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Research Article

Performance and Instability of Oilseed Crops in Pakistan

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Abstract: This comprehensive study spanning from 1971-72 to 2021-22 consistently discerned distinct patterns of variability and instability within Pakistan's oilseed crops. Analyzing instability in the cultivation area, yield, and production of oilseed crops is crucial for effective planning and strategy formulation. The study encompasses the analysis of nine oilseed crops, namely cotton, rapeseed-mustard (including canola), sesame, groundnut, sunflower, castor seed, linseed, soybean, and safflower. The Coefficient of Variation (CV) and the Cuddy-Della Valle Instability Index (CDVI) were employed to assess fluctuations and instability in the cultivation area, production, and yield of these crops. The findings highlighted that cotton exhibited a high degree of instability in production and yield, while rapeseed-mustard (including canola) consistently displayed a high degree of production volatility, underscoring the critical need for a sustainable and steady supply of these commodities. Sesame output revealed frequent instability, demanding prompt and effective mitigation actions. Groundnut production consistently demonstrated mild inconsistency, emphasizing the need for vigilant monitoring to ensure supply stability. Sunflower cultivation faced substantial insecurity, necessitating comprehensive stabilization techniques. Soybean production continually grappled with significant insecurity across all factors, emphasizing the importance of robust risk management. Safflower production consistently posed challenges due to extreme instability, requiring ongoing solutions. Linseed regularly manifested moderate instability, indicating room for improvement with better management. Castor seed production showed considerable volatility in cultivation area and production but low yield instability, underscoring the significance of targeted stability solutions. Addressing insecurity in Pakistan's oilseed crop sectors is crucial for food security, requiring proactive measures like improved forecasting, resource allocation, and informed policy-making for long-term stability.

Keywords: Oilseed Crops, Coefficient of Variation, Cuddy-Della Valle Instability Index, Food Security, Pakistan

1. INTRODUCTION

Oilseed crops have served as the foundation of numerous agricultural economies since ancient times, playing a significant role in global agricultural industries and trade [1]. Internationally, oilseeds are celebrated for being a plentiful source of food, feed, energy, and employment. The by-products derived from oilseeds not only contribute to livestock nutrition but also function as valuable fertilizers for crop production. Poor productivity of oilseed crops can be attributed to several major factors, including a lack of technologies, cultivation in conditions with insufficient inputs, and the need to address both biotic and abiotic stresses [2]. Pakistan produced its own edible oil entirely up to the 1950s. As the demand for edible oils increased, imports were introduced to supplement the native supply. As a result, imports became a considerable component of consumption by the middle of the 1970s, accounting for 41% of it in the years 1974–1975 [3]. Local production in Pakistan encompasses eight oil-bearing seed crops, which can be categorized into traditional crops (cottonseed, rapeseed-mustard, groundnut, sesame, and linseed) and non-traditional crops (sunflower, safflower, and soybean). Among these, cotton, rapeseed-mustard, sunflower, and canola stand out as the primary contributors [4]. During the Green Revolution, non-traditional oilseed crops

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such as sunflower, soybean, and safflower were introduced. However, the area under cultivation for these oilseed crops is still quite small. Because of the steady increase in edible oil consumption, the oilseed sector has grown significantly in importance in Pakistan's economy [5]. Palm oil, the primary imported edible oil, significantly influences edible oil and ghee prices in Pakistan. Sunflower, canola, cotton, and rapeseed-mustard constitute the major oilseed crops in the country [6]. Pakistan's domestic demand for edible oils has predominantly relied on imports, with a substantial proportion of the nation's edible oil requirements being met through foreign sources. Only 20% of the total domestic edible oil consumption is satisfied by local production. The primary oilseed crops cultivated within Pakistan comprise cottonseed, sunflower, canola, and soybean. Historically, cottonseed, rapeseed-mustard, and sunflower have stood out as the primary oilseed crops in the country [7].

The oilseed crops play a crucial role in Pakistan's economy by meeting more than 17% of the domestic demand for edible oil. Additionally, significant biodiesel crops such as rapeseed and mustard, soybean, sunflower, and safflower are cultivated [8, 9]. Despite its fertile land, an efficient canal system, and an economy deeply rooted in agriculture, Pakistan continues to heavily rely on imported edible oil due to insufficient domestic oilseed production [10]. Pakistan is the eighth-largest consumer and fourth largest importer of edible oil in the world. Rapid urbanization and the fast-food industry have tripled per capita consumption from 6 kg to 24 kg per annum [11]. Pakistan imported 2.754 million tons of edible oil with a total value of Rs 662.657 billion in 2022; while the estimated overall availability of edible oil in the country for this period stands at 3.214 million tones [12]. Hybrid varieties have the capacity to produce yields ranging from 3500 to 3900 kg per hectare, representing a significant increase, potentially two to three times the typical yield [13]. The widespread use of advanced technologies, such as high yielding varieties and stress-resistant crops, along with expanded irrigation and crop insurance, has successfully stabilized oilseed crop production and productivity [14].

Pakistan's reliance on imported edible oils underscores the critical need for a coordinated effort to boost domestic oilseed production, increase yields through hybrid types, and encourage the cultivation of unconventional oilseed crops. The study aims to achieve the following objectives: (i) To assess the Coefficient of Variation and Cuddy-Della Valle Instability Index for analyzing fluctuations in oilseed crops cultivation, production, and yield in Pakistan; and (ii) To identify crops with high production volatility, and propose risk management strategies for these crops. The ultimate aim of this research addresses Pakistan's significant dependence on imported edible oils by employing a dual-pronged strategy. It involves analyzing fluctuations in the sector and proposing risk management strategies specifically designed for high-production crops. The study provides a comprehensive toolkit for policymakers, equipping them with the necessary insights to navigate the complexities of the edible oil sector.

2. MATERIALS AND METHODS

The study used secondary time series data from Pakistan's Agricultural Statistics and the Pakistan Economic Survey from 1970-71 to 2021-22 to examine agricultural production instability across a 52-year period. Agricultural insecurity was measured using the coefficient of variation (CV) and the Cuddy Della Valle Index (CDVI). The coefficient of variation may overstate instability when there is a noticeable trend, especially in regions with continual production increases. In contrast, the Cuddy Della Valle Index overcomes this constraint by using the coefficient of determination (R^2) to de-trend the CV. This method provides a more comprehensive measure of agricultural production insecurity, with lower CDVI suggesting less instability and higher scores indicating greater instability. The combination of both the coefficient of variation and the Cuddy Della Valle Index allows for a more thorough understanding of crop production volatility during the study period.

2.1. Coefficient of Variation Estimation

The Coefficient of Variation (CV) is a statistical measure used to assess the relative variability or risk in a dataset, commonly in finance, investment, or quality control. It is a dimensionless figure expressed as a percentage, computed by dividing the standard deviation (which measures the spread of

data) by the mean (the average) and then multiplying the outcome by 100. A higher CV indicates greater relative variability, implying heightened risk or uncertainty, whereas a lower CV suggests reduced relative variability, indicating lower risk or uncertainty. This metric aids in making informed decisions across various domains. Researchers such as Hazell [15], Singh and Ranjan [16], and Abdullah *et al*. [17] have used the coefficient of variation to estimate the instability of agricultural production and poverty.

- The calculation of the Coefficient of Variation for the mentioned variables was carried out using the formula provided below:

$$CV = \sigma / \bar{x} \times 100 \qquad (1)$$

Where;
σ = standard deviation
$\bar{x}$ = mean

2.2. Cuddy-Della Valle Index Estimation

The instability index is a metric employed for assessing the fluctuations or variability of a particular variable over a period. In 1978, the Cuddy-Della Valle Instability Index was introduced as a method to de-trend data and accurately portray the direction of instability. This index effectively captures both the explained and unexplained variations in the variable of interest, offering a more accurate depiction of the true state of instability. Previous studies by Sihmar [18], Kumar *et al*. [19], and Ramoliya *et al*. [20] have adopted the instability index in their work to gauge the variability in the area, production, and yield of agricultural crops. To analyze instability in the area, production, and productivity of oilseed crops in Pakistan, the Cuddy-Della Valle Index, a statistical tool, was employed.

- The mathematical expression for this Cuddy-Della Valle Instability Index (CDVI) formula is as follows:

$$I = CV \times \sqrt{1 - Adj.R^2} \qquad (2)$$

Where,
I = Instability index (percent)
CV = Coefficient of variation (percent)
Adjusted R^2 = Coefficient of determination

The ranges of the Cuddy-Della Valle Instability Index are as follows:

Low instability: 0-15
Medium instability: >15 and < 30
High instability: >30

3. RESULTS AND DISCUSSION

In this study, the primary emphasis is on the variability of three key variables: area, production, and yield. The coefficient of variation, which is the standard deviation divided by the mean and given as a percentage, was used to measure relative variability. This calculation offers valuable insights into the range to which data points deviate from the mean. The instability index, on the other hand, serves as a metric designed to depict the variability of a specific variable across time. It classifies this variability into distinct levels: high, medium, and low instability. This classification provides valuable insights into the temporal consistency or volatility exhibited by the variable under consideration.

3.1. Oilseed Crops Statistics in Pakistan

Table 1 summarizes Pakistan's oilseed crop statistics for the agricultural year 2021-22. The data show the cultivated area, production quantity, and yield of various oilseed crop. Cotton dominates the environment, with a cultivated area of 1936.9 thousand hectares, producing 8328.8 thousand tones and yielding 4300 kg/ha. Rapeseed/Mustard and canola has an area of 368 thousand hectares and yields 557.4 thousand tones at a rate of 1515 kg/ha. Sesame, grown on 199.9 thousand hectares, produced 128.1 thousand tones at a yield of 641 kg/ha. Groundnut and Sunflower occupy significant areas of 153.7 thousand hectares and 53.38 thousand hectares, respectively, producing 145 thousand tons and 83.52 thousand tons, with yields of 943 kg/ha and 1565 kg/ha, respectively. The table underscores the diverse cultivation landscape of oilseed crops in Pakistan, providing valuable insights into the agricultural sector's productivity and distribution.

3.2. Cotton Crop Instability in Pakistan

Cotton (*Gossypium spp*.), a prominent natural fiber, is a key cash crop grown commercially in over 50 nations worldwide. China, India, the United States, Pakistan, and Uzbekistan are the five largest cotton-growing countries. Cotton is a key economic driver for Pakistan, contributing 0.8% to the GDP and representing 4.1% of the total value

Table 1. Oilseed Crops Statistics in Pakistan (2022).

Oilseed Crops	Area (000 ha)	Production (000 tons)	Yield (kg/ha)
Cotton	1936.9	8328.8	4300
Rapeseed-Mustard & Canola	368.00	557.40	1515
Sesame	199.90	128.10	641
Groundnut	153.70	145.00	943
Sunflower	53.38	83.52	1565
Castor seed	4.95	4.54	917
Linseed	2.19	1.56	713
Soybean	0.06	0.05	873
Safflower	-	-	-

Source: Agricultural Statistics of Pakistan, 2022 [6].

addition in the agricultural sector. As the fifth-largest cotton producer globally, Pakistan holds a 6.0% share in the world's cotton production and ranks as the third-largest consumer of cotton. The statistics for the cotton crop in Pakistan during the 2021–22 period reveal a substantial production of 8328.8 thousand tons over an extensive area of 1937 thousand hectares, with a productivity rate of 4300 kg per hectare [6]. However, a deeper analysis of the Variability Index for Cotton in Pakistan spanning from 1971 to 2022 raises concerns about the instability within the cotton sector. The Coefficient of Variation (CV) for area stands at 17.05%, indicating relatively low instability in terms of geographical coverage. In contrast, both production and yield exhibit considerably higher instability with CV values of 55.03% and 50.35%, respectively. The corresponding Instability Index further underscores this volatility, with production and yield registering 34.80% and 31.44%, signifying high instability (Table 2). These findings suggest that while the geographic extent of cotton cultivation remains relatively stable, the actual production and yield of the crop are characterized by significant fluctuations over the years, posing challenges for the sustainability and predictability of the cotton industry in Pakistan. Efforts to address and mitigate the factors contributing to this high instability in production and yield are crucial for the long-term resilience of the cotton sector in the country.

Table 2. Variability Index (%) for Cotton in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	17.05	13.64	Low instability
Production	55.03	34.80	High instability
Yield	50.35	31.44	High instability

Source: Author's own calculations.

3.3. Rapeseed-Mustard and Canola Crop Instability in Pakistan

Rapeseed-mustard (*Brassica campestris* L.), a significant and traditional oilseed crop, is grown in 53 countries across six continents globally. In Asia, it is particularly prominent in India, Pakistan, China, and Bangladesh [21]. Mustard and its various varieties stand as the second-largest source, contributing about 38% to the country's edible oil production. Mustard is renowned for its high oil content, ranging from 40% to 44%, making it an appealing choice [22]. In Pakistan, the rapeseed-mustard including canola crop's statistics for the 2021–22 period were 368 thousand hectares in terms of area, 557.5 thousand tones in production, and a productivity rate of 1515 kg per hectare [6]. Table 3 indicates a complete summary of the variability of major agricultural characteristics (area, production, and yield) for rapeseed-mustard and canola crop in Pakistan from 1971 to 2022. These components coefficients of variation and instability index are as follows: area (28.4% and 18.9%), production (31.4% and 30.9%), and yield (27.2% and 13.4%), respectively. In terms of the "area" under cultivation, the instability index (18.9), indicating "moderate instability". This indicates that changes in cultivated land area are visible but not extremely unpredictable. The "production" component, on the other hand, has a substantially higher instability score of 30.9, suggesting "high instability". This shows that the annual yield of these crops in Pakistan

Table 3. Variability Index (%) for Rapeseed-Mustard and Canola in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	28.4	18.9	Medium instability
Production	31.4	30.9	High instability
Yield	27.2	13.4	Low instability

Source: Author's own calculations.

Table 4. Variability Index (%) for Sesame Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	54.6	35.4	High instability
Production	74.2	55.0	High instability
Yield	14.7	12.7	Low instability

Source: Author's own calculations.

varies significantly from year to year. Meanwhile, the "yield" variable has an instability score of 13.4, indicating "low instability". This means that agricultural production should remain relatively steady over time. The report emphasizes that crop production in rapeseed-mustard and canola was noticeably volatile, showing a sustained tendency of volatility. This insecurity can be attributable to decreases in both cultivated area and output levels.

3.4. Sesame Crop Instability in Pakistan

Sesame (*Sesamum indicum* L.) belongs to the family Pedaliaceae, is an autogamous plant and is categorized as a short-day plant. It is renowned as the "queen of oilseeds" [23]. The seeds of sesame contain high-quality edible oil (43-55%), characterized by its high stability and resistance to rancidity [24]. Additionally, sesame serves as a valuable source of vitamins and minerals, including calcium and phosphorus [25]. In Pakistan, sesame cultivation spans an area of 199.9 thousand hectares, resulting in an annual production of 128.1 thousand tons with an average yield of 641 kg per hectare [6]. Table 4 presents the variability of three critical characteristics of sesame crop production (area, production, and yield) in Pakistan from 1971 to 2022. The coefficient of variation and instability index are as follows: area (54.6% and 35.4%), production (74.2% and 55.0%), and yield (14.7% and 12.7%), respectively. The instability index reveals different patterns within these variables. The "area" has "high instability" with a 35.4 rating, showing significant year-to-year variations in land allocation for sesame cultivation. Similarly, "production" demonstrates "high instability" with a 55.0 index, indicating significant volatility in sesame output levels over the given period. Yield, on the other hand, displays "low instability" with an index of 12.7, signifying a relatively stable sesame crop yield per unit area from year to year. These data highlight the significant diversity and instability observed in both sesame crop cultivation area and production, while simultaneously emphasizing the generally constant character of sesame crop yields.

3.5. Groundnut Crop Instability in Pakistan

Groundnut (*Arachis hypogaea* L.), commonly known as peanut, is a key 'kharif' oilseed crop with a high 50% oil content, primarily cultivated in rain-fed area of Punjab and irrigated areas of Sindh and Khyber Pakhtunkhwa. Over the last two decades, both cultivation and production have consistently increased in these regions [4]. In 2022, the cultivation area of groundnut spanned 135.7 thousand hectares, yielding a total production of 145 thousand tons at an average rate of 943 kg per hectare [6]. Table 5 shows the variability of three critical variables related to groundnut crop (area, production, and yield) in Pakistan from 1971 to 2022. The coefficient of variation and instability index for these components are as follows: area (33.3% and 17.3%), production (26.8% and 21.6%), and yield (19.2% and 11.0%), respectively. In the case of "area", the instability index states 17.3, indicating "medium instability". This means that the area of groundnut production fluctuates noticeably but not dramatically from year to year. Similarly, the instability score for "production" is 21.6, suggesting "medium instability". This implies that groundnut production in Pakistan exhibits considerable fluctuation throughout the provided time period. The "yield" variable, on the other hand, has an instability score of 11.0, indicating "low instability". This implies that groundnut crop production per unit area is generally steady year after year. These findings suggest that, despite both acreage and production vary moderately, groundnut crop yield remains rather consistent across time. According to the instability indexes, both area and production are experiencing medium degrees of instability, indicating variations without significant volatility.

Table 5. Variability Index (%) for Groundnut Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	33.3	17.3	Medium instability
Production	26.8	21.6	Medium instability
Yield	19.2	11.0	Low instability

Source: Author's own calculations.

3.6. Sunflower Crop Instability in Pakistan

Sunflower (*Helianthus annuus* L.) a member of the Asteraceae family, originated in eastern North America and was domesticated by Native Americans around 3000 B.C., with 65 species, including 14 annual plants. Sunflower holds a crucial position among oilseed crops cultivated globally, serving as a primary provider of high-quality oil and dietary fiber. Its substantial nutritional contributions play a significant role in promoting human health [26]. Sunflower ranks as the third major crop worldwide, following soybeans and groundnuts [27]. Sunflower seeds increased an oil content up to 40-50% and a digestible protein content up to 30%, making them a significant food source for humans [28]. In the 2021-22 period, the cultivated area for sunflower in Pakistan was 53.4 thousand hectares, resulting in a total production of 83.5 thousand tons and a productivity rate of 1565 kg per hectare [6]. Table 6 presents the variability of three critical variables (area, production, and yield) relevant to sunflower crop production in Pakistan from 1971 to 2022. The coefficient of variation and the instability index for these factors are as follows: area (109.1% and 85.2%), production (114.2% and 89.9%), and yield (27.4% and 18.6%), respectively. The "area" dedicated to sunflower agriculture stands out with an extraordinarily high instability rating of 85.2, classifying it as "high instability". This label emphasizes that the allocation of land for sunflower cultivation fluctuates dramatically and unpredictably from year to year. Similarly, sunflower "production" reflects this high degree of unpredictability, with an instability rating of 89.9 indicating "high instability". This shows that sunflower production in Pakistan had considerable and irregular fluctuations over the period. The "yield" parameter, on the other hand, has a significantly smaller instability index of 18.6, putting it in the category of "medium instability". This shows that, while sunflower crop yield per unit area fluctuates noticeably, it does not reach the extremes found in area and production.

3.7. Castor Seed Crop Instability in Pakistan

The castor bean (*Ricinus communis* L.), which belongs to the Euphorbiaceae family, originated in East Africa and eventually spread to warm-temperate, subtropical, and tropical climates around the world. Castor beans, with their high fatty content, are extracted for use in pharmaceutical and industrial applications [29]. The cultivated land dedicated to castor seed has decreased from 45.9 thousand hectares in 1978-79 to 4.95 thousand hectares during 2021-22 [6]. Table 7 depicts the significant dynamics of castor seed crop variability across major agricultural variables (area, production, and yield) in Pakistan from 1971 to 2022. The coefficient of variation and instability index for three critical components are: area (104.0% and 87.6%), production (110.2% and 97.9%), and yield (24.0% and 22.0%), respectively. Notably, the instability score for "area" is very high (87.6), suggesting "high instability". This shows extreme and unpredictable variation in the land area allocated for castor seed production year after year. Similarly, the instability score for "production" is far greater, reaching 97.9, indicating "high instability". This suggests that castor seed production in Pakistan is highly erratic, with sharp changes across time. "Yield," on the other hand, has a steadier profile.

Table 6. Variability Index (%) for Sunflower Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	109.1	85.2	High instability
Production	114.2	89.9	High instability
Yield	27.4	18.6	Medium instability

Source: Author's own calculations.

Table 7. Variability Index (%) for Castor Seed Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	104.0	87.6	High instability
Production	110.2	97.9	High instability
Yield	24.0	22.0	Medium instability

Source: Author's own calculations.

3.8. Linseed Crop Instability in Pakistan

Linseed (*Linum usitatissimum* L.), also known as common flax, is a significant global crop, ranking as the third-largest fiber crop and fifth major oilseed crop [30]. It is suitable for temperate zones [31], and is used in varnishes, linoleum, putty, leather preparation, and medicinal purposes [32]. Linseed is cultivated in Pakistan, primarily in Punjab and Sindh provinces, covering 2.19 thousand hectares and producing approximately 1.56 thousand tons annually with an average yield of 713 kg per hectare [6]. Table 8 depicts the dynamics of linseed crop variations in key agricultural variables (area, production, and yield) in Pakistan from 1971 to 2022. The coefficient of variation and the instability index for three important components are: area (39.3% and 20.0%), production (34.4% and 19.5%), and yield (14.4% and 10.8%), respectively. An instability score of 20 indicates "medium instability" in terms of cultivable land area. This demonstrates that the area dedicated to linseed cultivation varies considerably but not significantly from year to year. Similarly, linseed "production" has a "medium instability" rating of 19.5, indicating a moderate level of variation over time. In comparison, "yield" has a lower instability rating of 10.8, suggesting "low instability". This suggests oscillations in linseed crop productivity.

Table 8. Variability Index (%) for Linseed Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	39.3	20.0	Medium instability
Production	34.4	19.5	Medium instability
Yield	14.4	10.8	Low instability

Source: Author's own calculations.

3.9. Soybeans Crop Instability in Pakistan

Soybean (*Glycine max* L.) has evolved as an important and adaptable field crop, accounting for 80% of global legume area and 68% of legume production worldwide [33, 34]. Because of their low fertilizer requirements, they are commonly referred to as "golden beans" or a "miracle crop". Soybeans were introduced into Pakistan in the 1960s and are primarily grown in Sindh and Khyber Pakhtunkhwa [35]. However, soybean cultivation and production have decreased dramatically in 1997-98, from 6.2 thousand hectares to 0.06 thousand hectares, and from 8.1 thousand tones to 0.05 thousand tones [6]. The coefficients of variation and instability index for these variables are as follows: area (102.7% and 84.0%), production (152.0% and 149.7%), and yield (59.0% and 52.8%), respectively. The instability index values are unusually high, at 84% for area, 149.7% for production, and 52.8% for yield. These data combined indicate that soybean agriculture in Pakistan is characterized by dramatic and unpredictable changes in cultivation area, production volumes, and crop yield per unit area. In summary, our findings highlight the critical need for strong measures to effectively manage and reduce the observed instability in numerous elements of soybean farming practices across the country.

Table 9. Variability Index (%) for Soybean Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	102.7	84.0	High instability
Production	152.0	149.7	High instability
Yield	59.0	52.8	High instability

Source: Author's own calculations.

3.10. Safflower Crop Instability in Pakistan

Safflower (*Carthamus tinctorius* L.) is an important oilseed rabi crop in semi-arid regions such as India, Iran, Egypt, Pakistan, and the Mediterranean countries [36]. In Pakistan, it's known as "kusum" and is largely cultivated for dye and oil [37], with Sindh and Baluchistan being important cultivation areas. As of 2021-22, Pakistan's safflower cultivation area was 31.7 thousand hectares, yielding 0.72 thousand tones at a production rate of 22.7 kg per hectare [6]. Table 10 summarizes the fluctuation of key agricultural indicators (area, production, and yield) for Pakistan's safflower crop from 1971 to 2022. The coefficient of variation and the instability index are as follows: area (132.5% and 105.1%), production (150.6% and 152.0%), and yield (187.3% and 167.5%). These findings emphasize the enormous variation and insecurity of safflower farming. The instability index supports this finding, designating both area and production as "highly unstable" with values of 105.1 and 152, respectively. Furthermore, safflower crop production has a "high instability" rating of 167.5, signifying harmful and irregular variations.

Table 10. Variability Index (%) for Safflower Crop in Pakistan (1971-2022).

Variables	CV	Instability Index	Inference
Area	132.5	105.1	High instability
Production	150.6	152.0	High instability
Yield	187.3	167.5	High instability

Source: Author's own calculation.

Managing this instability is crucial for successful agricultural planning and risk management in Pakistan's safflower farming sector.

3.11. Overall Instability in Pakistan's Oilseed Crops

Table 11 demonstrates the comprehensive variability of oilseed crops in Pakistan. The collective analysis of oilseed crops in Pakistan reveals a pervasive instability spanning from 1971 to 2022. Cotton, a significant oilseed crop in Pakistan, shows moderate variability in area, production, and yield. However, it also shows significant fluctuations in both production and yield, indicating its susceptibility to factors like climate, pest attacks, and agricultural practices. Rapeseed-Mustard and Canola, another vital oilseed crop, also shows significant variability in the cultivated area but also faces challenges in maintaining high production levels and yields. Sesame, characterized by its high oil content, also shows considerable variability across all parameters. Groundnut, another major oilseed crop, shows moderate variability in area, production, and yield, but relatively stable trends. Sunflower, known for its high oil content and adaptability to various soil types, also shows high variability across all parameters. Castor seed, with its high oil content and versatility, also shows high variability in cultivation area, production, and yield. Linseed, though less prominent, also shows moderate variability in cultivation area, production, and yield. Soybean, known for its high protein and oil content, also faces challenges in achieving consistent output levels. Safflower, characterized by its drought tolerance and high oil content, also shows high variability in cultivation area, production, and yield.

3.12. Perceptual Map (Positioning Map) based on Instability Index of Oilseed Crops

Figure 1 presents a perceptual map addressing the instability in the area, production, and yield of various oilseed crops in Pakistan. Cotton, rapeseed-mustard and canola, linseed, and groundnut show moderate instability, while sunflower, castor seed, soybean, and safflower demonstrate significant fluctuations in all three parameters. Safflower is the most volatile, with a significant increase in cultivation area, production, and yield. Similarly, Sunflower, Castor seed, and Soybean also depict notable instability in their production and yield metrics. These findings are consistent with the results reported by Jainuddin *et al.* [14] and Ramoliya *et al.* [20]. To tackle these challenges, it is crucial to invest in research, technology, and market development for climate-resilient crops prone to high instability. Implementing price support systems and capacity-building programs for farmers can further aid in managing the risks associated with crop instability. Adapting policy guidelines to meet the specific demands of crops and regions is essential for fostering sustainable agriculture in Pakistan.

Table 11. Overall Instability Index (%) of Oilseed Crops in Pakistan (1971-2022).

Oilseed Crops	Area	Production	Yield
Cotton	13.64*	34.80***	31.44***
Rapeseed-Mustard & Canola	18.9**	30.9***	13.4*
Sesame	35.4***	55.0***	12.7*
Groundnut	17.3**	21.6**	11.0*
Sunflower	85.2***	89.9***	18.6**
Castor seed	87.6***	97.9***	22.1**
Linseed	20.0**	19.5**	10.8*
Soybean	84.1***	149.5***	52.8***
Safflower	105.1***	152.1***	167.5***

Source: Authors' own calculations; (Low instability*, Moderate instability**, High instability***).

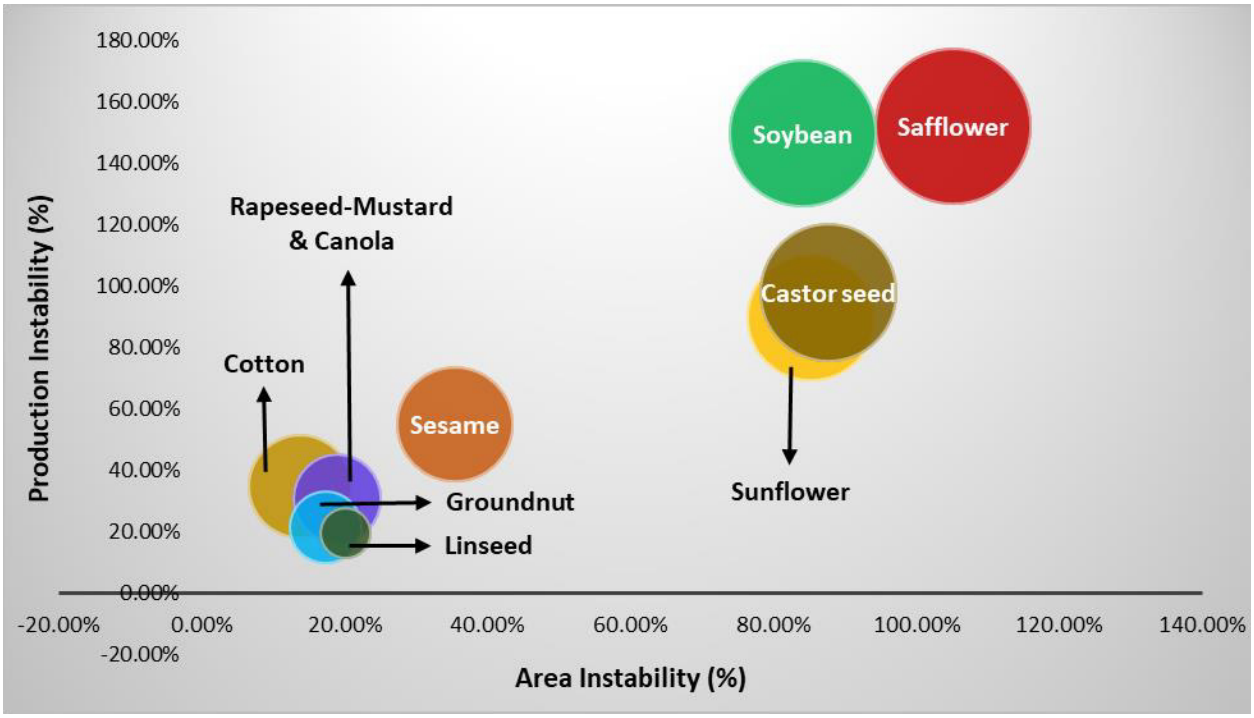

Fig. 1. Perceptual Map of Oilseed Crops based on Instability Index.

4. CONCLUSIONS AND RECOMMENDATIONS

The study on the variability and instability in oilseed crops in Pakistan, covering the period from 1970–71 to 2021–22, demonstrates significant fluctuations in cultivation area and production. Specifically, sunflower, soybean, safflower, and castor seed crops show severe and unpredictable changes and high degrees of instability. The greater values of the instability index point to a higher degree of instability, emphasizing the need for effective agricultural planning and risk management in these sectors. The findings of this analysis provide valuable insights for policymakers and stakeholders in Pakistan's agricultural industry. Based on the study's results, the following suggestions are proposed:

- Implement innovative crop forecasting techniques for informed decision-making.
- Develop resource allocation strategies for improved efficiency.
- Formulate stabilization policies for diversification, crop insurance, and price stability.
- Invest in research for resilient crop varieties, capacity-building programs, market access improvement, and sustainable agricultural practices.

5. DECLARATION

The authors acknowledged that the manuscript submitted in their own original work. The manuscript has not been published and nor considered for publication elsewhere. If accepted for publication, the article's copyright will be transferred to The Pakistan Academy of Sciences.

6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

7. REFERENCES

1. M. Patel, M.R. Chandrakar, S. Pandey, S.B. Wasnik, and J. Parte. Growth performance and instability of major oilseeds in Chhattisgarh. *The Pharma Innovation Journal* 11(5): 1815-1821 (2022).
2. P. Chitra. Potential and Utilization of By-Products of Oilseeds in Animal Feed Industry. *Biotica Research Today* 3(8): 655-657 (2021).
3. M. Afzal. Managing water resources for environmentally sustainable irrigated agriculture in Pakistan. *The Pakistan Development Review* 35(4): 977-988 (1996).
4. A.W. Rana, S. Gill, and I. Akram. Promoting oil seed crops in Pakistan: Prospects and constraints. *International Food Policy Research Institute* (2022). https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/135063/filename/135274.pdf
5. H.A. Badar, M.S. Javed, A.S. Ali, and Z.A. Batool.

Production and marketing constraints limiting sunflower production in Punjab (Pakistan). *International Journal of Agriculture and Biology* 4(2): 267-271 (2002).
6. GoP. Agricultural Statistics of Pakistan, 2021-2022. *Ministry of National Food Security and Research, Government of Pakistan, Islamabad, Pakistan*. (2022). https://mnfsr.gov.pk/SiteImage/Misc/files/ASP%2021-22.pdf
7. M. Ijaz, A. Sattar, A. Sher, S. Ul-Allah, M.Z. Mansha, K.A. Khan, and S. Farooq. Sulfur application combined with planomicrobium sp. Strain MSSA-10 and farmyard manure biochar helps in the management of charcoal rot disease in sunflower (Helianthus annuus L.). *Sustainability* 13(15): 8535 (2021).
8. Z. Flagella, T. Rotunno, E. Tarantino, R. Di Caterina, and A. De Caro. Changes in seed yield and oil fatty acid composition of high oleic sunflower (Helianthus annuus L.) hybrids in relation to the sowing date and the water regime. *European Journal of Agronomy* 17(3): 221-230 (2002).
9. D. Pimentel, and T.W. Patzek. Ethanol production using corn, switch grass, and wood; biodiesel production using soybean and sunflower. *Natural Resources Research* 14: 65-76 (2005).
10. F.U. Rehman, I. Saeed, and A. Salam. Estimating growth rates and decomposition analysis of agriculture production in Pakistan: pre and post sap analysis. *Sarhad Journal of Agriculture* 27(1): 125-131 (2011).
11. USDA. United States Agricultural Export Yearbook. *United States Department of Agriculture, USA* (2021). https://fas.usda.gov//sites/default/files/2022-04/Yearbook-2021-Final.pdf.
12. GoP. Pakistan Economic Survey, 2021-2022. *Economic Advisor's Wing, Finance Division., Islamabad, Pakistan* (2022).
13. M. Farooq, S. Iqbal, M.Z. Afridi, M. Munsif, M. Tauseef, and K. Rehman. Optimization of nitrogen for increasing the productivity of canola. *Agricultural Research and Technology* 3: 1-5 (2017).
14. S.M. Jainuddin, S.S. Patil, G.M. Hiremath, G.B. Lokesh, and V. Naik. Instability and Seasonal Production Analysis of Oilseed Crops in India. *International Journal of Advances in Agricultural Science and Technology* 8(1): 1-12 (2021).
15. P.B.R. Hazell. Instability in Indian food grain production. *International Food Policy Research Institute* Research Report-30 (1982). https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/117407/filename/117408.pdf.
16. R.K.P. Singh, and K.P. Ranjan. Growth and instability in production of principal food grain crops: a case of backward economy. *Bangladesh Journal of Agricultural Economics* 21(1-2): 1-20 (1998).
17. M. Abdullah, S. Ghazanfar, J. Ahmed, and I. Khan. Growth and instability analysis of rice production and export of Pakistan. *European Journal of Economic Studies* 11(1): 4-15 (2015).
18. R. Sihmar. Growth and instability in agricultural production in Haryana: A district level analysis. *International Journal of Scientific and Research Publications* 4(7): 1-12 (2014).
19. J. Kumar, A. Roy, A. Kumar, and S.P. Singh. Economic analysis and marketing efficiency of litchi in Muzaffarpur district of Bihar. *The Pharma Innovation Journal* 11(4): 690-693 (2022).
20. R.K. Ramoliya, S.P. Padaliya, H.B. Sadariya, and A.B. Mahera. Growth and instability of major oilseed crops in Gujarat. *International Journal of Agriculture Sciences* 14(3): 11145-11148 (2022).
21. S. Kamdi, H. Ingole, S. Bhure, M. Meshram, D. Tajane, and P. Patil. Stability analysis in Indian mustard. *The Pharma Innovation Journal* 11(7): 4351-4354 (2022).
22. F. Qureshi. Mustard Oil: A Homegrown Alternative to Reduce Edible Oil Import Bill. Institute for Strategic Studies, Research and Analysis (ISSRA) National Defense University Islamabad–Pakistan. *Insight* Number: DSS-8 (2023). https://ndu.edu.pk/issra/pub/insight/2023/Mustard-Oil/Mustard-Oil.pdf
23. A. Priyadarshini, C. Umesha, and M.R. Meshram. Influence of phosphorus and potassium levels on growth, yield and economics of sesame (*Sesamum indicum* L.) under eastern Uttar Pradesh condition. *Biological Forum-An International Journal* 13(1): 645- 650 (2021).
24. M. Alpaslan, E. Boydak, M. Hayta, S. Gerçek and M. Simsek. Effect of row spacing and irrigation on seed composition of Turkish sesame (*Sesamum indicum* L.). *Journal of the American Oil Chemists' Society* 78 (9): 933-935 (2001).
25. M.A. Malik, M.F. Saleem, M.A. Cheema and S. Ahmed. Influence of different nitrogen levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. *International Journal of Agriculture and Biology* 5(4): 490-492 (2003).
26. S. Khan, S. Choudhary, A. Pandey, M.K. Khan, and G. Thomas. Sunflower oil: Efficient oil source for human consumption. *Emergent Life Sciences Research* 1: 1–3 (2015).
27. C. Meric F. Dane, and G. Olgun. Histological Aspects of Anther Wall in Male Fertile and Cytoplasmic Male Sterile *Helianthus annuus* L. (Sunflower). *Asian Journal of Plant Sciences* 3(2):145-150 (2004).
28. S. Ahmad, and F.U. Hassan. Oil and fatty acid

composition of spring sunflower. *Pakistan Journal of Biological Sciences* 3(12): 2063-64 (2000).
29. M. Landoni, G. Bertagnon, M. Ghidoli, E. Cassani, F. Adani, and R. Pilu. Opportunities and challenges of castor bean (*Ricinus communis* L.) genetic improvement. *Agronomy* 13(8): 2076 (2023).
30. X. Deng, S.S. Long, D. He, X. Li, Y. Wang, D. Hao, and X. Chen. Isolation and characterization of polymorphic microsatellite markers from flax (*Linum usitatissimum* L.). *African Journal of Biotechnology* 10(5): 734-739 (2011).
31. A. Rastogi, A. Siddiqui, B.K. Mishra, M. Srivastava, R. Pandey, P. Misra, and S. Shukla. Effect of auxin and gibberellic acid on growth and yield components of linseed (*Linum usitatissimum* L.). *Crop Breeding and Applied Biotechnology* 13(2): 136-143 (2013).
32. S. Gul, A.A. Rajper, F.A. Kalhoro, S.A. Kalhoro, A. Ali, F.A. Shah, and M. Ahmed. Screening selected linseed (*Linum usitatissimum* L.) genotypes for yield performance in Sindh, Pakistan. *Natural Sciences* 8(2): 53 (2016).
33. D.F. Herridge, M.B. Peoples, and R.M. Boddey. Global inputs of biological nitrogen fixation in agricultural systems. *Plant Soil* 311:1–18 (2008).
34. J. Naamala, S.K. Jaiswal, and F.D. Dakora. Microsymbiont diversity and phylogeny of native bradyrhizobia associated with soybean (*Glycine max* L. Merr.) nodulation in South African soils. *Systematic and Applied Microbiology* 39(5): 336–344 (2016).
35. H. Khurshid, D. Baig, S.A. Jan, M. Arshad, and M.A. Khan. Miracle crop: The present and future of soybean production in Pakistan. *MOJ Biology and Medicine* 2(1): 189–191 (2017).
36. V. Singh, Y.G. Prasad, and M. Lakshminarayana. Insect pests of safflower and their management. *IPM System in Agriculture* 5: 552 (1999).
37. V.M. Chavan (Ed.). Niger and Safflower. *Indian Central Oil Seeds Committee, Hyderabad, India* (1961).