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Comparative Analysis of Instability and Growth of Pearl Millet and Maize in India

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ABSTRACT

The present paper explores the instability and growth in area, production, and yield of pearl millet and maize in India. For this, the Cuddy-Della Valle (CDV) instability index and compound annual growth rate (CAGR) are evaluated using secondary time series data on area, production, and yield of pearl millet and maize pertaining to the period of thirty years viz., 1994-2023. The comparative analysis has been made across three periods viz., Period-I (1994-2008), Period-II (2009-2023) and the overall period (1994-2023). The results of the investigation reveal that, during the overall period, pearl millet reported highest instability in terms of production (i.e., 15.51%) followed by yield (i.e., 10.74%) and area (i.e., 7.44%). In a similar manner, maize reported highest instability in terms of production (i.e., 10.37%) followed by yield (i.e., 7.49%) and area (i.e., 3.25%). Furthermore, during the overall period, the growth rates in production, area and yield of maize are observed to be the highest as compared to that of pearl millet.

Keywords Coefficient of variation, Coefficient of determination, Instability index, Compound annual growth rate.

INTRODUCTION

Staple crops constitute a significant position in the human diet. In terms of nutritional perspective, staple crops are rich in carbohydrates, fats, fibers, and several vital nutrients, which are essential components for sustaining human health. Among the staple crops, pearl millet and maize have gained popularity in recent times as pearl millet is drought-resistant and grows in poor soils, whereas maize is high-yielding and adaptable. Both pearl millet (*Pennisetum glaucum*) and maize (*Zea mays* L.) belong to the Poaceae family. These crops have industrial significance, and are essential for livestock feed, with pearl millet providing nutritious fodder and maize serving as a primary ingredient in animal diets. Overall, these crops play a vital role in ensuring food security, economic stability, and sustainable agriculture, especially in developing nations.

India stands as the largest producer of pearl millet, accounting for 50% of the global output. In

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the year 2023-24, India's total pearl millet production reached 10.72 million tons, witnessing a yield of 1.45 tons per hectare. Moreover, during the year 2023-24, India's overall maize production reached 37.67 million tons, with a yield of 3.35 tons per hectare (Directorate of Economics & Statistics, DA&FW, Govt of India 2024).

In recent years, numerous researchers and scientists have conducted studies related to statistical analysis of agricultural crops, which are essential in terms of policy formulation regarding food security and sustainable agriculture. Dhakre and Sharma (2010) conducted growth analysis of area, production and productivity of maize in Nagaland. Handral and Sethy (2017) investigated the growth and instability of Bajra and Jowar in India. Kumar and Paul (2017) evaluated growth and instability of maize production in Andhra Pradesh from 1990 to 2015. Basavaraj *et al.* (2020) studied trends in maize, bajra, and sorghum in Hyderabad-Karnataka region between 1991 and 2018, observing rising productivity in bajra and sorghum, but a decrease in area and production, and suggesting that minimum support price (MSP) incentives could enhance growth. Joshi *et al.* (2023) explored the growth of wheat, rice, and maize in Uttar Pradesh during 1991 to 2021. Rani *et al.* (2023) analyzed growth trend of pearl millet and its impact on Indian economy. Saravand *et al.* (2023) investigated growth performance and instability of pearl millet in Gujarat. Bairwa *et al*. (2024) examined the growth, decomposition and instability in area, production, and productivity of pearl millet in Jodhpur and Rajasthan.

Some other recent notable contributions towards time series analysis of crops, other than pearl millet and maize, have been made by Joshi *et al.* (2021), Kumar and Menon (2022), Rana and Kumar (2022), Sumit *et al*. (2022), Kumar *et al.* (2024), Mishra *et al.* (2025) and Prakash *et al.* (2025).

The objective of present investigation is to examine the instability and growth rates in area, production, and yield of staple food crops viz., pearl millet and maize, in India, across three periods viz., period-I (1994-2008), period-II (2009-2023), and the pooled (or overall) period (1994-2023). Moreover, the comparative assessment has also been made across the concerned periods. To carry out the empirical analysis, the statistical measures such as Cuddy-Della Valle (CDV) instability indices and compound annual growth rates (CAGRs) are computed.

MATERIALS AND METHODS

In the present analysis, a secondary time series data concerning the production, area, and yield of pearl millet and maize in India has been collected from the Directorate of Economics & Statistics, DA&FW, Government of India, covering the period from 1994 to 2023. The investigation is carried across three periods viz., period-I (1994-2008), period-II (2009-2023) and the overall period (1994-2023).

To examine the level of instability in pearl millet and maize across the concerned periods, the Cuddy-Della Valle (CDV) instability index is computed using the following formula:

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

Where, R^2 denotes the coefficient of determination, which is obtained on fitting linear model to the concerned time series data on area, production, and yield of pearl millet and maize. Also, CV denotes the coefficient of variation.

The compound annual growth rate (CAGR) in area, production and yield of pearl millet and maize, is obtained on using the following function:

$$y_t = y_0 (1+r)^t$$

Where,

y_t = Observed time series value of area, production, or yield (as the case may be) of pearl millet and maize at time t

y_0 = Initial time series value of area, production, or yield

r = Compound annual growth rate

Here, the compound annual growth rate (r) is evaluated in terms of percentage as follows:

$$r = \left[\left(\frac{y_t}{y_0}\right)^{1/t} - 1\right] \times 100$$

RESULTS AND DISCUSSION

The secondary time series data regarding the production, area, and yield of major staple food crops in India, specifically pearl millet and maize, from 1994 to 2023 is summarized in Table 1. Additionally, the statistical coefficients viz., coefficient of variation (CV), coefficient of determination (R^2), and the Cuddy-Della Valle instability index (I) for production, area, and yield of these staple crops are elaborated in Tables 2– 4, respectively. The values of R^2 are derived on fitting linear models to the concerned time series data on production, area, and yield of the respective staple food crops. Finally, the compound annual growth rates (CAGRs) for production, area, and yield of pearl millet and maize have been examined, and the findings are presented in Table 5.

The Table 2 reveals a significant decline in instability of pearl millet production during period-II as

Table 1. Time series data on production, area and yield of pearl millet and maize in India.

Year	Pearl millet			Maize		
	P	A	Y	P	A	Y
1994	7.16	10.22	0.70	8.88	6.14	1.45
1995	5.38	9.32	0.58	9.53	5.98	1.59
1996	7.87	9.98	0.79	10.77	6.26	1.72
1997	7.64	9.89	0.77	10.82	6.32	1.71
1998	6.96	9.30	0.75	11.15	6.20	1.80
1999	5.78	8.90	0.65	11.51	6.42	1.79
2000	6.76	9.83	0.69	12.04	6.61	1.82
2001	8.28	9.53	0.87	13.16	6.58	2.00
2002	4.72	7.74	0.61	11.15	6.64	1.68
2003	12.11	10.61	1.14	14.98	7.34	2.04
2004	7.93	9.23	0.86	14.17	7.43	1.91
2005	7.68	9.58	0.80	14.71	7.59	1.94
2006	8.42	9.51	0.89	15.10	7.89	1.91
2007	9.97	9.57	1.04	18.96	8.12	2.33
2008	8.89	8.75	1.02	19.73	8.17	2.41
2009	6.51	8.90	0.73	16.72	8.26	2.02
2010	10.37	9.61	1.08	21.73	8.55	2.54
2011	10.28	8.78	1.17	21.76	8.78	2.48
2012	8.74	7.30	1.20	22.26	8.67	2.57
2013	9.25	7.81	1.18	24.26	9.07	2.67
2014	9.18	7.32	1.25	24.17	9.19	2.63
2015	8.07	7.13	1.13	22.57	8.81	2.56
2016	9.73	7.46	1.30	25.90	9.63	2.69
2017	9.21	7.48	1.23	28.75	9.38	3.07
2018	8.66	7.11	1.22	27.72	9.03	3.07
2019	10.36	7.54	1.37	28.77	9.57	3.01
2020	10.86	7.65	1.42	31.65	9.89	3.20
2021	9.78	6.84	1.43	33.73	9.96	3.39
2022	11.43	7.57	1.51	38.09	10.74	3.55
2023	10.72	7.38	1.45	37.63	11.24	3.35

Note: P = Production (in million tons), A = Area (in million hectares), and Y = Yield (in tons per hectare). (Source: Directorate of Economics & Statistics, DA&FW, Govt of India).

Table 2. Values of various statistical coefficients for production of pearl millet and maize in India.

Crops	Period-I (1994-2008)			Period-II (2009-2023)			Overall period (1994-2023)		
	CV	R^2	I	CV	R^2	I	CV	R^2	I
Pearl millet	23.69	0.241	20.64	13.07	0.325	10.74	20.86	0.447	15.51
Maize	24.29	0.853	9.31	22.75	0.903	7.09	42.67	0.941	10.37

Table 3. Values of various statistical coefficients for area of pearl millet and maize in India.

Crops	Period-I (1994-2008)			Period-II (2009-2023)			Overall period (1994-2023)		
	CV	R^2	I	CV	R^2	I	CV	R^2	I
Pearl millet	7.14	0.071	6.89	9.92	0.451	7.35	13.20	0.682	7.44
Maize	11.05	0.87	3.99	8.73	0.877	3.06	18.14	0.968	3.25

Table 4. Values of various statistical coefficients for yield of pearl millet and maize in India.

Crops	Period-I (1994-2008)			Period-II (2009-2023)			Overall period (1994-2023)		
	CV	R^2	I	CV	R^2	I	CV	R^2	I
Pearl millet	20.08	0.451	14.88	15.39	0.754	7.63	27.46	0.847	10.74
Maize	13.68	0.633	8.29	14.67	0.842	5.83	25.53	0.914	7.49

compared to period-I with a transition of 9.9%. Also, a slight decline in instability of maize production is observed during period-II as compared to period-I. The overall period reported highest instability in pearl millet production (i.e., 15.51%) as compared to maize production (i.e., 10.37%). Moreover, it is observed from Table 3 that there is a slight rise in instability in area of pearl millet, whereas a slight decline is observed in instability in area of maize, during period-II as compared to period-I. The overall period revealed highest instability in area of pearl millet (i.e., 7.44%) as compared to area of maize (i.e., 3.25%). Furthermore, Table 4 exhibits a significant decline in instability in yield of pearl millet during period-II as compared to period-I with a transition of 7.25%. Also, a slight decline in instability in yield of maize is observed during period-II as compared to period-I. The overall period witnessed highest instability in yield of pearl millet (i.e., 10.74%) as compared to yield of maize (i.e., 7.49%). Hence, the key findings of the investigation reveal that the pattern of instability in yield of pearl millet and maize is similar to that of instability in production of pearl millet and maize.

The Table 5 reveals that pearl millet witnessed significant growth in production (i.e., 3.63%) and yield (i.e., 5.02%) during period-II as compared to the period-I. Moreover, during all the concerned periods, i.e., period-I, period-II and the overall period, negative growth rates are observed in area of pearl millet. Hence, area under pearl millet cultivation declined during the concerned periods of investigation. Furthermore, in terms of growth rate of maize, the period-I witnessed significant growth in production (i.e., 5.87%), area (i.e., 2.06%) and yield (i.e., 3.73%), as compared to the period-II. During the overall period, the growth rates in production, area and yield of maize are observed to be the highest as compared to that of pearl millet.

The possible reasons for negative growth rate in area under pearl millet cultivation in India can be attributed by numerous external factors such as resource scarcity, lack of subsidies, climate variability, pest attacks, and shifting of farmers towards other profitable and higher-yielding crops like wheat, rice, and sugarcane. In order to reverse this trend in pearl millet, efforts are needed in terms of policy support, market development, improved varieties, and farmers' motivation towards pearl millet cultivation.

Table 5. Compound annual growth rates (CAGRs) for production, area and yield of pearl millet and maize in India.

Crops	Period-I			Period-II			Overall Period		
	P	A	Y	P	A	Y	P	A	Y
Pearl millet	1.56	-1.10	2.69	3.63	-1.33	5.02	1.40	-1.12	2.55
Maize	5.87	2.06	3.73	4.18	1.53	2.61	5.11	2.11	2.94

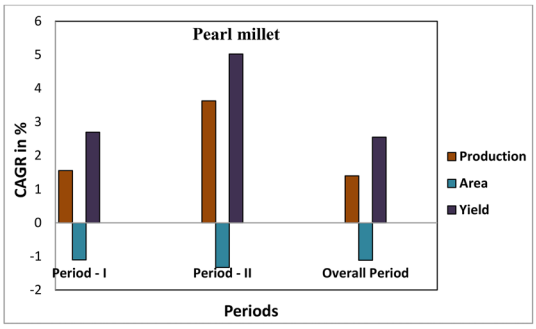

Fig. 1. Period-wise CAGR in production, area, and yield of pearl millet in India

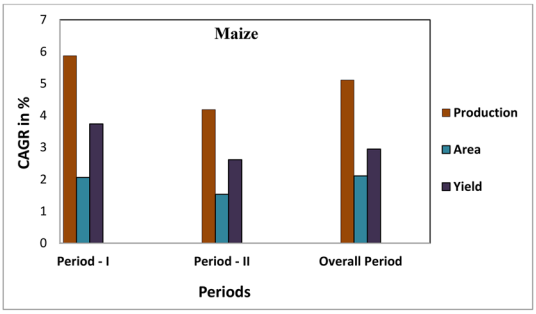

Fig. 2. Period-wise CAGR in production, area, and yield of maize in India

The compound annual growth rates (CAGRs) for production, area, and yield of pearl millet and maize in India across different periods are illustrated graphically in Figs. 1–2, respectively.

CONCLUSION

In the present study, a comparative evaluation of instability and growth rates in production, area, and yield of staple food crops in India viz., pearl millet and maize have been made across three periods viz., Period-I (1994-2008), Period-II (2009-2023) and the overall period (1994-2023).

The results of the study reveal that, during the overall period, pearl millet reported highest instability in terms of production followed by yield and area. In a similar manner, maize reported highest instability in terms of production followed by yield and area.

Moreover, in terms of growth rates, pearl millet witnessed significant growth in production and yield during period-II as compared to the period-I. However, negative growth rates are observed in area of pearl millet during all the concerned periods, i.e., period-I, period-II and the overall period. Hence, it can be concluded that area under pearl millet cultivation declined during the concerned periods of investigation. Furthermore, in terms of growth rate of maize, the period-I witnessed significant growth in production, area and yield as compared to the period-II. During the overall period, the growth rates in production, area and yield of maize are observed to be the highest as compared to that of pearl millet.

The outcomes of the investigation offer crucial insights for policymakers and scientists regarding development of strategies for boosting pearl millet and maize production, thereby meeting global food security and nutritional sustainability. Since, area under pearl millet cultivation declined during the concerned periods of investigation, hence focus of attention is required regarding the promotion of pearl millet cultivation among the farmers. Also, efforts are needed in terms of subsidies, incentives and agricultural resources for motivating potential farmers regarding pearl millet and maize cultivation.

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