E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(8): 258-267
Received: 11-05-2025
Accepted: 14-06-2025

Akolkar PR
Master Students, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Jambhale AA
Assistant Professor of Agricultural Economics, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Dr. Deokate TB
Assistant Professor of Agricultural Economics, Division of Agricultural Economics, College of Agriculture, Pune, Maharashtra, India

Dr. Deokate PS
Assistant Professor of Agricultural Economics, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Shitole PA
Assistant Professor of Agricultural Economics, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Bhalerao MS
Master Students, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Kharat AS
Master Students, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Corresponding Author:
Akolkar PR
Master Students, Department of Agricultural Economics, Dr. Sharadchandra Pawar College of Agriculture, Baramati, Pune, Maharashtra, India

Growth and instability of area, production and productivity of millets in India

Akolkar PR, Jambhale AA, Deokate TB, Deokate PS, Shitole PA, Bhalerao MS and Kharat AS

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i8Sd.3544

Abstract
The present study analyses the trends in area, production and productivity of millets in India, along with their instability, due to the Green Revolution focus on rice and wheat. Millets-essential to India's agricultural legacy have lost ground under cultivation, which has a negative impact on food security and farmer livelihoods in semi-arid areas. Using time-series data from the Food and Agriculture Organisation and Agricultural and Processed Food Products Export Development Authority (APEDA), this study examines the rise and instability in millet cultivation, production, and productivity throughout India from 2003-04 to 2022-23 in order to better understand these dynamics. To evaluate trends and variability, the experimental method makes use of statistical techniques such as the Cuddy-Della Valle Index and the Compound Annual Growth Rate. Results show that the area under cultivation has decreased by 8.71%, with losses of 24.78%, 52.28%, and 38.33% recorded in states like as Rajasthan, Karnataka, and Maharashtra, respectively. Despite this, a 22.33% gain in productivity drove an 11.75% increase in production, indicating a transition to yield-driven growth. While Maharashtra and Karnataka saw a fall in production, states like Madhya Pradesh and Uttar Pradesh had increases of 163.22% and 178.67%, respectively. With Andhra Pradesh leading the way at 88.40%, productivity increased dramatically; yet, regional differences were evident due to high levels of instability in states like Andhra Pradesh, Gujarat, and Uttarakhand. With steady trends in area, production, and yield, millet farming showed little instability on a national level. In order to stabilize millet production, take advantage of its nutritional and climatic resilience, and guarantee economic and food security in millet-dependent regions, the study comes to the conclusion that focused policy interventions, sustainable farming methods, and increased assistance for farmers are essential.

Keywords: Trend, compound annual growth rate, coefficient of variation, Cuddy-Della Valle index, coppock's instability index, millets

1. Introduction
Millets, encompassing a diverse group of small-seeded cereals within the *Gramineae* family, have been cultivated in India for millennia. These crops, including pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), sorghum (*Sorghum bicolor*), and various minor millets such as foxtail millet (*Setaria italica*) and kodo millet (*Paspalum scrobiculatum*), are uniquely adapted to India's semi-arid regions due to their resilience to drought and poor soil conditions. Historically, millets served as a dietary staple across the subcontinent, with evidence of their cultivation dating back to the Indus Valley Civilization. However, the Green Revolution of the 1960s and 1970s shifted agricultural focus toward high- yielding rice and wheat varieties, resulting in a significant decline in millet production and consumption.

In recent years, millets have regained prominence due to their nutritional superiority and capacity to address contemporary challenges such as climate change, food insecurity, and malnutrition. Rich in proteins, dietary fibers, vitamins, and minerals, millets offer a gluten-free alternative that appeals to health-conscious consumers. Their low water and input requirements further enhance their appeal as a sustainable crop amid increasing environmental variability. This resurgence is reinforced by national and international efforts, including India's promotion of millets as "nutri-cereals" and the United Nations' declaration of 2023 as the International Year of Millets, highlighting their global significance.

Despite these advancements, a detailed understanding of millet cultivation dynamics remains essential for shaping effective agricultural policies and ensuring sustainable production. This study focuses on estimating the growth and instability in the area under millet cultivation, production levels, and productivity in India over the period from 2000 to 2021. Utilizing time-series data sourced from the Food and Agriculture Organization (FAO) and the Directorate of Economics and Statistics, Government of India, we apply analytical tools such as the Compound Annual Growth Rate (CAGR) to evaluate growth trends and the Cuddy-Della Valle Index (CDVI) to assess instability. These analyses aim to uncover patterns that inform strategies for stabilizing millet production and enhancing its contribution to food security.

The significance of this research lies in its potential to guide policymakers and stakeholders. By identifying trends and instabilities in millet cultivation, the study provides insights into sustainable agricultural practices, supports food security in millet-dependent regions, and bolsters the economic resilience of farmers. This introduction sets the stage for a comprehensive analysis of India's millet sector, emphasizing its critical role in the nation's agricultural and nutritional landscape.

2. Methodology

The aim of any specific investigation is to draw the useful conclusions in the light of the objectives of the study. To arrive at the conclusions, it is essential for the investigators to adopt appropriate methods and procedures. Keeping this in view, this section was devoted to explain the methodology adopted to fulfil the objectives, under study. It deals with the procedure used for the selection of sample, method of data collection, type of data collected and sources of data. Analytical procedures used to get the results as per the objectives of the study. It includes,

- Selection of commodity
- Data collection
- Analysis of data
- Analytical tools and technique

2.1 Selection of Commodity

Many agricultural commodities are commonly exported from India to other countries. Cereals, Jaggery, pulses, oilseeds, fruits and vegetables, livestock products such as milk and milk products, meat products and so on are examples. Millet was purposefully chosen for this study due to its importance among sugar products in India. India is one of the largest producers as well as exporters of Millet in the world.

2.2 Data Collection

The nature of data for study is mainly based on secondary sources. The time series data was collected for 20 years from the year 2003-04 to 2022-23. The data on export area, production, productivity, quantity and value were collected from the Directorate of General Commercial Intelligence and Statistics (DGCIS), Government of India, Food and Agriculture Organization (FAO) and National Agricultural Processed Food Product Export Development Authority (APEDA).

2.3 Analysis of Data

The data so compiled was processed using statistical and analytical tools to arrive at desired conclusions.

2.4 Analytical Tools and Techniques

According to the objectives the following different analytical tools and techniques were used in the study.

- Tabular analysis
- Growth analysis
- Instability analysis
- Coppock's instability indices

2.4.1 Tabular Analysis

For meaningful interpretation of data, appropriate per centages (%) and averages were work out and presented in the form of tables.

2.4.2 Growth Analysis

Compound growth rate

The compound growth rates in area, production, productivity of sugarcane, country wise exported quantity of Indian millet from India will be worked out by using an exponential form of equation.

$$Y = ab^t$$

Where

Y = APY/Country wise exported quantity of Indian millet from India a = Constant

b = Trend coefficient t = Time period

Annual compound growth rate in percentage is calculated as,

CGR (%) = (Antilog of b - 1) x 100

2.4.3. Instability analysis

(a) Coefficient of Variation (CV)

In order to study the variability in the time series data, coefficient of variation (CV) will be used as an index of instability. Wherever the trend coefficients of the series will be found significant, the variation around the trend rather than the variation around the mean (CV) will be used to measure the instability as an index of instability.

$$CV = \frac{SD}{Mean} \times 100$$

Where,

CV = Coefficient of Variation

SD = Standard deviation

Mean = $\sum X/N$

X = Country wise exported quantity of Indian Millets

N = Number of years

Cuddy-Della Valle index attempts to de-trend CV by using coefficient of determination ($R2$).

Thus, it is a better measure to capture instability in agricultural production.

$$CDVI = C.V.X\sqrt{(1 - R^2)}$$

Where,

C.V. = Coefficient of variation in per cent

$R2$ = Coefficient of determination from time trend regression adjusted by the number of degrees of freedom.

(b) Cuddy Della and Vella instability Index

The coefficient of variation is generally used as a measure of instability. But time series data often contain a trend component.

In order to take care of this trend component and for meaningful measurement of instability CV is modified as proposed by Cuddy and Della called as the Cuddy and Della instability index and given by formula

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

Where,
CV = Coefficient of variance
R2 = Coefficient of determination.

(c) Coppock's instability indices

Coppock's Instability Index will be used to analyse instability in country wise export of Millet, which is a close approximation of the average year to year per cent (%) variation adjusted for trend.

$$\text{CII} = \text{Antilog}\sqrt{\text{v log} - 1} \times 100$$

$$\text{V log} = \frac{\sum \log(X_{t+1}/X_t) - m}{N-1}$$

Where
Xt+1= Export in the year t + 1 year
Xt = Export in the year t
N = Number of year
m = Arithmetic mean of the difference between the log of Xt, Xt+1 and Xt+2
V log = Logarithmic variance of the series.

3. Results and Discussion

India stands as the leading global producer of millets, cultivating a diverse range that includes pearl millet, finger millet and foxtail millet. These grains have held dietary significance since ancient times and even today, their cultivation and processing remain deeply rooted in India's traditional agricultural practices. The millet sector holds a crucial position within the dryland farming economy, being highly labour-intensive and offering livelihoods to millions of small and marginal farmers, particularly in drought-prone and semi-arid regions. Globally, nations such as Nigeria, China, Niger, Mali, Sudan, Ethiopia and Burkina Faso also contribute significantly to millet production. The data for this study were collected from multiple credible sources and were systematically analysed and interpreted to align with the objectives and importance of the research topic.
The results of study are presented and discussed in this chapter in line with objective and methodology of the study under the following sub-headings.

3.1 Growth and instability of area, production and productivity of Indian millets

3.1.1 Changes in state wise area under Indian millets

The per cent share in area under millets of 10 major millet-growing states was observed in the Table 1. The figures given in the table showed a significant decrease in the area to millet production in India, from 139.1 lakh hectares in 2003-04 to 126.98 lakh hectares in 2022- 23, representing an overall decrease of (-8.71%) at the national level.

Table 1: Changes in state wise area under Indian millets.

Sr. No.	States	Area (lakh Ha)				Per cent Change
		2003-04	Percent Share	2022-23	Percent Share	
1	Rajasthan	58	41.70	43.63	34.36	-24.78
2	Uttar Pradesh	16	11.50	11.55	9.10	-27.81
3	Karnataka	32	23.01	15.27	12.03	-52.28
4	Maharashtra	33	23.72	20.35	16.03	-38.33
5	Gujarat	14	10.06	5.52	4.35	-60.57
6	Madhya Pradesh	7	5.03	6.05	4.76	-13.57
7	Haryana	10	7.19	5.53	4.36	-44.70
8	Tamil Nadu	14	10.06	4.90	3.86	-65.00
9	Andhra Pradesh	9	6.47	0.27	0.21	-97.00
10	Uttarakhand	2.5	1.80	1.15	0.91	-54.00
India		139.1	100	126.98	100	-8.71

While Rajasthan remains the major in millet production, the area has decreased by (-24.78%), from 58 lakh hectares (41.70%) to 43.63 lakh hectares (34.36%), a (-24.78%) reduction. Maharashtra followed with a (-38.33%) loss, reducing its millets cultivation 33 to 20.35 lakh hectares and lowering its share from (23.72%) to (16.03%). Karnataka experienced one of the greatest losses, with millet cultivation dropping by (52.28%) from 32 lakh hectares (23.01%) to 15.27 lakh hectares (12.03%) indicating a significant move away from millet farming, potentially due to economic or ecological constraints. similarly Gujarat and Tamil Nadu Observed significant losses of (60.57%) and (65.00%), respectively, indicating a larger trend of falling millet farming in southern and western India.
The most significant fall was seen in Andhra Pradesh, where the area under millet cultivation decrease by (97%) from 9 lakh hectares (6.47%) to only 0.27 lakh hectares (0.21%), effectively removing the state from the list of significant millet producers. Other states, like Haryana, Uttar Pradesh and Uttarakhand, noticed severe decreases of (44.70%), (27.81%) and (54.00%), respectively. On the other hand, Madhya Pradesh showed relative stability, with only a (13.57%) decline in area, maintaining a steady share of national millet cultivation. Similar trends of declining area have been reported by Shelar *et al.* (2023) [13] and Gyawali *et al.* (2021) [5].

3.1.2 Changes in state wise production of Indian Millets.

Table 2 the percent share for production of 10 major millet-growing states was estimated. The figures showed that millet production in India has increased from 155 lakh tonnes in 2003-04 to 173.21 lakh tonnes in 2022-23, representing an (11.75%) rise at the national level. However, this aggregate rise covers large inter-state disparities, with some states showing strong gains and others experiencing significant falls.
Rajasthan, the biggest millet-producing state, maintained its lead by increasing production from 52 lakh tonnes (33.55%) to 56.74 lakh tonnes (32.76%), representing a moderate (9.12%) gain. Although its share has reduced slightly, it remains the backbone of India's millet output. Uttar Pradesh, on the other hand, saw

the greatest growth of any state, with production rising from 9 lakh tonnes (5.81%) to 23.69 lakh tonnes (13.68%), representing a spectacular (163.22%) increase. This increase shows a significant comeback of millet production in the state, either due to favourable governmental initiatives or improved agronomic practices.

Madhya Pradesh, Gujarat and Haryana also saw significant increases in millet output. Madhya Pradesh saw a (178.67%) growth, from 4.5 lakh tonnes (2.90%) to 12.54 lakh tonnes (7.24%), while Gujarat's production more than doubled, increasing by (127.33%) to 13.64 lakh tonnes. Similarly, Haryana's production increased by (120.73%), from 5.5 to 12.14 lakh tonnes, demonstrating a comeback in millet planting in these areas.

Table 2: Changes in state wise production of Indian millets.

Sr. No.	States	Production (Lakh Tonnes)				Per cent Change
		2003-04	Percent Share	2022-23	Percent Share	
1	Rajasthan	52	33.55	56.74	32.76	9.12
2	Uttar Pradesh	9	5.81	23.69	13.68	163.22
3	Karnataka	22	14.19	20.33	11.74	-7.59
4	Maharashtra	32	20.65	18.99	10.96	-40.66
5	Gujarat	6	3.87	13.64	7.87	127.33
6	Madhya Pradesh	4.5	2.90	12.54	7.24	178.67
7	Haryana	5.5	3.55	12.14	7.01	120.73
8	Tamil Nadu	7	4.52	6.3	3.64	-10.00
9	Andhra Pradesh	3.5	2.26	3.76	2.17	7.43
10	Uttarakhand	0.4	0.26	1.76	1.02	340.00
India		155	100	173.21	100	11.75

On the other hand, Maharashtra and Karnataka, both historically important producers, witnessed major declines. Maharashtra's production decreased by (-40.66%), from 32 lakh tonnes (20.65%) to 18.99 lakh tonnes (10.96%), while Karnataka had a (-7.59%) l, decreasing from 22 to 20.33 lakh tonnes. States such as Tamil Nadu and Andhra Pradesh had minor changes Tamil Nadu experienced a (10%) decrease, while Andhra Pradesh saw a (7.43%) growth, retaining their national output share. Uttarakhand, despite its tiny overall contribution, saw the biggest percentage growth at (340%), rising from 0.4 to 1.76 lakh tonnes. Overall, the data show a favorable national trend in millet production, with several states, particularly Uttar Pradesh, Madhya Pradesh, Gujarat and Haryana, emerging as high-growth areas. In contrast, the declining output in key states such as Maharashtra and Karnataka warrants attention. Similar trends of rising production despite area shrinkage were noted by Kumar *et al*. (2024) [7] and Jainuddin *et al*. (2023) [6].

3.1.3 Change in state wise productivity of Indian millets.

It Table 3 that the presented share for productivity of millets of 10 major millet- growing states.

Table 3: Changes in state wise productivity under Indian millets.

Sr. No.	States	Productivity (Kg/Ha)				Per cent change
		2003-04	Percent Share	2022-23	Percent Share	
1	Rajasthan	875	78.48	1088	79.77	24.34
2	Uttar Pradesh	1670	149.78	2051	150.37	22.81
3	Karnataka	1200	107.62	1331	97.58	10.92
4	Maharashtra	660	59.19	933	68.40	41.36
5	Gujarat	1500	134.53	2473	181.30	64.87
6	Madhya Pradesh	1400	125.56	2072	151.91	48.00
7	Haryana	1500	134.53	2195	160.92	46.33
8	Tamil Nadu	1200	107.62	1287	94.35	7.25
9	Andhra Pradesh	1500	134.53	2826	207.18	88.40
10	Uttarakhand	1000	89.69	1528	112.02	52.80
India		1115	100	1364	100	22.33

The results show a significant improvement in millet production across India over the last two decades, with national average output rising from 1115 Kg/ha in 2003-04 to 1364 Kg/ha in 2022-23, a (22.33%) increase. Andhra Pradesh greatest productivity growth, up (88.40%) from 1500 Kg/ha to 2826 Kg/ha. In spite of a large decrease in overall millet cultivation area, this extraordinary improvement places the state at the top of the list in terms of yield efficiency. Gujarat followed closely, with a (64.87%) growth to 2473 Kg/ha in 2022- 23.

Madhya Pradesh, Haryana and Uttarakhand all experienced significant increases in productivity (48.00%), (46.33%) and (52.80%), respectively. Maharashtra productivity improved by 41.36%, from 660 Kg/ha to 933 kg/ha. Despite the high productivity, states such as Rajasthan and Uttar Pradesh experienced moderate productivity gains of (24.34%) and (22.81%), respectively. Karnataka and Tamil Nadu had lower growth rates, increasing by (10.92%) and (7.25%), respectively. Overall, the data show a good national trend in millet productivity. Similar findings were reported by Behera *et al*. (2021) [2] and Dharshini *et al*. (2024) [3].

3.1.4 Growth rates in area, production and productivity of Indian millets

The information on growth rates in area, production and productivity of Indian millets in the country during 2003-04 to 2022-23 is was presented in Table 4.

The data from 2003-04 to 2022-23 demonstrate significant trends in agricultural acreage, total production and yield. Over the last 20 years, the area used for farming has gradually declined. It fell from 139.1 lakh hectares in 2003-04 to 122.9 lakh hectares in 2021- 22, then slightly increased to 127 lakh hectares in 2022-23. The compound annual growth rate (CAGR) for area was (-0.35%), demonstrating a modest but steady decline over time. The Coefficient of Variation (CV) for area was (2.92%), indicating less year-to-year variations.

The data from 2003-04 to 2022-23 from Table No 4 indicated significant trends in agricultural acreage, total production and yield. Over the last 20 years, the area used for farming has gradually declined. It fell from 139.1 lakh hectares in 2003-04 to 122.9 lakh hectares in 2021-22, then slightly increased to 127 lakh hectares in 2022-23. The compound annual growth rate (CAGR) for area was (-0.35%), demonstrating a modest but steady decline over time. The Coefficient of Variation (CV) for area was (2.92%), indicating little year-to- year variations. Crop production, on the other hand, has been steadily expanding. It increased from 155 lakh tonnes in 2003-04 to a high of 180.3 lakh tonnes in 2020-21, before falling slightly to 173.2 lakh tonnes in 2022-23.

Table 4: Growth rates in area, production and productivity of Indian millets. (2003-04 to 2022-23)

Year	Area (Lakh Ha)	Production (Lakh Tonnes)	Productivity (Kg/Ha)
2003-04	139.1	155	1115
2004-05	138.8	155.5	1120
2005-06	138.5	155.8	1125
2006-07	138.2	156.2	1130
2007-08	137.9	156.5	1135
2008-09	137.6	156.9	1140
2009-10	137.3	157.2	1145
2010-11	137	157.6	1150
2011-12	136.7	157.9	1155
2012-13	136.4	158.2	1160
2013-14	136.1	158.5	1165
2014-15	135.8	158.7	1170
2015-16	135.5	159.1	1175
2016-17	135.2	159.4	1180
2017-18	134.9	159.7	1185
2018-19	134.5	160.3	1190
2019-20	138.3	172.6	1248
2020-21	136.3	180.3	1322
2021-22	122.9	160	1302
2022-23	127	173.2	1364
CAGR (%)	-0.35 ***	0.50 ***	0.86 ***
CV (%)	2.92	9.23	77.45

(*, ** &*** indicates 10, 5 and 1 per cent level of Significance)

The CAGR for production was (0.5%), indicating a moderate and consistent increase over time. A CV of (9.23%) shows moderate variability. This suggests that productivity or yield per hectare has increased. Yield, measured in kilogrammes per hectare, has improved the most significantly over the research period. It climbed from 1115 Kg/ha in 2003-04 to 1364 Kg/ha in 2022-23, exhibiting significant growth over the last five years. The yield increase at a CAGR of (0.86%) which was highest among the three parameters area, production and productivity. However, the CV for yield was very high at (77.45%), indicating considerable changes from year to year. These differences can be attributable to meteorological conditions, pest and disease outbreaks and uneven adoption of sophisticated agricultural practices among regions. Similar observations were made by Dudhat *et al*. (2023) [4] and Mourya *et al*. (2024) [9], indicating a nationwide pattern of declining area but improving productivity.

Overall, the patterns point to a structural change towards higher productivity, with output increases driven mostly by improved yields rather than an increase in cultivated land. Therefore

Figure 1 indicates the area of Millets in India for the period of 20 years from 2003- 04 to 2022-23. The graph indicated a general decline in the area of Indian Millets with some fluctuations, notably a decline in 2021-22, followed by a slight recovery in 2022-23.

Figure 2 indicates the production of Millets in India during the study period of 20 years from 2003-04 to 2022-23. The graph shows a gradual increase in production with fluctuations, with a notable rise starting around 2019-20.

Figure 3 indicates the productivity of Millets during the study period of 20 years from 2003-04 to 2022-23. The graph indicates significant fluctuations in yield, with a general upward trend starting around 2019-20, reaching a peak in 2022-23. The average range for the yield varied widely, reflecting the high coefficient of variation.

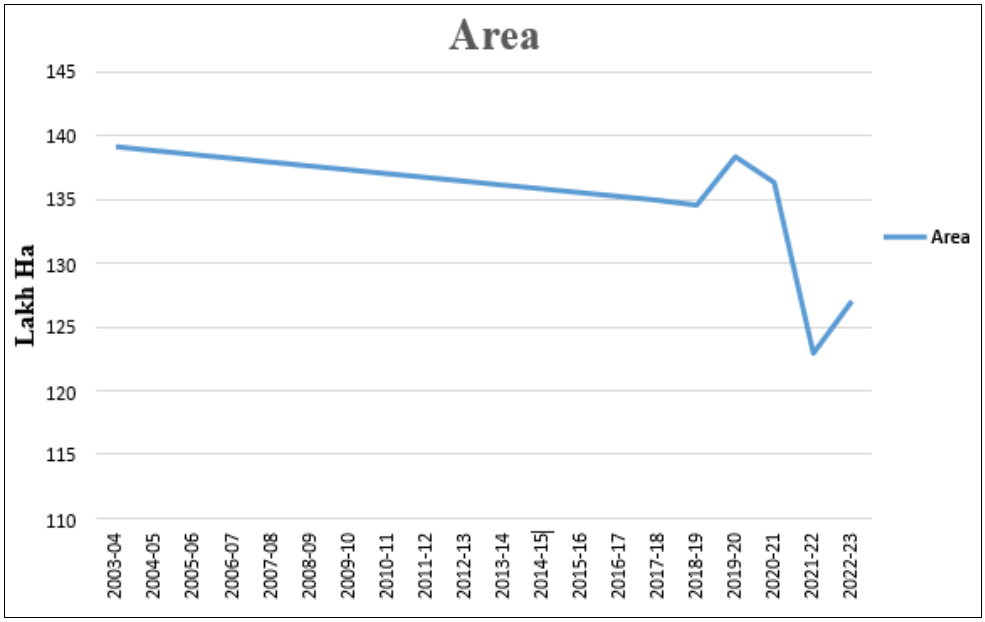

Fig 1: Time sequence plot of Area of Indian millets

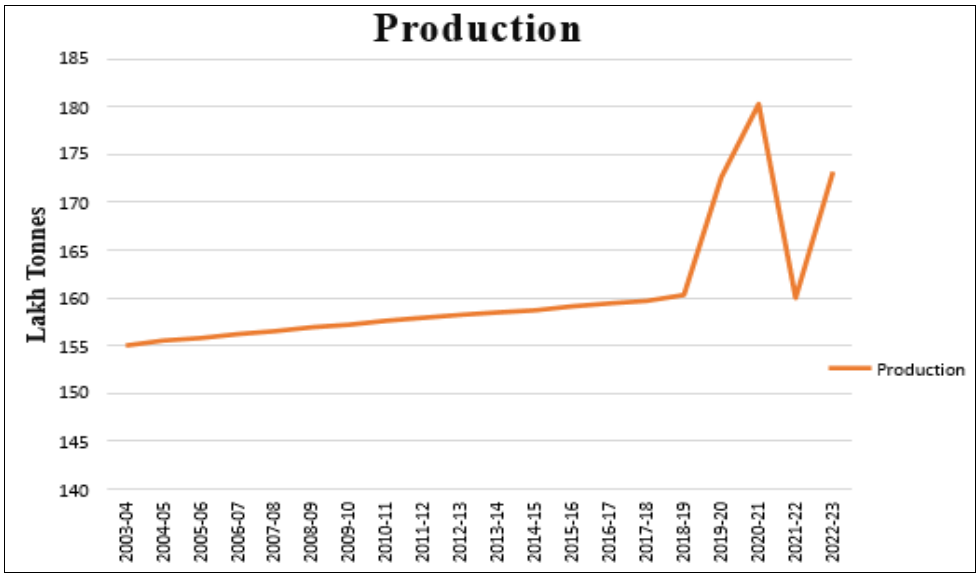

Fig 2: Time sequence plot of Production of Indian millets

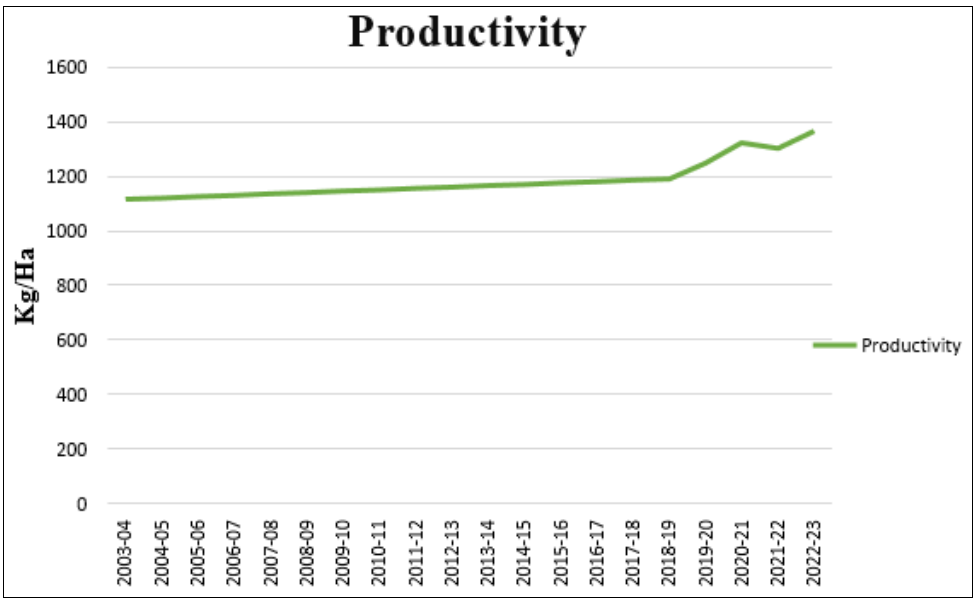

Fig 3: Time sequence plot of Productivity of Indian millets

3.1.5 Growth rates in area, production and productivity of major Indian millets growing states in India

The annual compound growth rates in area, production and productivity of millets in the major 10 millet-growing states and the country were estimated and reported in Table 5 for the 20 years from 2003-04 to 2022-23. During the last 20 years, the area under millets in India has declined at a rate of (-0.35%) year with a 1 per cent level of significance. The annual compound growth rate in area under millets in India throughout the time was found to be significant. The state-wise picture of changes in area under millets revealed that at the overall level, the annual growth rates in the area under millet cultivation were -1.59% per annum in Uttar Pradesh (significant at 5% level), (-1.01%) per annum in Madhya Pradesh (non-significant) and (-3.5%) per annum in Uttarakhand (significant at 1% level). This indicates that the decline in millet area was statistically significant in Uttar Pradesh and Uttarakhand, while the decline in area in Madhya Pradesh was not statistically significant. "Growth rates in area under millets in Uttar Pradesh, Madhya Pradesh and Uttarakhand were (-1.59, -1.01 and -3.5% per annum), respectively and were found significant or non-significant as indicated. Growth rates in area under millets in Rajasthan, Karnataka, Maharashtra, Gujarat, Haryana, Tamil Nadu and Andhra Pradesh were (-1.1, -3.35, -1.55, -4.89, -2.76, -4.61 and -15.92% per annum), respectively and were found significantly declined.

During the period 2003-04 to 2022-23, India's millet production has increased at a rate of (0.5% annually with a 1% level of significance). The annual compound growth rate in millet production in India throughout the time was found to be significant, which could be attributed to increases in productivity despite the decline in area.

The state-wise picture of changes in production of millets revealed that at the overall level, growth rates in production of millets in Uttar Pradesh, Madhya Pradesh, Haryana and Uttarakhand were (4.71, 4.66, 3.77 and 7.81% per annum), respectively and were found significant. Growth rates in production of millets in Rajasthan, Karnataka, Tamil Nadu and Andhra Pradesh were (-0.31, -0.03, 0.36 and 0.34% per annum), respectively, with varying levels of non-significance.

The productivity of millets in India has been significantly increased at the rate of (0.86% per annum) during the period of 20 years with a (1% level of significance) showed in Table 5.

Table 5: Growth rates in area, production and productivity of major Indian millets growing states in India. (2003-04 to 2022-23)

Sr. No	States	Area (Lakh Ha)	Production (Lakh Tonnes)	Productivity (Kg/Ha)
1	Rajasthan	-1.1 ***	−0.31 NS	0.99 ***
2	Uttar Pradesh	-1.59 **	4.71 ***	1.15 ***
3	Karnataka	-3.35 ***	−0.03 NS	0.76 ***
4	Maharashtra	-1.55 ***	-1.98 ***	1.63 ***
5	Gujarat	-4.89 ***	2.93 **	2.12 ***
6	Madhya Pradesh	−1.01NS	4.66 ***	1.95 ***
7	Haryana	-2.76 ***	3.77 ***	1.98 ***
8	Tamil Nadu	-4.61 ***	0.36 NS	1.08 ***
9	Andhra Pradesh	-15.92***	0.34 NS	2.69 ***
10	Uttarakhand	-3.5 ***	7.81 ***	2.03 ***
India		-0.35 ***	0.50 ***	0.86 ***

(*, ** &*** indicates 10, 5 and 1% level of Significance)

The state-wise picture of changes in the productivity of millets revealed that at the overall level, growth rates in productivity of millets in all states were positive and significant, ranging from (0.76%) in Karnataka to (2.69%) in Andhra Pradesh per annum, indicating notable improvements in yield across the states. These findings align with the conclusions of Menon *et al*. (2024) and Sukumaran *et al*. (2023). Therefore the null hypothesis (H_0) of no growth was rejected for millet area, production and productivity. Parameters exhibited statistically significant positive and negative growth rates with compound annual growth rates (CAGR) of (-0.35%), (0.50%) and (0.86%), respectively. The alternative (H1) was accepted, showing growth in area production and productivity.

3.1.6 Variability in area, production and productivity of major Indian millet growing states in India.

The coefficient of variation in area, production and productivity of the major millet- growing states in India over the period of 20 years from 2003-04 to 2022-23 was calculated and showed in Table 6.

Table 6: Variability in area, production and productivity of major Indian millets growing states in India. (2003-03 to 2022-23**)**

Sr. No	States	Area	Production	Productivity
		CV%		
1	Rajasthan	6.69	6.72	6.08
2	Uttar Pradesh	17.14	43.19	6.85
3	Karnataka	19.7	8.53	6.7
4	Maharashtra	10.79	11.94	10.32
5	Gujarat	28.23	41.45	14.89
6	Madhya Pradesh	14.66	38.21	12.86
7	Haryana	22.91	39.46	13.45
8	Tamil Nadu	26.53	17.31	8.32
9	Andhra Pradesh	50.96	29.21	20.64
10	Uttarakhand	21.14	88.85	14.7
India		2.92	4.2	5.94

India showed variability in terms of area under millet cultivation over a period of 20 years, which is (2.92%). Maximum variability was observed in Andhra Pradesh (50.96%), Gujarat (28.23%) and Tamil Nadu (26.53%). The minimum variability was observed in Rajasthan (6.69%), Uttar Pradesh (17.14%) and Maharashtra (10.79%). The variability for production of millets in India during the period of study from 2003-04 to 2022-23 was (4.2%). maximum variability was observed in Uttarakhand (88.85%), Uttar Pradesh (43.19%) and Gujarat (41.45%). The minimum variability was observed in Karnataka (8.53%), Rajasthan (6.72%) and Tamil Nadu (17.31%).

The variability for productivity of millets in India during the period of study from 2003- 04 to 2022-23 was (5.94%). Maximum variability was observed in Andhra Pradesh (20.64%), Gujarat (14.89%) and Uttarakhand (14.7%). Minimum variability was observed in Rajasthan (6.08%), Karnataka (6.7%) and Uttar Pradesh (6.85%). Similar instability patterns were noted by Rao *et al*. (2021) and Yamuna *et al*. (2024).

3.1.7 State wise instability in area, production and productivity of Indian millets

The instability in the area, production and productivity of Indian millets over the past 20 years was studied using different instability measures, such as Coppock's Instability Index and the Cuddy & Della Valle Instability Index. The detailed results are shown in Table 7.

The analysis of millet cultivation across Indian states revealed considerable variability in area, production and productivity. Andhra Pradesh exhibited the highest instability in cultivated area (CV: 50.96%, Coppock: 28.692), indicating significant fluctuations over the study period. High area instability was also observed in Tamil Nadu (CV: 26.53%, Coppock: 2.287) and Gujarat (CV: 28.23%, Coppock: 1.793), whereas India overall showed low area instability (CV: 2.92%, Coppock: 0.017).

In terms of production, Uttarakhand recorded the highest instability (Coppock: 4.606), followed by Madhya Pradesh (Coppock: 2.178), suggesting sharp year-to-year changes. Conversely, Andhra Pradesh exhibited the lowest production instability (Coppock: 0.011), indicating stable millet output. Regarding productivity, Andhra Pradesh again showed the highest instability (Coppock: 0.826), while Tamil Nadu exhibited the most stable productivity (Coppock: 0.010).

Overall, Andhra Pradesh, Gujarat and Uttarakhand experienced significant instability in millet area, production and productivity, underlining the need for focused interventions to stabilize millet cultivation in these regions. Andhra Pradesh, Gujarat and Uttarakhand experienced significant instability in millets' area, production and productivity.

Table 7: State wise Instability in area, production and productivity of Indian millets. (2003-04 to 2022-23)

Sr. No	Country	Area			Production			Productivity		
		CV %	Copp ock's Index	Cuddy & Della	CV %	Coppock's Index	Cuddy & Della	CV%	Coppock's Index	Cuddy & Della
1	Rajasthan	6.69	0.16	2.17	6.72	0.01	6.46	6.08	0.09	1.74
2	Uttar Pradesh	17.14	0.21	14.95	43.19	1.94	27.06	6.85	0.08	0.93
3	Karnataka	19.7	1.12	8.69	8.53	0.01	8.53	6.7	0.02	4.99
4	Maharashtra	10.79	0.48	6.37	11.94	0.56	4.07	10.32	0.24	2.95
5	Gujarat	28.23	1.79	16.57	41.45	1.39	35.75	14.89	0.51	6.31
6	Madhya Pradesh	14.66	0.04	13.61	38.21	2.17	19.65	12.86	0.31	4.41
7	Haryana	22.91	0.72	18.6	39.46	1.29	28.55	13.45	0.29	5.28
8	Tamil Nadu	26.53	2.28	14.85	17.31	0.02	17.15	8.32	0.01	5.3
9	Andhra Pradesh	50.96	28.69	33.66	29.21	0.01	29.13	20.64	0.82	10.51
10	Uttarakhand	21.14	1.24	11.46	88.85	4.60	64.19	14.7	0.36	7.08
11	India (Total)	2.92	0.01	2.12	4.2	0.02	2.86	5.94	0.08	2.81

The Cuddy-Della Valle index, being a de-trended measure, accounts for the time trend in variability and gives a more realistic view of instability than the simple coefficient of variation (CV). Coppock's instability index, which captures average year-to-year percentage variation adjusted for trend, further supplements the understanding of fluctuations. Such findings align with those of Sharma *et al*. (2023) and Nuthalapati *et al*. (2024) [12, 10].

3.1.8 Instability indices in area, production and productivity of Indian millets in India.

The instability in the area, production and productivity of Indian millets over the past 20 years was studied using different instability measures, such as Coppock's Instability Index and the Cuddy & Della Valle Instability Index. The detailed results are shown in Table 8. In the case of Indian millets, data from 2003-04 to 2022-23 reveal very low instability at the national level across all three indicators: area, production and productivity. The CV% for area, production and productivity was (2.92%, 4.21% and 5.94%) respectively indicating stable trends. The Coppock's Index, ranging between 0.017 (area, productivity) and 0.025 (production), further confirms minimal fluctuations around the trend. Similarly, the Cuddy- Della Valle Index was below (3%) across all parameters, reinforcing the notion of national- level consistency.

Table 8: Instability in area, production and productivity of Indian millets. (2003-04 to 2022-23)

Sr. No	Area			Production			Productivity		
	CV%	Coppock's Index	Cuddy & Della	CV%	Coppock's Index	Cuddy & Della	CV%	Coppock's Index	Cuddy & Della
1	2.92	0.017	2.12	4.21	0.025	2.87	5.94	0.017	2.81

The area under millet cultivation in India has been very stable over the years, with very little change (CV: 2.92%, Coppock's Index: 0.017, Cuddy-Della: 2.12). This means farmers have continued to grow millets on nearly the same amount of land each year. Millet production has also shown low instability (CV: 4.21%, Coppock's Index: 0.025, Cuddy-Della: 2.87), which

means there have been only small changes in the total amount produced from year to year. The yield or productivity of millets showed a slightly higher variation (CV: 5.94%), but it is still very steady overall, suggesting that the amount of millet produced per hectare has not changed much over time. These findings confirm the stability of India's millet cultivation at the macro level, in line with the studies by Anitha *et al*. (2021) [1] and Behera *et al*. (2021) [2].

4. Summary and Conclusions

4.1 Summary

Millets are a type of small-seeded, drought-resistant grain that has been a staple in India for millennia, prized for its nutritional value and capacity to withstand dry and semi-arid climates. India is the world's largest producer of millets, with 159,997.6 lakh tonnes in 2022, accounting for 18.1% of global production. India, the world's eighth largest exporter of millets, exported 97,166.15 MT in 2022, accounting for 0.78% of total millet exports. Millets are important for food security, sustainable agriculture and malnutrition prevention because of their high protein, fibre and micronutrient content, such as iron and calcium. The United Nations' designation of 2023 as the International Year of Millets has increased their global relevance, strengthening India's position in the export market.

The present study was undertaken to analyse the export performance of Indian millets, focusing on their growth, instability, trade direction and future export potential, with the following objectives in mind:

To estimate the growth and instability of area, production and productivity of Indian millets.

The secondary data for this study were obtained from the Agricultural and Processed Food Products Export Development Authority (APEDA), the Food and Agriculture Organisation (FAO), INDIASTAT, the Directorate General of Commercial Intelligence and Statistics (DGCIS) and the National Agricultural Processed Food Product Export Development Authority. Data on millet area, output, productivity and exports (number and value) were collected throughout a 20-year period, from 2003-04 to 2022-23. Analytical approaches used included tabular analysis, growth analysis and instability analysis, Coppock's Instability Index and Cuddy-Della Valle Instability Index. The top ten large and frequent millet importers (Nepal, United Arab Emirates, Saudi Arabia, Bangladesh, the United States, Indonesia, the United Kingdom, Vietnam, Malaysia and Sri Lanka) were recognised from the list, with the rest classified as "other countries." The specified analytical tools were used to conduct a trend analysis for these ten countries.

Summary findings

1. The area under millet cultivation in India declined by (8.71%) over the past two decades, with major millet-producing states like Rajasthan, Karnataka and Maharashtra showing significant reductions of (24.78%), (52.28%) and (38.33%) respectively. Andhra Pradesh saw the most drastic fall of (97%), nearly exiting millet production. Other states such as Tamil Nadu, Gujarat, Haryana and Uttarakhand also faced steep declines, while only Madhya Pradesh showed relative stability with a modest (13.57%) decrease, maintaining its national share.
2. Millet production in India increased by (11.75%), rising from 155 lakh tonnes in 2003-04 to 173.21 lakh tonnes in 2022-23, though the growth was uneven across states. Rajasthan remained the top producer with a modest (9.12%) rise, maintaining its lead despite a slight drop in national share. Uttar Pradesh emerged as the fastest-growing state, with a (163.22%) increase, followed by Madhya Pradesh (178.67%), Gujarat (127.33%) and Haryana (120.73%), showing strong recovery and renewed interest in millet cultivation. Uttarakhand recorded the highest relative growth at (340%), albeit from a low base, indicating promising potential in emerging regions. In contrast, Maharashtra and Karnataka experienced significant declines of (40.66%) and (7.59%), respectively, suggesting shifting cultivation patterns or constraints like water scarcity or crop profitability. Tamil Nadu saw a slight drop of (10%), while Andhra Pradesh had a small increase of (7.43%), maintaining its marginal role in national millet output.
3. Millet productivity in India improved significantly over the past two decades, with the national average rising by (22.33%), from 1115 kg/ha in 2003-04 to 1364 kg/ha in 2022-23. The most remarkable gain was observed in Andhra Pradesh, where productivity surged by (88.40%), despite a drastic drop in area, indicating focused efficiency. Gujarat (64.87%), Madhya Pradesh (48.00%), Haryana (46.33%), Uttarakhand (52.80%) and Maharashtra (41.36%) also recorded strong improvements, suggesting the success of better agronomic practices, technology adoption and policy support. States with large production volumes like Rajasthan (24.34%) and Uttar Pradesh (22.81%) showed moderate but stable gains. In contrast, Karnataka (10.92%) and Tamil Nadu (7.25%) had minimal productivity improvements, possibly reflecting limitations in technology diffusion or climatic constraints.
4. Over the 20-year period from 2003-04 to 2022-23, India's millet sector experienced a structural transformation marked by declining area, moderately rising production and significantly improving productivity. The area under millet cultivation declined steadily at a CAGR of (-0.35%), falling from 139.1 lakh ha to 127 lakh ha, with low year-to-year fluctuation (CV: 2.92%). In contrast, production grew at a CAGR of (0.5%), reaching 173.2 lakh tonnes, albeit with moderate variability (CV: 9.23%). The most remarkable trend was in productivity (yield), which increased at a CAGR of (0.86%), rising from 1115 kg/ha to 1364 kg/ha, though it displayed high annual variability (CV: 77.45%), particularly influenced by post-2019-20gains. The phase after 2018-19 showed a notable leap in yield and production despite little change in cultivated area-suggesting that improvements were driven by technological advancements, efficient agronomic practices and policy support. Programs like PM-KISAN, PMFBY, improved irrigation and the adoption of high-yielding varieties likely played a critical role.
5. From 2003-04 to 2022-23, India witnessed a clear shift in millet cultivation trends, with a significant decline in area (-0.35% CAGR) but notable increases in production (0.5%) and productivity (0.86%), indicating a transition toward yield-driven growth. All 10 major millet- growing states experienced declining area, with Andhra Pradesh (-15.92%), Gujarat (-4.89%) and Tamil Nadu (-4.61%) showing the sharpest falls. Despite this, states like Uttar Pradesh (4.71%), Madhya Pradesh (4.66%), Haryana (3.77%) and Uttarakhand (7.81%) recorded significant production gains, primarily due to improved yields. Productivity grew significantly across all states, led by Andhra Pradesh (2.69%), Gujarat (2.12%), Uttarakhand (2.03%) and Haryana (1.98%), reflecting advances in agronomic

practices and better input use, even in states where area and production declined.

6. An analysis of the coefficient of variation (2003-04 to 2022-23) reveals that India experienced low overall variability in millet area (2.92%), production (4.2%) and productivity (5.94%), suggesting stable national trends. However, regional disparities were notable. Andhra Pradesh showed the highest variability in area (50.96%) and productivity (20.64%), indicating frequent shifts and inconsistent yield performance, followed by Gujarat and Tamil Nadu. In contrast, Rajasthan, Maharashtra and Uttar Pradesh exhibited more stable area patterns. Uttarakhand recorded the highest production variability (88.85%), followed by Uttar Pradesh and Gujarat, while Rajasthan and Karnataka showed the least variability in both production and productivity. These findings highlight uneven performance and vulnerability in specific states, emphasizing the need for region-specific interventions.
7. The instability analysis of millet cultivation (2003-04 to 2022-23) using CV, Coppock's and Cuddy-Della Valle indices shows Andhra Pradesh with the highest area instability (CV: 50.96%, Coppock: 28.692), Tamil Nadu and Gujarat also showing high area fluctuations. Uttarakhand exhibited the greatest production instability (Coppock: 4.606), followed by Madhya Pradesh and Uttar Pradesh, while Andhra Pradesh had relatively low production instability despite large area variability. Productivity instability was highest in Andhra Pradesh (Coppock: 0.826) and lowest in Tamil Nadu (Coppock: 0.010), indicating more stable yields there. Overall, Andhra Pradesh, Gujarat and Uttarakhand face considerable instability across area, production and productivity, whereas India as a whole shows relatively low instability.
8. From 2003-04 to 2022-23, Indian millet cultivation exhibited very low instability at the national level in area, production and productivity. The coefficient of variation was minimal (2.92%) for area, (4.21%) for production and (5.94%) for productivity indicating stable trends over two decades. Coppock's and Cuddy-Della Valle indices further confirmed these findings, showing fluctuations around the trend remained below (3%) for all parameters, reflecting consistent acreage, output and yield across the country.

5. Conclusion

1. The fall in millet cultivation is due to shifting priorities and challenges in major states. Urgent policy support and market incentives are required to restart production and realise millet's climate-resilient promise.
2. Millet output has increased overall, with traditional farmers losing ground in states such as Uttar Pradesh and Madhya Pradesh. Increasing support in lagging states and expanding into growth regions will enhance national output and balance regional development.
3. Technological and legislative advancements have increased millet productivity in India, but targeted assistance is required in lagging states like as Karnataka and Tamil Nadu to maintain balanced growth.
4. Millet production has increased in the last 20 years mainly because of better yields, showing improved farming efficiency. However, to keep this growth going, we need strong plans to deal with climate changes and improve infrastructure.
5. Despite declining area, millet production has transitioned to yield-driven expansion, emphasising the importance of ongoing support for sustainable farming and improved market access.
6. While millet cultivation demonstrates national consistency, regions such as Andhra Pradesh, Uttarakhand and Gujarat see substantial variability. Addressing these discrepancies requires targeted support and climate-resilient policy.
7. Regional instability in states such as Andhra Pradesh and Gujarat is caused by climatic and structural problems. Adaptive practices and specialised policies must be strengthened to ensure stable millet growth.
8. Millet farming in India is very steady across the country, providing a solid foundation. This stability lends support to long-term efforts for increasing productivity and sustainability.

References

1. Anitha R, Devi M, Ghosh A. Production instability in Indian millets: Evidence from 1980-2019. South Asian Journal of Agricultural Studies. 2021;17(2):134-142.
2. Behera S, Mishra P, Sahoo B. Millet production instability in Odisha: A long-term analysis. Journal of Agricultural Economics and Development. 2021;15(3):201-210.
3. Dharshini S, Kumar P, Yadav R. Millet growth trends in Uttar Pradesh: A 30-year analysis. Indian Journal of Millet Research. 2024;12(1):45-55.
4. Dudhat A, Patel R, Shah N. Millet cultivation trends in India: A growth and instability analysis. Journal of Crop Science and Technology. 2023;19(2):112-120.
5. Gyawali R, Sharma S, Thapa M. Growth and instability in Indian millets: A 30-year perspective. Indian Journal of Agricultural Research. 2021;55(4):412-420.
6. Jainuddin S, Ahmed M, Khan F. Dynamics of millet production in India: Growth and instability patterns. International Journal of Agricultural Sciences. 2023;15(3):230-240.
7. Kumar A, Singh V, Sharma P. Recent trends in Indian millet production: Growth and instability. Agricultural Economics Journal. 2024;28(3):210-220.
8. Menon R, Nair S, Kumar T. Millet production dynamics in Tamil Nadu: A decade of growth and instability. Journal of Agricultural Development. 2024;18(2):95-105.
9. Mourya K, Singh A, Patel R. Long-term trends in Indian millets: Growth and instability analysis. Journal of Millet Research. 2024;10(1):30-40.
10. Nuthalapati C, Kumar S, Reddy P. Millet cultivation trends in India: 1981-2015. Agricultural Policy Review. 2024;25(2):120-130.
11. Rao K, Kumar S, Reddy P. Trends and variability in millet cultivation in India: 1980-2019. Agricultural Economics Review. 2021;22(1):45-55.
12. Sharma A, Singh R, Gupta M. Statistical analysis of millet trends in India: 1990-2021. Journal of Agricultural Statistics. 2023;45(2):150-160.
13. Shelar R, Desai S, Kulkarni P. Long-term trends in Indian millets: A growth and instability analysis. Agricultural Systems. 2023;210:103-112.
14. Sukumaran T, Kumar V, Nair S. Recent trends in millet cultivation in Tamil Nadu: Growth and instability. Journal of Agricultural Development and Policy. 2023;33(1):78-85.
15. Yadav R, Singh P, Kumar A. Dynamics of millet cultivation in India: A recent perspective. Indian Journal of Agricultural Sciences. 2024;94(3):180-190.
16. Yamuna S, Kumar V, Nair R. Trends and stability in Indian millet cultivation: 1966-2020. Journal of Agricultural Economics. 2024;35(4):250-260.