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Growth dynamics of vegetable cultivation in Chhattisgarh: A compound annual growth rate analysis of tomato, potato and brinjal across selected districts (2013-14 to 2023-24)

¹Tanuja Ekka, ²AK Gauraha and ³Hulas Pathak

¹Department of Agri-Business and Rural Management, College of Agriculture, Raipur, Chhattisgarh, India

²Department of Agri-Business and Rural Management, College of Agriculture, Raipur, Chhattisgarh, India

³Department of Agri-Business and Rural Management, College of Agriculture, Raipur, Chhattisgarh, India

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Corresponding Author: ¹Tanuja Ekka

Abstract

Vegetables are a critical component of India's agricultural economy and a principal source of dietary diversity for smallholder farming households. Despite the expanding policy focus on horticultural diversification in Chhattisgarh, rigorous quantitative evidence on vegetable growth performance at sub-state scales remains limited. This study estimates compound annual growth rates (CAGRs) for area, production, and productivity of tomato, potato, and brinjal in Chhattisgarh and three of its principal vegetable-producing districts Raipur, Durg, and Bilaspur over the period 2013-14 to 2023-24, using secondary data from the Directorate of Horticulture and Farm Forestry, Government of Chhattisgarh. Growth rates were estimated through a semi-logarithmic trend model, with statistical significance assessed at the 1%, 5%, and 10% levels; all computations were performed in R statistical software. At the state level, output growth across all three crops was predominantly extensification-driven: area and production CAGRs were statistically significant, while productivity gains were modest and marginally significant. Tomato recorded area and production CAGRs of 1.97% and 2.43% respectively, against a productivity gain of only 0.46%; brinjal and potato exhibited similar patterns. District-level analysis revealed pronounced spatial heterogeneity concealed by state aggregates. Durg recorded strong area expansion in tomato (CAGR: 8.92%) accompanied by significant productivity decline (-2.11%), illustrating the yield-dilution costs of rapid extensification. Raipur experienced sharp contraction in potato cultivation (area CAGR: -10.94%) despite stable yields, indicating economic rather than agronomic disincentives. Bilaspur showed area contraction across all three crops alongside modest productivity gains, consistent with selective producer exit. These findings underscore the need for district-specific horticultural development strategies that prioritise productivity enhancement, post-harvest infrastructure, and market integration over uniform area-expansion approaches.

Keywords: Agricultural diversification, brinjal, compound annual growth rate, extensification, horticulture, potato, tomato, vegetable cultivation

Introduction

Vegetables occupy a central place in India's agricultural economy, contributing approximately 10 per cent of total agricultural output value and accounting for nearly 46 per cent of the country's horticultural area (NHB, 2023). Beyond their economic significance, vegetables are critical sources of micronutrients and dietary diversity, particularly for rural and low-income households. In the context of Indian smallholder agriculture, vegetable cultivation also serves as a relatively short-duration, high-value enterprise that can meaningfully augment farm incomes and reduce livelihood vulnerability (Birthal *et al.*, 2015).

In states where food production has historically been concentrated in a single staple crop, vegetable horticulture has gained increasing policy attention as a vehicle for agricultural diversification. Chhattisgarh, often characterised as a rice-dominant agrarian economy,

exemplifies this transition. With approximately 4.8 million hectares under cultivation within a total geographical area of 13.5 million hectares, the state's horticulture sector has expanded considerably over the past decade, supported through the National Horticulture Mission and Rashtriya Krishi Vikas Yojana. Among vegetables, tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum*), and brinjal (*Solanum melongena*) are the most widely cultivated crops, collectively accounting for a substantial share of the state's vegetable area, production, and marketed surplus (Directorate of Horticulture and Farm Forestry, GoC, 2023). The growth performance of India's vegetable sector has been examined at the national and major-state levels by several scholars. Chand and Raju (2009) ^[1] documented that output growth in Indian vegetables has been predominantly extensification-driven, with area expansion outpacing productivity gains. Kumar *et al.* (2015) ^[3] reinforced this

finding, noting persistent yield stagnation across key vegetable crops despite rising input use. More recent state-level studies including those for Maharashtra (Naik and Jain, 2018) ^[5], Andhra Pradesh (Reddy *et al.*, 2019) ^[10], and Madhya Pradesh (Sharma *et al.*, 2020) ^[11] have employed compound annual growth rate (CAGR) frameworks to assess trends in area, production, and productivity, offering actionable insights for regional policy. Chhattisgarh, however, remains conspicuously underrepresented in this literature. More critically, even where state-level estimates exist, sub-state disaggregation is rarely attempted, which conceals the spatial heterogeneity in growth performance that is essential for targeted intervention planning. This study addresses that gap. Using secondary time-series data for the period 2013-14 to 2023-24, CAGR analysis was employed to examine growth trends in area, production, and productivity of tomato, potato, and brinjal at both the state level and in three major vegetable-producing districts Raipur, Durg, and Bilaspur located within the Chhattisgarh Plains agro-climatic zone. The specific objectives of the study are: (i) to estimate state- and district-level CAGRs for area, production, and productivity of the three selected crops; (ii) to identify whether output growth has been driven primarily by area expansion or productivity improvement; and (iii) to derive evidence-based implications for horticultural development planning in Chhattisgarh. By providing district-disaggregated growth estimates for a recent eleven-year window, the study offers an empirical foundation for reorienting vegetable development policy from area-subsidy-driven expansion towards productivity-led intensification.

2. Materials and Methods

2.1 Data source and study period

The study is based on secondary time-series data covering area (thousand hectares), production (thousand metric tonnes), and productivity (metric tonnes per hectare) of tomato, potato, and brinjal in Chhattisgarh over the period 2013-14 to 2023-24. Data were sourced from official publications of the Directorate of Horticulture and Farm Forestry, Government of Chhattisgarh, and district-wise horticultural statistics compiled by the State Agriculture Department. The eleven-year study period was selected to capture medium-term growth trends and account for recent structural disruptions in vegetable cultivation. All data were cross-validated against *Horticulture Statistics at a Glance* (Ministry of Agriculture and Farmers Welfare, GoI) to ensure internal consistency.

2.2 Study area

Chhattisgarh, a central Indian state covering approximately 1, 35,192 sq. km, encompasses diverse agro-ecological

settings from the northern Surguja uplands to the fertile Chhattisgarh Plains and the forested Bastar Plateau in the south. District-level analysis was restricted to Raipur, Durg, and Bilaspur, all located within the Chhattisgarh Plains Agro-climatic zone, which is characterised by fertile alluvial Soils and intensive vegetable cultivation. These districts were selected for their prominence as major vegetable-producing centres and their agro-climatic representativeness of the plains region. Raipur exemplifies peri-urban horticulture; Durg represents the agriculturally advanced central plains; and Bilaspur reflects the cultivation dynamics of the northern belt.

2.3 Analytical framework

Growth dynamics were examined using the Compound Annual Growth Rate (CAGR), estimated by fitting a semi-logarithmic trend model of the form:

$$\text{Log } Y = \log a + t \log b$$

Where Y is the dependent variable (area, production, or productivity), t is the time trend, a is the intercept, and b is the slope coefficient. CAGR was derived as:

$$\text{CAGR (\%)} = (\text{Antilog } b - 1) \times 100$$

The statistical significance of regression coefficients was assessed using the t -test, with significance reported at the 1% (***), 5% (**), and 10% (*) levels; non-significant estimates are denoted 'ns'. Time-series plots were examined for structural discontinuities, and any identified breaks were contextualised with reference to climatic, policy, or market events over the study period. All computations, regression estimations, and graphical outputs were performed using **R statistical software** (version 4.3.x).

3. Results and discussion

The CAGR estimates for area, production and productivity of tomato, potato and brinjal at the state and district levels are presented in Tables 1 to 12 and summarised in Table 13. The analysis proceeds from aggregate state-level dynamics to district-level heterogeneity across Raipur, Durg and Bilaspur.

3.1 State-level growth performance

3.1.1 Tomato

Tomato area in Chhattisgarh expanded from 50.375 to 61.215 thousand hectares over the study period, while production rose from 814.2 to 1,035.3 thousand metric tonnes, having peaked at 1,182.7 thousand metric tonnes in 2019-20. Productivity varied narrowly within 16.16 to 18.78 MT/ha. The CAGRs of 1.97 per cent for area and 2.43 per cent for production (both significant at 5 per cent), against a modest productivity gain of only 0.46 per cent (significant at 10 per cent), confirm that growth was overwhelmingly area-driven (Table 1). This extensification pattern corroborates findings from comparable studies in other

Indian states (Kumar *et al.*, 2015; Naik & Jain, 2018) ^[3, 5], improvement in tomato cultivation, where areal expansion has consistently outpaced yield

Table 1: Trend in area, production and productivity of tomato in chhattisgarh

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	50.375	814.216	16.16
2014-15	53.051	886.104	16.71
2015-16	54.907	908.93	16.55
2016-17	62.803	1,083.98	17.26
2017-18	62.161	1,088.67	17.50
2018-19	64.383	1,114.80	17.32
2019-20	64.717	1,182.65	18.27
2020-21	61.333	1,151.49	18.78
2021-22	61.380	1,062.08	17.30
2022-23	61.635	1,070.05	17.36
2023-24	61.215	1,035.34	16.92
CAGR (%)	1.97**	2.43**	0.46*

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

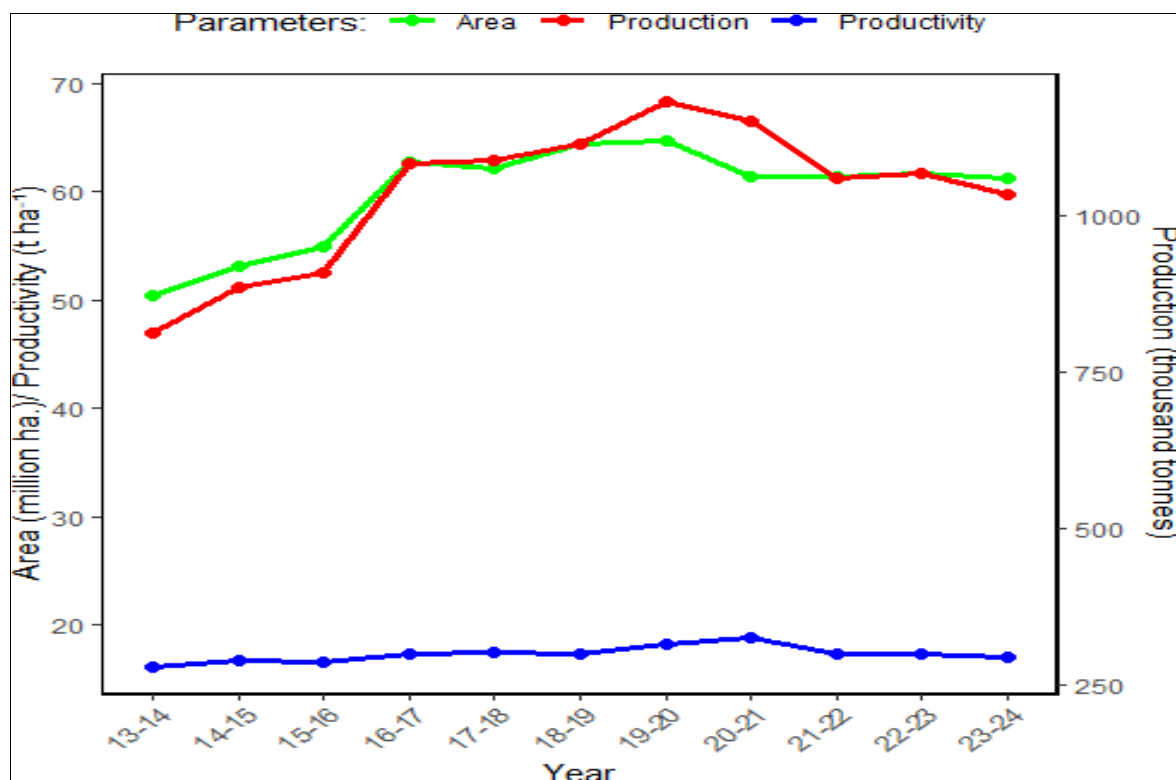


Fig. 1: Temporal trends in area, production and productivity of tomato in Chhattisgarh

3.1.2 Potato

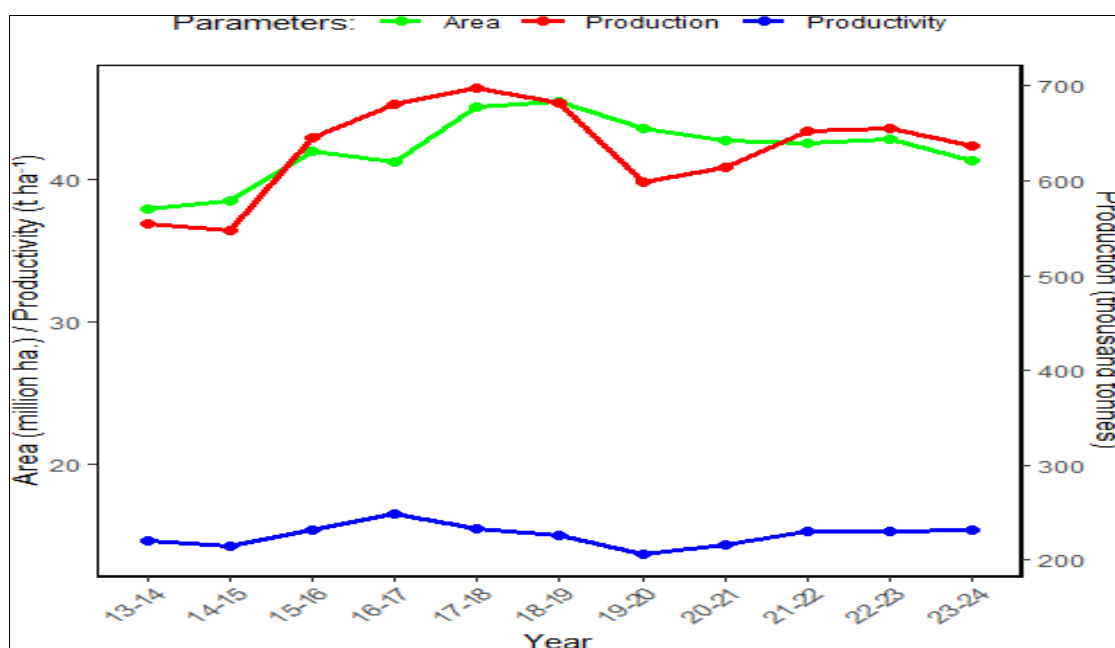
Potato cultivation exhibited a less stable trajectory (Table 2). Area peaked at 45.433 thousand hectares in 2018-19 before retreating to 41.33 thousand hectares; production similarly peaked at 697.3 thousand metric tonnes in 2017-18 and moderated to 636.2 by 2023-24. Area CAGR of 0.87 per cent (significant at 10 per cent) and production CAGR of 1.43 per cent (significant at 5 per cent) indicate moderate

and intermittent growth, while a productivity CAGR of 0.55 per cent (significant at 10 per cent) signals insufficient technological dynamism to anchor self-sustaining intensification. The mid-period expansion and subsequent contraction are consistent with patterns observed by Reddy *et al.* (2019) ^[10] for structurally vulnerable crops facing input cost pressures and inadequate market infrastructure.

Table 2: Trend in area, production and productivity of potato in chhattisgarh

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	37.889	553.98	14.62
2014-15	38.487	547.69	14.23
2015-16	41.952	644.82	15.37
2016-17	41.202	680.52	16.52
2017-18	45.083	697.28	15.47
2018-19	45.433	682.34	15.03
2019-20	43.541	598.32	13.74
2020-21	42.750	614.06	14.37
2021-22	42.584	652.22	15.32
2022-23	42.782	655.43	15.32
2023-24	41.330	636.16	15.39
CAGR (%)	0.87*	1.43**	0.55*

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

**Fig 2:** Temporal trends in area, production and productivity of potato in chhattisgarh

3.1.3 Brinjal

Brinjal displayed the most coherent expansionary pattern of the three crops (Table 3), with area rising from 33.069 to 39.05 thousand hectares and production from 585.978 to 740.358 thousand metric tonnes. Yields held steady within a 17.73 to 18.96 MT/ha corridor, with a single anomalous dip in 2020-21. CAGRs of 1.63 per cent for area and 2.34 per cent for production (both significant at 5 per cent), set

against a productivity gain of merely 0.70 per cent (significant at 10 per cent), again confirm an extensification-driven growth path. The pronounced yield plateau calls for varietal and agronomic interventions to translate areal stability into genuine productivity gains, as emphasised by Sharma *et al.* (2020) ^[11] in the context of solanaceous vegetables.

Table 3: Trend in area, production and productivity of brinjal in chhattisgarh

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	33.069	585.978	17.73
2014-15	33.421	606.711	18.16
2015-16	35.173	642.335	18.27
2016-17	37.149	685.84	18.46
2017-18	38.038	707.18	18.59
2018-19	38.205	710.371	18.59
2019-20	37.942	691.245	18.22
2020-21	42.750	614.056	14.37
2021-22	38.630	718.289	18.59
2022-23	38.974	729.132	18.71
2023-24	39.050	740.358	18.96
CAGR (%)	1.63**	2.34**	0.70*

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

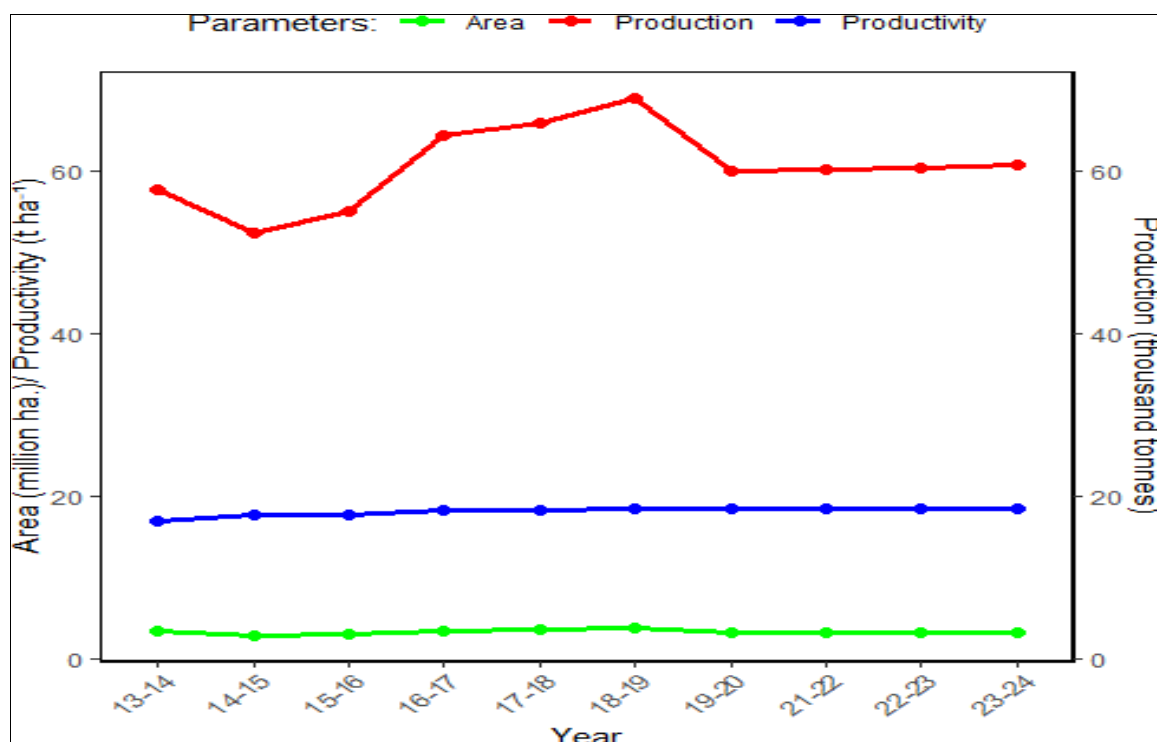


Fig 3: Temporal trends in area, production and productivity of brinjal in Chhattisgarh

3.2 District-level growth dynamics

State aggregates conceal substantial spatial heterogeneity. The district-level analysis reveals divergent and, in several instances, opposing dynamics across Raipur, Durg and Bilaspur underscoring the imperative for geographically differentiated policy responses.

3.2.1 Raipur district

In Raipur, tomato area expanded to a peak of 4.58 thousand hectares in 2018-19 before declining sharply to 2.664 thousand hectares by 2023-24, with production following a similar arc (Table 4). CAGRs of -2.67 per cent for area and -1.76 per cent for production (significant at 5 and 10 per cent respectively), against an insignificant productivity change, reflect farmer disengagement attributable to urbanisation-induced land pressure, price volatility and

inadequate cold-chain infrastructure. In stark contrast, potato experienced near-total withdrawal (Table 5): area collapsed from 3.887 to 0.680 thousand hectares and production from 67.232 to 11.475 thousand metric tonnes, yielding CAGRs of -10.94 per cent and -9.98 per cent (both significant at 1 per cent). Critically, yields remained stable throughout (15.62-17.29 MT/ha), suggesting a behavioural-economic rather than technological contraction farmers obtaining reasonable yields nonetheless exiting in favour of more remunerative alternatives. Brinjal, however, constituted the lone case of productivity-led growth in the study (Table 6): area was broadly stable (CAGR -0.38 per cent, non-significant), yet productivity grew at a statistically significant 0.74 per cent per annum (5 per cent level), demonstrating that yield-enhancing pathways are achievable even at modest tempos.

Table 4: Trend in area, production and productivity of tomato in Raipur

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	3.452	57.968	16.79
2014-15	3.552	62.617	17.63
2015-16	3.900	55.226	14.17
2016-17	4.292	76.314	17.78
2017-18	4.325	78.945	18.26
2018-19	4.580	82.086	17.93
2019-20	4.126	75.142	18.21
2020-21	4.230	75.215	17.78
2021-22	2.638	46.041	17.46
2022-23	2.651	46.281	17.47
2023-24	2.664	48.523	18.22
CAGR (%)	-2.67**	-1.76*	0.55 ns

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

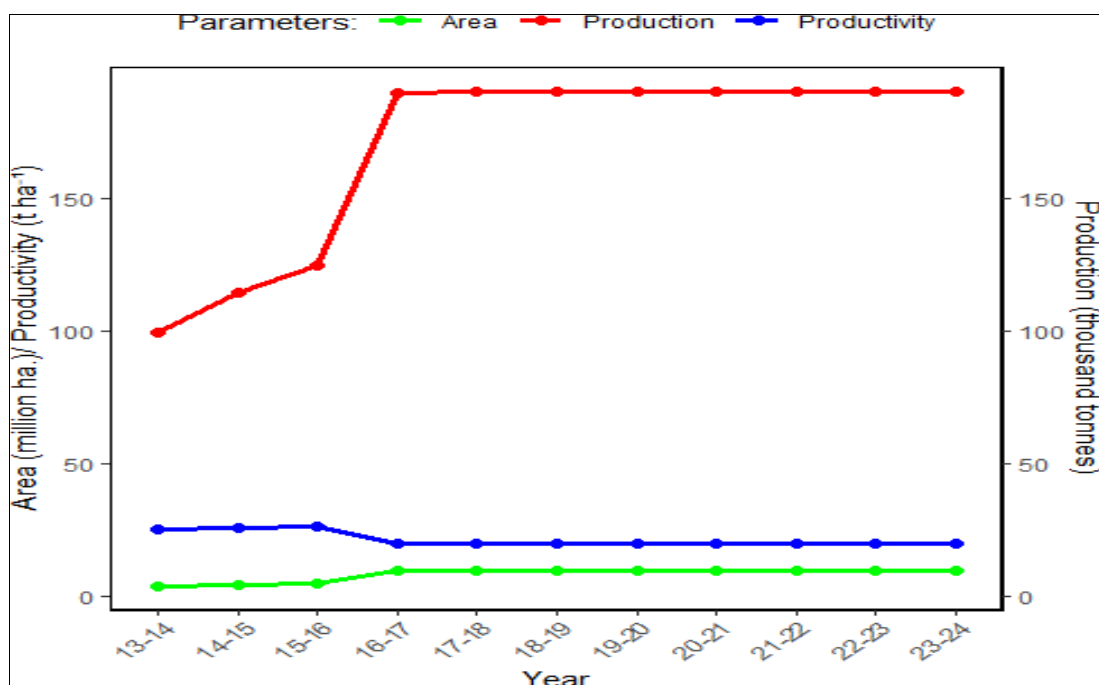


Fig 4: Temporal trends in area, production and productivity of tomato in raipur

Table 5: Trend in area, production and productivity of potato in raipur

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	2.595	40.540	15.62
2014-15	2.995	49.118	16.40
2015-16	3.300	54.120	16.40
2016-17	3.836	63.320	16.52
2017-18	3.834	64.652	16.87
2018-19	3.887	67.232	17.29
2019-20	2.023	34.118	16.87
2020-21	2.028	34.202	16.87
2021-22	0.677	11.418	16.87
2022-23	0.680	11.475	16.87
2023-24	0.680	11.475	16.87
CAGR (%)	-10.94***	-9.98***	0.19 ns

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

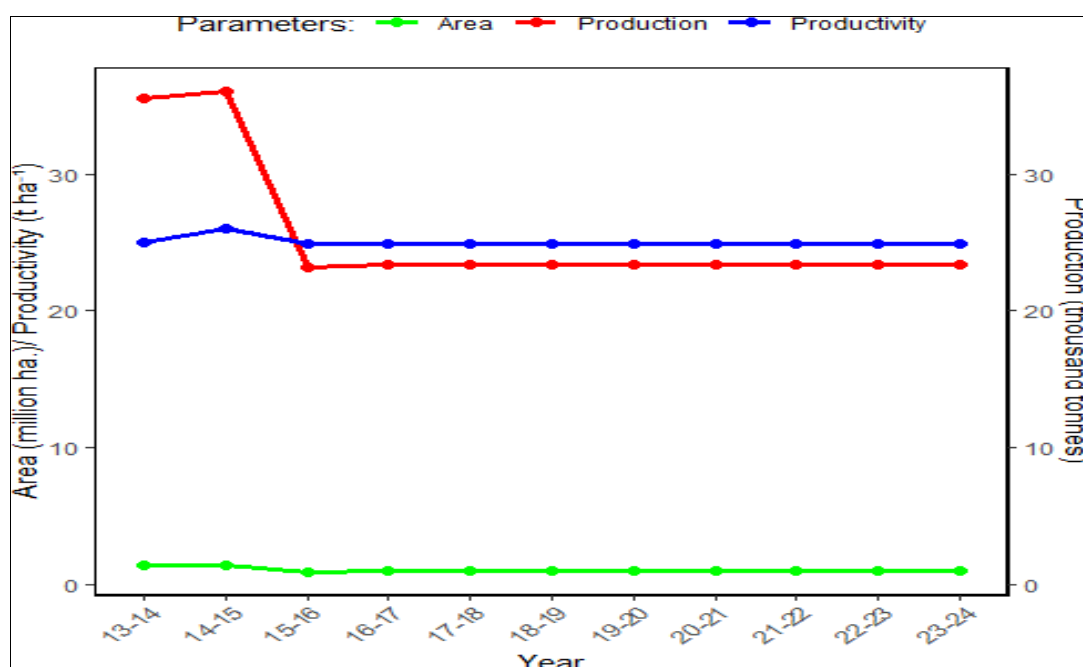
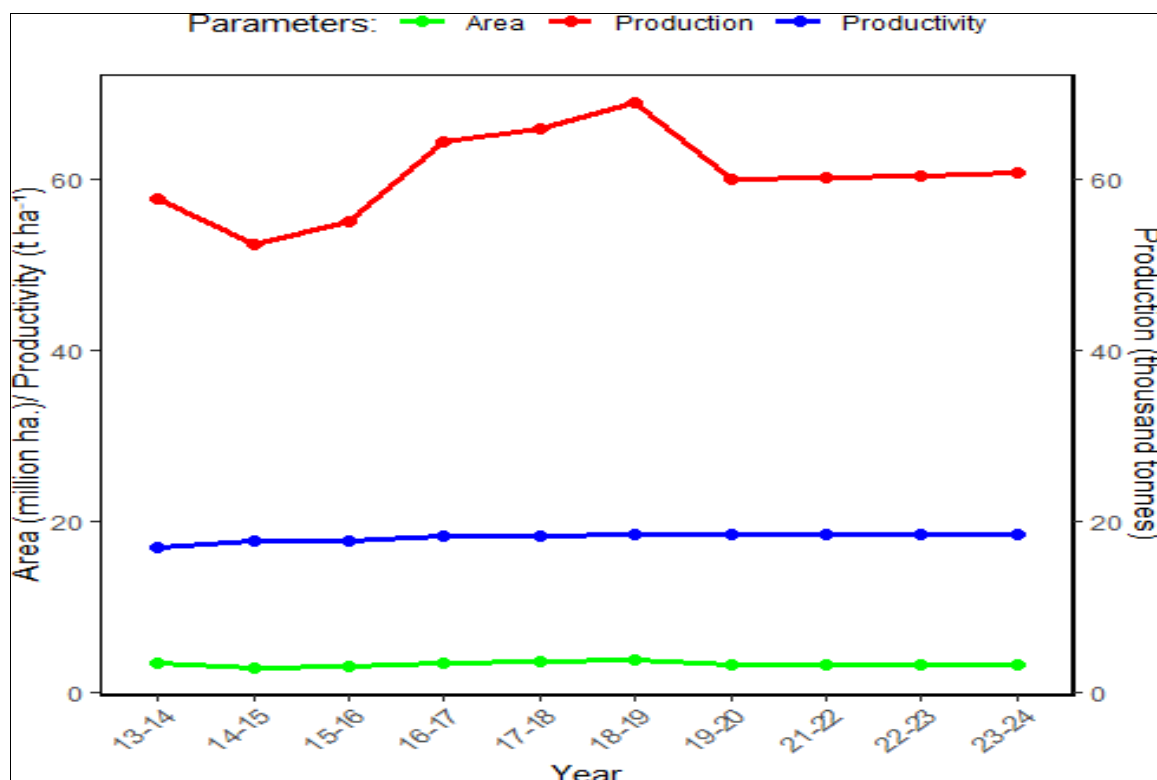


Fig 5: Temporal trends in area, production and productivity of potato in raipur

Table 6: Trend in area, production and productivity of brinjal in raipur

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	3.410	57.688	16.93
2014-15	2.950	52.397	17.76
2015-16	3.100	55.061	17.76
2016-17	3.516	64.421	18.33
2017-18	3.584	65.863	18.37
2018-19	3.727	68.844	18.47
2019-20	3.258	59.958	18.41
2021-22	3.272	60.138	18.38
2022-23	3.288	60.438	18.38
2023-24	3.305	60.740	18.38
CAGR (%)	-0.38 ns	0.29 ns	0.74**

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

**Fig 6:** temporal trends in area, production and productivity of brinjal in raipur

3.2.2 Durg district

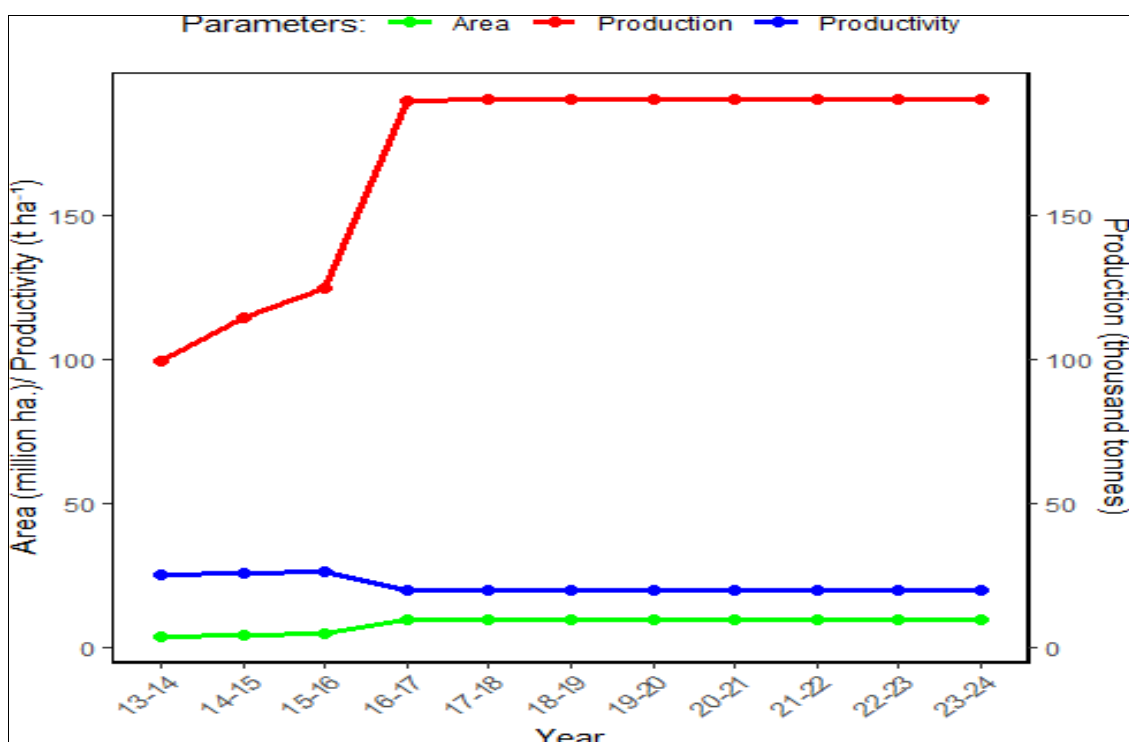
Durg exhibits internally heterogeneous performance across the three crops. Tomato area registered a highly significant CAGR of 8.92 per cent (Table 7), driven by a structural break in 2016-17 when cultivated area nearly doubled from 4.723 to 9.5 thousand hectares and production leapt from 124.5 to 190.0 thousand metric tonnes. However, this rapid areal expansion was accompanied by a significant productivity decline of -2.11 per cent per annum (5 per cent level), as post-expansion yields stabilised at 20.00 MT/ha against a pre-expansion level exceeding 26 MT/ha. This yield dilution consistent with the inclusion of below-average-yield fields and less experienced cultivators echoes findings from Mathur and Singh (2017) ^[4] for other vegetable crops experiencing rapid area mobilisation. Potato in Durg followed a contractionary path, with area

declining from 1.422 to 0.940 thousand hectares and production from 35.55 to 23.4 thousand metric tonnes following an early-period withdrawal, both stabilising at reduced levels thereafter (Table 8). CAGRs of -4.05 per cent and -3.98 per cent (significant at 5 per cent) for area and production, alongside a negligible productivity change, indicate institutional and market-side constraints rather than technological failure. By contrast, brinjal recorded healthy positive growth with area and production CAGRs of 2.47 and 2.32 per cent respectively (both significant at 1 per cent), consolidating at a yield plateau of approximately 25.22 MT/ha the highest among all crop-district combinations (Table 9). The Durg pattern thus illustrates two concurrent paradoxes: rapid area-led growth accompanied by yield dilution in tomato, and stable but ceilinged growth in brinjal.

Table 7: Trend in area, production and productivity of tomato in durg

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	3.974	99.350	25.00
2014-15	4.410	114.660	26.00
2015-16	4.723	124.498	26.37
2016-17	9.500	190.000	20.00
2017-18	9.505	190.100	20.00
2018-19	9.507	190.140	20.00
2019-20	9.507	190.140	20.00
2020-21	9.507	190.140	20.00
2021-22	9.507	190.140	20.00
2022-23	9.507	190.140	20.00
2023-24	9.507	190.140	20.00
CAGR (%)	8.92***	6.61***	-2.11**

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

**Fig 7:** Temporal trends in area, production and productivity of tomato in durg**Table 8:** Trend in area, production and productivity of potato in durg

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	1.422	35.550	25.01
2014-15	1.385	36.010	25.99
2015-16	0.930	23.140	24.88
2016-17	0.940	23.398	24.89
2017-18	0.940	23.406	24.90
2018-19	0.940	23.406	24.90
2019-20	0.940	23.406	24.90
2020-21	0.940	23.406	24.90
2021-22	0.940	23.406	24.90
2022-23	0.940	23.406	24.90
2023-24	0.940	23.406	24.90
CAGR (%)	-4.05**	-3.98**	0.06 ns

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

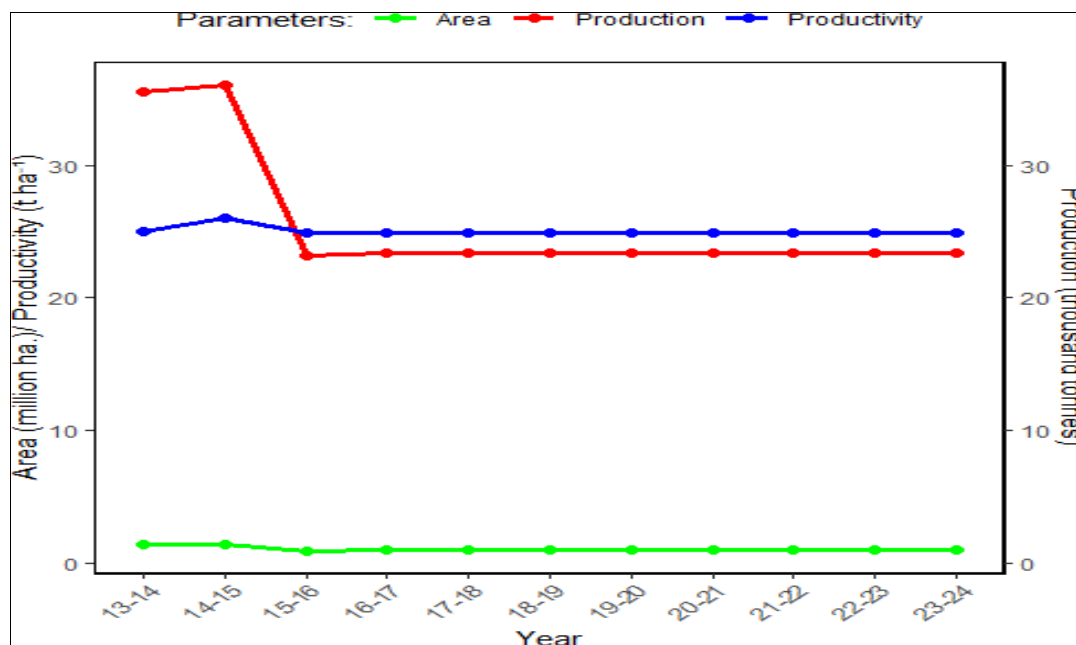


Fig 8: Temporal trends in area, production and productivity of potato in durg

Table 9: Trend in area, production and productivity of brinjal in durg

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	3.330	83.250	25.01
2014-15	4.055	103.403	25.52
2015-16	4.341	109.421	25.21
2016-17	4.375	110.290	25.22
2017-18	4.380	110.420	25.22
2018-19	4.382	110.470	25.22
2019-20	4.382	110.470	25.22
2020-21	4.383	110.495	25.22
2021-22	4.383	110.495	25.22
2022-23	4.383	110.495	25.22
2023-24	4.383	110.495	25.22
CAGR (%)	2.47***	2.32***	0.06 ns

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

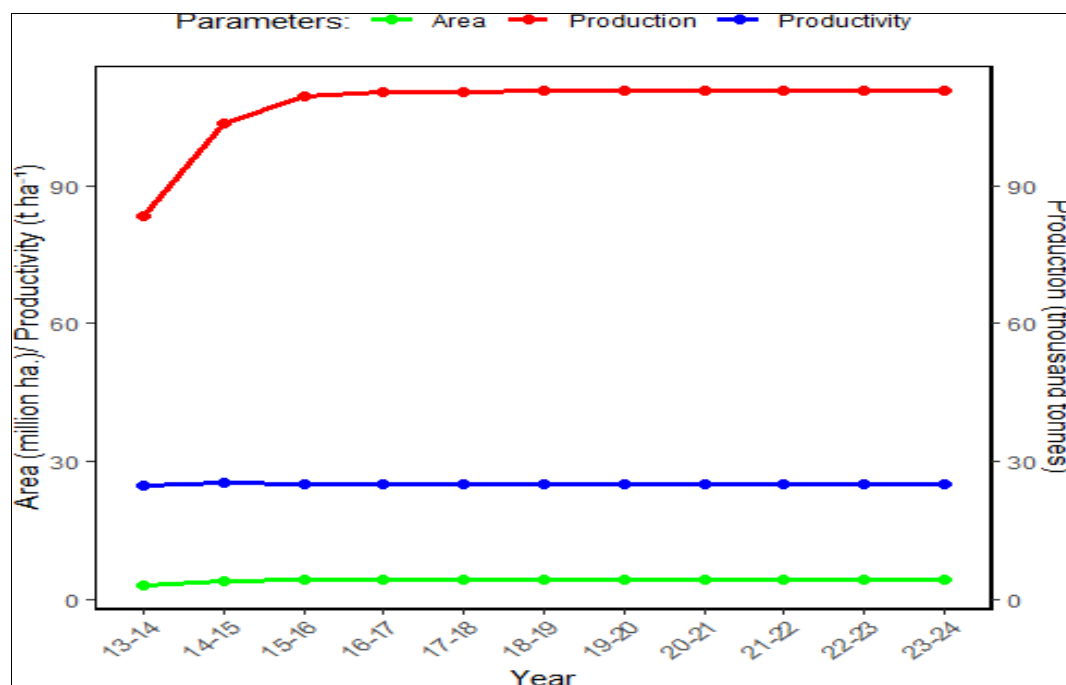


Fig 9: Temporal trends in area, production and productivity of brinjal in durg

3.2.3 Bilaspur district

Bilaspur's vegetable economy experienced the most dramatic disruption of the three districts, with a pronounced structural break in 2020-21 affecting all three crops. Prior to this break, tomato area and production grew moderately; in 2020-21, area was nearly halved to 3.523 thousand hectares and production collapsed to 49.451 thousand metric tonnes, both remaining suppressed through 2023-24 (Table 10). CAGRs of -7.10 per cent for area and -5.90 per cent for production (both significant at 1 per cent) are accompanied, counter-intuitively, by a 1.27 per cent productivity gain (significant at 5 per cent). This pattern is consistent with selection-driven intensification: the exit of less efficient growers concentrated cultivation among more productive farmers, producing an inadvertent yield improvement through structural attrition.

Potato in Bilaspur displayed a parallel trajectory but without the compensating yield improvement (Table 11): CAGRs of -4.04 per cent for area and -4.68 per cent for production (both highly significant at 1 per cent), with a non-significant productivity decline of -0.66 per cent. The absence of yield recovery distinguishes this from the tomato case, pointing to a more comprehensive cultivator exit without any selection-efficiency dividend. Brinjal in Bilaspur replicated the tomato pattern, with area collapsing from 1.956 to 0.812 thousand hectares post-2020-21 and production halving, yet productivity improving from approximately 12.54 to 15.60 MT/ha (CAGR of 2.06 per cent, significant at 5 per cent) (Table 12). The concentration of brinjal cultivation among fewer, more efficient producers raises equity considerations regarding smallholder inclusion and rural livelihoods.

Table 10: Trend in area, production and productivity of tomato in bilaspur

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	7.260	89.900	12.39
2014-15	7.405	91.695	12.38
2015-16	7.841	97.093	12.38
2016-17	7.881	97.588	12.39
2017-18	7.843	97.737	12.47
2018-19	7.905	97.885	12.38
2019-20	7.950	98.442	12.39
2020-21	3.523	49.451	14.04
2021-22	3.529	49.562	14.05
2022-23	3.533	49.618	14.05
2023-24	3.537	49.674	14.05
CAGR (%)	-7.10***	-5.90***	1.27**

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

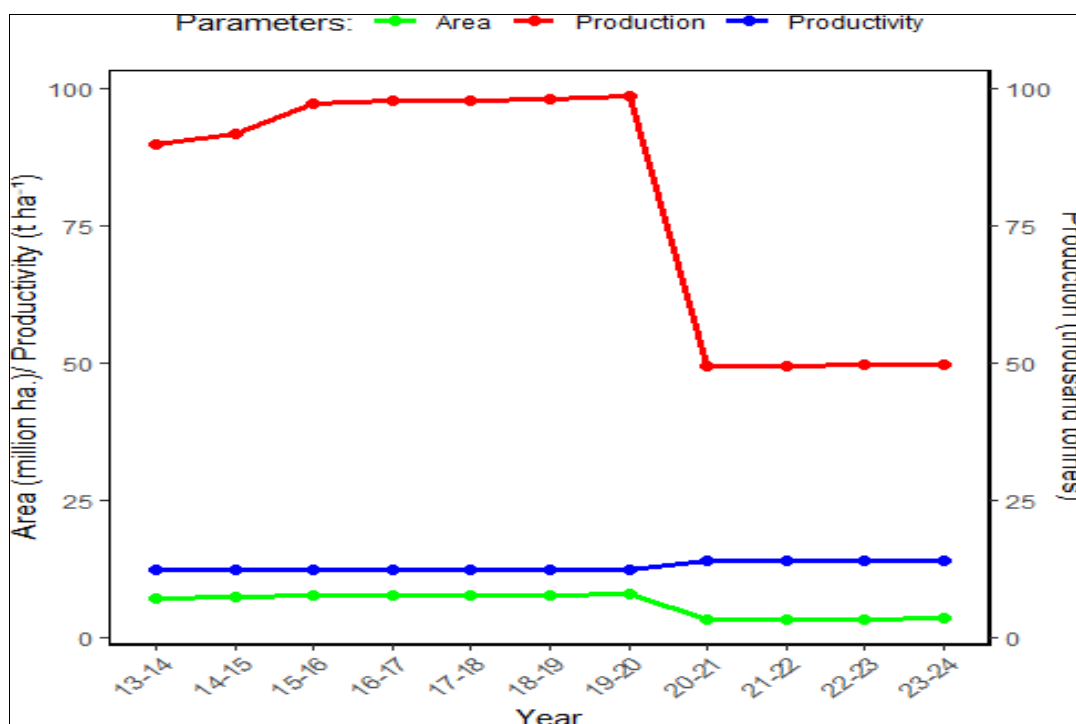
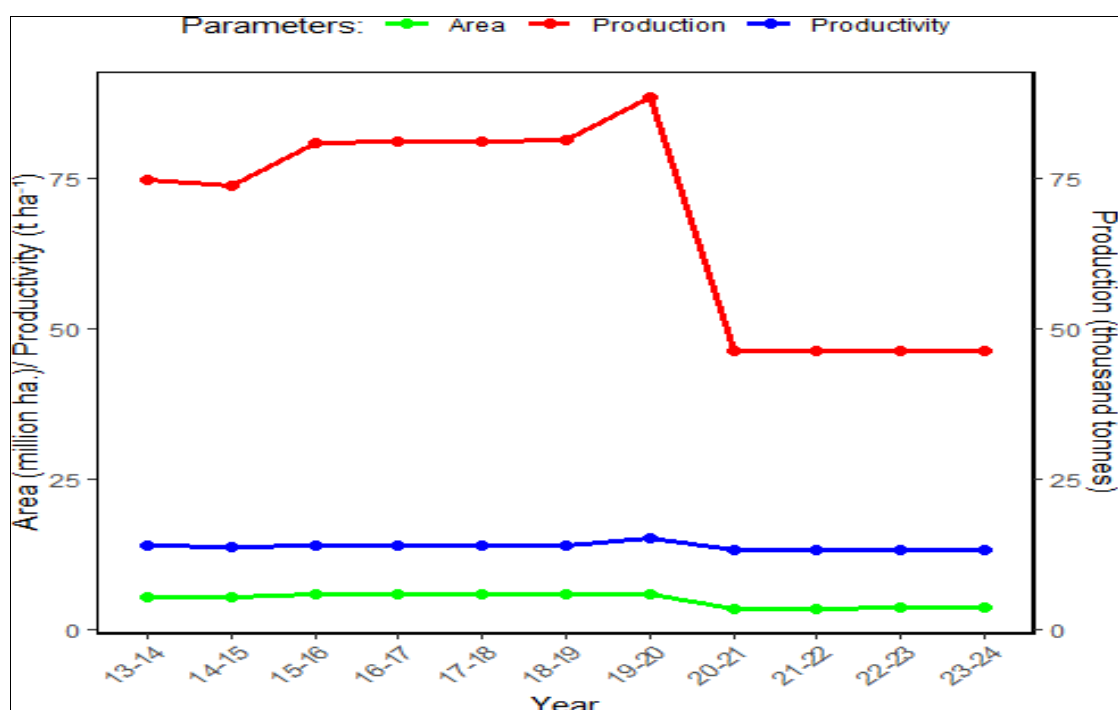


Fig 10: Temporal trends in area, production and productivity of tomato in bilaspur

Table 11: Trend in area, production and productivity of potato in bilaspur

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	5.338	74.732	14.00
2014-15	5.418	73.689	13.60
2015-16	5.767	80.715	14.00
2016-17	5.799	80.966	13.96
2017-18	5.811	81.134	13.96
2018-19	5.824	81.315	13.96
2019-20	5.860	88.318	15.08
2020-21	3.522	46.170	13.11
2021-22	3.527	46.271	13.12
2022-23	3.533	46.318	13.11
2023-24	3.533	46.318	13.11
CAGR (%)	-4.04***	-4.68***	-0.66 ns

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

**Fig 11:** Temporal trends in area, production and productivity of potato in bilaspur**Table 12:** Trend in area, production and productivity of brinjal in bilaspur

Year	Area ('000 ha)	Production ('000 mt)	Productivity (MT/ha)
2013-14	1.723	21.954	12.75
2014-15	1.748	22.273	12.74
2015-16	1.862	23.715	12.75
2016-17	1.894	23.762	12.55
2017-18	1.905	23.900	12.55
2018-19	1.918	24.540	12.79
2019-20	1.956	24.540	12.54
2020-21	0.812	12.740	15.69
2021-22	0.821	12.810	15.60
2022-23	0.832	12.979	15.60
2023-24	0.835	13.026	15.60
CAGR (%)	-6.94***	-5.10***	2.06**

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; ns = not significant

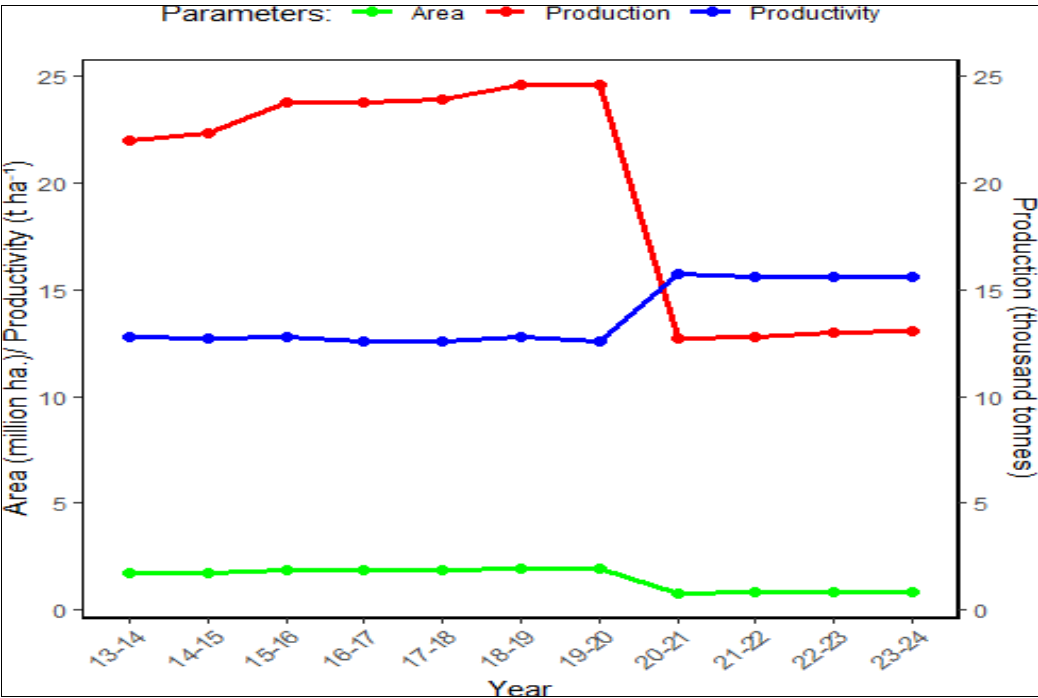


Fig 12: Temporal trends in area, production and productivity of brinjal in bilaspur

3.3 Summary of CAGR estimates

Table 13: Summary of CAGR estimates for area, production and productivity of three vegetables across Chhattisgarh and selected districts (2013-14 to 2023-24)

Crop & Location	Area CAGR (%)	Production CAGR (%)	Productivity CAGR (%)
Tomato - Chhattisgarh	1.97**	2.43**	0.46*
Tomato - Raipur	-2.67**	-1.76*	0.55 ns
Tomato - Durg	8.92***	6.61***	-2.11**
Tomato - Bilaspur	-7.10***	-5.90***	1.27**
Potato - Chhattisgarh	0.87*	1.43**	0.55*
Potato - Raipur	-10.94***	-9.98***	0.19 ns
Potato - Durg	-4.05**	-3.98**	0.06 ns
Potato - Bilaspur	-4.04***	-4.68***	-0.66 ns
Brinjal - Chhattisgarh	1.63**	2.34**	0.70*
Brinjal - Raipur	-0.38 ns	0.29 ns	0.74**
Brinjal - Durg	2.47***	2.32***	0.06 ns
Brinjal - Bilaspur	-6.94***	-5.10***	2.06**

Note: *** $p<0.01$; ** $p<0.05$; * $p<0.10$; ns = not significant. All analyses performed using R statistical software.

4. Conclusion and suggestions

This study examined growth dynamics in the cultivation of tomato, potato, and brinjal across Chhattisgarh and three of its principal vegetable-producing districts Raipur, Durg, and Bilaspur over the period 2013-14 to 2023-24 using CAGR analysis. The findings reveal that output growth at the state level has been driven predominantly by area expansion rather than productivity improvement, a pattern well-documented in the broader Indian vegetable agriculture literature (Chand and Raju, 2009; Kumar *et al.*, 2015) ^[1, 3]. Across most crop-district combinations, area and production CAGRs were statistically significant while productivity growth remained weak or insignificant, indicating that extensification continues to be the primary growth mechanism in the absence of sustained technological and institutional support. Beneath the state aggregate, pronounced spatial heterogeneity is evident. Durg recorded significant areal expansion in tomato and brinjal, yet without commensurate

agronomic support, this expansion has been accompanied by yield stagnation a pattern consistent with the dilution effects of rapid extensification. In contrast, Raipur and Bilaspur experienced contraction in area and production across most crops. In Raipur, potato yields remained technically stable despite cultivator exit, suggesting that the binding constraint is economic rather than agronomic specifically, inadequate market infrastructure and poor post-harvest incentives. In Bilaspur, a marked decline in cultivated area across all three crops coincided with yield stability or modest improvement, indicative of selective producer exit under external market pressure rather than systemic agronomic failure. These divergent trajectories underscore the limitations of uniform, state-wide horticultural policy and the necessity of spatially differentiated interventions. Several policy directions follow from these findings. District-specific horticultural development plans should be prioritised over aggregate state-level approaches. Contraction-affected districts require diagnostic assessments

of the drivers of area withdrawal and targeted responses including price-assurance mechanisms, cold-chain investment, and strengthened market linkages to restore cultivator confidence. In expansion-prone districts such as Durg, productivity-enhancement support must accompany area mobilisation to prevent yield dilution. More broadly, post-harvest infrastructure and market integration deserve greater policy priority: the exit of potato cultivators from Raipur and Durg despite viable yields illustrates that economic disincentives, rather than agronomic constraints, are frequently the proximate cause of sectoral retreat. Investment in cold storage, rural processing facilities, Farmer Producer Organisations, and e-trading platforms can improve market access and reduce income volatility. For high-volatility crops such as tomato, risk management instruments including expanded crop insurance coverage and real-time market price advisories are essential complements to production-side interventions. Over the longer term, a strategic reorientation from input-subsidised area expansion toward productivity-led intensification, supported by investment in improved varieties, integrated nutrient management, and extension capacity, is necessary for sustainable vegetable sector development in Chhattisgarh.

Future research should investigate the determinants of inter-district productivity variation through econometric decomposition, examining the roles of irrigation access, input quality, market proximity, and extension contact intensity. Household-level analysis of cultivator decision-making, particularly regarding area withdrawal in Raipur and Bilaspur, would complement the aggregate perspective adopted here. Value-chain and post-harvest loss assessments for the three focal crops would further illuminate the structural constraints that aggregate growth estimates necessarily obscure.

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