
*Journal of Scientific Research and Reports*

***Volume 30, Issue 8, Page 686-699, 2024; Article no.JSRR.120904***
***ISSN: 2320-0227***

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

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: https://doi.org/10.9734/jsrr/2024/v30i82290

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/120904

***Original Research Article***

***Received: 05/06/2024***
***Accepted: 09/08/2024***
***Published: 13/08/2024***

## 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 using scatter plot technique in Excel, such as linear, polynomial, logarithmic, power, and exponential functions to analyze the trend and forecast. 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 (CAGR -2.51% and -1.84% for area; -1.44% and -0.49% for production respectively),

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***Cite as:*** *N, Yamuna, D. V. Kolekar, and Rakesh N. 2024. "Trend and Instability Analysis of Area, Production, Productivity of Millets in India". Journal of Scientific Research and Reports 30 (8):686-99. https://doi.org/10.9734/jsrr/2024/v30i82290.*

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 (ranging from 5.90 to 21.11). Forecasted trends for the next decade predict further declines in area and production but suggest a potential reversal in the increasing yield trend (sorghum yield is estimated to be decrease from 889.85 Kg/Ha to 872.9 Kg/Ha in 2030). 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, developing evidence-based agricultural policies. This is important in order to enhance the area and production under millets, and also to align with global sustainability goals.

*Keywords: Millets; trend; instability; area; production; yield.*

## 1. 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 [1].

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 [2]. 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 [3].

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 [4]. 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 [5,6].

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 [7].

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 [2]. 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 [4,8].

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 [9]. 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 [10].

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.

## 2. 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 using scatter plot technique in Excel 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. [4] and Prasad, [6] 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 was computed to study trend and coefficient of variation (CV), and instability index were computed to study the stability.

To estimate the annual compounding growth rate of area, production and yield, growth model used by Vennila and Murthy [11]; Sathish Kumar et al. [4] and Ayalew [12] 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.

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

$Y_t$ 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 to logarithmic form to convert exponential equation into linear form and find growth rate.

$$lnY_t = lnA + (\ln B)t + \varepsilon$$

Then CAGR (in per cent) is calculated as:

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

To analyse instability in area, production, and productivity Cuddy-Della Valle index (CDVI) was used (Ayalew [13] 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.

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

$ADR^2$ is Adjusted R square value (adjusted coefficient of determination)
CV is Coefficient of Variation
SD is Standard Deviation

**List 1. Best fitted models equations is as given below**

| | Area (000 Ha) | Production (000 tonnes) | Yield (Kg /Ha) |
|---|---|---|---|
| **Sorghum** | $y = 0.106x^3 - 11.22x^2 + 53.61x + 17559$ | $y = 0.122x^3 - 15.82x^2 + 430.2x + 7664.$ | $y = -0.152x^2 + 16.17x + 460.3$ |
| **Pearl millet** | $y = -0.482x^2 - 70.03x + 12529$ | $y = 1.506x^2 + 14.72x + 4937.$ | $y = 0.375x^2 - 3.229x + 428$ |
| **Finger millet** | $y = 0.043x^3 - 4.159x^2 + 78.55x + 2127.$ | $y = 0.039x^3 - 4.429x^2 + 127.5x + 1538.$ | $y = 16.29x + 779.8$ |
| **Minor Millets** | $y = 6998e^{-0.04x}$ | $y = 0.039x^3 - 2.975x^2 + 23.37x + 1750.$ | $y = 0.011x^3 - 0.763x^2 + 15.65x + 319.4$ |

## 3. RESULTS AND DISCUSSION

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. 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. [1] 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 though being most important millet 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 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 in order to analyse trend. 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 (-4.64% CAGR) 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. [4]. 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 (-0.98% CAGR). For production and productivity also Pearl millet itself had highest growth rate among others (1.47%, 2.47% CAGR respectively). Minor millets had the highest decline and least growth in area, production and productivity (-4.64%, -3.60% and 1.09% CAGR respectively). 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 due to increasing number of improved varieties and implementation of improved package of practices.

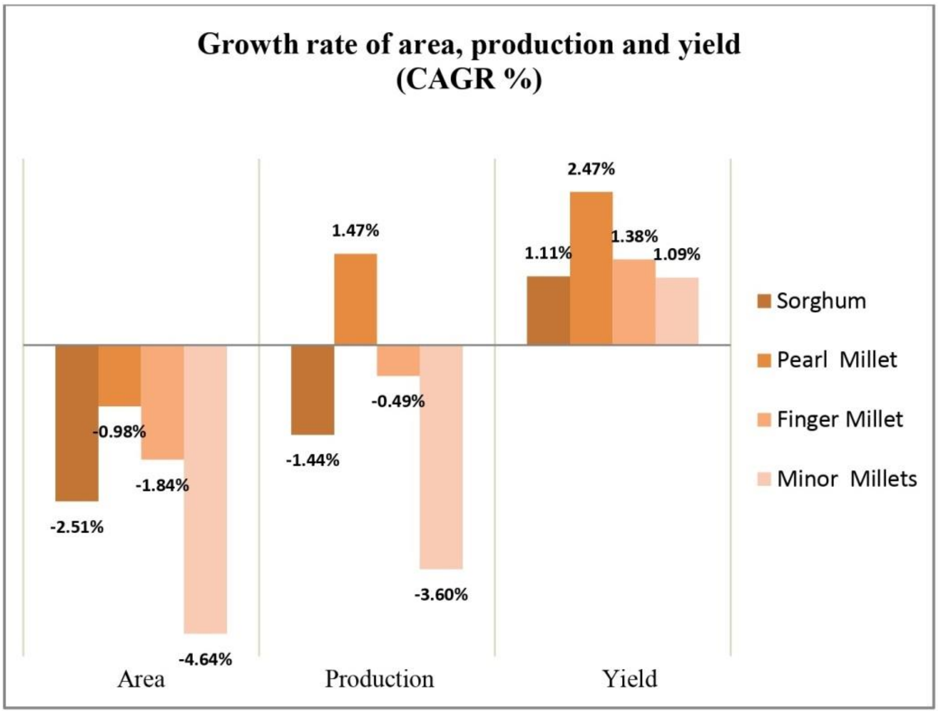
**Table 1. Descriptive statistics of area, production, productivity of millets over the years**

| | 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 |

**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 %)**

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 [11] 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 since Sorghum is the most important millet. 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. These stability indices can be considered while studying security of millet production; accordingly, Pearl millet is the most insecure crop because of its highest index values for production and productivity among others. 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.

**Table 3. Trend and Instability Analysis of millets over the years**

| | Area (000 Ha) | Production (000 tonnes) | Yield (Kg /Ha) |
|---|---|---|---|
| **Sorghum** | | | |
| 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 |

**Trend analysis and forecast of Sorghum:** 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 up to 872.59 Kg/Ha. Hence, measures should be taken to tackle this decreasing trend in terms of providing incentives to increase area, using improved varieties, creating awareness among consumers regarding benefits of millets etc. Prasad [6] 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'.

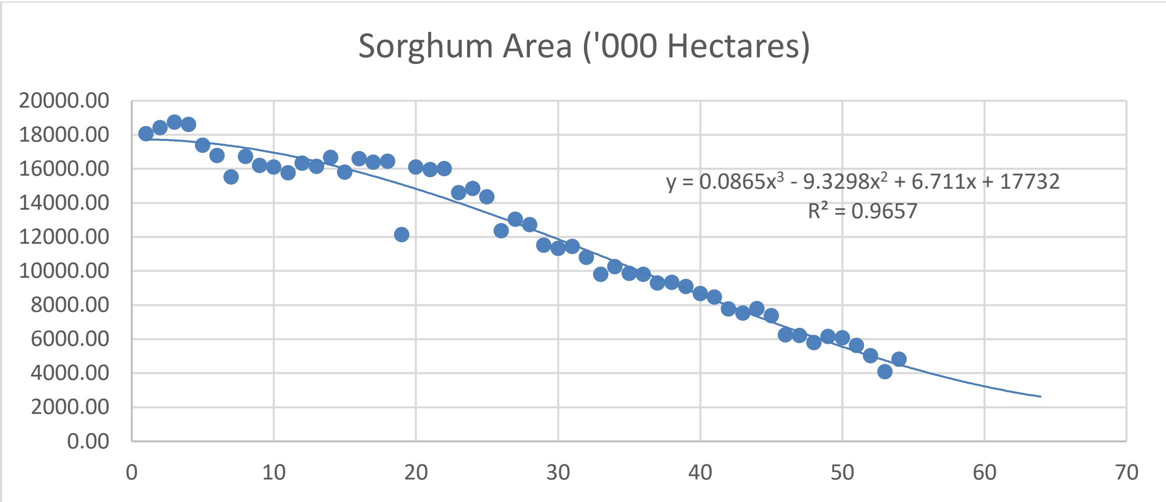



**Fig. 1. Trend of Sorghum Area**

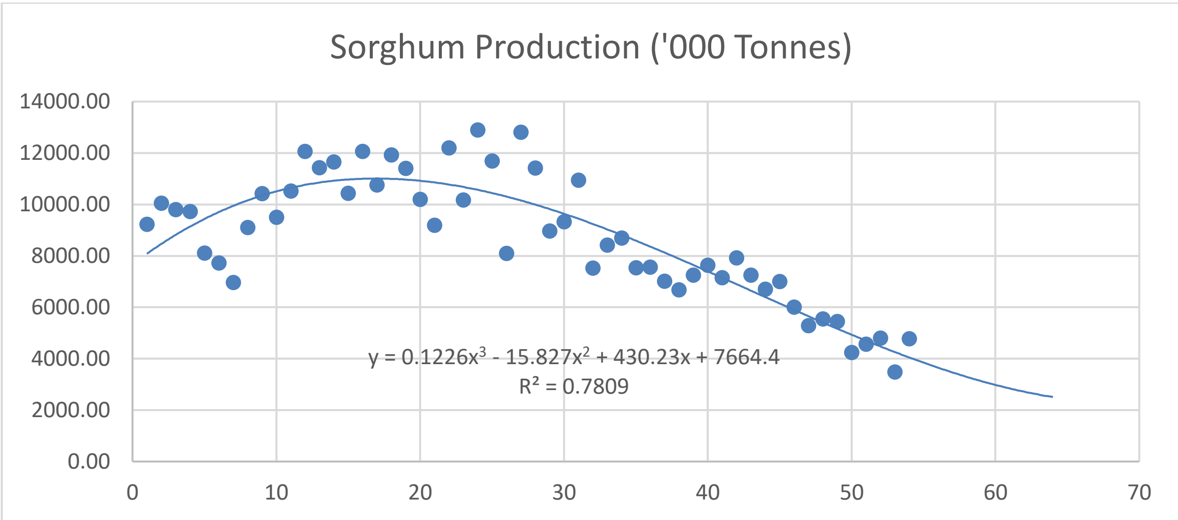



**Fig. 2. Trend of Sorghum Production**

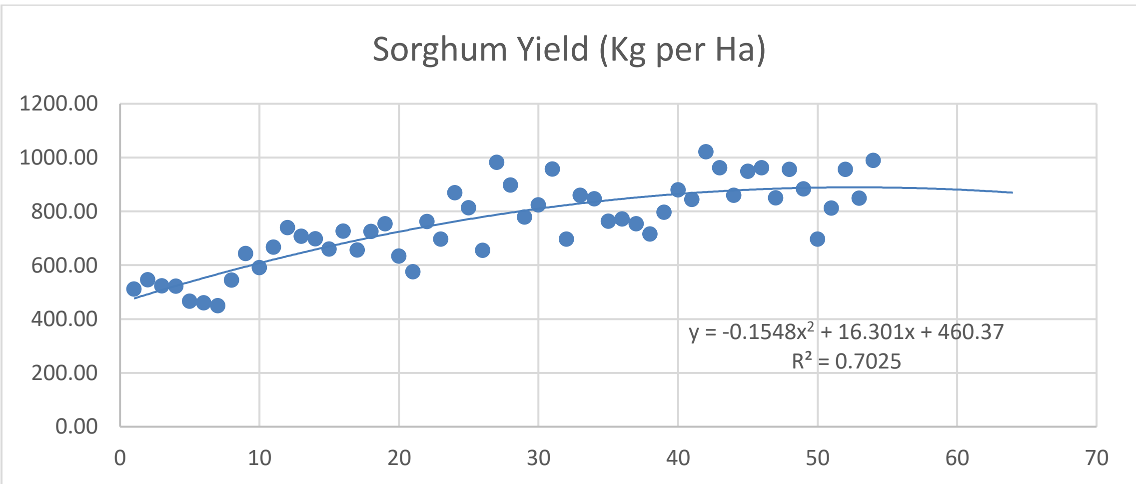



**Fig. 3. Trend of Sorghum Yield**

**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 |

**Trend analysis and forecast of Pearl millet:**

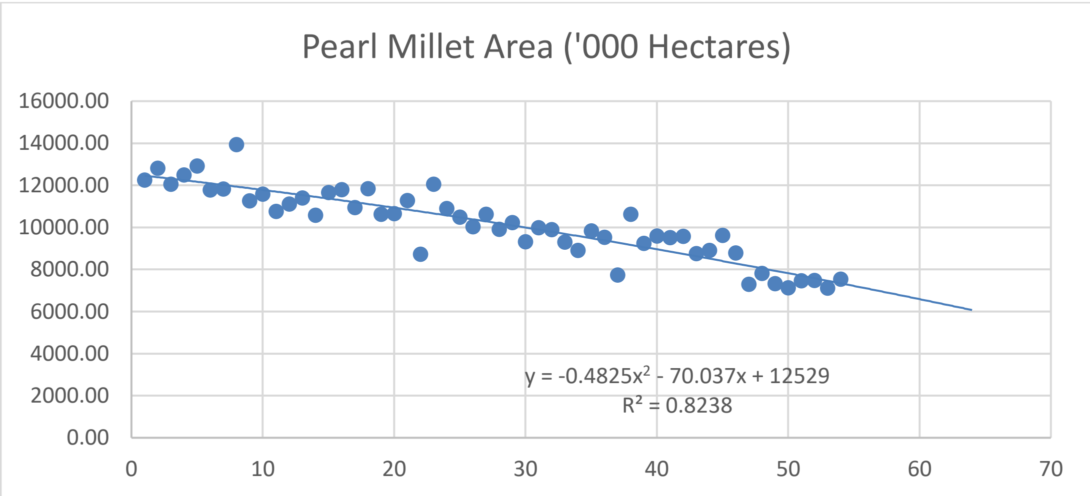



**Fig. 4. Trend of Pearl Millet Area**

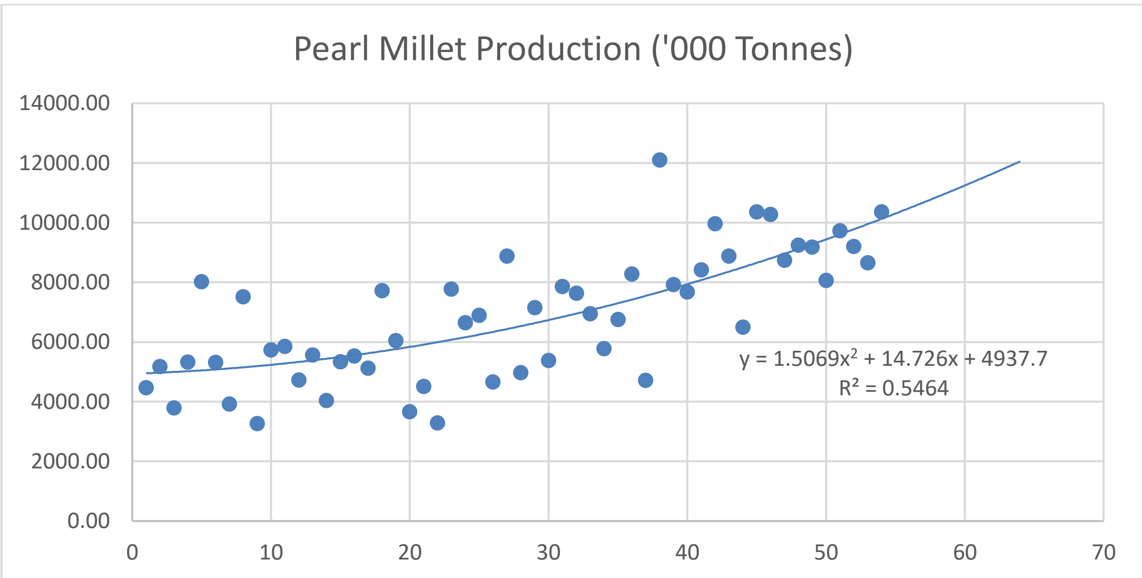



**Fig. 5. Trend of Pearl Millet Production**

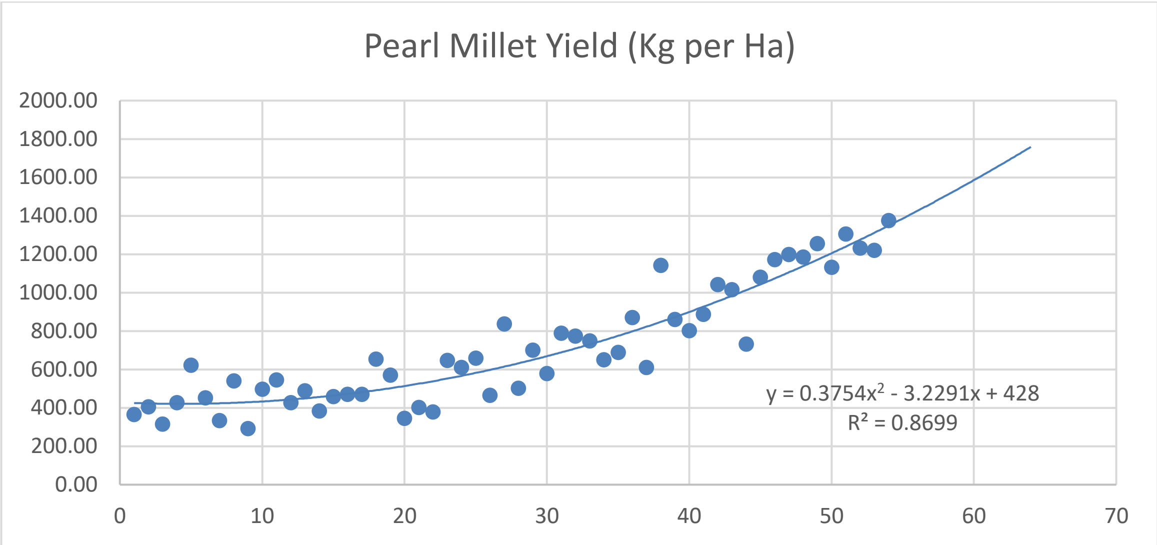



**Fig. 6. Trend of Pearl Millet Yield**

**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 |

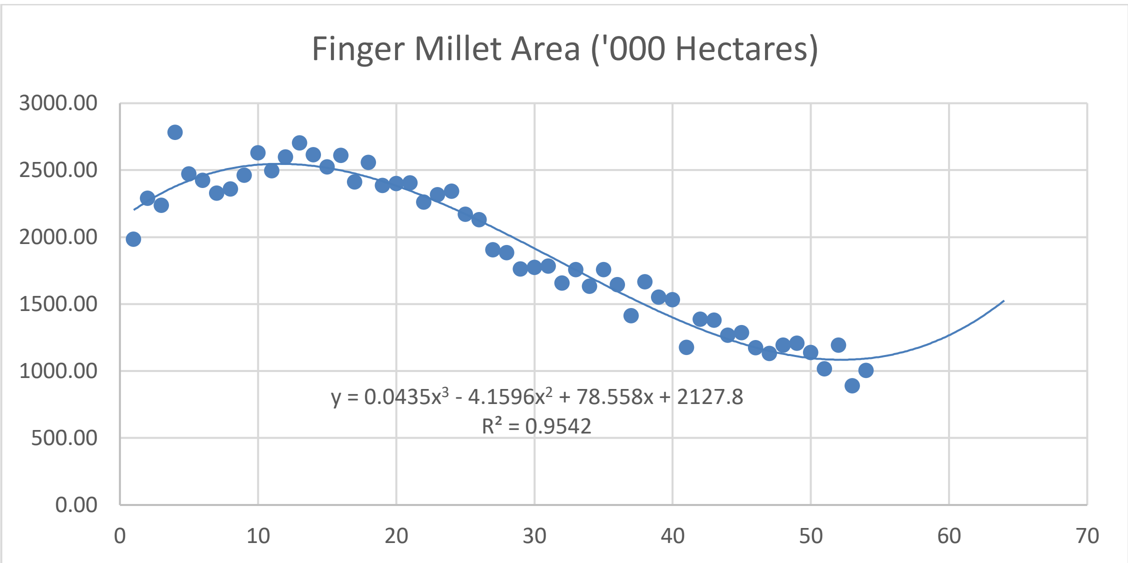



**Fig. 7. Trend of Finger Millet Area**

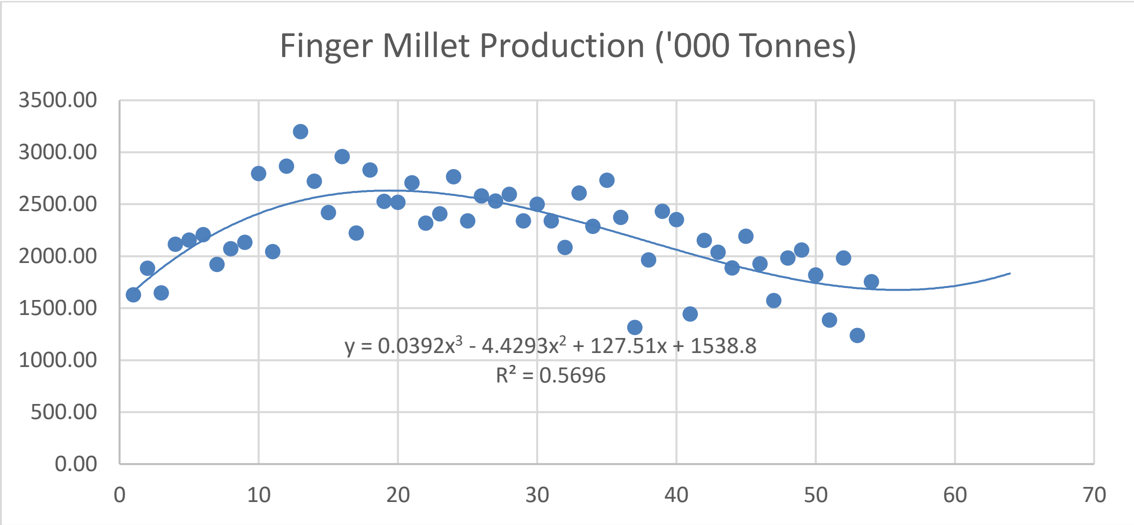



**Fig. 8. Trend of Finger Millet Production**

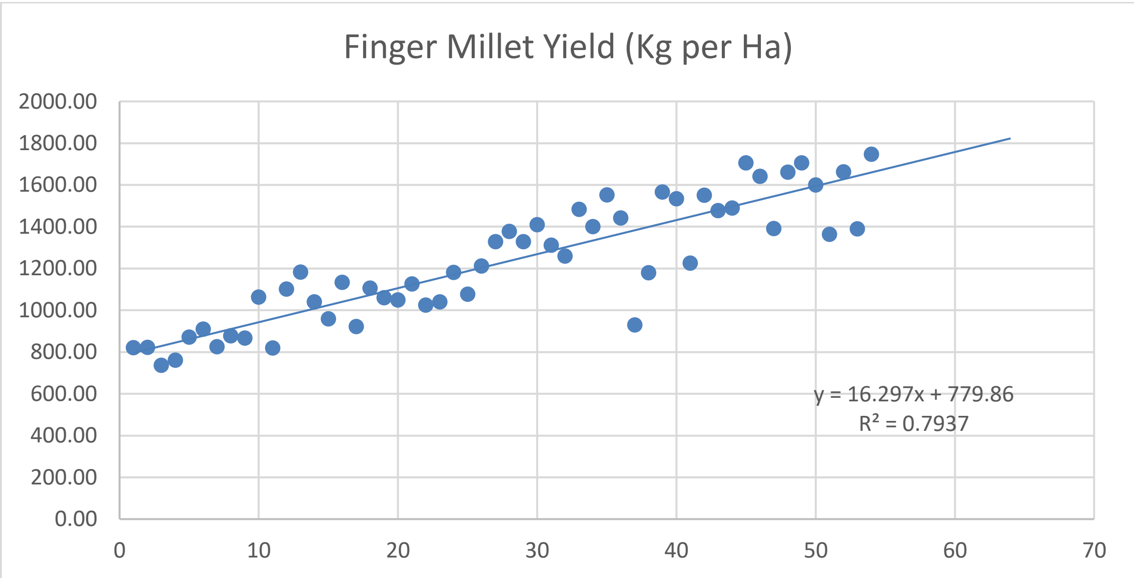



**Fig. 9. Trend of Finger Millet Yield**

**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 |

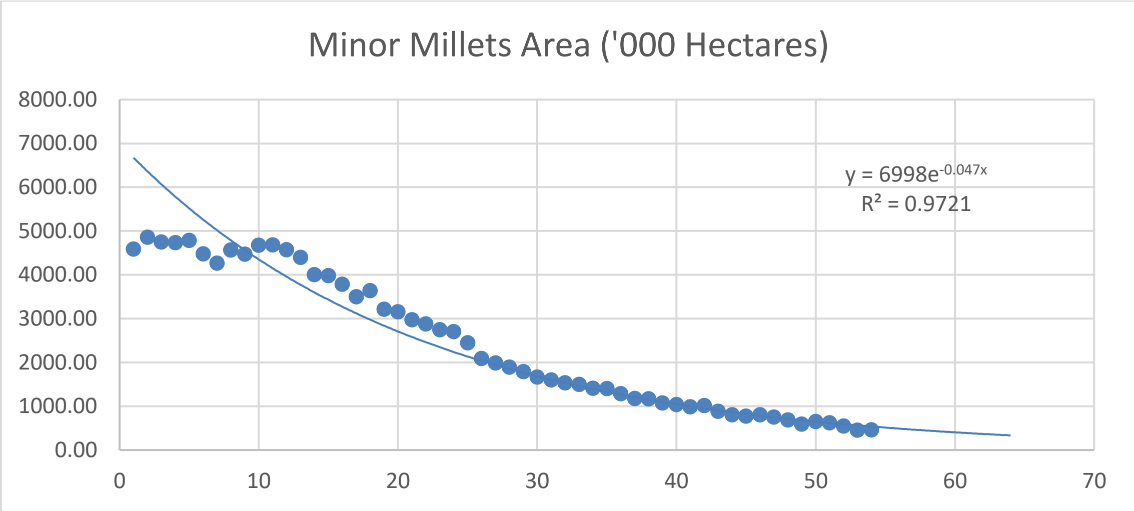



**Fig. 10. Trend of Minor Millets Area**

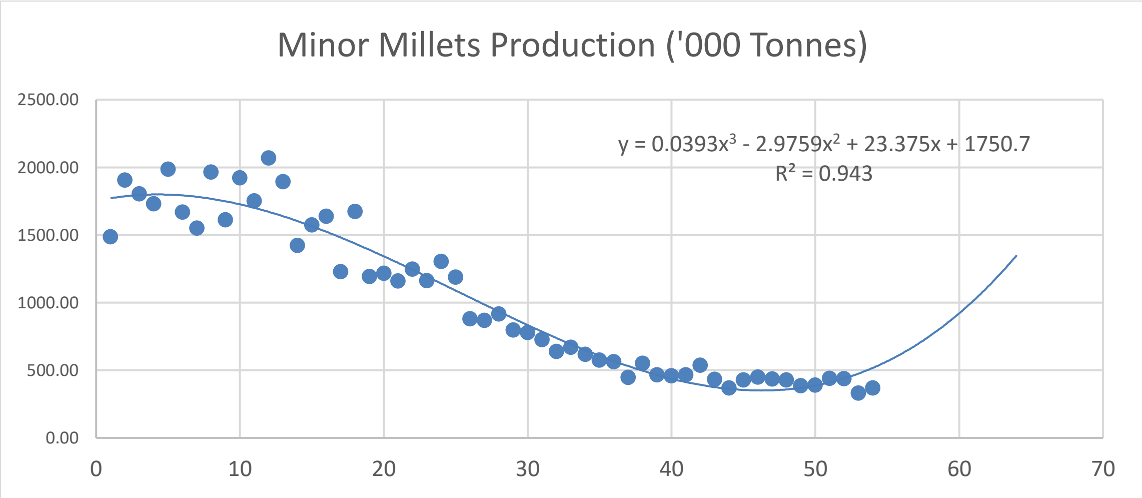



**Fig. 11. Trend of Minor Millets Production**

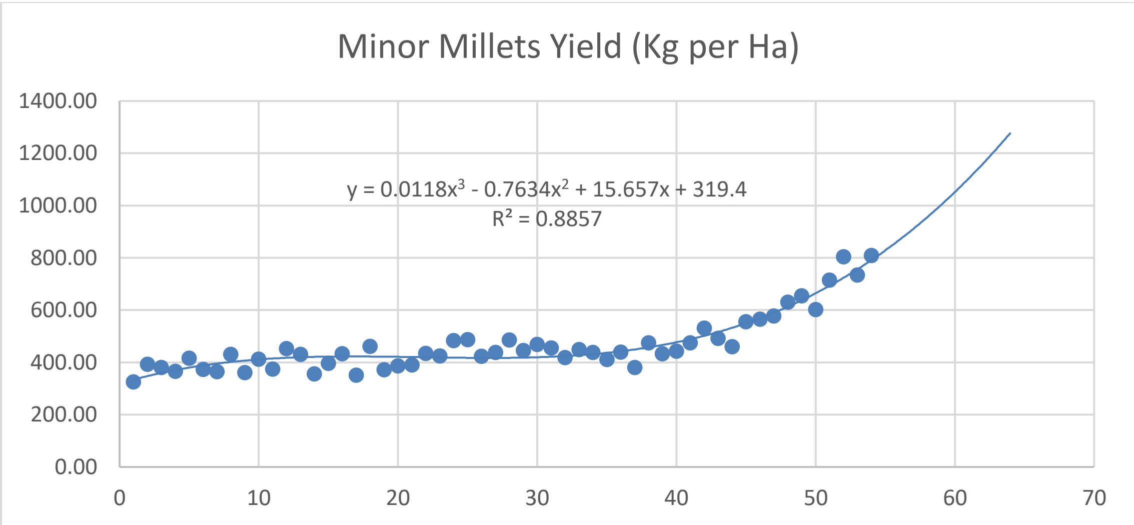



**Fig. 12. Trend of Minor Millets Yield**

**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 |

**Trend analysis and Forecast of Pearl millet:** 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) and fitted for polynomial regression of degree two with $R^2$ value 0.823. Conversely Tripathi et al. [13] 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) and fitted for polynomial of degree 2 with $R^2$ value 0.546 and 0.869 respectively. Though the area is decreasing the production is increasing over the years, this increase in production is mainly attributed to increasing in productivity. 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:** Area of finger millet has also followed decreasing trend because of same reason as of other millets (1984.20 to 1004.46 thousand hectares) and fitted for polynomial function of degree 3 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 function 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 [11] 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 mainly due to linearly increasing productivity. 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:** 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). The area was best fitted to the exponential function and production was fitted to polynomial function of degree 3 with $R^2$ 0.972 and 0.943 respectively. 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) due to increasing yield. Yield on the other hand continues to increase and may reach 1079 Kg/ha. Kumar et al. [4] 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 verities, and the adoption of new cultivation technology [14-16].

Increasing area under all millets is practically not possible since land is a limiting factor. In order to ensure food security increasing production should be targeted via improving productivity. Therefore, adoption of high yielding varieties, improved package of practices, research and development plays a vital role in making use of millets as a sustainable, resilient alternative for cereal crops. Awareness of its nutritional benefits should be created even among lower and middle income groups to make it more profitable for farmers. Promotion of value addition will also help in increasing consumption and value of the millets.

## 4. CONCLUSION

In conclusion, the analysis of trends using scatter plot technique, 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 values 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.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

1. Chat GPT 3.5 for improving grammar of the manuscript and validating meaning of the sentences.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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*The peer review history for this paper can be accessed here:*
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