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GROWTH TREND ANALYSIS OF SORGHUM CULTIVATION: A COMPARATIVE STUDY OF U.P BUNDELKHAND REGION AND INDIA

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ABSTRACT

Sorghum (*Sorghum bicolor* L.) is an important coarse cereal crop cultivated mainly in the semi-arid and rainfed regions of India. Over a thirty-two-year period, from 1991–1992 to 2022–2023, the present study analyses the growth trends, instability, and sources of change in sorghum area, production, and productivity in India and the U.P. Bundelkhand region. Compound annual growth rate (CAGR), coefficient of variation, and decomposition analysis were used to analyze time-series data. The findings show that sorghum production and area have significantly decreased at the national and regional levels, with the Bundelkhand region showing a more significant decrease. Overall, productivity showed a positive growth trend, particularly at the national level, indicating the impact of better crop management techniques and improved varieties. High instability in area, production, and productivity in Bundelkhand reflects climate vulnerability and dependency on monsoon rainfall. Decomposition analysis revealed, the yield effect was the primary factor influencing changes in sorghum production while decreasing area remained to be a key constraint. The study highlights the need for region-specific policy measures to support sorghum cultivation in drought-prone regions like Bundelkhand.

***Keywords* :** Instability, decomposition, yield, interaction, policy.

Introduction

During the 1950s, sorghum, which covered more than 16 million hectares, was one of the main cereal staples in India. Its area drastically decreased over time, falling to significantly lower levels by approximately 48%. The third advance estimates for 2024–2025 state that sorghum was grown on approximately 39.84 lakh hectares and supplied an average of 1,225 kg/ha, or 48.80 lakh tonnes. Sorghum remains one of the major millet crops in semi-arid regions and contributes significantly to India's output of coarse cereals, even though its area has decreased since the mid-20th century.

In semi-arid areas of the country, marginal and small farmers grow sorghum (*Sorghum bicolor* (L.) Moench), which is the fifth most important crop after wheat, rice, maize, and pearl millet. It is one of the main staple food crops for the world's poor and food-insecure people (Basavaraja *et al.*, 2005). Since sorghum is grown with minimal precipitation (400 to 500 mm) and usually without the application of fertilizers or other inputs, it is frequently recommended for farmers to grow it in harsh conditions where other crops perform inadequately. However, both in India and around the world, it is grown for a number of uses.

The total area under sorghum cultivation in India in 2022–23 was 3.53 million hectares, with an average productivity of 10.79 quintals per hectare and a production of 3.810 million tonnes. In contrast, the Bundelkhand region alone reported a significantly higher area under sorghum cultivation 6.54 million hectares with a productivity of 16.076 quintals per hectare and a production of 10.523 million tonnes. This suggests that Bundelkhand not only cultivated sorghum on a wider area than the national average, but also attained a far better level of productivity. In comparison to the national picture, the higher yield in Bundelkhand may indicate more effective agricultural methods, favourable agroclimatic conditions, or better input utilisation in the area.

Uttar Pradesh is the sixth-largest producer of sorghum in the nation. Though the U.P.'s sorghum crop area decreased from 0.18 million hectares in 2016–2017 to 0.17 million hectares in 2022–2023, production and productivity showed a steady upward trend. Productivity has risen from 10 quintals per hectare to an all-time high of 15.78 quintals per hectare, while production has increased from 0.18 million tonnes to 0.27 million tonnes.

According to records from pre-commercialisation, the U.P. Bundelkhand region had a sizable area cultivated both major and minor millets, with a significant percent share in both area and production. Banda, Chitrakoot, Hamirpur, and Jalaun are the principal sorghum-growing districts in the Uttar Pradesh Bundelkhand region. Banda district led the way in output in 2022–2023, with 4.03 million tonnes, followed by Hamirpur (2.46 million tonnes), Chitrakoot (2.19 million tonnes), and Jalaun (0.87 million tonnes). Hamirpur (1.58 million hectares), Chitrakoot (1.71 million hectares), Jalaun (0.70 million hectares), Mahoba (0.36 million hectares), and Banda (2.07 million hectares) were the top five sorghum-growing regions in U.P. Bundelkhand. With 19.44 quintals per hectare, Banda ranks first in terms of productivity, followed by Chitrakoot (12.78 quintals per hectare), Mahoba (16.1 quintals per hectare), Jalaun (15.43 quintals per hectare), Lalitpur (15.93 quintals per hectare), Jhansi (15.93 quintals per hectare), and Hamirpur (15.31 quintals per hectare). (Source: Directorate of Economics & Statistics, DAC & FW). Understanding the changes over time in every region depends critically on the area, productivity, and production of sorghum growth rate. Identifying trends in the field is very helpful because it provides the historical context of how sorghum cultivation affected growers' lives in both positive and negative ways. This allows us to determine the best and worst times for sorghum cultivation in terms of area, production, and productivity. It is now crucial to determine sorghum production, productivity, and area trends and instability in India and U.P Bundelkhand region.

Materials and Methods

This specific study uses secondary data for the period 1991–92 to 2022–23. Analysis was carried out using Coefficient of Variation (CV) to measure data variability, Compound Annual Growth Rate (CAGR) to examine average yearly growth, and area decomposition to understand the contribution of different factors to overall changes. Yield was also calculated to assess productivity trends. All calculations were performed using standard statistical techniques to ensure reliability and accuracy of the results (Kalia *et al.*, 2021).

Growth rate

The Compound Annual Growth Rate (CAGR) for the area, production, and productivity of sorghum crop in the India and Bundelkhand region of U.P was calculated using time series data for 32 years from 1991-92 to 2022-2023 by fitting the exponential form as given below:

$$Xt = ab^{t}$$

$$\text{Log } Xt = \text{Log } a + t \text{ Log } b$$

Compound growth rate(r) = (Antilog b – 1) * 100

Where, Xt = Area/production/ productivity of sorghum in the year

t = Period which takes the value 1, 2, 3,4………. N

a = constant /Intercept b = Regression Coefficient

The ‘t’ test was used to test the significance of the compound growth rate.

Instability was measured by using co-efficient of variation.

The standard deviation as percentage of means called as co-efficient of variation.

$$CV = \sigma / \mu \times 100$$

Where,

CV = Co-efficient of variation

σ = Standard deviation of the variable

μ = Mean of the variable

Decomposition analysis

Decomposition is a technique to discern out the effect of technology or environmental damage or any other impact on production. The following decomposition model was used for estimation of contribution of area and yield towards change in production (positive/negative) is expressed as:

$$\Delta P = A0\ \Delta Y + Y0\ \Delta A + \Delta A \Delta Y$$

Change in production = Area Effect + Yield Effect + Interaction Effect.

Area Effect: percentage share of area in total production.

$$AE = Y0 (An – A0) / Pn – P0 × 100$$

Yield Effect: Percentage of share of average yield in total production

$$YE = Y0 (Yn – Y0) / Pn – P0 × 100$$

Interaction Effect:

$$IE = (An – A0) (Yn – Y0) / Pn – P0 × 100$$

Where,

A0= Triennium average of area in base year

An= Triennium average of area in current year

P0= Triennium average of production in base year

Pn=Triennium average of production in current year

Y0= P0/A0

Yn= Pn/An

Results and Discussion

The compound growth rate and Instability of area, production and productivity of Sorghum were calculated and shown in the Table 1.

Table 1: Compound growth trend and Instability Analysis in area, production and productivity of Sorghum in India and U.P. (Bundelkhand region)

Sorghum	Particulars	India	Uttar Pradesh (Bundelkhand region)
Area	Beginning year area(000' ha)	12360	257820
	End year area (000' ha)	3530	65461
	No. of observation	32	32
	CAGR	-3.81	-4.72
	R^2	0.95	0.9 *
	CV	34.18	52.57
Production	Beginning year area (000' tonnes)	8100	730937
	End year area (000' ha)	3810	105235
	No. of observation	32	32
	CAGR	-3.117	-4.67
	R^2	0.85	0.36
	CV	32.00	117.38
Yield	Beginning year area (quintal/hectare) 1991-92	6.55	2.85
	End year area quintal/hectare 2022-2023	10.79	16.076
	No. of observation	32	32
	CAGR	0.729	0.058
	R^2	0.25	0.000111
	CV	13.36	54.22

Table 1 shows the compound growth trend and instability analysis of sorghum in terms of area, production, and productivity for India and the Bundelkhand region of Uttar Pradesh from 1991–1992 to 2022–2023. The findings show that sorghum cultivation is continuously declining, especially in terms of area and production, while productivity shows inconsistent regional performance.

At the national level, sorghum cultivation declined drastically from 12360 thousand hectares in 1991–1992 to 3530 thousand hectares in 2022–2023, with a notable negative compound annual growth rate (CAGR) of –3.81 percent. A consistent downward trend over the period of the study is indicated by the strong coefficient of determination (R^2 = 0.95). the findings of previous study results, the importance of coarse cereals in India is declining as a result of shifting consumption patterns and policy bias towards rice and wheat (Kumar *et al.,* 2012) (Birthal *et al.,* 2015). This contraction in area reflects a gradual shift of farmers away from sorghum towards more profitable crops.

Sorghum area declined significantly in the Bundelkhand region, with acreage falling from 257820 thousand hectares to 65461 thousand hectares and a larger negative CAGR of -4.72 percent. Significant instability in the cultivated area is shown by the coefficient of variation (52.57%), which suggests that farmers' acreage decisions fluctuate frequently. The decline in coarse cereal cultivation in rainfed areas has been linked to low profitability and irregular rainfall patterns. This study was supported by (Raju *et al.,* 2011) (Maikasuwa *et al.*, 2013) (Malathi *et al.*, 2016) (Narmadha *et al.,* 2017), (Kumar *et al.*, 2016).

Production of sorghum followed a pattern remarkably similar to local patterns. Production declined from 8100 thousand tonnes in 1991–1992 to 3810 thousand tonnes in 2022–2023, with a negative compound annual growth rate of –3.12 percent. The comparatively high R^2 value (0.85) indicates that the decrease in cultivated area accounts for a significant portion of the production decrease. At the national level, reasonably constant annual output fluctuations are indicated by moderate production instability (CV = 32%). These results are in accordance with previous studies that found area reduction to be the main cause of India's decreased production of coarse cereals (Kumar *et al.*, 2014).

On the other hand, sorghum production in Bundelkhand decreased drastically from 730937 thousand tonnes to 105235 thousand tonnes, with a negative CAGR of –4.67 percent. The extremely significant coefficient of variation (117.38%) and low R^2 value (0.36) indicate that production is highly unstable. The volatility observed in the region's agricultural system primarily arises from its heavy dependence on monsoon rainfall, frequent drought occurrences, and limited irrigation facilities (Singh *et al.*, 2019). Sorghum cultivation fluctuated over the years. The reason may be due to a lack of government support, Market demand, increase in the cultivation of commercial crops in previous years due to the globalization of agriculture. and lack of awareness many people in the country are not aware of the health benefits of Sorghum, or due to other competing kharif cereals and pulses, and other reasons from agronomy prospective Sorghum is an exhaustive crop because its roots penetrate soil up to deep and also it concentrates nitrogen into unavailable due to high C:N ratio (80:1) by the act of soil microorganisms through the decay of root and stubbles and such type of crop is weighty feeder of nutrients meanwhile of this nature growers hesitate to cultivate the sorghum in the double-cropped area.

During the study period, sorghum productivity improved with the declining trends in both area and production. At the national level, yield increased at a positive CAGR of 0.73 percent, from 6.55 quintals per hectare in 1991–1992 to 10.79 quintals per hectare in 2022–2023. The low R^2 value (0.25), however, indicates that productivity growth was inconsistent across time. The comparatively low yield instability (CV = 13.36%) suggests that yield enhancement may have been facilitated by innovations in technology, such as the introduction of improved cultivars and enhanced crop management techniques (Reddy *et al.*, 2013).

Productivity in the Bundelkhand region increased significantly from 2.85 to 16.08 quintals per acre. However, as shown by a CV of 54.22 percent and a very low R^2 value, the growth rate remained small (CAGR = 0.058 percent) and remarkably unstable. This suggests that rather than consistent technological advancement, yield increases were primarily inconsistent and based on favorable weather. Considerable yield variability has been observed in rainfed crops in drought-prone areas (Joshi *et al.*, 2018). Productivity improvements in sorghum cultivation have been attributed to the adoption of high-yielding varieties and increased input use (Hile *et al.*, 2013).

Overall, the findings indicate that a steady decline in cultivated area is the primary cause of the decline in sorghum production in both Bundelkhand and India. In Bundelkhand, productivity increases are still inconsistent and insufficient, despite the fact that they have partially compensated for production losses at the national level. The results show the importance of region-specific interventions to increase the economic sustainability of sorghum agriculture in drought-prone areas, such as the promotion of drought-tolerant sorghum varieties, the growth of irrigation facilities, and governmental support.

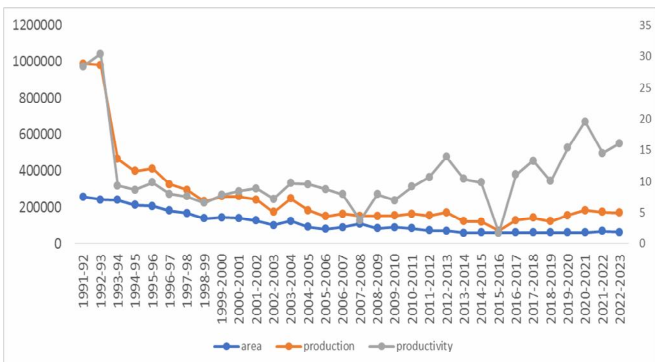

Fig. 1: Trends in Area, Production and Productivity in Bundelkhand Region (1991–92 to 2022–23)

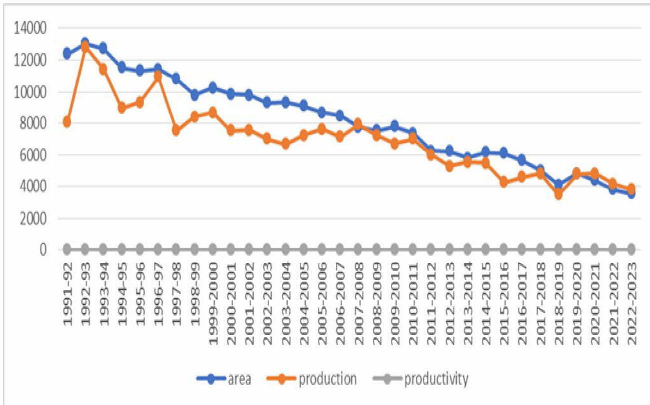

Fig. 2: Trends in Area, Production and Productivity in India (1991-92 to 2022-2023)

Table 2: Decomposition of Area, Production and Productivity of Sorghum in India, and U.P. Bundelkhand region

Components	India	U.P. Bundelkhand
Area effect Δ A.Y0 %	-1221.4	505.777
Yield effect Δ Y.A0 %	1349.8	871.3
Interaction effect ΔA. Δ Y %	-6570.4	322.9

The decomposition study (Table 2) reveals significant differences in the sources of sorghum production change between the U.P. Bundelkhand region and India. The negative area effect (–1221.4%) at the national level indicates a significant decrease in the area devoted to sorghum, consistent with previous studies suggesting a long-term shift away from coarse cereals toward more lucrative crops (Rao *et al.*, 2016), (Birthal *et al.*, 2019). However, Bundelkhand shows a positive area effect (505.77%), indicating the continued importance of sorghum in rainfed, drought-prone agro-ecological regions (ICRISAT, 2019).

The yield effect is positive in both areas, contributing 871.3% in Bundelkhand and 1349.8% in India, showing that changes in sorghum production are mostly driven by increased productivity. Adoption of improved cultivars and enhanced crop management techniques have led to similar yield-driven growth trends at the national level (Source: Government of India, 2022). However, Bundelkhand's comparatively lower yield contribution points to enduring region-specific limitations, such as inconsistent rainfall and restricted access to contemporary inputs (Reddy *et al.*, 2018).

The interaction effect, which is significantly negative for India (-6570.4%), shows a drastic difference, showing that rapid area declines outweighed yield improvements. On the other hand, Bundelkhand's positive interaction effect (322.9%) suggests that yield enhancement and area expansion are complementary, leading to more stable production expansion (Rajput *et al.*, 2024). Overall, the results indicate that while sorghum production in India is primarily yield-driven, growth is still constrained by declining area, while Bundelkhand has a more resilient and balanced production structure.

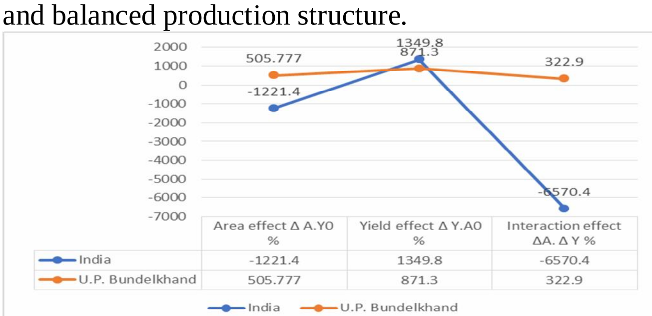

Fig. 3: Decomposition of agricultural production change into area effect ($\Delta A \cdot Y_0$), yield effect ($\Delta Y \cdot A_0$) and interaction effect ($\Delta A \cdot \Delta Y$) in India and U.P. Bundelkhand.

Conclusion

The findings of the study indicate that the decline in sorghum cultivation in India and the U.P. Bundelkhand region is mainly driven by a continuous reduction in the area under the crop. Although improvements in productivity have been observed over the years, these gains have not been adequate to compensate for the loss in cultivated area and overall production. In the Bundelkhand region, large fluctuations in area, output, and yield reflect the dependence of sorghum cultivation on rainfall and the limited availability of irrigation facilities.

The analysis further reveals that yield growth has contributed positively to sorghum production, while contraction of cultivated area has emerged as the major limiting factor. In this context, policy measures should emphasize the promotion of drought-tolerant sorghum varieties, strengthening irrigation and water-conservation infrastructure, and providing assured price and market support to farmers. Enhanced extension services and greater awareness of sorghum's nutritional and climate-resilient qualities can help sustain its cultivation. Focused and region-specific policy interventions are therefore essential to support sorghum-based farming systems in drought-prone regions such as Bundelkhand.

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