9% from 2.36 Mt in Nov-Dec 2021 to 3.08 Mt in Nov-Dec 2022. [7]. Vegetable oils worth US $billion 9.52 in 2019 were imported in 2019-20, which rose to the value of US $18.70 billion in 2021–22 [8].

Although India has the largest cultivated area under oilseed in the world, the current consumption level of crucial nutrients such as oil and fats is below the minimum nutrition requirement. The growth in oilseed output has lagged far behind the growth in demand, forcing the government to resort to large-scale imports of edible oil to bridge the gap. Considering the sizeable drain on foreign exchange caused by edible oil imports to meet domestic requirements, the effort achieving self-sufficiency assumed importance. Towards achieving self-efficiency in oilseed, the government has set up a technology mission on oilseed [9]. As a result of concerted efforts of the technology mission on all seeds, there has been a phenomenal increase in the oilseed production during the past few years. However, as a high percentage of the cultivated area under oil seed in the country still depends on rainfall, the oil seed production fluctuates from year to year. In light of the nation's high dependency on edible oil imports, research pertaining to oilseed production in India is crucial. Being a largely rainfed crop, oilseed production is plagued with high instability. An analysis of fluctuation in crop output apart from growth has major importance to determine the instability among the oilseed production and factors that are responsible for the change in output of the crop. Variability helps in the allocation of resources by finding the factors responsible for yield instability for more targeted interventions. Analyzing instability can lead to the adoption of more sustainable farming practices and enable farmers to adapt to climate change impacts and changing market conditions. An attempt to find the range of instability will be beneficial for policymaking with respect to oilseed production in the country. The instability data can be used by policymakers to formulate strategies that support farmers, enhance food security and stabilize the market. The study provides great importance in various aspects of output production or food security aspects as well. It can look into various context for the policy maker as oilseeds are the second most important of protein source. Moreover, oilseeds are also the major source of the alternative source of protein. Thus, it is vital to understand the current scenario of the area, production and productivity of oilseeds and what are the various factors which are affecting the output and how those factors affecting can be addressed and what measures could be taken to improve the output would help the policy makers to make a policy on the issues. This article consists of an analysis of sources of oilseed growth and changing patterns of area production and productivity of oilseeds in different periods from 1990-91 to 2019-20.

2. MATERIALS AND METHODS

The present study is completely based on secondary data and time series data of area production and yield of major oilseed crops for the period of thirty years from 1990-91 to 2019-20. The period of the study was divided into three sub-periods, *i.e*. (1990-91 to 1999-00), (2000-01 to 2009-10) and (2010-11 to 2019-20). The data were analyzed for all three periods. The present study was confined to the three major oilseeds, *rapeseed-mustard*, *groundnut* and *soybean*. Crops were selected purposively due to their higher contribution to overall oilseed production. The secondary time series data for the last thirty years on area, production and yield of oilseeds were collected from various issues of the Directorate of Agriculture, Agriculture, Farmers Welfare & Co-operation Department, Government of Rajasthan and other official sources.

2.1 Cuddy Della Vella Index

Instability is the deviation from trend. In various literature, researchers have applied the coefficient of variation (CV%) as a measure of instability. Instability indices were worked out to examine the extent of instability in area, production and yield of oilseed crops. Only CV does not explain the suitable trend component inherent in the time series data; hence, the instability index was computed applying the measure of variability suggested by Cuddy-Della Valle index. The formula for computation is given as under:

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computed applying measure of variability suggested by Cuddy- Della Vella Index The formula for computation is given as under [10].

$$\text{Cuddy-Della Vella Index} = CV^*\sqrt{1 - R^2}$$

Where, CV is the coefficient of variation and R^2 is the coefficient of determination from a time series trend regression adjusted by the number of degrees of freedom.

The present study divides the CDVI value into three categories, which represent the different ranges of instability. The ranges of instability are as follows:

Low instability = between 0 to 15
Median instability = greater than 15 and lower than 30
High instability = greater than 30

2.2 Decomposition Analysis

To measure the relative contribution of area and yield to the total output change for individual crop, the component analysis model has been used [11].

The model is given as follows:

$P_o = A_o \times Y_o$ and
$P_n = A_n \times Y_n$ (1)

A_o, P_o and Y_o are area, production and productivity in base year and A_n, P_n and Y_n are values of the respective variable in n th year item respectively.

Where, A_o and A_n = Area

Y_o and Y_n = Yield in the base year and nth year respectively.

$P_n - P_o = \Delta P$
$A_n - A_o = \Delta A$
$Y_n - Y_o = \Delta Y$ (2)

For equation (1) and (2) we can write

$$P_o + \Delta P = (A_o + \Delta A)(Y_o + \Delta Y)$$

Hence

$$P=[(Y_0\Delta A)/\Delta P]*100 + [(A_0\Delta Y)/\Delta P]*100+[(\Delta A\Delta Y)/\Delta P*100]$$

Production = Area effect + yield effect + Interaction effect

3. RESULTS AND DISCUSSION

3.1 Instability Analysis

Oilseed cultivation in India is predominantly dependent on rainfall and this leads to a higher magnitude of instability in the production of oilseeds. It has become an issue of major concern as the fluctuation adversely affects the income of farmers. For the estimation of internal annual fluctuation in area, production and productivity of oilseed crops in Rajasthan and India the instability index was used. To determine the instability among area production and productivity time series data of 30 years, i.e., 1990-91 to 2019-20, has been analyzed.

3.1.1 Instability analysis of major oilseeds crops in Rajasthan

Variation in the area production and productivity of major oilseed crops produced in Rajasthan is illustrated in Table 1.

3.1.1.1 Period I (1990-91 to 1999-00)

During this first decade of the study, the CDVI result depicted that low instability was recorded for *rapeseed-mustard*. The instability index for area production and productivity was recorded at 10.14, 13.94 and 11.65 percent, respectively. In the case of *groundnut* productivity, it has shown medium instability of 16.58 percent. In the case of *soybean* medium instability was recorded. The instability index for production was 24.39 percent, while area and productivity were almost equally unstable, with instability of 16.91 percent and 16.17 percent. Sogra (2018) estimated similar results for instability analysis of major oilseed production in Rajasthan [12].

3.1.1.2 Period II (2000-01 to 2009-10)

During this period, a low to high range of variation in *rapeseed-mustard* cultivation was observed. Area and production have shown high instability of 32.49 percent and 34.49 percent, respectively. The productivity of *rapeseed-mustard* reflected low instability with a variation of 13.34 percent. A low to medium range of instability was observed in the case of *groundnut*. Production and productivity have resulted in medium instability of 29.74 percent and 25.58 percent, respectively. *Soybean* shows a medium range of instability. Fluctuations in productivity were found to be highest with a variation of 27.85 percent, followed by production (25.17%) and area (19.31%). These results coincide with the magnitude of instability reported Laxminarayan

(2018) in Madhya Pradesh for the period of 1985-86 to 2015-16 [13].

3.1.1.3 Period III (2010-11 to 2019-2020)

Rapeseed-mustard reported a trend of low instability during the period. The lowest instability was found in the productivity of *rapeseed-mustard* with a variation of 10.02 percent, followed by production (12.20%) and area (12.06%). The instability of *groundnut* also remained low for the period. Among all three parameters, production of *groundnut* has shown the highest (9.47%) instability. A similar trend of variability for area was found in a study conducted by Nayak et al. [14]. The range of instability remains low to high for *soybean*, with the moderate fluctuation of 20.50 percent and 25.30 percent for production and productivity, while the instability index for area was 14.29 percent.

3.1.2 Instability analysis of major oilseeds crops in India

There has been a wide range of variability in area production and productivity of major oilseed crops cultivated in India. The instability index for the crops is shown in Table 2.

3.1.2.1 Period I (1990-91 to 1999-00)

Area of *rapeseed-mustard* shows the lowest instability of 5.62 percent. Variation of production and productivity was found at 10.80 percent and 12.05 percent. *Groundnut* has also shown a trend of low instability with index values of 2.50 percent, 14.09 percent and 14.57 percent for area production and productivity. Area production and productivity of *soybean* reflected a low range of instability with the fluctuation of 5.99 percent, 9.90 percent and 6.75 percent. Similar results were reported by Kumar *et al*. (2019), stating instability of 4.31 percent, 15.55 percent and 11.99 percent for area production and productivity in the period of 1996-97 to 2000-01 [15].

3.1.2.2 Period II (2000-01 to 2009-10)

In terms of area and production, *rapeseed-mustard* remained moderately unstable with variations of 17.72 percent and 21.99 percent, while productivity was found to be more stable with variations of 8.71 percent and this can be confirmed with reported instability of 8.6 percent by Kalia et al. [16]. *Groundnut* cultivation has shown a low to medium range of instability, production has shown highest fluctuation of 24.78 percent, followed by productivity (21.88%) and area (6.92%) over the period. Fluctuation of only 3.39 percent was recorded for the area under *soybean* cultivation. Production and productivity also reported low instability, with fluctuations of 12.98 percent and 14.29 percent. Similar results have been reported by Kumari for instability in major oilseed production in India [17].

During this period, all three crops remain low to moderately unstable. *Rapeseed-mustard* was most stable, with the lowest instability of area (7.20%), production (9.70%) and productivity (7.76%) among all the crops. In terms of area of *groundnut* and *soybean*, it shows low instability

Table 1. Instability in area, production and productivity of major oilseeds crops produced in Rajasthan from 1990-91 to 2019-20

1990-91 to 1999-00			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area (%)	10.14	13.56	16.91
Production (%)	13.94	13.56	24.39
Productivity (%)	11.65	16.58	16.17
2000-01 to 2009-10			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area (%)	32.49	11.34	19.31
Production (%)	34.40	29.74	25.17
Productivity (%)	13.34	25.58	27.85
2010-11 to 2019-2020			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area (%)	12.06	7.44	14.29
Production (%)	12.20	9.47	20.50
Productivity (%)	10.02	6.62	25.30

Source: computed

with 8.31 percent and 7.53 percent. These results are in line with instability calculated by Ramoliya et al. [18]. The instability index for production and productivity of *groundnut* was found to be 19.80 percent and 16.92 percent, while for *soybean* it was 16.40 percent and 16.57 percent. These findings are in line with findings of a study conducted by Jainuddin *et al*. for the instability of major oilseed crops in India during 2010-11 to 2019-20 [19].

3.2 Decomposition Analysis

The growth analysis helps to determine the increase in the production of crops, while it does not explain the factor that is responsible for the change in production. To find the sources that are affecting the growth of output, the change in production was analyzed based on area, yield and interaction effect. With the help of this additive decomposition model, the relative contribution of area, productivity and their interaction on oilseed production in Rajasthan and India has been estimated.

3.2.1 Decomposition of output of major oilseeds crops produced in Rajasthan

The contribution of area yield and interaction effect on major oilseed crop produced in Rajasthan is presented in Table 3.

Table 2. Instability in area, production and productivity of major oilseeds crops produced in India from 1990-91 to 2019-20

1990-91 to 1999-00			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area (%)	5.62	2.50	5.99
Production (%)	10.80	14.09	9.90
Productivity (%)	12.05	14.57	6.75
2000-01 to 2009-10			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area (%)	17.72	6.92	3.39
Production (%)	21.99	24.79	12.98
Productivity (%)	8.71	21.88	14.29
2010-11 to 2019-20			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area (%)	7.20	8.31	7.53
Production (%)	9.74	19.80	16.40
Productivity (%)	7.76	16.92	16.57

Source: computed

Table 3. Contribution of area, yield and their interaction effect on production output of major oilseeds crops produced in Rajasthan from 1990-91 to 2019-20

1990-91 to 1999-00			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area effect (%)	68.08	87.97	91.35
Yield effect (%)	24.48	9.88	2.09
Interaction effect (%)	7.43	2.15	6.56
2000-01 to 2009-10			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area effect (%)	48.45	69.98	73.38
Yield effect (%)	32.66	17.29	29.39
Interaction effect (%)	18.89	12.74	-2.76
2010-11 to 2019-20			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area effect (%)	56.52	80.50	-90.23
Yield effect (%)	35	9.22	129.08
Interaction effect (%)	8.48	10.28	61.15

Source: computed

Table 4. Contribution of area, yield and interaction effect on production output of major oilseeds crops produced in India from 1990-91 to 2019-20

1990-91 to 1999-00			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area effect (%)	40.01	70.86	84
Yield effect (%)	57.50	39.95	5.82
Interaction effect (%)	2.49	-10.82	10.18
2000-01 to 2009-10			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area effect (%)	42.90	118.44	58.06
Yield effect (%)	45.76	-22.12	27.67
Interaction effect (%)	11.34	12.74	14.27
2010-11 to 2019-20			
	Rapeseed-mustard	***Groundnut***	***Soybean***
Area effect (%)	-1.19	52.29	-227.24
Yield effect (%)	101.34	32.63	257.7
Interaction effect (%)	-0.15	15.08	69.54

Source: computed

3.2.1.1 Period I (1990-91 to 1999-00)

Table 4 reveals that area effect has a major contribution in the change of oilseed production of *rapeseed-mustard, groundnut* and *soybean*, being 68.08 percent, 87.97 percent and 91.35 percent. There has been the least impact of the interaction effect on the change in production of *rapeseed-mustard* (7.43%) and *groundnut* (9.88%), while in the case of *soybean*, there was a 6.56 percent contribution of interaction for the change in production, which is similar to results reported by Paliwal (2011) for the decomposition of the output of *soybean* in Rajasthan [20].

3.2.1.2 Period II (2000-01 to 2009-10)

There has been major impact of area effect for rapeseed- mustard, groundnut and *soybean* contributing 48.45 percent 69.98 percent and 73.38 per cent change in production. Yield effect (13.66%) and interaction effect (18.89%) also have positive effect on the growth of rapeseed mustard production. Yield effect for *soybean* has been reported 29.39 per cent while interaction effect remain negative. These results are in line with conclusions given by More et al. [21].

3.2.1.3 Period III (2010-11 to 2019-20)

Area effect has the highest contribution among all the factors that were responsible for the growth of Production of *rapeseed-mustard* and groundnut. It was recorded 56.52 percent for *rapeseed-mustard* and 80.50 percent *groundnut*, while area effect was found negative for *soybean* (-90.23%). The prominent change in production of *soybean* was due to a yield effect of 129.08 percent and a contribution of the interaction effect which was 61.15 percent. These results coincide with the results reported by Hedge [22].

3.2.2 Decomposition of output of major oilseeds crops produced in India

The source of growth of output of major oilseed crops produced in India is demonstrated in Table 4.

3.2.2.1 Period I (1990-91 to 1999-00)

Decomposition analysis reveals that area effect was the main factor responsible for the growth of *groundnut* (70.86%) and *soybean* (84%). Similar results were presented by Agarwal et al. [23] for the decomposition output of *soybean* production in Madhya Pradesh [23]. Whereas the yield effect (57.50%) was the highest contributing factor for the change in the production of *rapeseed-mustard*, followed by the area effect (40.01%) and interaction effect (2.49%).

3.2.2.2 Period II (2000-01 to 2009-10)

The major source of growth of *groundnut* and *soybean* in India was the area effect, which was 118.44 percent and 58.06 percent, respectively. In the case of *rapeseed-mustard*, both the area effect (45.76%) and the yield effect (45.76%) were almost equally responsible for the growth in production, which can be comparable with the 40.12 percent area effect and 52.17 percent yield effect contribution for total oilseed production reported by Joseph [24]. Expansion in the area of *soybean* was the major factor driving the change in production, showing an area effect of 58.06 percent. These results can be supported by similar results of the study conducted by Tewari et al. [25].

3.2.2.3 Period III (2010-11 to 2019-20)

Area and yield effect were reported negative (1.19 and -0.15 %) for the growth of *rapeseed-mustard* production. The growth in production of *groundnut* was mainly due to the area effect (52.29%), followed by yield (32.63%) and interaction effect (15.08%). There has been a major contribution of yield effect for growth of *rapeseed-mustard* and *soybean* in India, which was 101.34 percent and 257.7 percent. A positive interaction effect of 69.54 percent was also recorded in the growth of *soybean.* These results are in line with Kumar *et al*, who claimed area, yield and interaction effect were the major sources of growth of *soybean* in Madhya Pradesh [26].

4. CONCLUSION

The oilseed sector has been an important area of concern and intervention for Indian policymakers in the post-reforms period when India became one of the largest importers of edible oils in the world, importing about half of the domestic requirement in the 1990s. CDVI index results revealed that in Rajasthan, *rapeseed-mustard* shows low instability during periods I and III, while during periods, instability ranges from medium to high. There was a range of low to medium instability of *groundnut* for all the periods. Whereas *soybean* recorded medium instability for every period. Analysis for instability

of crops in India reveals that for period I all the crops show low stability. Low instability was recorded for *soybean* during period II and for *rapeseed-mustard* during period III. Decomposition of output reveals that the major factor responsible for the growth of production was the area effect for periods I and II, but during period III, the yield effect has a prominent impact on *soybean* production. In India, the area effect was found positive for periods I and II, while it negatively affected the production of *rapeseed-mustard* and *groundnut* during period III.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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