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Production growth, sources of output change and instability of major nutri-cereals across Indian states

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Abstract
Nutri-cereals contribute to food and nutritional security and support farming in diverse rainfed environments. Yet their production trajectories differ across crops and states, with implications for yield improvement, acreage retention and extension planning. This study assessed changes in area, production and yield of bajra, jowar, ragi and small millets across major producing states of India during 2001–02 to 2022–23. The period was divided into 2001–02 to 2010–11, 2011–12 to 2022–23 and the overall period. Secondary time-series data were analysed using annual compound growth rates, a modified area–yield decomposition model and the Cuddy–Della *Valle* instability index. In the overall period, Madhya Pradesh recorded significantly the highest growth in bajra area (4.01%) and production (8.70%), while *Karnataka* recorded significantly the highest yield growth (5.05%). For jowar, Tamil Nadu led in area growth (1.16%), whereas, Rajasthan recorded the highest production (4.80%) and yield (4.99%) growth. Tamil Nadu showed the strongest overall growth in ragi production (2.63%) and yield (4.63%). In small millets, *Odisha* led significantly in area (1.57%) and production (3.04%) growth, while Madhya Pradesh recorded the highest yield growth (8.57%). Yield effects were important in the production growth of jowar and small millets, whereas, national bajra growth reflected positive area and yield contributions. Production instability was generally greater than area and yield instability in several crop–state combinations. The findings point to the need for crop- and region-specific extension, improved access to suitable technologies, yield-risk management and reliable market support.

Keywords: Nutri-cereals, Growth, Decomposition, Instability, Agricultural extension, India

Introduction

Millets, often described as nutri-cereals, are important components of diversified food systems because they are adapted to a range of agro-ecological conditions and contribute to dietary diversity. In India, pearl millet (bajra), sorghum (jowar), finger millet (ragi) and small millets are cultivated across states with different production environments, input-use patterns and market access conditions. Their importance extends beyond aggregate foodgrain output: they support livelihoods in semi-arid and rainfed regions, where the production of other cereals may be constrained. Despite renewed policy and consumer interest, the area devoted to several millet crops has contracted over time in a number of important producing states. Changes in area, yield and their interaction can produce different output trajectories. Aggregate production growth alone therefore does not reveal, whether output expansion has resulted from acreage growth, productivity improvement or a combination of both. Similarly, a rising trend may coexist with substantial year-to-year instability, exposing farm households to production and income risk. Previous studies have applied growth and instability measures to agricultural crops and regions (Acharya *et al.*, 2012; Bairwa *et al.*, 2024) [1, 2]. Recent work has also examined pearl millet growth and decomposition in Rajasthan . A multi-crop and multi-state comparison combining temporal growth, sources of output change and detrended instability can help to identify where extension and production-development interventions are most relevant. The study aimed to: (i) estimate temporal changes in area, production and yield of selected nutri-cereals in major producing states; (ii) quantify the relative contributions of area, yield and their interaction to production change; and (iii) assess the instability of area, production and yield across the selected crops and states.

Materials and methods

Study coverage and data

The analysis covered four crops: bajra, jowar, ragi and small millets. The selected states were Rajasthan, Uttar Pradesh, Maharashtra, Haryana, Gujarat, Madhya Pradesh and *Karnataka* for bajra; Maharashtra, *Karnataka*, Rajasthan, Tamil Nadu, Uttar Pradesh, Madhya Pradesh and Andhra Pradesh for jowar; *Karnataka*, Tamil Nadu, Uttarakhand, Maharashtra, *Odisha* and Andhra Pradesh for ragi; and Madhya

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Pradesh, Uttarakhand, Tamil Nadu, Maharashtra, Chhattisgarh, *Odisha* and *Karnataka* for small millets. The selection was based on the area occupied by the crops in the last decade and the availability of time-series observations.

Secondary annual data on area, production and yield were compiled for 2001–02 to 2022–23 from government agricultural statistics, including the Directorate of Agriculture and the Directorate of Economics and Statistics, Government of India, and other public sources cited in the thesis. The periods were: Period I, 2001–02 to 2010–11; Period II, 2011–12 to 2022–23; and the overall period, 2001–02 to 2022–23.

Compound growth rate

Compound growth rates were estimated by fitting an exponential trend, $Y_t = ab^t u_t$. The logarithmic form, $\ln Y_t = \ln a + t \ln b$, was estimated by ordinary least squares. The compound growth rate was calculated as [antilog(ln b) − 1] × 100. The statistical significance of the estimated trend coefficient was assessed using a *t*-test. The variables analysed were area, production and yield.

Modified decomposition analysis

The contribution of area, yield and their interaction to production change was estimated using the modified decomposition model. Since production *P* is the product of area A and yield Y, the change between a base period and year t was expressed as $\Delta P_t = A_0\Delta Y_t + Y_0\Delta A_t + \Delta A_t\Delta Y_t$. The three terms represent the yield effect, area effect and interaction effect, respectively. The modified approach uses annual observations over the period rather than relying only on two endpoint averages. Each component was expressed as a percentage of the total change in production.

Instability measurement

Instability was measured using the Cuddy–Della *Valle index*: CDV = CV × $\sqrt{(1 - \text{adjusted } R^2)}$, where CV is the coefficient of variation and adjusted R^2 is the adjusted coefficient of determination from the time-trend regression. The adjustment reduces the influence of the underlying trend on measured dispersion. Instability was classified as low (0–15%), medium (15–30%) and high (above 30%). Where the estimated compound growth trend was not statistically significant, the coefficient of variation was used as specified in the original analysis.

Results

Growth in bajra

Madhya Pradesh recorded significantly the highest overall growth in bajra area (4.01%) and production (8.70%) during 2001–02 to 2022–23 (Table 1). *Karnataka* recorded the highest overall yield growth (5.05%). At the all-India level, bajra area declined by 1.56 per cent per annum, while production and yield increased by 1.46 per cent and 3.06 per cent, respectively. In Period I, Rajasthan recorded the highest significant area growth (2.31%), Madhya Pradesh led production growth (7.23%), and Haryana recorded the highest yield growth (5.37%). In Period II, Madhya Pradesh recorded significantly the strongest increase in area (6.93%) and production (9.68%), while *Karnataka* led yield growth (3.07%).

Growth in jowar

Over the overall period, Tamil Nadu recorded significantly the highest positive area growth (1.16%), while Rajasthan led production growth (4.80%) and yield growth (4.99%). At the all-India level, area declined by 4.56 per cent and production by 3.40 per cent annually, whereas yield increased by 1.21 per cent. In Period I, Rajasthan recorded positive area and production growth. During Period II, Tamil Nadu recorded the highest area growth (4.90%), while Uttar Pradesh led production (4.55%) and yield growth (4.16%).

Growth in ragi

Ragi area declined in all selected states during overall period. Tamil Nadu recorded significantly the highest overall growth in production (2.63%) and productivity (4.63%). At the national level, area and production declined by 1.93% and 0.93% per annum, respectively, while yield increased by 1.01%. In Period II, *Karnataka* recorded positive area growth (1.69%), while Tamil Nadu led productivity gains (2.32%).

Growth in small millets

In overall period, *Odisha* recorded significantly positive growth in area (1.57%) and production (3.04%), while Madhya Pradesh recorded the highest yield growth (8.57%). At the all-India level, area and production declined by 5.49 per cent and 1.86 per cent, respectively, while yield increased by 3.84 per cent.

Sources of production growth

For bajra, yield improvements were important in Period I (Table 2), while area effects became more prominent in selected states during Period II. In overall period, national production change was attributed to a positive area contribution of 61.40 per cent and a yield contribution of 39.41 per cent. Haryana (114.22%) and *Karnataka* (57.88%) showed substantial area effects, while Rajasthan recorded a yield effect of 103.35 per cent. For jowar, yield was the dominant contributor to production growth in the overall period at the national level, while area and interaction effects declined. State-level yield contributions were particularly high in Madhya Pradesh, *Karnataka* and Rajasthan during Period I. In Period II, Rajasthan recorded a yield effect of 110.12 per cent, while Madhya Pradesh had the largest area effect (59.13%). For ragi, at the national level, in overall-period decomposition attributed 72.48 per cent of production change to area, 26.60 per cent to yield and 0.92 per cent to the interaction effect. The contribution pattern shifted from yield-led growth in Period I towards area expansion in Period II in several states. For small millets, yield effects were prominent in Period I and nationally over the overall period, while area expansion contributed strongly to growth in selected states during Period II.

Production instability

Production was generally more volatile than area and yield, although the intensity varied by crop and state. For bajra, *Karnataka* recorded the highest overall production instability (37.43%), followed by Rajasthan (33.55%). National bajra area instability remained low across periods, while production instability ranged from low to medium. For jowar, Tamil Nadu recorded the highest area instability (116.83%), Andhra Pradesh the highest production instability (137.55%), and Rajasthan the highest yield instability (126.09%). The national jowar series also showed high overall production and yield instability. Ragi was comparatively more stable than jowar. Tamil Nadu was the only state highlighted for high production instability in both sub-periods, at 31.64 per cent in Period I and 30.56 per cent in Period II. For small millets, Madhya Pradesh recorded high area instability during Period I (59.87%), while *Karnataka* recorded the highest production instability during Period II (39.38%). At the national level, small-millet area and production instability remained low despite high instability in several state-level series. *The overall-period growth estimates are summarised in Table 1, while selected decomposition and instability findings are presented in Table 2.*

Discussion

The findings demonstrated that production performance differed substantially across crops and states. Bajra production increased nationally, despite a decline in area, indicating that yield improvement more than offset acreage contraction. In contrast, the decline in jowar and ragi production occurred alongside declining area, while yield gains were comparatively modest. Small millets also showed declining national area and production despite positive yield growth. These patterns underline the importance of distinguishing area-led and yield-led changes when interpreting aggregate production trends. The decomposition results further showed that the sources of output change were crop-specific. Area made the larger national contribution to overall-period bajra and ragi production change, whereas, yield dominated the national contribution for jowar and small millets.

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Contributions exceeding 100 per cent in some state-level estimates were possible where another component contributed negatively to total production change. The instability results indicated that production variability was particularly pronounced in several jowar state-level series and in selected bajra and small-millet states. Earlier studies have also used growth and instability measures to examine crop performance across regions (Acharya *et al.*, 2012; Bairwa *et al.*, 2024; Sharma *et al.*, 2022) [1, 2, 3]. The present multi-crop comparison extended this type of assessment across selected nutri-cereals and major producing states. The results support differentiated extension strategies rather than a uniform millet-development package. In states where acreage is contracting, extension and development agencies could work with farmer groups and farmer producer organisations to strengthen access to quality seed, locally suitable varieties, assured procurement and market linkages. Where yield instability is high, advisory services could prioritise climate-risk management, timely sowing, soil-moisture conservation, water harvesting, integrated nutrient management and crop protection. Where yield growth is positive, but area is declining, productivity gains need to be connected with remunerative market opportunities to encourage farmers to retain the crop.

State-specific priorities emerging from the evidence include addressing production volatility in *Karnataka* and Rajasthan for bajra; addressing acreage decline and high variability in major jowar-producing states; consolidating ragi yield gains, while arresting area contraction; and building on Odisha's positive small-millet area and production trajectory, while addressing high state-level instability. These implications were inferred from secondary production statistics; extension programme effectiveness was not directly evaluated.

Conclusion

The production performance of nutri-cereals in India was crop- and state-specific. Madhya Pradesh led overall bajra area and production growth, *Karnataka* led bajra yield growth, Rajasthan was the strongest overall jowar production and yield performer, Tamil Nadu led ragi production and yield growth, and *Odisha* led small-millet area and production growth. The decomposition results showed that area and yield contributions varied across crops and periods, while the instability analysis identified important production risks in several state-level series. The findings underline the need to combine yield-enhancing technology with risk management, market assurance and region-specific extension support.

Table 1. Overall-period compound growth rates and leading state results (2001–02 to 2022–23).

Crop	All-India area growth (%)	All-India production growth (%)	All-India yield growth (%)	Leading overall state result
Bajra	−1.56	1.46	3.06	Madhya Pradesh: area 4.01%, production 8.70%; *Karnataka*: yield 5.05%
Jowar	−4.56	−3.40	1.21	Tamil Nadu: area 1.16%; Rajasthan: production 4.80%, yield 4.99%
Ragi	−1.93	−0.93	1.01	Tamil Nadu: production 2.63%, yield 4.63%
Small millets	−5.49	−1.86	3.84	*Odisha*: area 1.57%, production 3.04%; Madhya Pradesh: yield 8.57%

Table 2. Selected decomposition and instability findings for the overall period and specified sub-periods.

Crop	Key decomposition result	Selected instability result
Bajra	National area effect 61.40%; yield effect 39.41%.	*Karnataka* production instability 37.43%; Rajasthan 33.55%.
Jowar	Yield effect dominated nationally; area and interaction effects declined.	Tamil Nadu area 116.83%; Andhra Pradesh production 137.55%; Rajasthan yield 126.09%.
Ragi	National area 72.48%; yield 26.60%; interaction 0.92%.	Tamil Nadu production instability 31.64% in Period I and 30.56% in Period II.
Small millets	Yield effect dominated nationally over the overall period.	Madhya Pradesh area instability 59.87% in Period I; *Karnataka* production instability 39.38% in Period II.

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