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Growth Dynamics and Trend Analysis of Wheat in Different Agro-Climatic Zones of Chhattisgarh

Payal Jaiswal[1*], Yogeshwari[2]

[1,2]Assistant Professor, Department of Agricultural Economics, Indira Gandhi Agricultural University, Raipur, C.G., INDIA

*Corresponding author: P Jaiswal; E-mail: payaljaiswal130@gmail.com

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ABSTRACT

This study evaluates the temporal growth dynamics and variability in the area, production, and productivity of wheat across three distinct agro-climatic zones of Chhattisgarh (Chhattisgarh Plains, Northern Hills, and Bastar Plateau) as well as for the state as a whole. Secondary time-series data covering a 16-year period from 2002–03 to 2017–18 were analyzed using triennium averages, absolute and relative changes, coefficient of variation (CV), and linear and compound annual growth rates (CGR). The findings reveal that at the state level, wheat production expanded at a significant compound growth rate of 3.83% per annum ($p < 0.01$), predominantly driven by productivity growth of 3.30% ($p < 0.01$) and a modest area expansion of 0.52% ($p < 0.10$). Across agro-climatic zones, the Chhattisgarh Plains registered the highest growth performance, with production and productivity increasing at compound annual rates of 4.45% and 3.61%, respectively. In the Northern Hills, despite a slight decline in wheat area (-0.15% CGR), production maintained a positive growth rate of 2.71% due to substantial yield improvements (2.86% CGR). Conversely, the Bastar Plateau exhibited significant contractions in both cultivated area (-6.84% CGR) and total production (-4.95% CGR), indicating a shift away from wheat in the southern zone despite a 2.04% yield gain. Overall, relative change analysis confirms that state-level production gains were largely yield-driven (41.53% productivity increase) rather than area-driven (3.65% area increase). The study highlights the necessity of region-specific policy interventions, focusing on bridging yield gaps, enhancing Rabi irrigation infrastructure, and supplying high-yielding, climate-resilient seed varieties to sustain wheat production in lagging zones.

KEYWORDS

Wheat, Compound Growth Rate, Agro-Climatic Zones, Chhattisgarh, Productivity, Trend Analysis

Introduction

Background and Literature Review

Agriculture remains the primary engine of the Indian economy, providing food security to the nation, supplying vital raw materials to the industrial sector, generating foreign exchange through exports, and offering direct or indirect livelihoods to nearly 55–60% of the population. Although the structural transformation of the Indian economy has led to a progressive decline in agriculture's share of Gross Value Added (GVA)—from 55.1% in 1950–51 to approximately 15–17% in recent years—the sector continues to be the single largest source of employment and rural poverty alleviation. Following the Green Revolution, the adoption of High-Yielding Varieties (HYVs), expansion of irrigation infrastructure, increased chemical fertilizer utilization, and farm mechanization led to a dramatic surge in national foodgrain production, rising from 52 million tonnes in 1951–52 to over 283 million tonnes in 2018–19.

Several empirical studies have examined these national trends. Mittal and Shiksha (2016) noted that while agriculture's relative contribution to national income fell over the post-independence decades, its role in absorbing labor and sustaining growth across non-agricultural sectors remained foundational. Neelam et al. (2020) confirmed that national foodgrain production has grown significantly (at an annual rate of 1.73%), but emphasized that land area under foodgrains has largely plateaued, making yield enhancement the primary driver of output growth. A similar reliance on yield-driven growth was observed in pulse production by Devi et al. (2017), who demonstrated through decomposition analysis that overall output increases over recent decades were predominantly driven by productivity gains rather than area expansion.

At the sub-national and regional levels, spatial variations in soil, climate, and infrastructure lead to distinct regional agricultural growth trajectories:

- **Deceleration and Regional Disparities:** In West Bengal, Sarkar et al. (2002) observed a decline in foodgrain growth trends during the economic reform period due to decelerating yield trends. In contrast, Dhar (2013) reported sustained higher foodgrain growth in the Central Brahmaputra Valley of Assam.
- **Crop-Specific Growth Patterns:** In Maharashtra, Kalamkar (2003) showed that while commercial crops experienced robust growth, foodgrains exhibited sluggish productivity gains. Similarly, Singh and Srivastava (2003) noted significant regional variability and instability in crop output across eastern, central, and western zones of Uttar Pradesh.

For state-level agricultural planning, evaluating regional dynamics within specific agro-climatic zones is critical. Established on November 1, 2000, the state of Chhattisgarh is fundamentally agrarian, with nearly 80% of its population engaged in agricultural production. Widely recognized as the "Rice Bowl of Central India," paddy occupies the majority of the cultivated area (68.8%). However, secondary foodgrains like wheat play a vital role in food security and crop rotation, accounting for 12.67% of the total foodgrain area across the state's three agro-climatic zones (Chhattisgarh Plains, Northern Hills, and Bastar Plateau).

In analyzing Chhattisgarh's agricultural dynamics, Shanker et al. (2010) identified substantial inter-zonal growth variations, noting high instability in Rabi crop production. Divya and Hulas (2018) further confirmed positive growth in area, production, and productivity for major foodgrains in Chhattisgarh from 2001 to 2015, but stressed the necessity of strengthening regional technology transfer and marketing infrastructure to sustain productivity.

Research Gap and Justification

While paddy receives considerable policy and research focus in Chhattisgarh, non-paddy foodgrains—particularly wheat—are crucial for enhancing cropping intensity, stabilizing farm income during the Rabi season, and achieving local food security. Facing population growth and strict limits on land expansion, sustaining agricultural growth in Chhattisgarh requires a precise understanding of whether localized wheat output expansion is driven by area expansion or productivity improvements.

Despite existing broad studies on foodgrains in Chhattisgarh, zone-wise empirical evidence on wheat performance—specifically comparing simple and compound growth rates along with variability metrics across distinct agro-climatic zones—remains limited. Evaluating how wheat area, output, and yield have evolved across the central plains, northern hills, and southern plateau provides crucial actionable insights for regional extension services, irrigation planning, and targeted crop diversification policies.

To address this research gap, the present study was undertaken with the following specific objective:

- To estimate the trend, growth, and variability in area, production, and productivity of wheat across the distinct agro-climatic zones of Chhattisgarh.

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Limitations of the Study

1. **Context-Specific Scope:** The findings are situation-specific and reflect the unique agro-climatic, infrastructural, and socio-economic conditions of Chhattisgarh.

2. **Secondary Data Reliance:** The estimations rely on secondary time-series data compiled from published state government records, and are inherently subject to the quality and parameters of those official datasets.

Materials and Methods

1. Description of the Study Area

Chhattisgarh is divided into three distinct agro-climatic zones based on climate, soil profile, and topography:

1. **Chhattisgarh Plains:** Central region comprising 16 districts (e.g., Raipur, Bilaspur, Durg, Dhamtari, Balodabazar).

2. **Northern Hills:** Northern region featuring dense forests and hilly terrain, covering 5 districts (Surguja, Koriya, Surajpur, Balrampur, Jashpur) and part of Raigarh.

3. **Bastar Plateau:** Southern tribal-dominated region covering 7 districts (Bastar, Dantewada, Kanker, Sukma, Bijapur, Narayanpur, Kondagaon).

2. Sampling & Data Sources

- **Crop Selection:** Wheat was selected based on its relative importance, accounting for 12.67% of the total foodgrain area in Chhattisgarh.
- **Study Period:** Time-series data spanning 16 years (2002–03 to 2017–18) were compiled for all 28 districts across the three agro-climatic zones.
- **Data Sources:** Secondary data were retrieved from official publications, including the Department of Agriculture, Directorate of Economics & Statistics (Chhattisgarh), and Statistical Abstracts of Chhattisgarh State.

3. Analytical Framework

Absolute and Relative Change

The absolute and relative change was estimated using following formula:

$$\text{Absolute change} = P_n - P_0$$

$$\text{Relative change (\%)} = \frac{P_n - P_0}{p_0} \times 100$$

Where,

P_n = Triennium Average of current year for area, production and yield

P_0 = Triennium Average of base year for area, production and yield

Trend

Trend analysis for area, production and productivity was estimated with the help of linear equation. The linear trend was fitted with the method of least square technique.

$$\mathbf{Y = a + b\,x}$$

Where,

Y = Trend value of dependent variable (Area, Production and Yield)

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x = Independent Variable (Time in year)

b = Regression / Trend Coefficient

a = Intercept / Constant

Linear growth rate (LGR) = $\frac{b}{\bar{Y}} \times 100$

$\bar{Y}$ = Mean of dependent variable

Estimation of compound growth rate in area, production and yield

Growth of any variable indicates its past performance. The analysis of growth was usually used in economic studies to find out the trend of particular variables over a period of time. It clearly indicated the performance of the variable under consideration and hence it can be very well used for making policy decisions. The growth in area, production and productivity under different crops was using the exponential growth function of the form:

$$Y = a\ b^t$$

Where,

Y = Trend value (Area, Production and Yield)

a = Constant

b = Trend Coefficient

t = Independent Variable (Time in year)

Compound growth rate

The compound growth rate per annum over the period for all the variables was calculated from the following formula:

C.G.R. (%) **= [Antilog of b-1] x 100**

Results and Discussion

The production of any crop is fundamentally determined by the acreage under cultivation and the yield realized per unit area. However, regional variations in adoption of modern production technology, irrigation availability, policy support, and local agro-climatic conditions significantly influence these components. To understand the dynamics of wheat performance across Chhattisgarh, the absolute and relative changes, variability, and growth trends (simple and compound) were evaluated across the three agro-climatic zones and the state as a whole for the period 2002–03 to 2017–18.

1. Absolute and Relative Change in Wheat Production Components

The absolute change (AC), relative percentage change (RC), and coefficient of variation (CV) of area, production, and productivity of wheat across Chhattisgarh's agro-climatic zones are presented in Table 1.

Table 1: Absolute & Relative Percentage Change and Coefficient of Variation in Area, Production, and Productivity of Wheat in Agro-Climatic Zones of Chhattisgarh (2002–03 to 2017–18)

Particulars	Change	Wheat Area (in ha)	Production (in tonnes)	Productivity (in tonnes/ha)
Chhattisgarh Plains	AC	5578	39289	0.44
	RC	7.67	58.57	47.57
	CV	6.75	22.78	18.50
Northern Hills	AC	-1302.33	7575.67	0.38
	RC	-5.03	25.27	32.00
	CV	3.88	18.33	17.36
Bastar Plateau	AC	-635.34	-830	0.52
	RC	-55.52	-43.32	30.71
	CV	35.01	26.47	12.27
Chhattisgarh	AC	3631.67	46035	0.42
	RC	3.65	46.51	41.53
	CV	4.90	19.89	17.29

Zone-Wise Empirical Observations:

Chhattisgarh Plains: Positive relative changes were recorded across all three parameters. Wheat acreage expanded by 7.67% (5,578 ha), while production expanded by 58.57% (39,289 tonnes). This major boost in production was largely driven by a 47.57% increase in productivity (0.44 tonnes/ha). The coefficient of variation was moderate for production (22.78%) and productivity (18.50%), reflecting relative stability in the central plain region due to better irrigation coverage and input accessibility.

Northern Hills: The area under wheat experienced a marginal negative relative change of -5.03% (-1,302.33 ha). However, productivity improved substantially by 32.00% (0.38 tonnes/ha), which offset the area loss and enabled a net production gain of 25.27% (7,575.67 tonnes). The low CV for area (3.88%) indicates high acreage stability over the 16-year period.

Bastar Plateau: The southern zone exhibited marked contractions in wheat cultivation. Area shrank by -55.52% (-635.34 ha) and total output declined by -43.32% (-830 tonnes). Although productivity increased by 30.71% (0.52 tonnes/ha), it was insufficient to compensate for the massive area reduction. The high CV in acreage (35.01%) reflects high instability and shifting cropping choices in this tribal-dominated region.

Chhattisgarh State overall: For the state as a whole, wheat acreage grew by a modest 3.65% (3,631.67 ha), whereas total output surged by 46.51% (46,035 tonnes). This gain was overwhelmingly underpinned by a 41.53% increase in state-wide wheat productivity (0.42 tonnes/ha). State-level instability remained moderate, with CVs of 4.90%, 19.89%, and 17.29% for area, production, and productivity, respectively.

These findings align with national trends reported by Neelam et al. (2020) and Devi et al. (2017), who demonstrated that post-2000 agricultural growth in India has been predominantly yield-led rather than area-led due to strict land supply constraints.

2. Growth and Trend Analysis of Wheat Output

To measure the trajectory of growth over time, Simple Growth Rates (SGR) and Compound Growth Rates (CGR) were calculated for wheat area, production, and productivity across all zones and the state overall (Table 2).

Table 2: Growth in area, production and productivity of wheat in agro-climatic zones of Chhattisgarh (in percentage)

Particulars	Growth Rate	Area (in ha)	Production (in tonnes)	Productivity (in tonnes/ha)
Chhattisgarh Plains	SGR	0.80	4.24	3.49
	CGR	0.82**	4.45***	3.61***
	SGR	-0.14	2.70	2.85
Northern Hills	CGR	-0.15*	2.71***	2.86***
	SGR	-6.73	-4.87	1.96
Bastar Plateau	CGR	-6.84***	-4.95***	2.04***
	SGR	0.50	3.69	3.22
Chhattisgarh	CGR	0.52*	3.83***	3.30***

SGR= Simple growth rate, CGR= Compound growth rate

***Significant at probability level 0.01, **Significant at probability level 0.05, *Significant at probability level 0.10

Detailed Interpretation and Discussion:

1. **State Performance:** Chhattisgarh recorded a highly significant compound annual growth rate in wheat production of 3.83% ($p < 0.01$). Decomposing this growth reveals that productivity growth (3.30% per annum, $p < 0.01$) contributed far more to total output expansion than acreage growth (0.52% per annum, $p < 0.10$). This confirms that government interventions focusing on high-yielding varieties (HYVs), mechanization, and improved fertilizer/irrigation management have yielded positive returns across the state. These results mirror the findings of Divya and Hulas (2018), who reported significant positive growth across major foodgrains in Chhattisgarh post-2001.

2. Chhattisgarh Plains: The central plain zone proved to be the primary engine of wheat production in the state, exhibiting significant compound growth in production (4.45% per annum, $p < 0.01$). This performance was driven by a strong yield CGR of 3.61% ($p < 0.01$) and a positive area CGR of 0.82% ($p < 0.05$). The presence of established irrigation structures in districts like Raipur, Durg, and Dhamtari facilitates reliable Rabi sowing, encouraging farmers to allocate land to wheat.

3. Northern Hills: In the northern zone, wheat production grew at a significant compound rate of 2.71% per annum ($p < 0.01$). Interestingly, this growth was achieved despite a minor downward trend in cultivated area (-0.15% CGR, $p < 0.10$). The strong productivity CGR of 2.86% ($p < 0.01$) effectively outweighed acreage reduction. This pattern is consistent with findings by Singh et al. (2015), who highlighted that yield improvements often sustain crop output in hilly and high-elevation regions where arable land expansion is naturally constrained.

4. Bastar Plateau: The southern plateau exhibited significant negative compound growth in both area (-6.84% per annum, $p < 0.01$) and production (-4.95% per annum, $p < 0.01$). Although productivity maintained a positive growth rate of 2.04% ($p < 0.01$), the sharp decline in wheat acreage severely suppressed total output. This downward trend suggests a systematic shift in farmer preferences towards alternative cash crops, coarse grains, or pulses during the Rabi season, alongside limited tube-well irrigation coverage in the southern plateau. Similar inter-zonal growth disparities during the Rabi season were previously identified by Shanker et al. (2010).

Synthesis of Results

Overall, the empirical results confirm that wheat growth across Chhattisgarh is predominantly yield-driven. However, stark spatial discrepancies exist:

The Chhattisgarh Plains act as a growth hub with concurrent expansion in area and yield.

The Northern Hills maintain growth purely through productivity gains while area stagnates. The Bastar Plateau experiences significant area attrition, dragging overall production into negative territory despite modest yield improvements.

To bridge these intra-state gaps and sustain state-wide wheat production, policy strategies must address region-specific bottlenecks—focusing on expanding micro-irrigation facilities and delivering region-adapted, heat-tolerant wheat varieties, particularly in the Bastar Plateau and Northern Hills.

Conclusion

The present study provides a comprehensive empirical evaluation of the growth performance, variability, and trend dynamics of wheat in the three agro-climatic zones of Chhattisgarh from 2002–03 to 2017–18. The findings demonstrate that wheat production at the state level experienced significant positive growth (3.83% CGR per annum), which was overwhelmingly driven by productivity enhancements (3.30% CGR) rather than area expansion (0.52% CGR). This reinforces the premise that agricultural output growth in post-2000 Chhattisgarh has transitioned into a yield-led regime.

However, the state-level aggregate masks stark inter-zonal disparities:

- **Chhattisgarh Plains:** Emerged as the primary growth driver, achieving robust and statistically significant increases in both acreage (0.82% CGR) and yield (3.61% CGR), resulting in a 4.45% annual growth in wheat output.
- **Northern Hills:** Sustained positive production growth (2.71% CGR) entirely through yield gains (2.86% CGR), which successfully offset a slight contraction in cultivated area (-0.15% CGR).
- **Bastar Plateau:** Faced severe area attrition (-6.84% CGR) and an overall output decline (-4.95% CGR), indicating high acreage instability and a systemic shift away from wheat cultivation during the Rabi season despite modest productivity improvements (2.04% CGR).

Policy Implications

To maintain production momentum and address intra-state growth imbalances, targeted policy interventions are required:

1. **Targeted Extension and Inputs in Lagging Zones:** In the Bastar Plateau and Northern Hills, efforts should focus on providing quality seeds of high-yielding, short-duration, and heat-tolerant wheat varieties tailored to late-sown conditions.

2. **Expansion of Rabi Irrigation:** Since wheat is predominantly a Rabi crop requiring assured moisture, expanding micro-irrigation infrastructure (e.g., tube wells, drip/sprinkler systems) in non-plain regions will help stabilize acreage and reduce yield variability.

3. **Bridging the Yield Gap:** Strengthening technological dissemination, balanced fertilizer application, and extension mechanization can help close the existing productivity gaps across all zones.

Scope for Future Research

Future studies can build upon these findings by employing decomposition models to quantify the exact interaction effects between area and yield, as well as utilizing time-series forecasting techniques (e.g., ARIMA or machine learning approaches) to project long-term production possibilities for Chhattisgarh.

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Figures

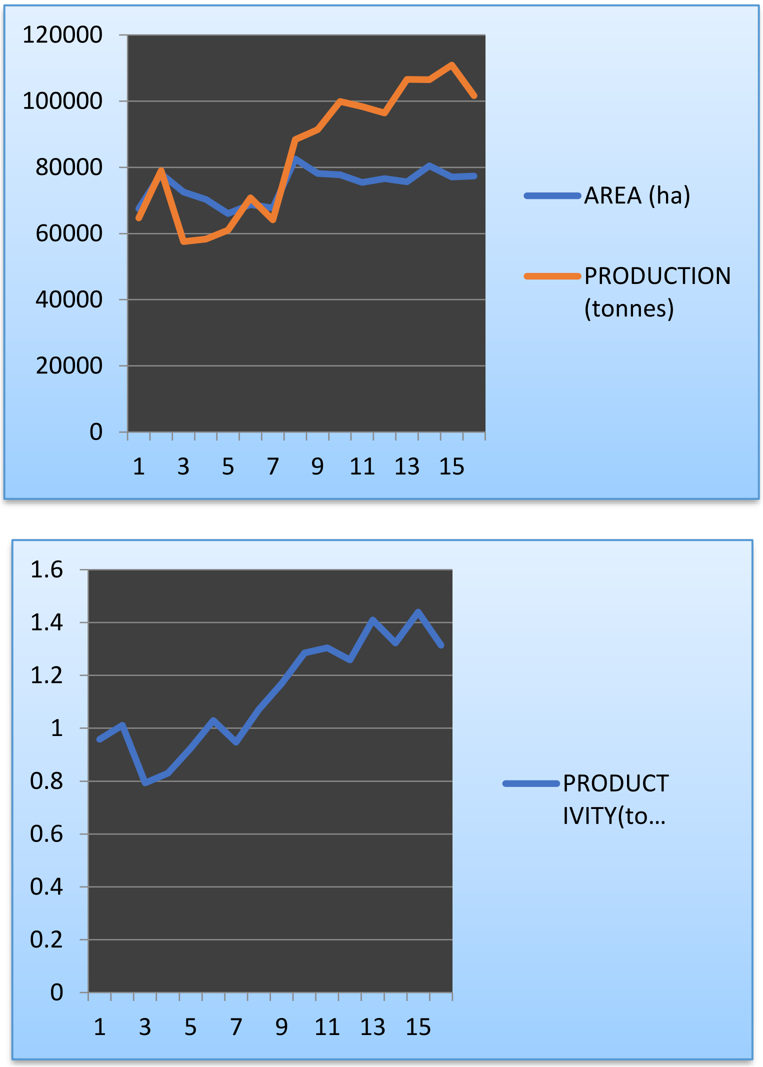

Fig. 1: Trend for area, production and productivity of wheat in Chhattisgarh

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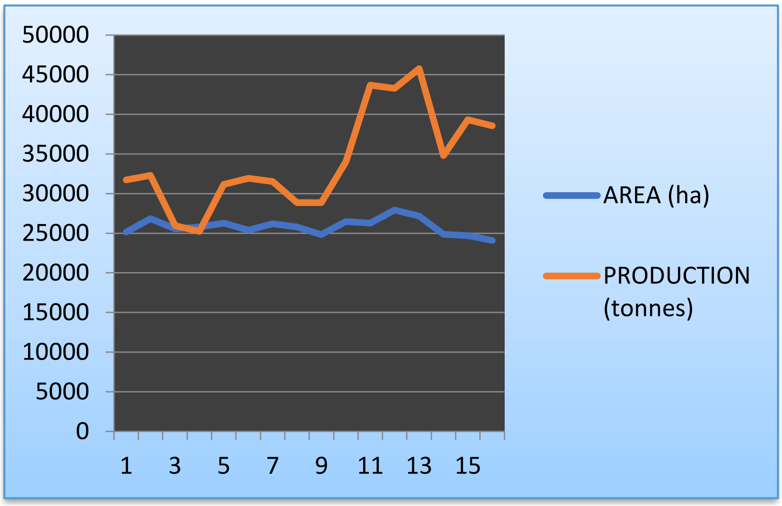
plains of Chhattisgarh



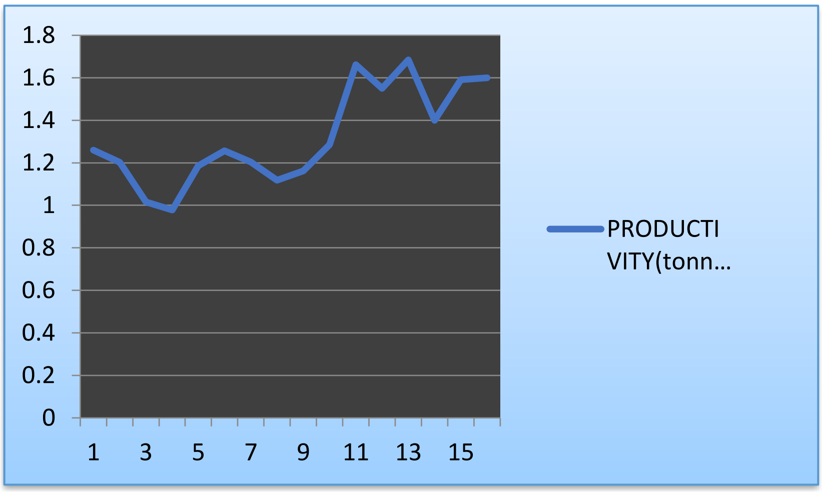


Fig.2: Trend for area, production and productivity of wheat in Northern hills of Chhattisgarh

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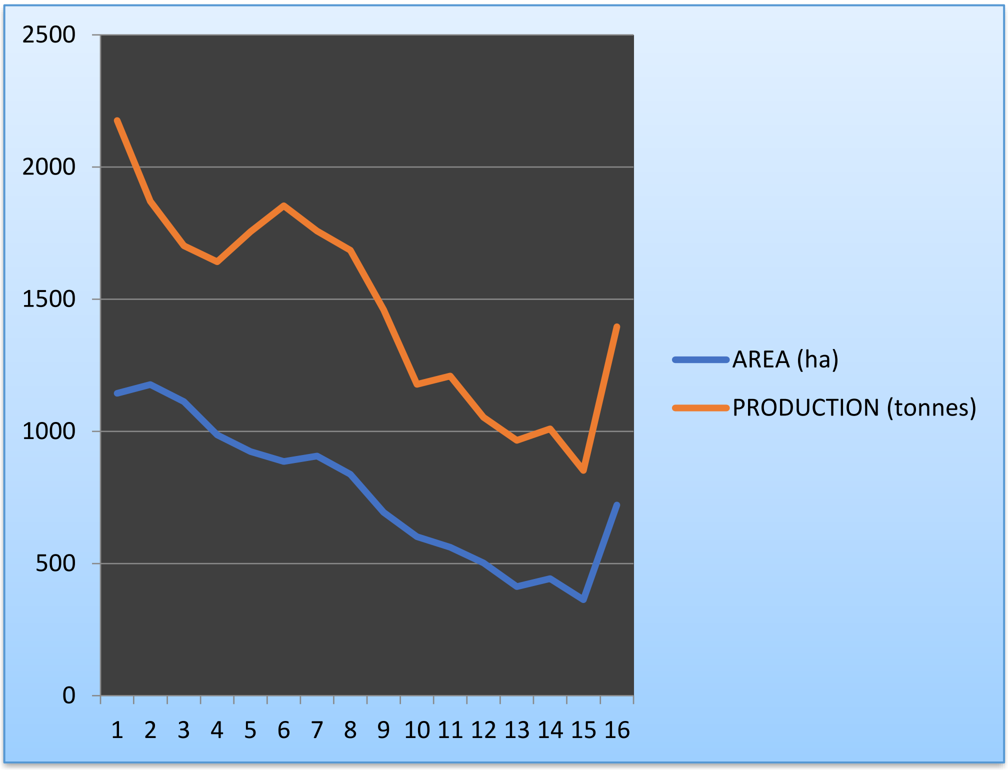

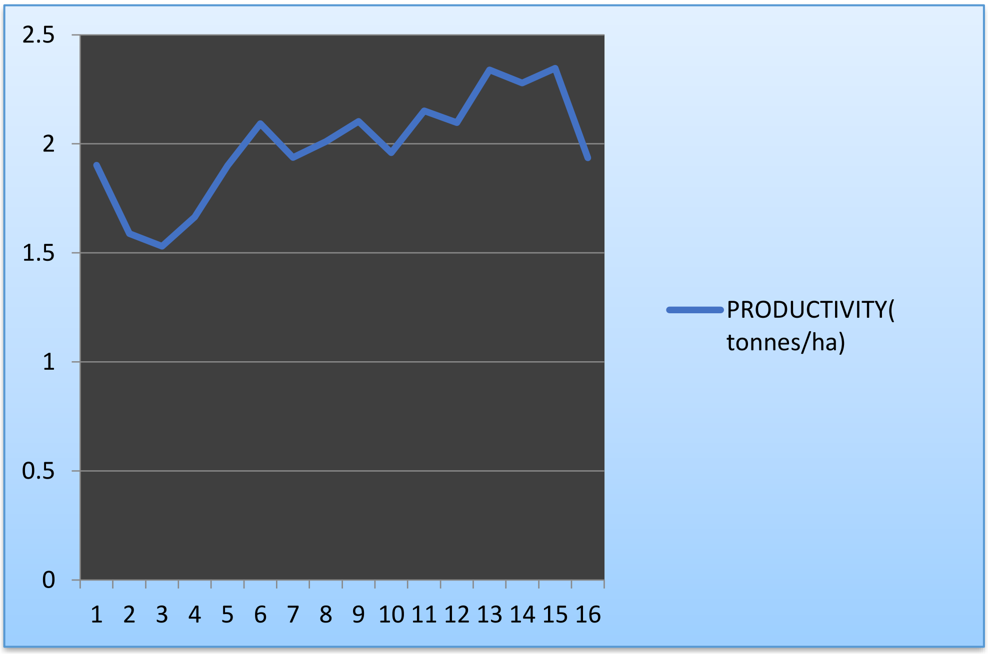

Fig. 3: Trend for area, production and productivity of wheat in Bastar plateau of Chhattisgarh

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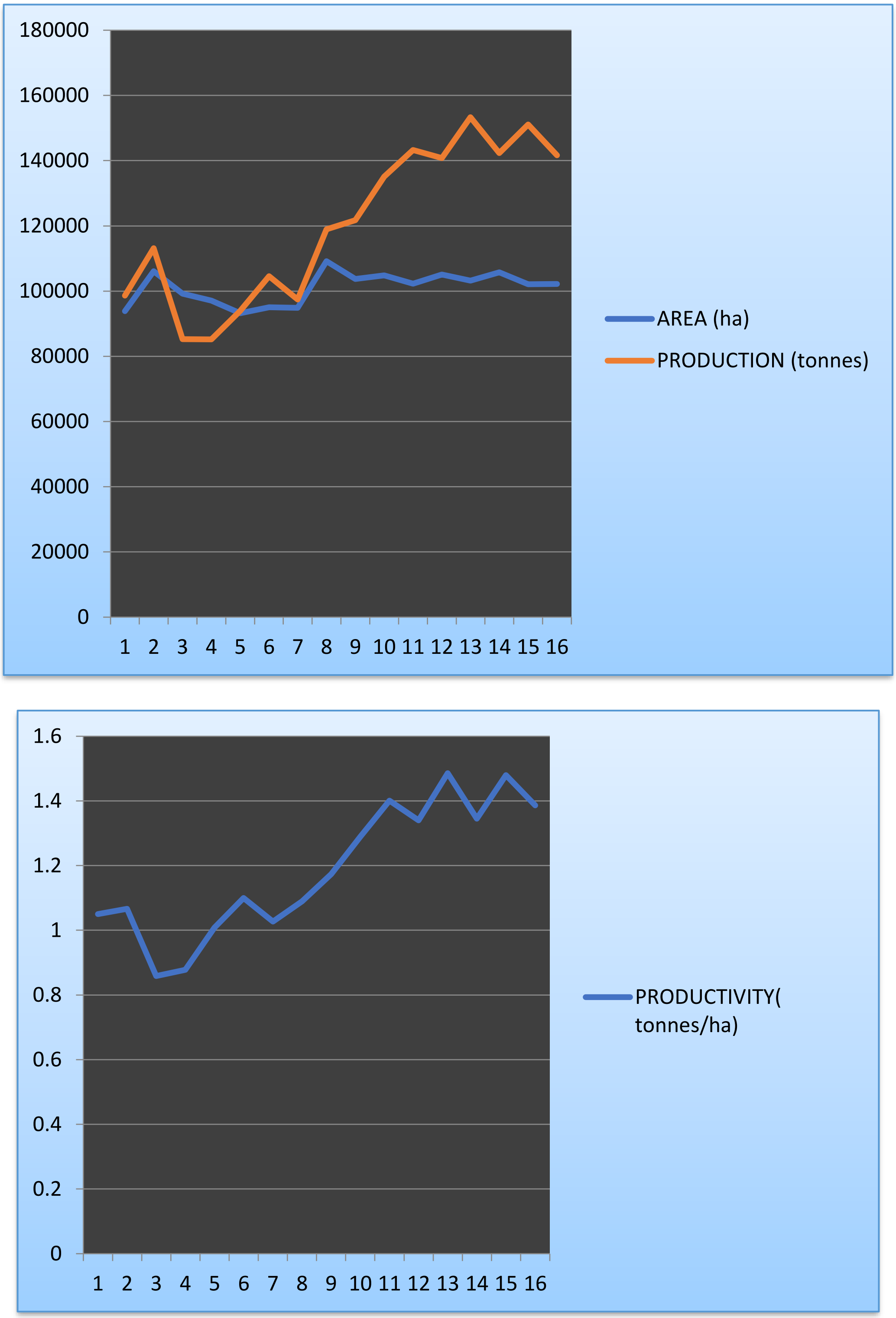

Fig. 4: Trend for area, production and productivity of wheat in Chhattisgarh