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Growth, instability and sources of change in chickpea production in Bundelkhand Region of Uttar Pradesh

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Abstract
Chickpea is a key pulse crop contributing to food, nutritional security, and sustainability in India, particularly in rainfed regions. This study analyses the growth, instability, and sources of change in chickpea production in the Bundelkhand region of Uttar Pradesh over the period 1991-92 to 2022-23. Time-series data on area, production, and yield were analysed by dividing the study period into a pre-policy phase (1991-92 to 2006-07) and a post-policy phase (2007-08 to 2022- 23). Compound Annual Growth Rate (CAGR), Cuddy-Della Valle Index, and decomposition analysis were employed. Results indicate that area under chickpea cultivation in Bundelkhand declined over the long run, while production increased substantially due to significant productivity gains. Growth was largely negative and unstable during the pre-policy phase but turned positive and productivity-led in the post-policy phase, reflecting the impact of policy interventions and technological adoption. However, instability in area, production, and yield increased over time, highlighting rising climatic and production risks. Decomposition results reveal a gradual shift from area-driven to yield-driven growth. The study underscores the need for climate-resilient varieties, strengthened extension services, and yield-enhancing strategies to ensure sustainable chickpea production in Bundelkhand's semi-arid conditions.

Keywords: Chickpea, productivity growth, instability analysis, Bundelkhand region, yield variability, decomposition analysis

Introduction
Pulses occupy a significant place in Indian agriculture, serving as an important source of protein for the predominantly vegetarian population. They play a dual role in enhancing nutritional security and supporting environmental sustainability by enriching soil fertility and utilizing natural resources more efficiently (Alexandratos, N., and Bruinsma, J., 2012) [3]. Pulses are rich in protein, fibre, complex carbohydrates, and essential vitamins and minerals. Their low fat and high fibre content make them beneficial for heart and digestive health. In addition to their nutritional value, pulses also help to improve soil fertility and support sustainable farming systems. Despite their importance, the availability of pulses per person has fallen from 60 grams per day in 1951 to 53.7 grams in 2022, which remains below the ICMR's recommended level of 65 grams per day (DA&FW, 2024).

To enhance domestic pulse production and reduce dependence on imports, India has launched several major policy initiatives focusing on area expansion, productivity enhancement, and market support. These efforts began with the All India Coordinated Research Project on Pulses (AICRP, 1966) and the Pulses Development Programme (1969), followed by large-scale national missions such as the National Food Security Mission on Pulses (NFSM, 2007) and the Accelerated Pulses Production Programme (A3P, 2010). Later, the Pradhan Mantri Annadata Aay Sanrakshan Abhiyan (PM-AASHA, 2018) was introduced to provide price support and ensure remunerative returns to farmers. Most recently, these efforts have culminated in the National Mission on Edible Oils and Pulses - Atmanirbhar Bharat Abhiyan (2025), which aims to achieve self-sufficiency in pulse production through technological interventions and improved supply chains.

India cultivates pulses on 28.90 million hectares, producing 26.06 million tonnes with an average yield of 902 kg per hectare during 2022-23 (DA&FW, 2023). Uttar Pradesh accounts for about 9.55 per cent of the national pulse area (2.76 million ha) and 10.90 per cent of total production (2.84 million tonnes), with an average yield of 1,031 kg per hectare, which is 14 per cent higher than the national average. Among major states, Rajasthan contributes the largest share of area (19.03 per cent) but with a lower yield of 658 kg per hectare, while Madhya Pradesh records the highest productivity (1,115 kg/ha) and contributes 24 per cent of total production.

Within the pulse group, chickpea is the dominant crop, covering 10.47 million hectares and producing 12.27 million tonnes nationally with a yield of 1,172 kg per hectare. Uttar Pradesh contributes 6.49 per cent of India's chickpea area (0.68 million ha) and 7.34 per cent of its production (0.90 million tonnes), achieving a yield of 1,321 kg per hectare, which is 13 per cent higher than the national average. This indicates that chickpea cultivation in Uttar Pradesh holds strong potential for improving pulse productivity and contributing to the state's overall food and nutritional security.

Although the Bundelkhand agro-climatic zone accounts for a relatively small portion of Uttar Pradesh's total chickpea cultivation about 2.5 per cent of the state's area (0.015 million ha) and 2.5 per cent of production (0.020 million tonnes), with average yield of 1,321.8 kg per hectare remains close to the state mean of 1,354 kg per hectare. This stable productivity under semi-arid conditions highlights Bundelkhand's resilience and its crucial role in supporting pulse- based dryland farming systems in Uttar Pradesh.

Bundelkhand region comprises seven districts namely Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda, and Chitrakoot. It is predominantly rainfed and resource-constrained, characterized by high climatic risk, limited investment, and socio-economic vulnerability (Samra, 2008; Mondal *et al*., 2016) [15]. The region often experiences water scarcity, natural resource degradation, and low crop productivity (1-1.5 q/ha). Poor soil fertility, low rainwater use efficiency (35-45 per cent), and frequent droughts contribute to severe soil erosion, limited irrigation coverage, and repeated crop failures, resulting in chronic shortages of food, fodder, and fuel (Palsaniya *et al*., 2008; Mondal *et al*., 2017) [16].

Although several government programmes have been introduced to raise pulse productivity and reduce regional gaps, the growth pattern of chickpea area, production, and yield in the region still shows irregular and unstable trends. Therefore, it is important to examine the growth rate, instability, and sources of change in production through to understand how chickpea cultivation has performed over time. This will help to know whether the changes in production are mainly due to area enhancement, improvement in yield, or both, and will provide useful insights for planning better policies to improve productivity and stability of chickpea cultivation under Bundelkhand's dry and variable climate.

In view of policy intervention to better understand the temporal changes, the study period from 1991-92 to 2022-23 has been divided into two phases. The first phase (1991-92 to 2006-07) represents the pre-policy period, characterized by limited government attention and frequent droughts. The second phase (2007-08 to 2022-23) corresponds to the implementation of key initiatives such as the National Food Security Mission (NFSM), Rashtriya Krishi Vikas Yojana (RKVY), and the Bundelkhand Package, aimed at enhancing pulse productivity and resilience along with initiatives like Pradhan Mantri Annadata Aay Sanrakshan Abhiyan (PM-AASHA) and the Atmanirbhar Bharat Abhiyan, all aimed at improving pulse productivity and promoting self- reliance in the region.

Methodology

Data Source: Time-series data on the area, production, and yield of chickpea for the period 1991-92 to 2022-23 was collected from the Directorate of Economics and Statistics (Government of India), the Uttar Pradesh Agriculture Department and NFSM reports. The year 1991-92 was taken as the baseline because it was an important year for pulse development, when the National Pulses Development Project (NPDP) was started under the Technology Mission on Oilseeds, Pulses and Maize (TMOP&M). This programme helped to improve pulse farming and increase its cultivation across the country.

For the purpose of analysis, the study period was divided into two phases and an overall period. Phase I (1991-92 to 2006-07) represents the early years with less policy support and frequent droughts that affected chickpea cultivation. Phase II (2007-08 to 2022-23) covers the period of major government programmes such as the National Food Security Mission (NFSM) and the Bundelkhand Package, which aimed to increase pulse production and productivity. The overall period (1991-92 to 2022-23) was considered to examine the long-term changes and combined effect of these policies.

Analytical Tools

The Compound Annual Growth Rate (CAGR) was computed to examine the trends in area, production, and productivity of chickpea.

Y = abt

where,

Y = Area / production / productivity of chickpea for year't' a = constant

b = Regression coefficient that shows the rate of change or growth rate in a series (1+r) t =time variable in year (1, 2, 3…….n)

r = growth rate Equation (1) was converted into the logarithmic form to make it in linear form as follow:

log Y = log a + t(log b)

Where, log b = log (1+r)

r = [antilog (log b) - 1]

Compound annual growth rate was computed as follows:

CAGR (per cent) = [antilog (log b) - 1] * 100

The student's t-test was applied to assess the significance of the regression coefficient.

To measure the level of fluctuation or instability in the area, production, and yield of chickpea over the years, the Cuddy Della Valle Index (CDVI) was used.

where, CV= Co- efficient of variation and $\bar{2}$= Adjusted Coefficient of determination.

Decomposition analysis helps break down the different parts of a parameter to understand their impact. In this study, it was used to measure how much the area, productivity, and their interaction contributed to the total production. This method helped to assess the role that changes in land area and crop yield played in the overall chickpea production. P = A0 (Yn - Y0) + Y0 (An - A0) + ΔAΔY 1= [(A ΔY)/P] + [(Y ΔA)/P] + [(ΔA

ΔY)/P]
Where, P = Change in production, A0 = Area in base year, An = Area in current year, Y0 = Yield in base year, Yn = Yield in current year, ΔA = Change in area (An - A0), ΔY = Change in yield (Yn - Y0).

Results and Discussion

District-wise Changes in Area, Production, and Productivity of Chickpea

It is essential to understand the regional agricultural performance by analyzing district- wise changes in chickpea area, production, and productivity to understand regional performance patterns, recognize zones of growth or decline, and guide location-specific planning for improving pulse productivity and farmer resilience in the Bundelkhand region of Uttar Pradesh. Table 1 shows how the area, production, and yield of chickpea changed across different districts of Bundelkhand, Uttar Pradesh, from 1991-92 to 2022-23. The findings indicate clear differences among districts in how the cultivated area increased or decreased.

Table 1: District-wise Changes in Area, Production, and Productivity of Chickpea

District	Area (ha) (1991-92)	Area (ha) (2022-23)	% Change in Area	Production (t) (1991-92)	Production (t) (2022-23)	% Change in Production	Yield (kg/ha) (1991-92)	Yield (kg/ha) (2022-23)	% Change in Yield
Jhansi	79652	106266	33.41	48977	155786	218.08	0.61	1.47	140.98
Lalitpur	60999	16038	-73.71	52852	25565	-51.63	0.87	1.59	82.76
Jalaun	76924	47609	-38.11	69988	57797	-17.42	0.91	1.21	32.97
Hamirpur	139225	70154	-49.61	70872	88113	24.33	0.51	1.26	147.06
Mahoba	48963	73054	49.20	43697	116813	167.32	0.89	1.60	79.78
Banda	140892	99767	-29.19	80003	130795	63.49	0.57	1.31	129.82
Chitrakoot	0	46735	0.00	0	51829	0.00	0.00	1.11	0.00
Bundelkhand	546655	459623	-15.92	366389	626698	71.05	0.67	1.36	102.99

Note: Chitrakoot district data are missing for 1991-92 to 1996-97 because it was earlier included in Banda district.

At the Bundelkhand level, chickpea area declined from about 546,655 ha to 459,623 ha (-15.92 per cent) over the study period, but district-specific changes varied substantially (Table 1). Jhansi and Mahoba observed notable area expansion, while Lalitpur, Hamirpur, Jalaun, and Banda showed significant area declines. These variations are consistent with findings of *Sah et al.* (2021) [19], who reported similar spatial disparities in pulse area and production across Bundelkhand districts, attributed to differences in resource availability and cropping patterns.

These patterns may result from competing cropping choices, resource constraints, and differential adoption of improved practices — themes also highlighted in studies emphasizing variability in technology adoption and front-line demonstrations for chickpea in the region (Singh & Singh, 2020; Chaturvedi *et al.*, 2018) [5, 25]. Districts with stronger institutional support and more effective extension networks often sustain or expand area under pulses due to better access to improved technologies and inputs (Dubey *et al.*, 2011) [8].

Despite an overall decline in area, total chickpea production in Bundelkhand increased from 366,389 t to 626,698 t (71.05 per cent), driven primarily by productivity gains. Districts with marked production increases included Jhansi (218.08 per cent), Mahoba (167.32 per cent), and Banda (63.49 per cent), whereas Lalitpur and Jalaun recorded declines due to more severe area contraction. This difference between production growth and area expansion shows that farming became more intensive, mainly due to better crop management and the use of high- yielding varieties., consistent with front-line demonstration results that reported substantial yield advantages of recommended practices over traditional ones (Singh & Singh, 2020; Chaturvedi *et al.*, 2018; Kar *et al*., 2020) [5, 13, 24].

Furthermore, evidence from participatory extension and value-chain analyses suggests that improved profitability has strengthened farmers' motivation to adopt yield-enhancing technologies (Dubey *et al*., 2011; Kumar *et al*., 2022) [8, 14]. Average chickpea yield at the regional level increased from 0.67 t/ha to 1.36 t/ha (102.99 per cent), with all districts showing positive growth. The most pronounced increases were in Hamirpur (147.06 per cent), Jhansi (140.98 per cent), and Banda (129.82 per cent). Such magnitudes of yield gain are consistent with the impacts of technology-focused interventions demonstrated across Bundelkhand and adjoining regions (Sah *et al.*, 2021; Kar *et al.*, 2020) [13, 19].

Growth rate of Area, Production, and Productivity of Chickpea

Examining the compound annual growth rate (CAGR) of chickpea area, production, and productivity provides insights into the long-term performance and growth dynamics of the crop in the Bundelkhand region of Uttar Pradesh, helping to assess technological progress and regional disparities over time. Table 2 presents the compound annual growth rates (CAGR) in area, production, and productivity of chickpea across districts of the Bundelkhand region during Phase I, Phase II, and the overall period. The results reveal a clear temporal shift in growth dynamics, characterized by widespread contraction during Phase I, followed by recovery and productivity-led growth during Phase II.

During Phase I, chickpea area exhibited a statistically significant negative growth trend across most Bundelkhand districts. Jhansi (−2.76 per cent), Lalitpur (−4.15 per cent), Jalaun (−1.91 per cent), Hamirpur (−3.15 per cent), and Banda (−2.67 per cent) all recorded area contractions, with the region overall declining by −1.07 per cent per annum. These patterns indicate a phase of structural adjustment in land use, influenced by increasing climatic variability, declining soil moisture, and a shift toward competing rabi crops such as wheat andmustard. Previous studies also reported substantial reductions in pulse acreage during the 1990s and early 2000s due to rainfed vulnerability, low profitability, and weak price incentives (Wani *et al.*, 2016; Sah *et al*., 2021; Singh *et al.*, 2024) [19, 23, 27].

Table 2: Growth rate of Area, Production, and Productivity of Chickpea

Districts	Periods	Area (%)	Production (%)	Yield (%)
Jhansi	Phase I	-2.76*	-1.32	1.48
	Phase II	4.00*	9.25*	5.05
	Overall	-1.07	0.57	1.66*
Lalitpur	Phase I	-4.15*	-3.92**	0.24
	Phase II	-4.21	-0.64	3.72*
	Overall	-5.58**	-4.35**	1.30*
Jalaun	Phase I	-1.91*	-0.78	1.15
	Phase II	0.18	2.83	2.65
	Overall	-2.71*	-1.96	0.77
Hamirpur	Phase I	-3.15*	-1.31	1.90*
	Phase II	0.16	5.00	4.83*
	Overall	-1.85**	-0.82	1.05
Mahoba	Phase I	4.11*	2.29	-1.75*
	Phase II	0.60	6.21	5.58
	Overall	0.62	0.97	0.36
Banda	Phase I	-2.67*	-1.68*	1.01
	Phase II	-1.29	4.40	5.76
	Overall	-2.76	-2.02	0.76*
Chitrakoot	Phase I	0.55*	-3.85	-3.72
	Phase II	-0.22	4.74	4.97
	Overall	-0.65*	0.62	1.23
Bundelkhand	Phase I	-1.07*	-0.42*	0.66
	Phase II	0.27	5.14	4.86*
	Overall	-1.44**	-0.57	0.89

*and ** indicate significance at 5 per cent and 1 per cent.

In contrast, Phase II reflects stabilization and partial revival of chickpea area in several districts. Jhansi recorded a significant positive area growth of 4.00 per cent per annum, while Mahoba and Jalaun registered marginal positive growth. However, Lalitpur continued to show negative trends, indicating persistent structural and resource constraints. Overall, Bundelkhand still experienced a slight area decline (−1.44 per cent), confirming that the region's chickpea expansion remains limited by agro-climatic and institutional factors (Sah *et al*., 2021; Singh *et al*., 2024) [19].

Production growth trends were consistent with area patterns during Phase I, with most districts exhibiting negative or insignificant changes. A decisive turnaround occurred in Phase II, when production growth became strongly positive across nearly all districts. Jhansi (9.25 per cent), Hamirpur (5.00 per cent), Mahoba (6.21 per cent), Banda (4.40 per cent), and Chitrakoot (4.74 per cent) recorded substantial gains, and Bundelkhand as a whole achieved a production growth rate of 5.14 per cent per annum. This phase marks a structural shift from area-led to productivity-led growth, driven primarily by improved technology adoption, better seed varieties, and enhanced agronomic practices disseminated through cluster frontline demonstrations (Chaturvedi *et al*., 2018; Shivran *et al*., 2020; Jha *et al*., 2020) [5, 22].

Productivity trends showed the most consistent progress. In Phase I, yield growth was positive but modest, with Jhansi (1.48 per cent) and Hamirpur (1.90 per cent) showing minor improvement, while Mahoba and Chitrakoot declined slightly due to climatic stress and limited adoption of improved technologies. In Phase II, yield growth accelerated sharply: Jhansi (5.05 per cent), Hamirpur (4.83 per cent), Banda (5.76 per cent), Mahoba (5.58 per cent), and Chitrakoot (4.97 per cent) exhibited significant gains, leading to a regional average growth of 4.86 per cent per annum. These results corroborate earlier demonstration-based studies showing that productivity gains in Bundelkhand chickpea systems are mainly technology-driven, supported by better seed treatment, balanced fertilization, and improved crop management (Sah *et al*., 2021; Chaturvedi *et al*., 2018; Singh *et al*., 2024) [5, 19].

Overall, the CAGR analysis clearly demonstrates a transition from area-led decline to productivity-led growth in Bundelkhand's chickpea cultivation. Phase I reflects contraction and stagnation, while Phase II captures the impact of policy support, technology dissemination, and enhanced farmer awareness. This temporal shift aligns with broader national evidence indicating that recent pulse growth has stemmed mainly from yield improvements rather than expansion of cropped area, especially in rainfed and semi-arid regions (Wani *et al*., 2016; Sah *et al*., 2021; Singh *et al*., 2024) [19, 23, 27]. However, persistent negative area growth and inter-district disparities suggest the need for continued investment in climate-resilient varieties, institutional strengthening, and market stabilization policies to ensure long-term sustainability (Sah *et al*., 2021; Singh *et al*., 2024) [19, 23].

Instability in Area, Production, and Productivity of Chickpea

Analyzing instability in the area, production, and productivity of chickpea in the Bundelkhand region of Uttar Pradesh helps to understand the extent of fluctuations over time, revealing the region's vulnerability to climatic, technological, and market-related risks that affect crop performance and farmer stability. Table 3 presents the extent of instability in area, production, and productivity of chickpea across major districts of the Bundelkhand region during Phase I, Phase II, and the overall period. Instability indices reflect fluctuations arising from climatic variability, changes in resource allocation, technological adoption, and policy influences.

Table 3: Instability in Area, Production, and Productivity of Chickpea

Districts	Periods	Instability Area (%)	Instability Production (%)	Instability Yield (%)
Jhansi	Phase I	21.25	32.80	17.98
	Phase II	38.58	61.86	43.11
	Overall	32.67	57.49	38.63
Lalitpur	Phase I	12.40	16.37	14.00
	Phase II	41.45	46.68	28.42
	Overall	29.73	36.44	25.61
Jalaun	Phase I	14.86	30.12	21.35
	Phase II	26.12	41.48	33.78
	Overall	23.95	36.86	29.13
Hamirpur	Phase I	14.16	15.29	17.55
	Phase II	21.27	43.43	35.71
	Overall	21.11	32.21	31.16
Mahoba	Phase I	16.73	27.71	15.20
	Phase II	37.28	70.44	49.25
	Overall	31.59	62.22	41.00
Banda	Phase I	12.68	16.56	14.20
	Phase II	30.25	54.61	43.97
	Overall	25.97	37.65	36.53
Chitrakoot	Phase I	80.60	82.32	80.37
	Phase II	17.87	45.77	39.59
	Overall	50.66	66.63	63.39
Bundelkhand	Phase I	8.89	16.34	12.79
	Phase II	22.16	48.15	37.96
	Overall	17.69	35.55	31.97

The results reveal a clear increase in area instability during Phase II compared to Phase I across almost all districts of

Bundelkhand. At the regional level, area instability rose sharply from 8.89 per cent in Phase I to 22.16 per cent in Phase II, resulting in an overall instability of 17.69 per cent. This indicates increasing uncertainty in acreage allocation to chickpea over time. Among districts, Chitrakoot exhibited exceptionally high area instability during Phase I (80.60 per cent), which declined substantially in Phase II (17.87 per cent), though the overall instability remained high (50.66 per cent). This suggests major structural shifts in land allocation during the initial period, possibly due to rainfall shocks and frequent crop substitution. In contrast, districts such as Jhansi, Lalitpur, and Mahoba recorded moderate area instability in Phase I but experienced sharp increases during Phase II, reflecting growing vulnerability to climatic stress and market uncertainties. Similar rising instability in pulse crop area has been reported in semi- arid regions of India, where farmers frequently shift acreage in response to rainfall variability and price fluctuations (Ahmad *et al.*, 2018; Sah *et al.*, 2021; Srivastava *et al.*, 2022) [2, 19, 26].

Production instability was consistently higher than area instability across districts, indicating that factors beyond acreage, such as weather variability, pest incidence, and yield fluctuations played a significant role. At the Bundelkhand level, production instability increased from 16.34 per cent in Phase I to 48.15 per cent in Phase II, with an overall instability of 35.55 per cent. District-wise analysis shows that Mahoba (70.44 per cent), Jhansi (61.86 per cent), and Banda (54.61 per cent) recorded very high production instability during Phase II. This sharp increase may be attributed to recurrent droughts, erratic rainfall patterns, and limited irrigation facilities prevalent in the region. Chitrakoot again stands out with extremely high production instability during Phase I (82.32 per cent), though it moderated somewhat in Phase II. These findings corroborate earlier studies that highlighted high instability in pulse production in rainfed regions due to climatic vulnerability and low technological penetration (Dubey *et al.*, 2011; Sah *et al.*, 2021; Singh *et al.*, 2024) [8, 19, 23].

Yield instability showed a pronounced increase during Phase II across all districts. For the Bundelkhand region as a whole, yield instability increased from 12.79 per cent in Phase I to 37.96 per cent in Phase II, resulting in an overall instability of 31.97 per cent. This underscore increasing uncertainty in chickpea productivity despite technological advancements. Districts such as Mahoba (49.25 per cent), Jhansi (43.11 per cent), Banda (43.97 per cent), and Chitrakoot (39.59 per cent) recorded very high yield instability during Phase II. This suggests that yield performance was highly sensitive to climatic stress, particularly terminal drought and temperature extremes during the rabi season. Earlier studies have also observed that yield instability in pulses tends to be higher than cereals due to their cultivation in marginal environments with limited input use (Gull *et al.*, 2020; Ahmad *et al.*, 2018) [2, 11].

Considering the overall period, Chitrakoot emerges as the most unstable district in terms of area (50.66 per cent), production (66.63 per cent), and productivity (63.39 per cent). Mahoba and Jhansi also exhibit high overall instability, particularly in production and yield. In contrast, districts such as Hamirpur and Jalaun show relatively lower, though still substantial, instability levels. The comparatively lower instability in some districts may be associated with relatively better access to irrigation, extension services, or adoption of improved varieties, as suggested by earlier regional studies (Sah *et al.*, 2021; Singh *et al.*, 2024) [19, 23].

The increasing instability observed from Phase I to Phase II in area, production, and productivity clearly indicates a growing vulnerability of chickpea cultivation in the Bundelkhand region. This rising variability reflects the cumulative impact of climate variability, recurrent droughts, progressive soil degradation, and the predominance of rainfed agriculture with limited irrigation infrastructure. Under such conditions, farmers face heightened production risk, which not only affects yield stability but also influences acreage decisions, thereby amplifying overall instability in chickpea cultivation (Dubey *et al.*, 2011; Sah *et al.*, 2021; Singh *et al.*, 2024) [8, 19, 23].

Decomposition of Growth in Chickpea Production

The decomposition analysis of chickpea production in the Bundelkhand region of Uttar Pradesh helps to identify the relative contribution of area, yield, and interaction effects to overall production growth, providing deeper insight into whether expansion or productivity improvement has been the main driver of change over time. The decomposition analysis of chickpea production growth into area effect, yield effect, and interaction effect provides valuable insights into the sources of production changes across districts of the Bundelkhand region during Phase I, Phase II, and the overall period (Table 4). The results clearly show that the factors influencing chickpea production growth vary across different districts and time periods.

Table 4: Decomposition of Growth in Chickpea Production

Districts	Periods	Area effect (%)	Yield effect (%)	Interaction effect (%)
Jhansi	Phase I	107.67	-22.39	14.72
	Phase II	96.92	-4.50	7.57
	Overall	94.26	-0.07	5.80
Lalitpur	Phase I	103.44	-16.80	13.35
	Phase II	-20.03	58.51	61.51
	Overall	404.49	-200.42	-104.07
Jalaun	Phase I	141.72	51.18	-92.91
	Phase II	22.85	55.12	22.03
	Overall	-158.44	61.12	197.32
Hamirpur	Phase I	107.11	-36.85	29.75
	Phase II	6.19	70.04	23.77
	Overall	-181.24	268.57	12.67
Mahoba	Phase I	-190.93	293.11	-2.18
	Phase II	35.42	31.49	33.10
	Overall	40.07	26.10	33.82
Banda	Phase I	188.63	-54.78	-33.85
	Phase II	68.37	37.11	-5.47
	Overall	42.46	56.90	0.64
Chitrakoot	Phase I	41.12	20.23	38.64
	Phase II	29.21	45.79	25.00
	Overall	35.88	31.49	32.63
Bundelkhand	Phase I	82.88	4.26	12.87
	Phase II	42.30	33.56	24.14
	Overall	32.25	40.82	26.93

The results reveal that chickpea production growth in Bundelkhand during Phase I was predominantly driven by the area effect across most districts. In Jhansi, chickpea production growth was mainly driven by the area effect, which contributed about 108 per cent, while the yield effect was negative, showing a decline in productivity. A similar situation occurred in Lalitpur, Jalaun, Hamirpur, and Banda, where the contribution of area expansion to production growth was much higher than that of yield improvement, indicating that the increase in output was primarily due to the enlargement of cultivated area rather than productivity gains. Mahoba recorded a contrasting trend where a negative area effect (-190.93 per cent) was offset by a high positive yield effect (293.11 per cent), indicating that productivity gains sustained output despite area contraction. Overall, Phase I represents an extensive growth pattern in chickpea cultivation, where land expansion compensated for poor technological adoption and low input efficiency (Singh & Usmani, 2024; Sah *et al.*, 2021; Kumar *et al.*, 2022) [14, 19, 23].

In Phase II, the contribution of yield and interaction effects increased considerably, signifying a shift toward productivity-led growth. Lalitpur recorded yield and interaction effects of 58.51 per cent and 61.51 per cent, respectively, while in Hamirpur the yield effect dominated with 70.04 per cent, showing improvement due to better management practices. Jalaun also exhibited a higher yield contribution (55.12 per cent), indicating adoption of improved seed and agronomic technologies. In Banda, both area (68.37 per cent) and yield (37.11 per cent) effects contributed positively, suggesting partial recovery in productivity. Mahoba and Chitrakoot displayed balanced growth with positive contributions from all three components, implying technological progress and favorable climatic response. Jhansi, however, continued to remain area-driven (96.92 per cent) with a slightly negative yield effect (-4.50 per cent), reflecting slower diffusion of improved practices. These results confirm the emergence of yield-based intensification of chickpea production across most districts during the later period (Agarwal & Yadav, 2017; Rani *et al.*, 2024) [1, 17].

Considering the overall period (1999-2019), chickpea production growth in Bundelkhand showed a clear transition from area-led to yield-led development. The regional yield effect (40.82 per cent) surpassed the area effect (32.25 per cent), confirming the increasing importance of productivity enhancement in sustaining growth. District-wise results indicate that Hamirpur (yield 268.57 per cent; area -181.24 per cent), Lalitpur (yield 58.51 per cent; interaction 61.51 per cent), and Banda (yield 56.90 per cent; area 42.46 per cent) achieved stronger yield-driven performance, whereas Jhansi remained primarily area-based (94.26 per cent). Chitrakoot showed balanced growth supported by favorable agro-climatic conditions. The decomposition analysis thus reveals a regional transformation where yield improvement has become the dominant driver of production growth, consistent with national-level evidence that recent pulse growth in India has been achieved mainly through technological advancement and improved productivity rather than horizontal expansion (FAO, 2021; Government of India, 2020) [10].

Conclusion

Chickpea cultivation in Bundelkhand has shifted from area-led to yield-led growth, with rising production despite declining area. While Phase II showed productivity gains due to technology and policy support, increasing instability reflects high climatic risk in this rainfed region. Sustained growth therefore requires a continued focus on climate-resilient, yield-enhancing technologies, protective irrigation, and stronger extension and risk-support mechanisms rather than area expansion. Policies should emphasize developing and distributing climate-resilient chickpea varieties, improving access to protective irrigation, encouraging balanced fertilizer use, supporting technology adoption through effective extension services, and ensuring price and risk protection through strengthened insurance and market support in Bundelkhand.

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