

Trend and Instability Analysis of Area, Production, Productivity of Millets in India

Abstract

The research aims to explore the trends and stability in the production, area, and productivity of millets in India over a span of 54 years, from 1966-67 to 2019-20. The study uses secondary data from ICAR millet statistics, and applies various mathematical models such as linear, polynomial, logarithmic, power, and exponential functions to analyze the trends. To estimate annual growth rates, dispersion, and instability, the study employs compound growth rates, coefficients of variation, and the Cuddy-Della Valle index. Results indicate an alarming decline in cultivation area and production, particularly in major millets like Sorghum and Finger millet, attributed to over-cultivation of major crops (cereals, pulses, and cash crops). However, millet yield demonstrates resilience and positive growth trends. The stability indices reveal varying degrees of instability among millet categories, emphasizing the need for tailored interventions. Forecasted trends for the next decade predict further declines in area and production but suggest a potential reversal in the increasing yield trend. The study underscores the nutritional significance of millets and their role in climate-resilient agriculture. The research indicates that there is a need for targeted measures to promote millet cultivation, such as the use of improved varieties, and creating awareness about their nutritional benefits. This is important in order to enhance the area and production under millet, and also to align with global sustainability goals. The findings provide a valuable foundation for developing evidence-based agricultural policies.

Key words: Millets, Trend, Instability, Area, Production, Yield

Introduction

Millets play a vital role in ensuring food and nutritional security and contributing significantly to the economic efficiency of farming in India. As a major producer of various millets, including Sorghum, Bajra, Finger millet, Korra, Little millet, Kodo millet, Proso millet, and Barnyard millet, India leads the world in millet production. With a cultivation area of 13.83 million hectares and a production of 17.26 million tonnes, India accounts for 20% of global production and 80% of Asia's production (Rani et al., 2023).

Traditionally integral to India's diets, millets are celebrated for their nutritional value and resilience. Known as superfoods, they are rich in dietary fibers and essential minerals like calcium, magnesium, and iron, offering wholesome dietary choices beneficial for managing health conditions such as diabetes, high cholesterol, and hypertension (Sivaramaneet *et al*, 2023). Recognizing the importance of millets, the United Nations declared 2023 as the International Year of Millets, aligning with India's advocacy. This designation aims to bring global attention to millets and their role in addressing food security, nutrition, and sustainable agriculture (Venkataramanan, 2023).

Millets exhibit adaptability to diverse soil and climatic conditions, thriving particularly well in well-drained loamy soil, with Maharashtra, Rajasthan, and Karnataka being prominent millet-producing states (Kumar *et al*, 2022). Millets are water-saving and drought-tolerant crops, offering resilience on low-fertility marginal land and reducing dependence on chemical fertilizers. Their optimal growing season spans from June to November, and they are known for their resilience to minimal precipitation, which is crucial for food security amidst climate change challenges (Gowri and Prabhu, 2017; Prasad, 2023).

Despite their significant nutritional value and climatic adaptability, millets remain underutilized. Growing awareness about their benefits and their inclusion in the public distribution system can drive growth rates in the area, production, and productivity of millets. Addressing high yield gaps, low prioritization in research, limited technological advancements, and restricted investments in millet seed development and production is crucial. Additionally, providing socio-ecological bonuses to millet farmers, as well as insurance and institutional finance, can support this cause (Gowri and Shivakumar, 2020).

However, the share of millets in the overall cereal production has diminished significantly, dropping from 26% to 6% between 1966 and 2021. To reverse this trend, better branding and introducing a greater variety of millets and processed millet products have immense potential in urban areas and for export markets (Sivaramane et al., 2023). The over-cultivation of major crops and the Green Revolution have led to a reduction in millet cultivation areas over the years, displacing these traditional, nutrient-rich crops (Kumar et al., 2022; Jena and Mishra, 2020).

The area under millet cultivation has shown a steep decline between 1956 and 2006, while wheat and rice, which were cultivated in less area than millets in 1955-56, have steadily overtaken millets (Anbukkani et al., 2017). In the last two decades, their importance as food staples, particularly in Asia, has been declining due to rising incomes, growing urbanization, and government policies favoring the production and consumption of fine cereals like rice and wheat (Parthasarathy and Basavaraj, 2015).

Despite the importance of millets, there is a lack of comprehensive analysis on the long-term trends and instability in their area, production, and productivity in India. This study focuses on analyzing trends in area, production, productivity of all millets, and its stability in India over the years, estimating future trends based on available past data. The study aims to address these gaps

by providing a detailed analysis to inform policies and strategies for enhancing millet cultivation in India.

Methodology

The present study has been undertaken to study the trends in area, production, and productivity of millets, their stability, and future estimates in India. The study has been conducted based on secondary data collected for millets; categorized into four groups namely Sorghum, Pearl millet, Finger millet, and Minor millets. Data was collected for the period of 54 years from 1966-67 to 2019-20 from millet statistics by ICAR (www.milletstats.com). Linear, polynomial, logarithmic, power, and exponential functions were fitted to analyze the trends in millets' area, production, and productivity. The regression function which has got higher R^2 value and minimum polynomial degree as compared to the others was selected as the best fitted model for the data (Similar methodology was used by Sathish Kumar et al, 2022 and Prasad, 2023 to study the millets trend). Based on the best fitted trend lines the values of area, production and yield were estimated for next ten years that is from 2020-21 to 2029-30. Besides these, compound growth rate, coefficient of variation (CV), and instability index were also computed to study the stability.

To estimate the annual compounding growth rate of area, production and yield growth model used by Vennila and Murthy, 2021; Sathish Kumar et al, 2022 and Ayalew 2015 was used.

The exponential compound annual growth rate is estimated using linear functions on time series data on millets' area, production, and productivity. The log exponential functional form was used to determine compound growth rate. It is one of the appropriate applicable forms to estimate the growth rate.

$$Y_t = AB^t e \quad (1)$$

Y_t is the variable (Area, Production, Productivity)

t is the time variable,

A is constant,

B is $(1+r)$, where ' r ' is compound growth rate

e is the error term.

Transforming equation 1 into logarithmic form to convert exponential equation into linear form and find growth rate

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

Then CAGR (in per cent) is calculated as:

$$CAGR = [\text{antilog}(\ln B) - 1] \times 100$$

To analyse instability in area, production, and productivity Cuddy-Della Valle index (CDVI) was used (Ayalew, 2015 had also used same method to study instability). Though the coefficient of variation (CV) is commonly used for estimating the dispersion with comparability across various units, it cannot be used in the case of time series data characterized by time trend. Any measure of instability needs to exclude the deviation in the data series that may arise due to secular trends or growth.

$$CDVI = CV \times (\sqrt{1 - ADR^2}), \text{ where } CV = \frac{\sigma}{\bar{X}} \times 100$$

ADR^2 is Adjusted R square value (adjusted coefficient of determination)

CV is Coefficient of Variation

SD is Standard Deviation

Results and Discussion

Table 1: Descriptive statistics of area, production, productivity of millets over the years

	Area (000 Ha)	Production (000 tonnes)	Yield (Kg /Ha)
Mean			
Sorghum	12126.46	8688.08	753.98
Pearl Millet	10120.69	6848.24	714.31
Finger Millet	1909.27	2220.97	1228.02
Minor Millets	2433.67	1023.47	467.60
Standard Deviation			
Sorghum	4396.03	2432.23	151.66
Pearl Millet	1677.98	2124.82	306.78
Finger Millet	554.48	433.56	287.79
Minor Millets	1557.50	568.14	110.38
Coefficient of Variation			
Sorghum	36.25	28.00	20.11
Pearl Millet	16.58	31.03	42.95
Finger Millet	29.04	19.52	23.44
Minor Millets	64.00	55.51	23.61

The central tendency (Mean) variation in the area, production and yield of all four millets categories (Sorghum, Pearl millet (Bajra), Finger millet and other minor millets) considered for the study are presented in Table 1. The values in the tables are conditionally formatted means cells are filled with colors ranging from light to dark shades based on the values in the cell from low to high to compare between crops. Over the years, sorghum has highest mean area and production as it is one of the important food grain in India after major cereals but yield is highest in case of Finger millet followed by sorghum. Rani *et al* (2023) in their study mentioned that Sorghum is the fourth most important food grain in India after rice, Wheat and Maize in terms of area (4.09 M ha) and production (3.47 m Mt). Standard deviation of area and production is more for Sorghum showing its greater variability over mean and least for Finger millet. But in terms of yield, Minor millets had least standard deviation. Coefficient of variation was highest for minor millets for both area and production whereas for yield it was highest for pearl millet. Considering

the low CV, Pearl millet, finger millet and Sorghum were considered as the most consistent in terms of area, production and productivity.

Table 2: Compound annual growth rate of millets over the years

	Area (000 Ha)		Production (000 tonnes)		Yield (Kg /Ha)	
	Regression coefficient	CAGR	Regression coefficient	CAGR	Regression coefficient	CAGR
Sorghum	-0.0254	-2.51%	-0.0145	-1.44%	0.0110	1.11%
Pearl Millet	-0.0098	-0.98%	0.0146	1.47%	0.0243	2.47%
Finger Millet	-0.0186	-1.84%	-0.0049	-0.49%	0.0137	1.38%
Minor Millets	-0.0474	-4.64%	-0.0366	-3.60%	0.0108	1.09%

Note: All CAGR are significant at 1 % level of significance.

Picture 1 : Growth Rate Of Area , Production And Yield (CAGR %)

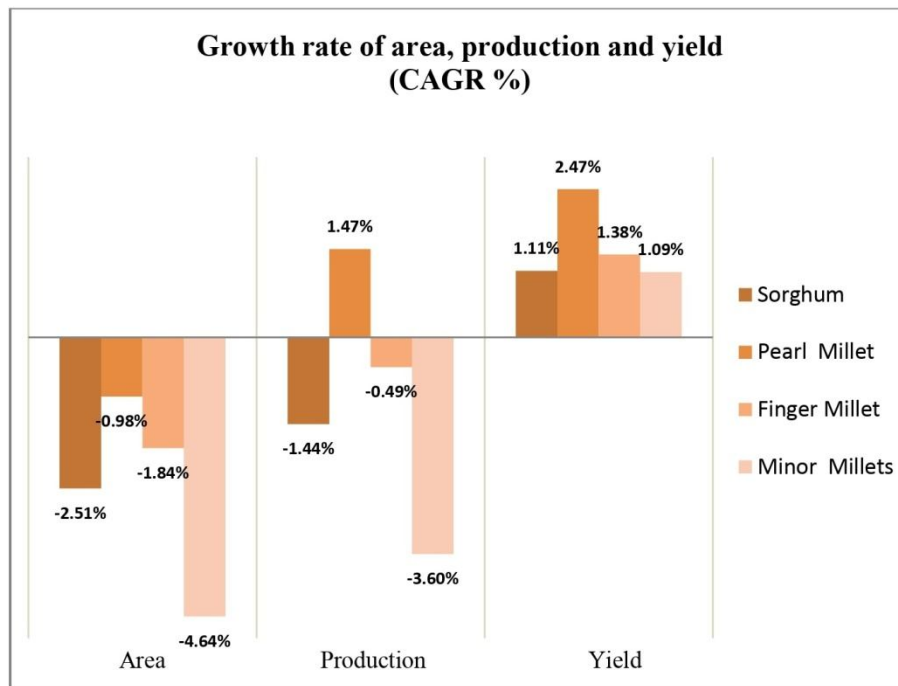


Table 2 shows regression coefficients of exponential function of the area, production and productivity of all the four millet categories as well as compound annual growth rates over the years. From the near zero p values it was confirmed that all CAGR percentages are significant at 1 percent significance level. All millets have witnessed decrease in area which is extreme in case

of minor millets as shown by negative CAGR this is mainly because of shift in area under millets towards major cereals crop. The results are in line with the study of Kumar *et al* (2022). His study showed that overall area of cultivation of minor millets has decreased from 2447 thousand hectares to 458 thousand hectares during the period 1990-91 to 2019-20 due to over-cultivation of major cereals, pulses, and cash crops; even though decreasing the cultivation area and production, the productivity of minor millets has been increasing. Among different millets pearl millet had least decrease in area which can be seen by its lowest negative CAGR value. For production and productivity also pearl millet itself had highest growth rate among others. Minor millets had the least growth and highest decline in area, production and productivity. Production also had the decreasing trend like area in all cases except for pearl millet which had slightly positive growth due to its increasing productivity. Productivity had been increasing in all crops and pearl millet had witnessed the highest productivity growth rate.

Table 3: Trend and Instability Analysis of millets over the years

	Area (000 Ha)	Production (000 tonnes)	Yield (Kg /Ha)
Shorgum			
Fitted equation	$y = 0.106x^3 - 11.22x^2 + 53.61x + 17559$	$y = 0.122x^3 - 15.82x^2 + 430.2x + 7664.$	$y = -0.152x^2 + 16.17x + 460.3$
R2	0.97	0.78	0.70
Adj R2	0.97	0.78	0.70
Cuddy Della Valley Instability Index	5.90	13.26	11.07
Pearl millet			
Fitted equation	$y = -0.482x^2 - 70.03x + 12529$	$y = 1.506x^2 + 14.72x + 4937.$	$y = 0.375x^2 - 3.229x + 428$
R2	0.82	0.55	0.87
Adj R2	0.82	0.54	0.87
Cuddy Della Valley Instability Index	7.04	21.11	15.69
Finger millet			
Fitted equation	$y = 0.043x^3 - 4.159x^2 + 78.55x + 2127.$	$y = 0.039x^3 - 4.429x^2 + 127.5x + 1538.$	$y = 16.29x + 779.8$
R2	0.95	0.57	0.79

Adj R2	0.95	0.56	0.79
Cuddy Della Valley Instability Index	6.29	12.94	10.76
Minor Millets			
Fitted equation	$y = 6998e^{-0.04x}$	$y = 0.039x^3 - 2.975x^2 + 23.37x + 1750.$	$y = 0.011x^3 - 0.763x^2 + 15.65x + 319.4$
R2	0.97	0.94	0.89
Adj R2	0.97	0.94	0.88
Cuddy Della Valley Instability Index	10.81	13.38	8.08

The instability analysis of area, production and productivity of all four millet categories over the years is depicted in Table 3. The Instability index of 0-15 shows low instability, 15-30 medium instability, more than 30 shows high instability. Except pearl millet production and yield all other parameters showed low instability with their index being less than 15. Pearl millet production and yield on the other hand showed moderate instability (with index 21.11 and 15.69 respectively). Overall, millets have shown low variability in terms of area, production, and productivity due to their adaptability to diverse climatic conditions and resilient growth hence less instable. Vennila (2021) in their study indicated that the instability indices for area, production and productivity for finger millet is positive which indicates less risk in growing finger millet in future. Among different crops sorghum had least instability for area and minor millets were most instable. In case of production finger millet, is least instable and pearl millet is the most. Minor millets showed most stability of productivity over the years and pearl millet did least. On an average production was least stable and area was most stable considering all crops together when area, production and productivity are compared for their stability among each other.

Trend analysis and forecast of Sorghum

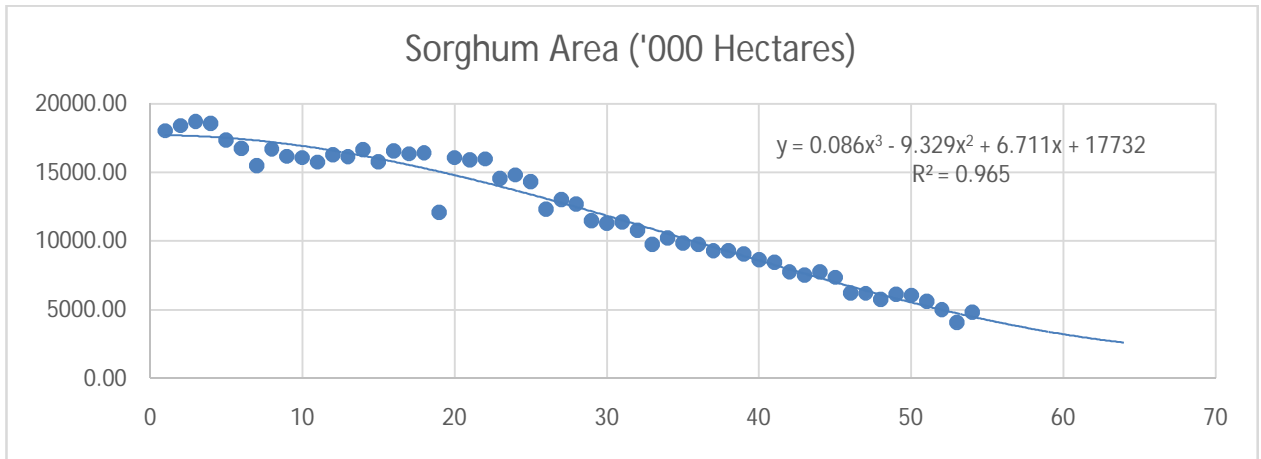


Fig 1: Trend of Sorghum Area

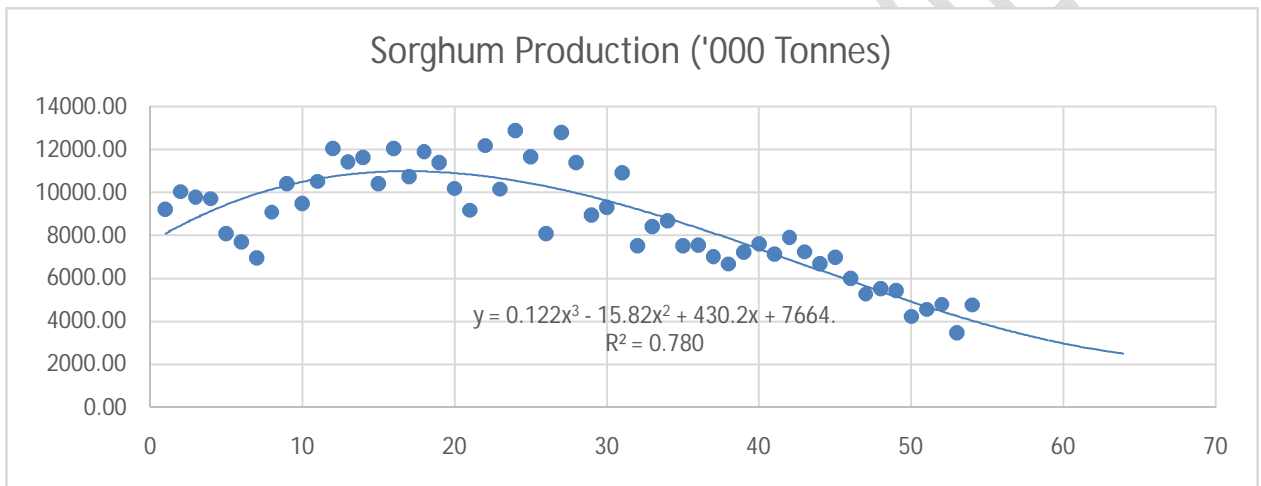


Fig 2: Trend of Sorghum Production

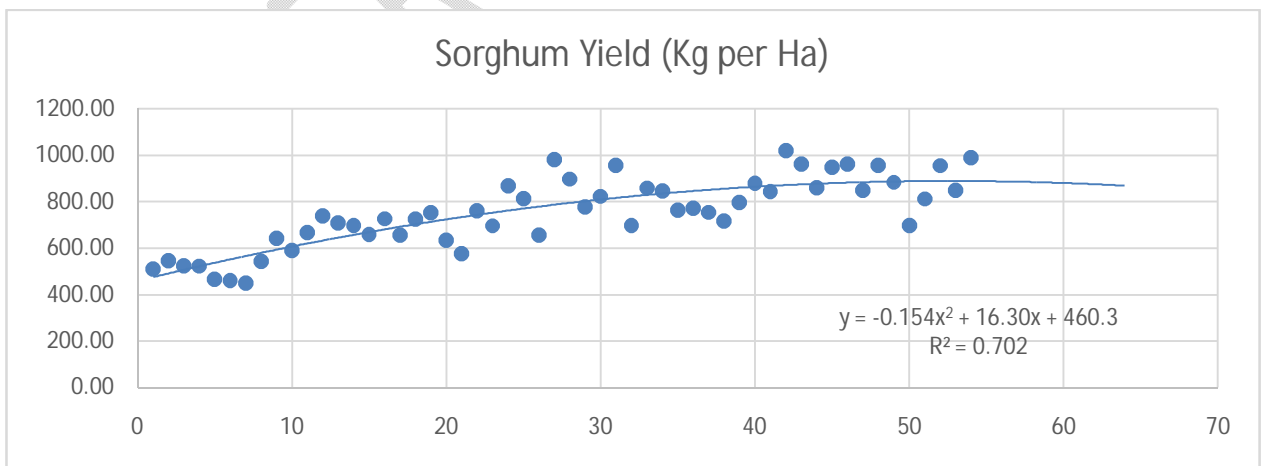


Fig 3: Trend of Sorghum Yield

Table 4: Forecasting of Sorghum

Year	Period	Area (000 Ha)	Production (000 tonnes)	Yield (Kg /Ha)
2020-21	55	4202.80	3767.25	889.85
2021-22	56	3990.54	3568.83	889.15
2022-23	57	3791.45	3379.77	888.14
2023-24	58	3606.17	3200.78	886.83
2024-25	59	3435.34	3032.62	885.22
2025-26	60	3279.60	2876.00	883.30
2026-27	61	3139.58	2731.66	881.08
2027-28	62	3015.91	2600.34	878.55
2028-29	63	2909.23	2482.75	875.72
2029-30	64	2820.18	2379.65	872.59

From the scatter plots plotted for different crops for their area, production and productivity trend over the years for the same was studied. Sorghum area, production is showing decreasing trends (from 18054.10 to 4823.76 thousand hectares and 9223.80 to 4772.10 thousand tonnes respectively from 1966 to 2020). The main reason for this decreasing trend is shift of area to major cereals as part of green revolution and adoption of commercial crops. Both of them fitted better for polynomial regression of degree 3 with coefficient of determination (R^2) of 0.965 and 0.78 respectively. Sorghum yield on the other hand showing increasing trend over the years (because of increase in yield potential of new varieties) with R^2 value 0.702 fitted for polynomial regression of degree 2. Based on the best fitted regression equations the area, production and productivity were forecasted for 10 years from 2020-21 to 2029-30 (Table 4). From the forecast it is shown that like the previous trend area and production continue to decrease further and reach 2820.18 thousand ha and 2379.65 thousand tonnes by 2030 respectively. Yield on the other hand which was increasing till 2020 will take a turn and start decreasing in future. Prasad (2023) in their study showed in the period of 10 years between

2011/12 to 2020/21 the growth rate in the area of millet was found in 'decreasing trend' while the growth rate of both production and productivity of millet was found in 'increasing trend'.

Trend analysis and forecast of Pearl millet

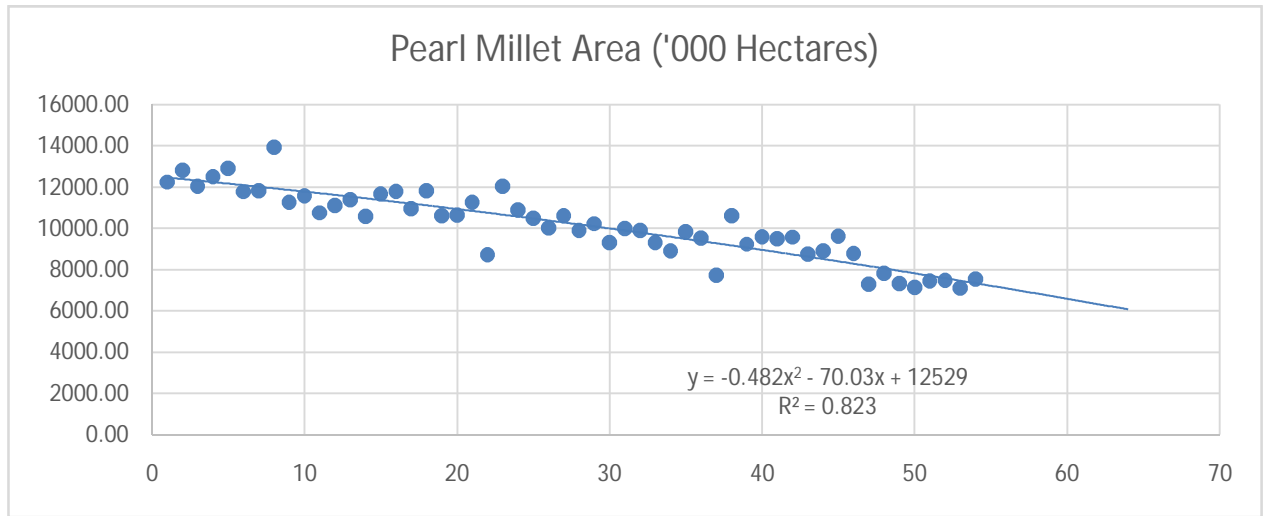


Fig 4: Trend of Pearl Millet Area

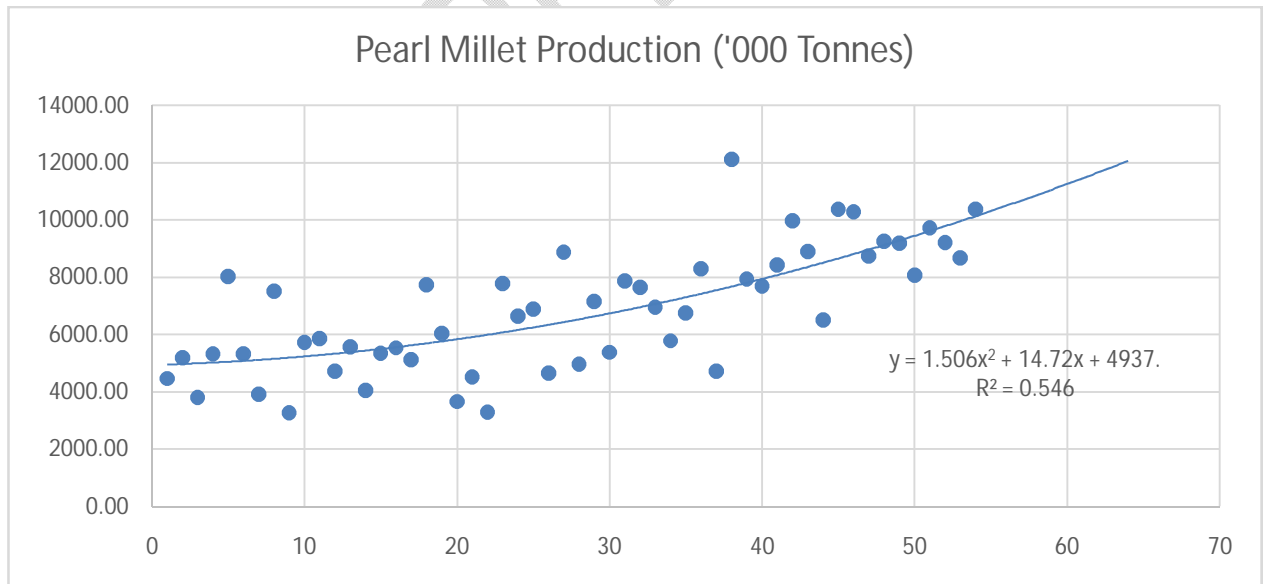


Fig 5: Trend of Pearl Millet Production

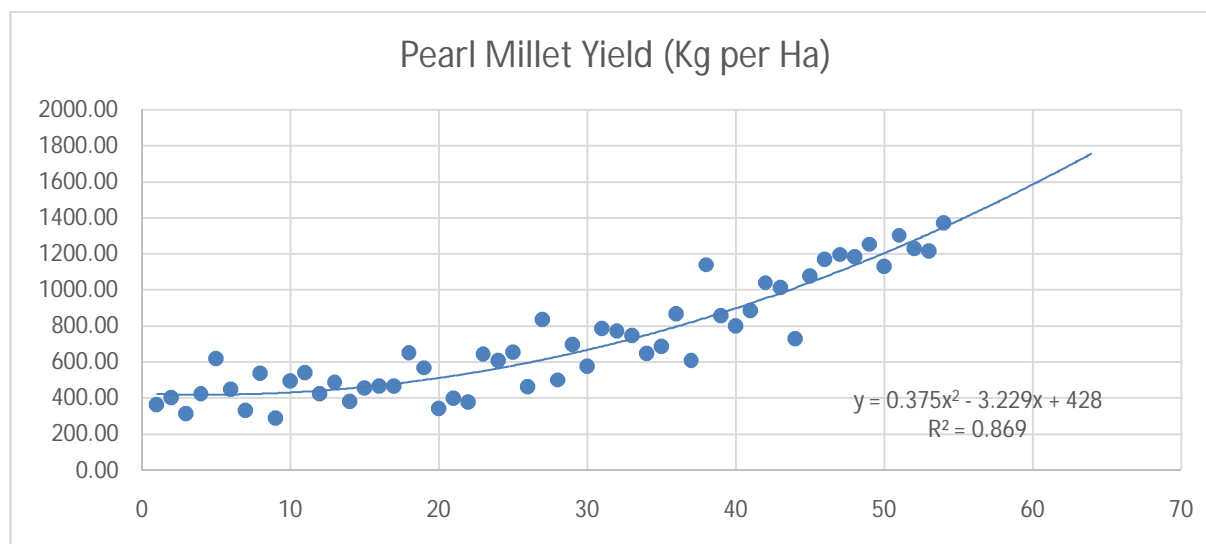


Fig 6: Trend of Pearl Millet Yield

Table 5: Forecasting of Pearl Millet

Year	Period	Area (000 Ha)	Production (000 tonnes)	Yield (Kg /Ha)
2020-21	55	7219.30	10302.25	1384.78
2021-22	56	7095.77	10484.14	1423.18
2022-23	57	6971.27	10669.03	1462.32
2023-24	58	6845.81	10856.94	1502.22
2024-25	59	6719.39	11047.87	1542.86
2025-26	60	6592.00	11241.80	1584.26
2026-27	61	6463.65	11438.75	1626.41
2027-28	62	6334.33	11638.70	1669.30
2028-29	63	6204.05	11841.67	1712.95
2029-30	64	6072.81	12047.66	1757.34

Area of Pearl millet was decreasing because of shift towards major cereals (from 12239.70 to 7542.68 thousand hectare in the span of 54 years) with R^2 value 0.823 and fitted for polynomial regression of degree two. Conversely Tripathi et al., (2013) in their study showed since 1950 the area under pearl millet has increased from 7.74 million ha to 13.93 million ha registering a growth of almost 7.68%. Both pearl millet production and yield were increasing in trend (from

4468.30 to 10362.68 thousand tonnes and 365.07 to 1374.00 Kg / ha) with R2 value 0.546 and 0.869 respectively and fitted for polynomial of degree 2. Pearl millet forecast shows area continue to decrease and finally reach 6072.81 thousand hectares by 2030 and production and productivity continue to increase to 12047.66 thousand tonnes and 1757.34 Kg/ha respectively (Table 5).

Trend analysis and forecast of Finger millet

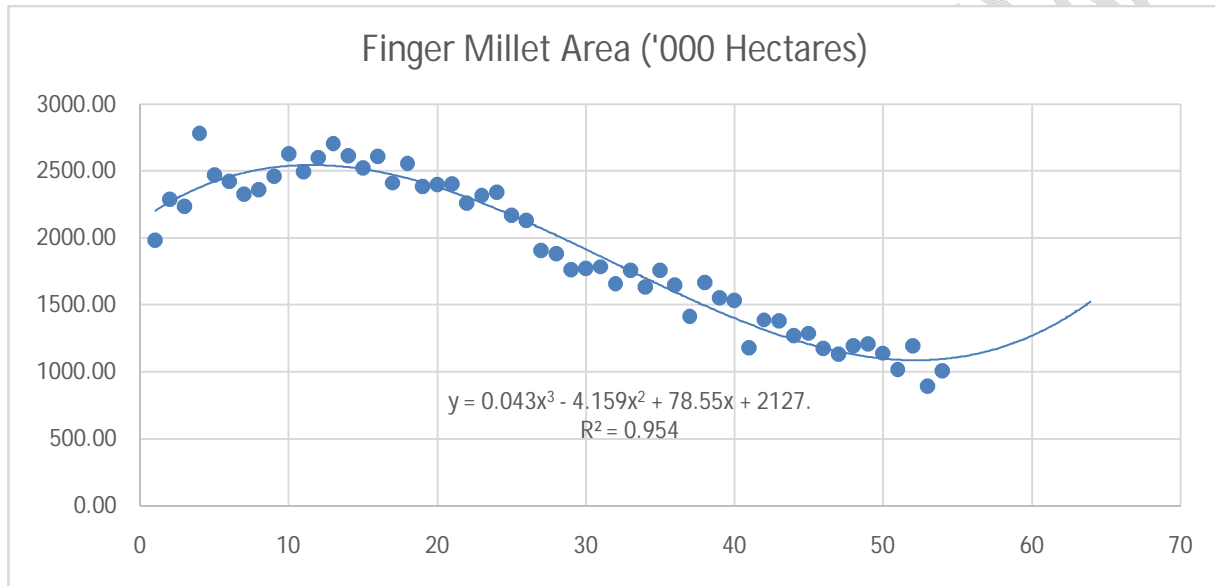


Fig 7: Trend of Finger Millet Area

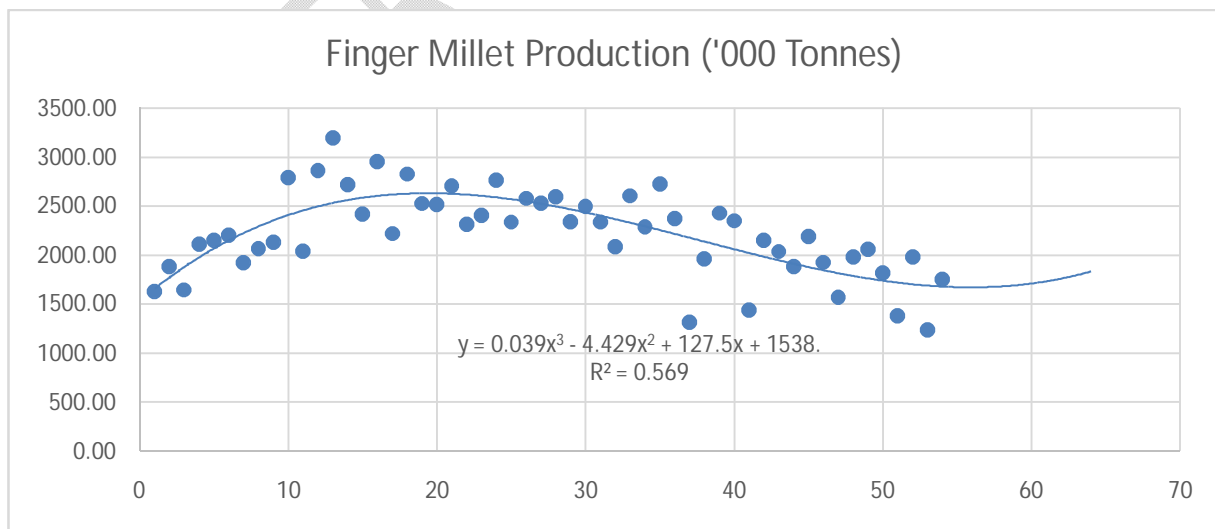


Fig 8: Trend of Finger Millet Production

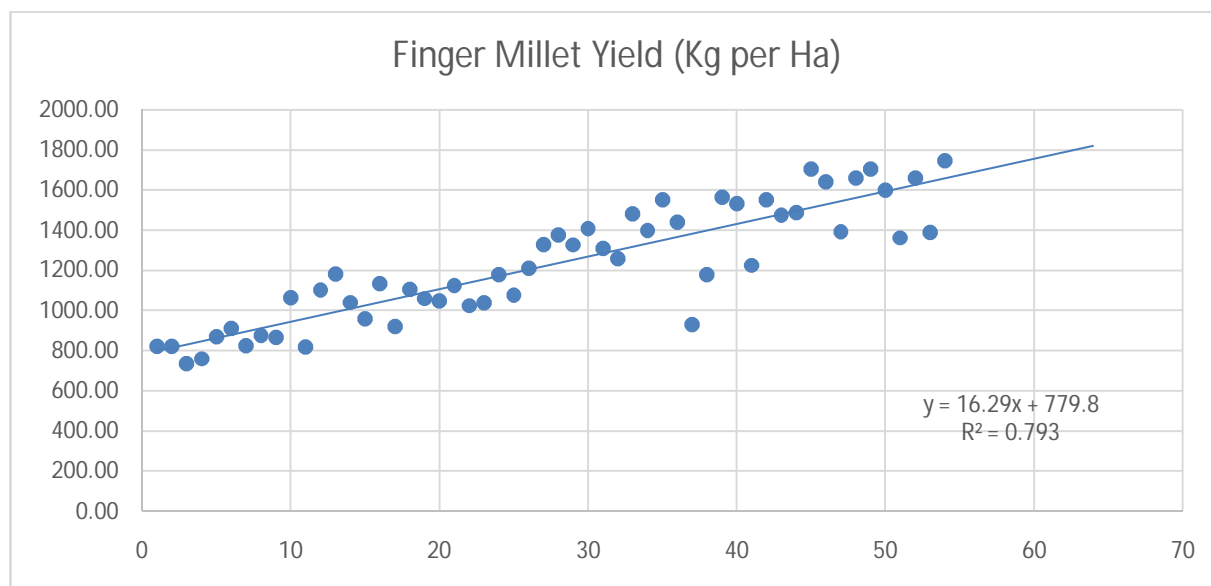


Fig 9: Trend of Finger Millet Yield

Table 6: Forecasting of Finger Millet

Year	Period	Area (000 Ha)	Production (000 tonnes)	Yield (Kg /Ha)
2020-21	55	1020.40	1641.40	1675.75
2021-22	56	1034.66	578.14	1692.04
2022-23	57	1055.06	638.84	1708.33
2023-24	58	1081.84	706.93	1724.62
2024-25	59	1115.27	782.64	1740.91
2025-26	60	1155.60	866.20	1757.20
2026-27	61	1203.09	957.85	1773.49
2027-28	62	1258.01	1057.83	1789.78
2028-29	63	1320.60	1166.37	1806.07
2029-30	64	1391.13	1283.70	1822.36

Area of finger millet has also followed decreasing trend because of same reason (1984.20 to 1004.46 thousand hectares) with R^2 value 0.954. Production shows convex trend to x axis and lately decreasing, with R^2 value 0.569 and best fitted for polynomial of degree 3. Yield on the other hand showed increasing linear trend (821.79 to 1747.27 Kg /ha) with R^2 value 0.793.

Vennila (2021) in their study showed the growth rate of area of finger millet in India showed

significant at 1 per cent level with negative trend which is due to diversification of crops and production showed significant at 5 per cent level but negative trend as it is the function of area and productivity. The productivity found insignificant negative trend which is due adoption of traditional varieties. Finger millet area continue to decrease as seen in its trend in the past and reach 1397.13 thousand hectares by 2030. Production of the finger millet was decreasing till 2020 which took a sharp dip in 2022 and take a turn and continue to increase up to 1283.70 thousand tonnes. Yield on the other hand continue to follow its previous increasing trend for next 10 years and reach 1800.36 Kg/ha by 2030 (Table 6).

Trend analysis and forecast of Minor millets

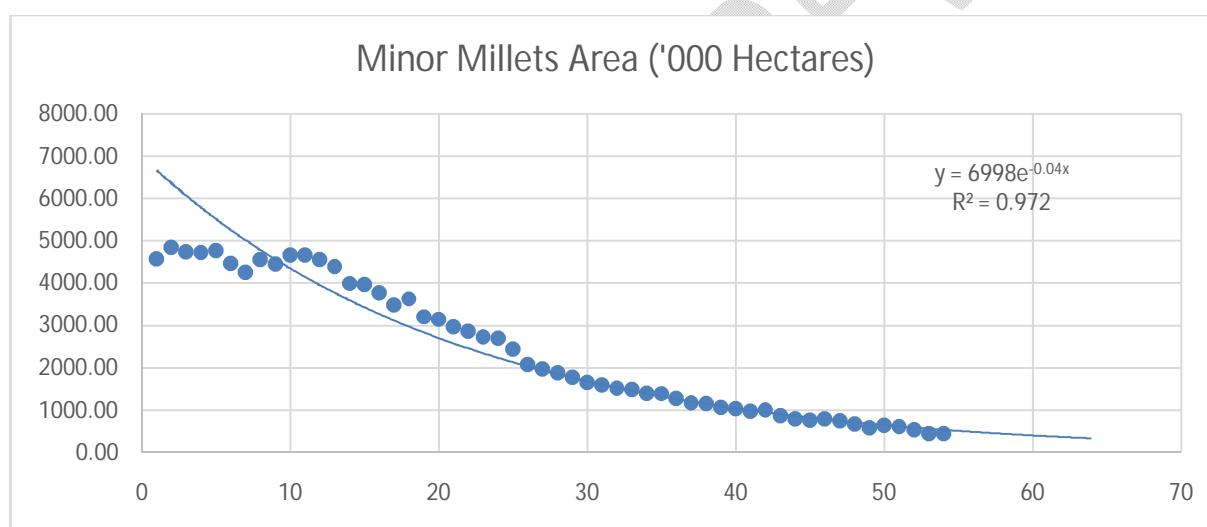


Fig 10: Trend of Minor Millets Area

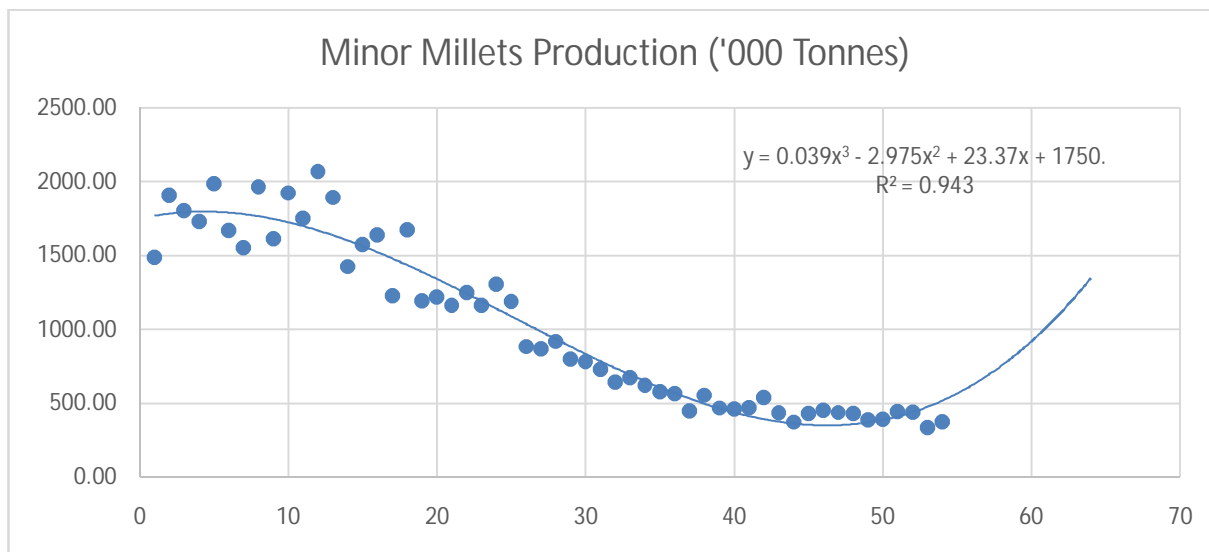


Fig 11: Trend of Minor Millets Production

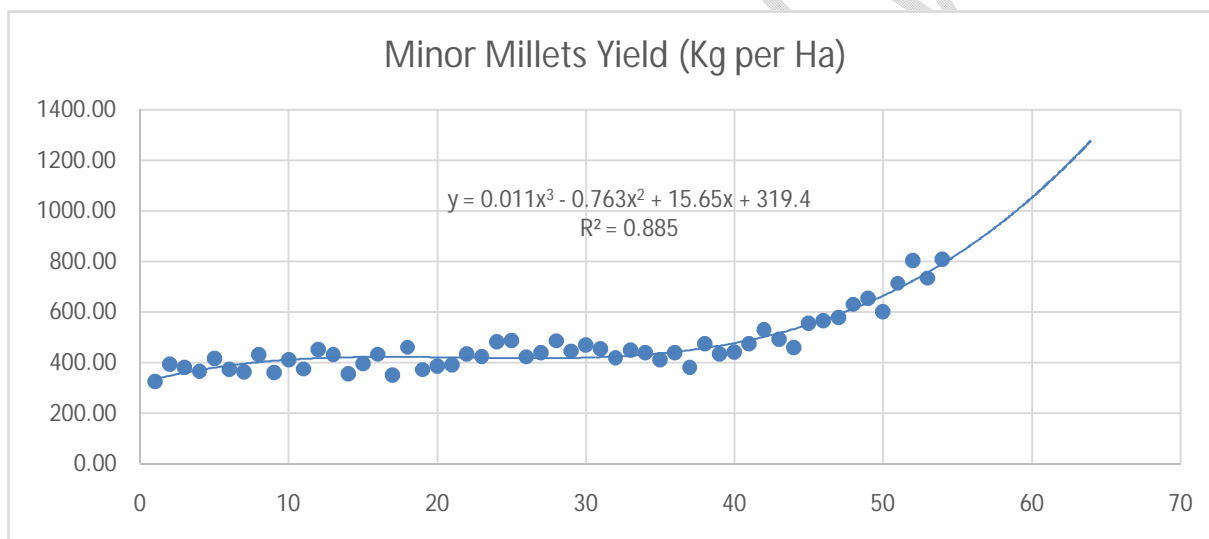


Fig 12: Trend of Minor Millets Yield

Table 7: Forecasting of Minor Millets

Year	Period	Area (000 Ha)	Production (000 tonnes)	Yield (Kg /Ha)
2020-21	55	775.40	524.60	702.20
2021-22	56	745.00	578.14	734.81
2022-23	57	715.79	638.84	769.59
2023-24	58	687.72	706.93	806.60
2024-25	59	660.75	782.64	845.92
2025-26	60	634.85	866.20	887.60
2026-27	61	609.95	957.85	931.72

2027-28	62	586.04	1057.83	978.34
2028-29	63	563.06	1166.37	1027.52
2029-30	64	540.98	1283.70	1079.34

Minor millets area and production have decreasing trend over the years like other millet crops (4584.00 to 458.35 thousand hectares and 1488.50 to 370.81 thousand tonnes respectively) with R^2 0.972 and 0.943 respectively. The area was best fitted to the exponential function and production was fitted to polynomial function of degree 3. Yield of minor millet had witnessed increasing trend (324.72 to 809.00 Kg / ha) with R^2 value of 0.885 and fitted for polynomial regression of degree 3. Minor millet prediction (Table 7) shows decreasing area for next 10 years like its trend and production which was decreasing take a turn and start increasing (1283.70 thousand tonnes by 2023). Yield on the other hand continues to increase and may reach 1079 Kg/ha. Kumar *et al* (2022) in their study indicated that cultivation area of minor millets was decreasing in trend and it will decline further in upcoming years. The increase of productivity has occurred due to availability of high-yielding varieties, nutrient-rich varieties, pest, and disease-resistant varieties, and the adoption of new cultivation technology.

Conclusion

In conclusion, the analysis of trends using scatter plot, CAGR and regression; and instability using SD, CV and Cuddy Della Valley Instability Index in the area, production, and productivity of millets in India reveals significant insights into the evolving dynamics of millet cultivation. The declining trend in the cultivation area and production, particularly evident in major millets like Sorghum (-2.51 % in area, -1.44% in production per annum) and Finger millet (-1.84% in area, -0.49% in production per annum), poses a challenge to India's food security. However, the study highlights the contrasting positive trajectory in millet yield (1.09% to 2.47%). The instability is low in all the millets (almost less than 15) showcasing the resilience

and adaptability of millets to diverse climatic conditions. The variability in trend and stability indices among different millet categories emphasizes the need for targeted interventions to address specific challenges faced by each crop. The forecasted trends for the next decade project further decreases in area and production but a potential reversal in the increasing yield trend, indicating the importance of sustainable agricultural practices. Policy implications should focus on reversing the declining trend by promoting millet cultivation through incentivizing farmers, introducing improved varieties, and creating awareness about the nutritional benefits of millets. Additionally, policies should aim to address the challenges faced by specific millet varieties, considering their demands. It is important to formulate evidence-based agricultural policies that can increase millet cultivation, aligning with the United Nations' vision of sustainable agriculture and food security.

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