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Dynamics of major millets in India

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Abstract
The study "Dynamics of Major Millets in India" examines 40 years of trends in sorghum, pearl millet, and finger millet using secondary data and statistical tools. It finds a consistent decline in cultivation area especially for sorghum and finger millet due to policy bias, urbanization, and dietary shifts. Despite this, productivity, particularly of pearl millet, has improved. Millet consumption has dropped but shows signs of revival driven by health awareness. Export growth was initially strong but has declined recently, with finger millet showing high instability. Regression analysis reveals that finger millet exports benefit from higher production and farm prices, while sorghum exports are limited by strong domestic demand and pricing. The study concludes that millets can regain prominence through focused policies, improved infrastructure, and better market integration.

Keywords: Sorghum, pearl millet, finger millet, cultivation trends, productivity, consumption, exports, policy, market integration, India

Introduction
Millets, including sorghum (Jowar), pearl millet (Bajra), and finger millet (Ragi), have historically been vital to India's agricultural and dietary landscape, particularly in arid and semi-arid regions. These climate-resilient crops require minimal water and grow well without chemical fertilizers, making them environmentally sustainable. However, the Green Revolution shifted focus toward rice and wheat, leading to a decline in millet cultivation. In recent years, rising health awareness and their adaptability to water-stressed conditions have renewed interest in millets. Nutritionally superior to rice and wheat, millets are rich in fiber, calcium, and micronutrients, offering a natural remedy to malnutrition. India, producing about 20% of global millets, harvested nearly 18 million metric tons in 2022-23, with Rajasthan, Maharashtra, and Karnataka as leading producers. Exports also increased, reaching 250,000 metric tons valued at USD 100 million. Despite this growth, instability in production and trade persists due to erratic rainfall, poor infrastructure, limited processing, price volatility, and weak market linkages. Export performance is further constrained by certification barriers, packaging issues, and lack of farmer awareness. Still, government initiatives such as the Millet Mission, PDS inclusion, and international promotion under "India Millets" are helping revive domestic and global interest. This study focuses on analyzing the growth trends, instability, and export dynamics of major millets in India, and aims to identify key factors influencing their production, consumption, and trade

Methodology
The study was based on secondary data. The data collected from the government websites of www apeda. gov.in www. agriculture statistic at glance.in www milletstats.com and Food and Agriculture Organization (FAO). The choice of the statistical and econometric tools of analysis was decided with reference to the objectives of the study and the nature of data collected. The analytical techniques used in the study for sorghum, pearl millet and finger millet was presented below.

2.1 Compound annual growth rate
The following exponential equation was used

$$Y = ab^t \tag{1}$$

Where
- Y = Production/ Consumption/ Export
- a = Constant
- b = Trend coefficient
- t = Time period

This equation was estimated after transforming (1) as follows

Log Y = Log a + t Log b (2)

Annual compound growth rate in percentage was calculated as.

CGR (%) = [Antilog (log b)-1] × 100 (3)

2.2 Co-efficient of Variation

$$C.V = \frac{\sigma}{\bar{x}} \times 100$$

Where,
- σ = Standard deviation,
- $S = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$
- $\bar{x}$ = Arithmetic mean
- x = Variable
- n = Number of observations

2.3 Trend analysis

Table 1: Linear and nonlinear models.

Sr. no.	Model	Name of model
1	$y=b_0+b_1t$	Linear
2	$y=b_0+b_1\ln(t)$	Logarithmic
3	$y=b_0 \cdot e^{b1t}$	Exponential
4	$y=b_0 \cdot t^{b1}$	Power
5	$y=b_0+b_1t+b_2t^2$	Second Degree Polynomial
6	$y=b_0+b_1t+b_2t^2+b_3t^3$	Third Degree Polynomial
7	$y=b_0+b_1t+b_2t^2+b_3t^3+b_4t^4$	Fourth Degree Polynomial

2.4 Multiple Factor Regression Coefficients
The multiple regression equation is given
- $Y = Y=a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5$
- Y = Export (million tons)
- a = Constant
- b = Regression coefficient
- X_1 = Production (million tons)
- X_2 = Domestic demand (Kg/month)
- X_3 = International price (USD/MT)
- X_4 = MSP (Rs/Quintal)
- X_5 = FHP (Rs/Quintal)

3. Results and discussion
Table 1 the compound growth analysis reveals a consistent decline in the cultivation area of all major millets, particularly sorghum and finger millet. Sorghum showed sharp reductions in both area -5.01 per cent and production -3.34 per cent in recent years, though slight productivity gains suggest improved efficiency. Pearl millet demonstrated resilience with minimal area decline and steady increases in both production and productivity up to 3.26 per cent. Finger millet experienced early declines in area and production, with productivity improvements limited to the initial period. Overall, rising productivity, especially in pearl millet, has helped cushion the impact of reduced cultivation.
Table 2 the compound growth analysis of millet exports shows strong initial growth followed by a clear decline in recent years. Sorghum exports surged by 83.94 per cent in Period 1 but fell to -9.10 per cent in Period 3. Bajra saw steady growth early on, with a 158.77 per cent rise in export value in Period 1, but declined slightly later. Ragi experienced early gains but dropped sharply by -28.14 per cent in exports and -24.66 per cent in value in the final period. These trends reflect early export potential followed by setbacks likely due to market saturation, policy changes, or reduced global demand, indicating a need for revised export strategies.
Table 3 From 1991 to 2011, millet consumption in India declined sharply across regions. Sorghum intake dropped steadily in both rural -5.98 per cent and urban -6.93 per cent areas. Pearl millet showed rural growth in the 1990s 11.32 per cent but declined thereafter -3.07 per cent, with urban consumption consistently falling. Finger millet data 2001-2011 also indicated a decline, with rural areas seeing -6.79 per cent and urban -1.55 per cent. These shifts reflect changing food preferences, increased availability of rice and wheat, urbanization, and declining policy support for millets
Table 4 the instability analysis shows sorghum had the highest area fluctuations, especially in Periods 1 29.51 per cent and 3 23.85 per cent, with growing volatility in production and productivity. Pearl millet had stable area trends but high instability in production 28.71 per cent in Period 1 and productivity. Finger millet showed moderate, consistent instability, with production peaking in Period 2 17.88 per cent and improved productivity stability by Period 3 9.51 per cent. Overall, sorghum was the most unstable in area, pearl millet in output, while finger millet emerged as the most stable crop in recent years.
Table 5 the instability index shows declining export volatility for sorghum and bajra, indicating improved stability over time. Sorghum's export instability dropped from 286.53 per cent in Period 1 to lower levels, with value instability falling from 214.96 per cent to 51.97 per cent. Bajra followed a similar trend, with export instability decreasing from 215.0 per cent to 26.92 per cent. In contrast, ragi's export instability rose sharply in Period 2 277.97 per cent and remained high in Period 3 191.03 per cent, with similar trends in value. This suggests that while sorghum and bajra exports have stabilized, ragi continues to face major fluctuations due to supply or policy issues.
Table 6 the instability indices in millet consumption show rising volatility for sorghum in both rural 16.61 to 22.06 per cent and urban areas 21.03 to 22.52 pe cent over time. Pearl millet showed marked improvement, with rural instability dropping from 89.72 per cent to 17.89 per cent and urban from 29.99 per cent to 14.85 per cent, indicating more consistent demand. For finger millet (data only for Period 2), rural consumption was slightly more unstable

21.01 per cent than urban 17.31 per cent. Overall, sorghum consumption has become more erratic, pearl millet more stable, and finger millet shows moderate rural-urban variation.

Table 7 trend analysis of sorghum in India reveals a steady decline in cultivation area $R^2 = 0.89$, driven by farmers shifting to more profitable crops. Production shows inconsistency $R^2 = 0.39$, likely due to weather variability and limited yield gains. Consumption follows a clear trend $R^2 = 0.84$, initially rising, then falling as diets shift toward rice and wheat. Exports show moderate fluctuation $R^2 = 0.69$, reflecting dependency on domestic surplus. Overall, area and consumption trends are more stable, while production and exports remain unpredictable

Table 8 trend analysis of pearl millet in India shows a fluctuating but overall declining cultivation area $R^2 = 0.63$, while production remains stable $R^2 = 0.58$, likely due to improved productivity. Consumption trends are highly irregular $R^2 = 0.06$, reflecting inconsistent dietary preferences. Exports display a strong trend $R^2 = 0.87$, with initial growth followed by a decline, possibly due to global competition or supply issues. Overall, pearl millet maintains stable production and strong export performance despite area loss and unpredictable domestic demand.

Table 9 trend analysis of finger millet shows a declining cultivation area with weak clarity $R^2 = 0.29$, but production remains strong and steady $R^2 = 0.97$, likely due to yield improvements. Consumption trends are moderately stable $R^2 = 0.48$, reflecting fluctuating food habits. Exports display a highly predictable trend $R^2 = 0.97$, with initial decline followed by recovery, indicating recent growth in trade. Overall, finger millet demonstrates strong performance in production and exports, despite instability in area and consumption.

Table 10 the regression analysis for sorghum exports shows that none of the key variables production, international price, MSP, FHP, or consumption have statistically significant effects, as indicated by large standard errors relative to the coefficients. All coefficients are negative, suggesting that higher domestic production, support prices, farm harvest prices, and consumption may suppress exports, possibly due to increased domestic demand or reducedprice competitiveness. The intercept is positive, indicating some baseline level of export independent of these factors. Overall, sorghum exports appear to be largely constrained by internal market dynamics rather than external price incentives.

Table 11 the regression results for pearl millet exports indicate that among all variables, only domestic consumption has a significant positive impact coefficient 0.24, suggesting that higher consumption is associated with increased exports, possibly due to overall market expansion. Other variables production, international price, MSP, and FHP have minimal and statistically insignificant effects, reflecting limited influence on export levels. The positive but small coefficients and high standard errors for these variables suggest that factors beyond price and supply, such as demand-driven dynamics and market linkages, play a more critical role in determining pearl millet export performance.

Table 12 the regression analysis for finger millet exports shows that higher production and favorable Farm Harvest Prices (FHP) significantly boost exports, highlighting their positive influence. In contrast, rising international prices and higher MSP negatively affect export performance, likely due to reduced price competitiveness and lower export incentives. Overall, finger millet exports are strongly influenced by domestic output and supportive farm-level pricing, with FHP playing a key role in promoting export-oriented surplus.

Table 2: Compound growth rate of area, production, productivity for major millets in India

Crop	Particular	Period 1 (1979-93)	Period 2 (1994-08)	Period 3 (2009-23)
Sorghum	Area	-0.002	-2.85***	-5.01***
	Production	-0.14	-1.97***	-3.34***
	Productivity	1.59*	0.90*	1.76**
Pearl millet	Area	-0.78*	-0.43	-1.39***
	Production	1.72	2.56**	1.83**
	Productivity	2.52**	3.00***	3.26***
Finger millet	Area	-2.06***	-2.17***	-0.60
	Production	-0.28	-1.80*	-1.19*
	Productivity	1.81***	0.38	-0.60

** denote 10,5 & 1 per cent level of significance. **Source:** Ministry of Agriculture & Farmer Welfare, GOI

Table 3: Compound growth rate of export for major millets in India

Crop	Particular	Period 1 (1979-93)	Period 2 (1994-08)	Period 3 (2009-23)
Sorghum	Export	83.94***	16.81	-9.10**
	Value	-37.26***	83.83***	-4.86**
Bajra	Export	21.6	18.68***	-3.07**
	Value	158.77***	21.82***	-1.06
Ragi	Export	51.11**	36.98*	-28.14***
	Value	-75.88***	81.34***	-24.66***

** denote 10, 5 & 1 per cent level of significance. **Source:** Ministry of Agriculture & Farmer Welfare, GOI

Table 4: Compound growth rate of consumption for major millets in India

Particular	Geography	Period 1 (1991-00)	Period 2 (2001-11)
Sorghum	Rural	-5.26***	-5.98***
	Urban	-5.46***	-6.93***
Pearl millet	Rural	11.32	-3.07*
	Urban	-3.07	-3.91***
Finger millet	Rural		-6.79***
	Urban		-1.55

** denote 10, 5 & 1 per cent level of significance. **Source:** Various NSSO round

Table 5: Instability in area, production, productivity of major millets in India

Crop	Particular	Period 1 (1978-93)	Period 2 (1994-08)	Period 3 (2009-23)
Sorghum	Area	29.51	13.03	23.85
	Production	11.94	13.92	19.84
	Productivity	17.74	11.22	13.27
Pearl millet	Area	8.05	7.17	9.94
	Production	28.71	23.70	13.10
	Productivity	26.04	20.06	15.41
Finger millet	Area	9.77	11.46	9.08
	Production	8.08	17.88	14.46
	Productivity	11.26	12.75	9.51

Source: Ministry of Agriculture & Farmer Welfare, GOI

Table 6: Instability in export of major millets in India

Crop	Particular	Period 1 (1978-93)	Period 2 (1994-08)	Period 3 (2009-23)
Sorghum	Export	286.53	185.53	161.74
	Value	214.96	161.92	51.97
Bajra	Export	215.0	104.63	26.92
	Value	124.52	124.24	24.99
Ragi	Export	189.68	277.97	191.03
	Value	189.11	275.90	190.29

Source: Ministry of Agriculture & Farmer Welfare, GOI

Table 7: Instability in consumption of major millets in India

Particular	Geography	Period 1 (1991-00)	Period 2 (2001-11)
Sorghum	Rural	16.61	22.06
	Urban	21.03	22.52
Pearl millet	Rural	89.72	17.89
	Urban	29.99	14.85
Finger millet	Rural		21.01
	Urban		17.31

Source: various NSSO round

Table 8: Trends in Area, production, consumption and export of sorghum in India

Sr. no	Particular	Model	R square	Coefficient			
				b1	b2	b3	b4
1	Area	Fourth degree of polynomial	0.89	-0.35	-0.009	-0.0005	0.0002
2	Production	Fourth degree of polynomial	0.39	-2.98	0.93	-0.11	0.0052
3	Consumption	Fourth degree of polynomial	0.84	0.15	-0.04	0.006	-0.0003
4	Export	Fourth degree of polynomial	0.69	0.10	-0.04	0.007	-0.0003

Table 9: Trends in Area, production, consumption and export of pearl millet in India

Sr. no	Particular	Model	R square	Coefficient			
				b1	b2	b3	b4
1	Area	Fourth degree of polynomial	0.63	-0.70	0.20	-0.01	0.00007
2	Production	Fourth degree of polynomial	0.58	0.03	-0.002	0.0001	0.00002
3	Consumption	Fourth degree of polynomial	0.06	-0.31	0.14	-0.02	0.0011
4	Export	Fourth degree of polynomial	0.87	0.42	-0.17	0.02	-0.001

Table 10: Trends in Area, production, consumption and export finger millet in India

Sr. no	Particular	Model	R square	Coefficient			
				b1	b2	b3	b4
1	Area	Fourth degree of polynomial	0.29	-0.79	0.18	-0.016	0.0005
2	Production	Fourth degree of polynomial	0.97	-0.03	0.02	-0.002	0.0009
3	Consumption	Fourth degree of polynomial	0.48	0.04	-0.05	0.01	-0.0005
4	Export	Fourth degree of polynomial	0.97	-0.92	0.24	-0.02	0.01

Table 11: The factors affecting the export of Sorghum in India

Particular	Coefficients	Standard Error
Intercept	0.49	0.23
Production	-0.019	0.02
International price	-2.85	2.67
MSP	-5.85	6.58
FHP	-9.45	0.0001
Consumption	-0.27	0.24
R2=0.25		

Table 12: The factors affecting the export of Pearl millet in India

Particular	Coefficients	Standard Error
Intercept	0.77	0.67
Production	0.006	0.07
International price	-0.007	0.03
MSP	-0.0004	0.0003
FHP	0.0005	0.0006
Consumption	0.24**	0.10
$R^2 = 0.40$		

Table 13: The factors affecting the export of Finger millet in India

Particular	Coefficients	Standard Error
Intercept	-0.18	0.28
Production	0.23**	0.12
International price	-0.001**	0.0004
MSP	-0.0001*	9.22
FHP	0.0002**	0.0001
$R^2 = 0.42$		

4. Conclusion

The study reveals a consistent decline in millet cultivation areas, especially for sorghum and finger millet, though productivity gains most notably in pearl millet have helped offset production losses. Consumption has steadily declined across regions due to dietary shifts, but recent trends show signs of revival. Export performance saw strong initial growth but has slowed or reversed in recent years, with ragi exports facing the most instability. Instability indices show sorghum as the most volatile crop, while pearl millet and finger millet have gained relative stability. Trend and regression analyses indicate that sorghum exports are largely constrained by domestic market dynamics, pearl millet exports are positively linked to consumption, and finger millet exports respond well to production increases and favorable farm prices. Overall, with focused policy support, infrastructure development, and market integration, millets can be revitalized for enhanced food security, nutritional value, and export potential**.**

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