



RESEARCH ARTICLE

Assessing the growth trends and fluctuations in the area, yield and production of minor millets in India

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Abstract

India is leading the growth of main crops such as rice and wheat and the development of minor millets with better nutritional value has been neglected. This research utilised secondary data obtained from different government publications and Internet properties. This research comprises 4 time periods, 1950-51 to 2021-22. Compound annual growth rates (CAGRs) were used to examine trends, illustrating a continuing decline in land area provided to minor millet farming, with an overall negative CAGR of -3.64 %. Production followed a similar decreasing trend, with a negative CAGR of -2.88 %, indicating a significant decrease in overall output throughout the years. In contrast, productivity fluctuated, resulting in an overall positive CAGR of 0.78 %, indicating a moderate development in yield per unit area. The instability indices revealed an increasing trend in the area, production and productivity challenges. These findings highlight the need to encourage sustainable farming and to develop knowledge about the nutritional advantages of small millets. This study provides valuable insights for policymakers and agricultural stakeholders in shaping the future of minor millet cultivation in India.

Keywords: area; CAGR; instability; minor millets; production; productivity

Introduction

India is the largest producer of rice, wheat and other cereals. The Government of India recently released the Second Advance Estimates of Major Crop Production for the agricultural year 2022-23. The foodgrain production for this year is projected to reach a staggering 3235.54 lakh tonnes (1). This impressive growth in production and productivity can be attributed to the adoption of modern techniques, which has essentially substituted the cultivation of other significant crops like minor millets. Millet, a type of grain, is cultivated in 2 categories in India: major and minor (2). Maize, sorghum and bajra are the major millets, whereas finger millet, foxtail millet, barnyard millet and kodo millet are the minor millets (3). Although major millets are grown in larger quantities by Indian farmers, they are minor millets with higher nutritional value. Surprisingly, the north-eastern area of India, which includes Manipur, Meghalaya and Nagaland, has adopted millet as their primary food source (4). Millets have immense nutritional advantages and these communities recognise the immense nutritional benefits offered by millets and include them in their regular food (5). India's dominance in cereal production, particularly rice and wheat, is a testament to the country's agricultural processes (6). The use of advanced technology has revolutionised farming practices, leading to increased yields and enhanced productivity. However, it is crucial to acknowledge the impact of this progress on the cultivation of minor

millets, which has been overshadowed by the focus on major crops. India's agricultural landscape is characterised by its remarkable production of cereals, with rice, wheat and other grains taking centre stage. While major millets are cultivated in larger quantities, minor millet offers superior nutritional value. The north-eastern region of India has recognised this and embraced millet as a staple food (7). India continues to technologically advance in the agricultural sector; it is essential to strike a balance between the cultivation of major and minor crops, ensuring both productivity and nutritional diversity.

Millets are highly adaptable and can thrive in a wide range of climatic and soil conditions. In India, the ideal time for millet cultivation is from June to November, when well-drained loamy soil is the most suitable for growth. The germination of millets requires a warm temperature ranging from 20 °C to 35 °C, but they are vulnerable to frost (8). These crops rely on rainfall and can be cultivated with relatively low precipitation levels. Major millets typically require an average rainfall of 450 mm, whereas minor millets can thrive with 350 mm of rainfall (9). In recognition of their higher energy and nutritional content than those of large millets, minor millets may serve as both a nutritious food source for people and an important fodder for animals. Protein, fibre, essential lipids and minerals, such as zinc, copper, calcium, phosphorus, magnesium and potassium, are prominent in these small millets (10). Furthermore, they are gluten-free, making them especially good for people with illnesses, such as cancer, diabetes, oxidative

stress, overweight or obesity, celiac disease and digestive problems.

In recent years, several researchers have turned to the compounded annual growth rate as a prediction technique for forecasting agricultural crop area, production and productivity. A comprehensive analysis of the growth and instability of Indian agriculture. Their findings revealed significant increases in the area dedicated to rice and maize cultivation as well as an increase in the production of pulses and wheat. Furthermore, they observed a notable improvement in wheat and pulse productivity during the specified period (11). The production and consumption of minor millets in India. Their research sheds light on the trends and patterns in these crops (12). The trends in area, production and productivity of minor millets in India. Their analysis provides valuable insights into the growth and performance of this crop (13). The primary objective of this study was to evaluate the growth rates of the area, production and productivity of minor millets in India by utilising the compound annual growth rate. Previous studies have predominantly focused on major agricultural and horticultural crops, with limited attention paid to minor millets. However, it is worth noting that minor millets possess a higher nutritional value than their major counterparts. In fact, the Indian government has designated 2022-23 as the International year of millet, further emphasising its significance. This study holds immense potential for uncovering the growth rates in the area, production and productivity of millets in India. It also proposes measures to increase millet cultivation and raise awareness among consumers about the nutritional benefits associated with these crops.

Materials and Methods

Database and research methodology

Status refers to the state or condition of something in relation to its circumstances. In this study, the status of minor millet was evaluated based on the area, production and productivity over the years. The focus was on minor millets, which are the least cultivated in India in terms of area, production and productivity. To gather data, various secondary sources were utilised to collect information on the area, production and productivity of minor millets from 1950-51 to 2021-22 (14). This period was divided into 4 periods: period I (1950-51 to 1979-80), period II (1980-81 to 1991-92), period III (1992-93 to 2007-2008) and period IV (2008-09 to 2021-22). To assess the growth rate, CAGRs were calculated using an exponential equation for minor millet.

$$Y_t = A B^t u_t \quad (\text{Eqn. 1})$$

Where,

Y_t = data on area or production or productivity in the year 't', A = intercept indicating Y in the base period ($t = 0$), $B = (1 + g)$ regression coefficient, t = time period in years, u_t = disturbance term for the year 't', g = average compound growth rate to be estimated.

Eqn. 1 was converted into logarithmic form in order to facilitate the use of linear regression. Taking the logarithm on both sides of the Eqn. 1.

$$\ln Y_t = \ln A + t (\ln B) + \ln u_t$$

This can be rewritten in the following form

$$Q_t = a + bt + vt$$

Where,

$$Q_t = \ln Y_t, a = \ln A, b = \ln B, vt = \ln u_t \quad (\text{Eqn. 2})$$

The values of a and b are estimated by using the ordinary least squares (OLS) estimation technique. Later, the original parameters 'A' and 'B' in Eqn. 1 were obtained by taking the anti-logarithm of the values a and b in Eqn. 2 as

$$A = \text{anti } \ln a, B = \text{anti } \ln b \quad (\text{Eqn. 3})$$

The average CAGR was calculated as

$$\text{CAGR} = (B-1) \times 100 \quad (\text{Eqn. 4})$$

The significance of the regression coefficient was tested using Students' t-test.

Measurements of instability

To measure agricultural instability, various methods can be employed, such as the coefficient of variation, Cuddy della valle index (CDVI), Coppock instability index (CII) and dispersion, etc. For this study, the CDVI, coefficient of variation (CV) and CII were used to measure instability (15).

The CDVI is particularly useful as it detrends the given series and provides a clear indication of the instability. However, the coefficient of variation has limitations when used as a measure of instability in time series data. It can overestimate the variation if there is a trend present. This means that regions with a constant rate of growing production may score high in terms of instability if the CV is used. In contrast, the cuddy-della valle index attempts to detrend the coefficient of variation by utilising the coefficient of determination.

The instability index of the CDVI is given by the expression.

$$\text{CDVI} = \text{CV} \sqrt{1 - \text{AdR}^2} \quad (\text{Eqn. 5})$$

Where,

CV = Coefficient of variation (in %), AdR^2 = Coefficient of determination calculated by time trend regression and adjusted by the number of degrees of freedom.

The CV is a measure of statistical significance used to determine the variation in the distribution of data points in a data series with respect to the mean. It can be obtained through acquiring the standard deviation and dividing it by the mean, then multiplying the result by 100.

$$\text{CV} = \frac{\text{Standard deviation}}{\text{Mean}} \times 100 \quad (\text{Eqn. 6})$$

However, the standard deviations differ significantly; this statistic serves the purpose when evaluating the level of variance across distinct data series. We calculated the coefficient of variation to analyse the level of variation in area, production and productivity during the entire period (%). This measure allows us to gauge the magnitude of variability in these factors.

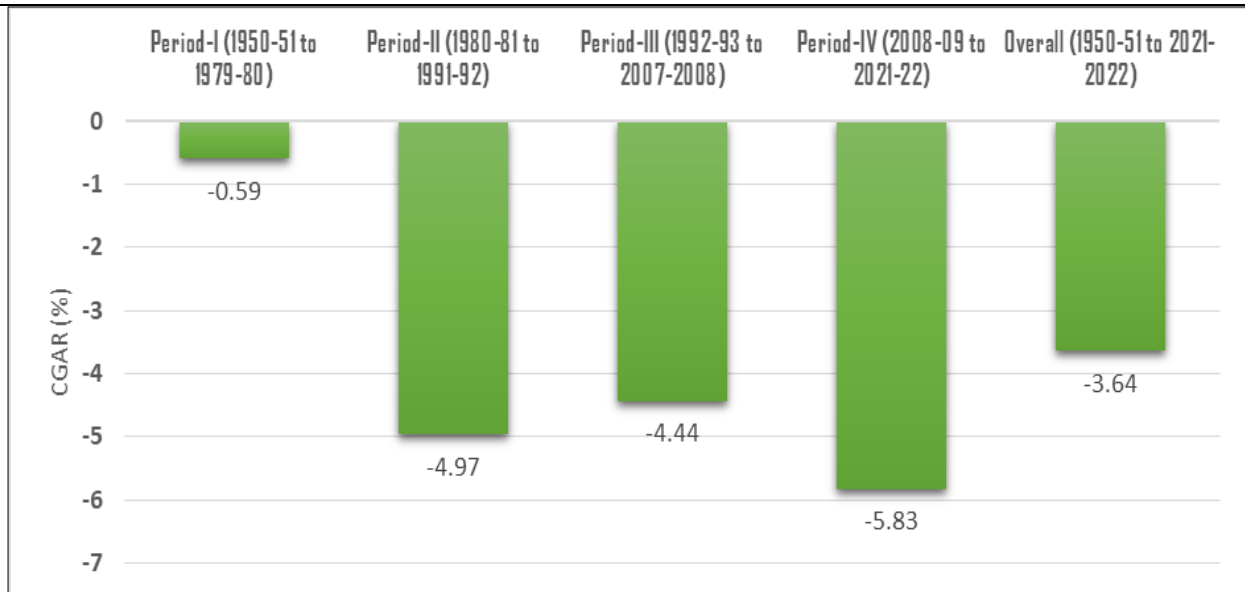
Result and Discussion

Growth rate in the area of minor millets

When considering Table 1 and Fig. 1, the overall period from 1950-51 to 2021-2022, the total area stands at 212138 (000' ha). During period III (1992-93 to 2007-2008), the downward trend in total area persisted, resulting in a significant decrease to 22702 (000' ha). This decline can be attributed to various factors, such as urbanisation,

Table 1. Trend of compound growth in the area of minor millets

Particulars	Period of study				
	Period I (1950-51 to 1979-80)	Period II (1980-81 to 1991-92)	Period III (1992-93 to 2007-2008)	Period IV (2008-09 to 2021-22)	Overall period (1950-51 to 2021-2022)
Total area('000 ha)	143349	37127	22702	8960	212138
No. of observation	30	12	16	14	72
CGAR (%)	-0.59	-4.97	-4.44	-5.83	-3.64

**Fig. 1.** Compound growth trend in the area of minor millets.

deforestation and changes in cropping patterns have played a major part in this decline. To maximise agricultural productivity, farmers often resort to monoculture or the cultivation of cash crops and commercial crops over large areas. However, the most alarming drop in total area occurred in the most recent period, period IV (2008-09 to 2021-22), where the total area plummeted to a mere 8960 (000' ha). This sharp decline raises concerns about the sustainability of land resources and calls for immediate action to address the underlying causes.

Examining the CGAR across all periods, negative values persist, suggesting a consistent decline in land area throughout the years. These negative CGAR values indicate a worrisome trend of diminishing land area over time. The moderate decrease in total area during period III, followed by a further decline in period IV, highlights the ongoing decline in land coverage. This consistent decline is further emphasised when considering the entire period from 1950-51 to 2021-2022, where the total area stands at 212,138 thousand hectares, indicating a substantial loss in land coverage. The negative CGAR values persist across all periods, with period I showing a slight decline of -0.59 %, intensifying in period II with a CGAR of -4.97 % and continuing the trend in Period III with a CGAR of -4.44 %. These figures underscore the urgent need for measures to address and mitigate the diminishing land area.

Growth rate in the production of minor millets

Table 2 and Fig. 2 provide a comprehensive analysis of minor millets production. In 1950-51, the total production of minor millets reached

Table 2. Trend of compound growth in the production of minor millets

Particulars	Period of study				
	Period I (1950-51 to 1979-80)	Period II (1980-81 to 1991-92)	Period III (1992-93 to 2007-2008)	Period IV (2008-09 to 2021-22)	Overall period (1950-51 to 2021-2022)
Total production ('000 Tonnes)	56639	15401	10193	5663	87896
No. of observation	30	12	16	14	72
CGAR (%)	-0.67	-3.69	-4.23	-1.55	-2.88

an impressive 56639 thousand tonnes. However, by the year 2021-22, this figure had significantly declined to 5663 thousand tonnes. Period I (1950-51 to 1979-80) witnessed a total production of 56639000 t. In Period II (1980-81 to 1991-92), the production decreased to 15401000 t. The trend continued in Period III (1992-93 to 2007-2008) with a further decline to 10193000 tonnes. However, in Period IV (2008-09 to 2021-22), there was a slight recovery with a production of 5663000 t. Overall, from 1950-51 to 2021-2022, the total production reached 87896000 tonnes. The CGAR for each period provides insights into the production trends. In period I, the CGAR was -0.67 %, indicating a slight decline. This decline worsened in period II with a CGAR of -3.69 %. Period III experienced the steepest decline with a CGAR of -4.23 %. However, in period IV, the decline slowed down with a CGAR of -1.55 %. The overall CGAR for the entire period from 1950-51 to 2021-2022 was -2.88 %.

Growth rate in the productivity of minor millets

The Table 3 and Fig. 3 provides data on total productivity (in kg/ha) of a certain agricultural product over 4 different periods: period-I (1950-51 to 1979-80), period-II (1980-81 to 1991-92), period-III (1992-93 to 2007-2008), period-IV (2008-09 to 2021-22) and Overall period (1950-51 to 2021-2022). In period I, the productivity (11830 kg/ha) was the highest among all the periods, indicating that the agricultural practices during this time were quite efficient. The negative CGAR (-0.07 %) suggests a slight decline in productivity over time. Compared to period I, the productivity (5009 kg/ha) dropped significantly in period II. However, there was a positive CGAR

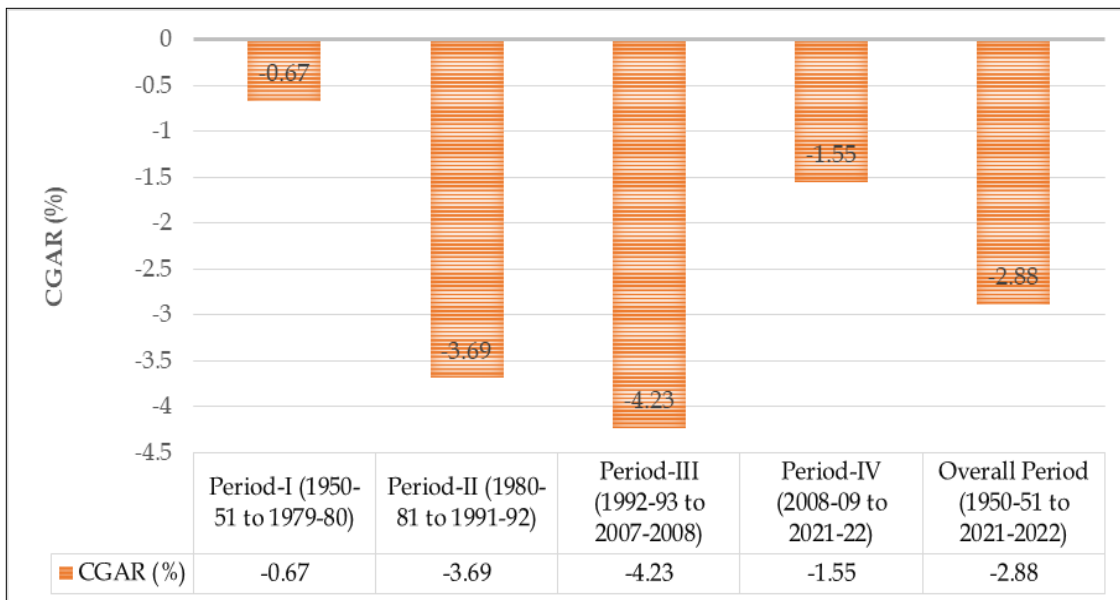


Fig. 2. Compound growth trend in production of minor millets.

Table 3. Trend of compound growth in the productivity of minor millets

Particulars	Period of study				
	Period I (1950-51 to 1979-80)	Period II (1980-81 to 1991-92)	Period III (1992-93 to 2007-2008)	Period IV (2008-09 to 2021-22)	Overall period (1950-51 to 2021-2022)
Total productivity (kg/ha)	11830	5009	7192	9232	33263
No. of observation	30	12	16	14	72
CGAR (%)	-0.07	1.34	0.21	4.55	0.78

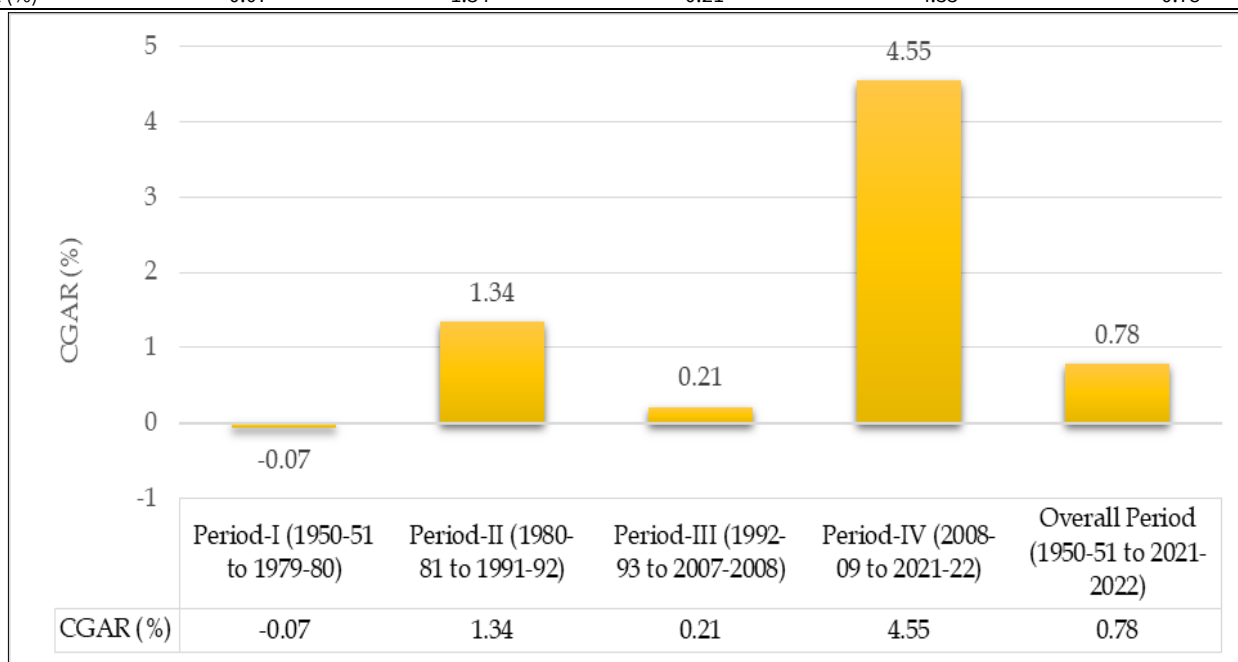


Fig. 3. Compound growth trend in productivity of minor millets.

(1.34 %), indicating a moderate growth in productivity over the years. In this period III, the productivity (7192 kg/ha) increased compared to period-II, but it was still lower than period-I. The CGAR (0.21 %) is positive but very small, indicating a slow growth in productivity. Period IV saw a significant increase in productivity (9232 kg/ha) compared to the previous periods. The CGAR of 4.55 % indicates a substantial growth in productivity, suggesting that there might have been significant advancements or improvements in agricultural practices. Considering the entire period, there has been an overall increase in productivity. The CGAR of 0.78 % indicates a moderate growth in productivity over the entire period.

The area, production, productivity and instability of minor

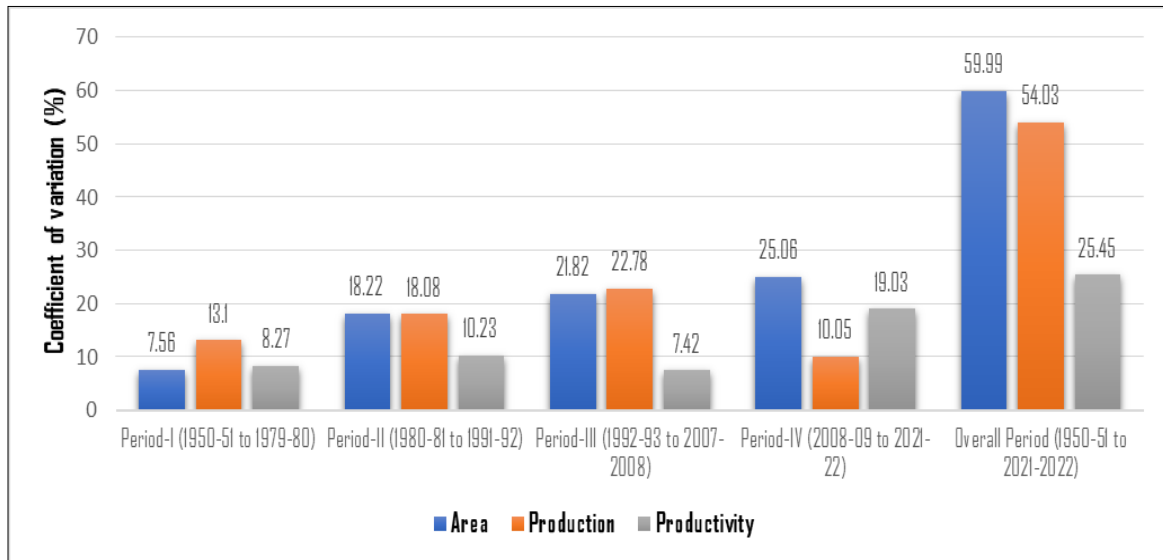
millets are comprehensively described in Table 4 and Fig. 4, with the CV performing as a measure of variability, for different periods of time spanning 1950–51 to 2021–22.

In the first period (1950-51 to 1979-80), the data reveal a relatively low CV for area at 7.56, indicating a relatively stable trend in the cultivation of minor millets during this timeframe. However, as we move into the second period (1980-81 to 1991-92), the CV for area spikes to 18.22, signifying a notable increase in the variability of land allocated for minor millet cultivation. This suggests a greater degree of uncertainty or fluctuation in the acreage devoted to these crops during this period. Similarly, when we examine the production of minor millets, we observe a similar trend. In the first period, the CV

Table 4. Instability in the area, production and productivity of minor millets

Particulars	Period I			Period II			Period III			Period IV			Overall period		
	CV	CDVI	CII	CV	CDVI	CII	CV	CDVI	CII	CV	CDVI	CII	CV	CDVI	CII
Area	7.56	5.35	39.63	18.22	3.23	44.43	21.82	3.37	45.75	25.06	4.988	47.59	59.99	14.34	86.53
Production	13.10	11.63	41.90	18.08	11.96	44.02	22.78	8.74	45.97	10.05	7.76	40.78	54.03	17.14	75.75
Productivity	8.27	8.25	39.98	10.23	8.99	40.72	7.42	7.31	39.60	19.03	5.33	44.68	25.45	17.45	54.41

CV: Coefficient of variation, CDVI: Cuddy-della valle index, CII: Coppock instability index, Period-I (1950-51 to 1979-80), Period-II (1980-81 to 1991-92), Period-III (1992-93 to 2007-2008), Period-IV (2008-09 to 2021-22) and Overall period (1950-51 to 2021-2022).

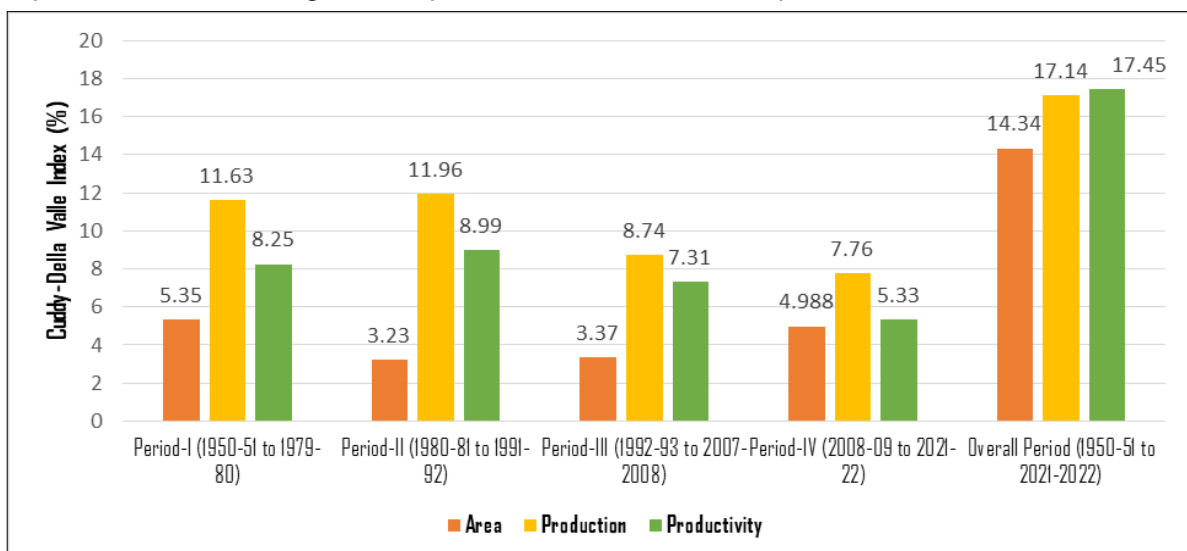
**Fig. 4.** Instability as measured by the CV in area, production and productivity of minor millets.

stands at 13.1, indicating a moderate level of variability in production. Moving into the second period, the CV for production rises to 18.08, denoting a more pronounced level of fluctuation in the output of minor millets.

The third period (1992-93 to 2007-2008) shows a further increase in the CV for both area and production, reaching 21.82 and 22.78, respectively. Interestingly, the fourth period (2008-09 to 2021-22) presents a divergence in the trends. While the CV for area continues to rise, reaching 25.06, the variability in production decreases to 10.05. This could potentially be attributed to factors such as advancements in agricultural practices, changes in cultivation patterns, or improved technology adoption, which may have led to a more stable production despite fluctuations in land allocation. When considering productivity, the data portrays a different narrative. In the first period, the coefficient of variation for productivity stands at 8.27, indicating a relatively stable trend.

However, in the subsequent periods, there is a noticeable increase in variability. The second period witnesses a rise to 10.23, followed by a drop in the third period to 7.42, before experiencing a significant surge to 19.03 in the fourth period. The overall period (1950-51 to 2021-2022) of the CV for productivity was 25.45, which is higher than period I but lower than period II and III, indicating a moderate level of variability in the yield per unit area over the entire timeframe. This suggests that the productivity of minor millets has been subject to a higher degree of fluctuation in recent years, with the most recent period showing the greatest variation.

Table 4 and Fig. 5 provide valuable insights into the stability and fluctuations within the domain of area, production and productivity of minor millets over different time periods from 1950-51 to 2021-22. In the initial period (1950-51 to 1979-80), the CDVI for the area stands at 5.35%. This indicates a moderate level of stability in the land occupied for minor millet cultivation. Transitioning into

**Fig. 5.** Instability based on CDVI in area, production and productivity of minor millets.

period II (1980-81 to 1991-92), the index drops to 3.23 %, reflecting a decrease in the variability of land use for minor millets. When we consider production, the first period exhibits a CDVI of 11.63 %. This signifies a relatively higher level of instability in the output of minor millets during this time frame. As we move into period II, there is a slight increase in the index to 11.96 %, indicating a marginal rise in production instability. This suggests that despite efforts to stabilise production, there remained a notable degree of fluctuation in the output of minor millets. In terms of productivity, the period I demonstrates a CDVI of 8.25 %, indicating a moderate level of variability. The second period witnesses a slight increase to 8.99 %, signifying a marginal uptick in productivity instability. This suggests that despite efforts to enhance productivity, there was still a degree of fluctuation in the yields of minor millets.

The period III (1992-93 to 2007-2008) shows a further decrease in the CDVI for all three categories - area, production and productivity. This implies a greater level of stability in these aspects during this period. However, in period IV (2008-09 to 2021-22), there is a noticeable increase in the index values for all three categories, indicating a rise in instability. This suggests that recent years have seen a return to a more variable scenario in terms of area, production and productivity of minor millets. Considering the overall period from 1950-51 to 2021-22, the CDVI values indicate an increasing trend of instability across area, production and productivity. This information is vital for policymakers and agricultural stakeholders to formulate strategies aimed at improving the stability and sustainability of minor millet cultivation in the future.

Table 4 and Fig. 6 illustrate the trends in instability for minor millets in terms of area, production and productivity over different time periods, ranging from 1950-51 to 2021-22. The CII is used as a metric to quantify these variations. In terms of area, there has been a consistent increase in instability over the decades. During the first period (1950-51 to 1979-80), the instability index stood at 39.63 %, which then increased to 44.43 % in the second period (1980-81 to 1991-92) and continued to rise in the subsequent periods, reaching 47.59 % in the most recent period (2008-09 to 2021-22). This indicates a growing level of uncertainty and fluctuations in the cultivation of minor millets over time. Similarly, the instability in production also displays a general upward trend. The first period saw an instability index of 41.9 %, which increased to 44.02 % in the second period. Although there was a slight dip in instability in the third period (1992-93 to 2007-2008) at 45.97 %, it again decreased to

40.78 % in the most recent period. Nonetheless, the overall trend suggests a rise in production instability. In contrast, productivity showed a more varied pattern. The first period began with an instability index of 39.98 %, which then increased slightly to 40.72 % in the second period. Surprisingly, there was a notable drop in instability during the third period, down to 39.6 %. However, in the most recent period, there was a significant increase, with an instability index of 44.68 %. This suggests a somewhat unpredictable pattern in productivity, with fluctuations occurring in different periods. Overall, when considering the entire span from 1950-51 to 2021-22, the data reveal a consistent rise in instability for all 3 parameters: area, production and productivity. This implies that the cultivation and yield of minor millets have become increasingly uncertain and subject to fluctuations over the years. This trend may be indicative of various factors such as changing climate patterns, shifts in agricultural practices, or economic influences impacting the production of these crops.

Conclusion

To conduct this study, a comprehensive collection of data spanning 72 years (from 1950-51 to 2021-22) has been gathered, encompassing information on the area of cultivation, production and productivity of minor millets. Despite a decrease in cultivation area and production, it is noteworthy that the productivity of minor millets has shown a consistent increase. An analysis of growth and instability in the area, production and productivity of minor millets in India provides valuable insights into the dynamics of this important crop category. Over the years, there has been a consistent decline in the cultivation area of minor millets, with the most significant drop observed in recent times. This trend raises concerns about the sustainability of land resources and emphasises the need for concerted efforts to address underlying causes such as urbanisation and changing cropping patterns. Similarly, the production of minor millets has shown a consistent decline, indicating a need for strategies to revitalise and promote their cultivation. The productivity of minor millets has experienced fluctuations over different periods, suggesting a need for targeted interventions to stabilise and enhance yields. In line with these findings, policymakers and agricultural stakeholders must focus on measures that promote the sustainable cultivation of minor millets. This includes targeted interventions to enhance productivity, stabilise production and address the underlying causes of declining

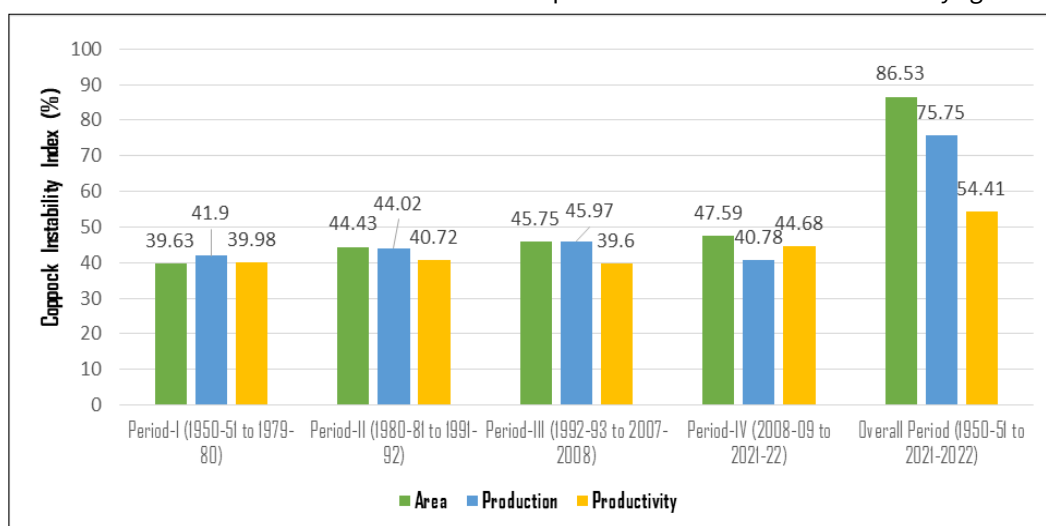


Fig. 6. Instability based on CII in area, production and productivity of minor millets.

cultivation area. Additionally, raising awareness among consumers about the nutritional benefits of minor millets can play a crucial role in revitalising their cultivation and consumption.

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Authors' contributions

BV contributed to the conceptualisation, framing the methodology, obtaining resources, carrying out the investigation, analysis and writing the original draft. AR helped in the statistical analysis, conducting the investigation, formulating the methodology, employing software and writing the original draft. DC has assisted with the analysis, investigation, methodological framework, software application and writing. ST took part in framing the methodology, utilisation of software, writing, review and editing. KKP contributed to writing, reviewing and editing the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflict of interest to declare.

Ethical issues: None

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