**Revista Latinoamericana de la Papa** **ISSN 1019-6609**
***Vol.29, No.1, 2025*** ***eISSN 1853-4961***

# Decomposition Analysis of Wheat Production Growth across Agro-Climatic Zones of Chhattisgarh, India

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Received: 05 March 2025 Revised: 12 May 2025 Accepted: 25 May 2025

## ABSTRACT

This study examines the structural components driving wheat production growth across the three distinct agro-climatic zones of Chhattisgarh, India—the **Chhattisgarh Plains**, **Northern Hills**, and **Bastar Plateau**—for the 16-year period spanning **2002–03 to 2017–18**. Secondary time-series data on the area, production, and yield of wheat were analyzed using the additive decomposition model formulated by **Dr. B. S. Minhas (1964)** to quantify the relative contributions of the **Area Effect (AE)**, **Yield Effect (YE)**, and **Interaction Effect (IE)** toward overall output changes.

The empirical findings reveal significant zonal heterogeneity in the drivers of wheat production growth:

- At the **aggregate state level**, wheat production growth in Chhattisgarh was overwhelmingly **yield-led (YE = 88.93%)**, with minor contributions from area expansion (AE = 7.83%) and their interaction (IE = 3.23%).
- Zone-wise analysis indicates that **yield improvements** dominated growth in the **Chhattisgarh Plains (YE = 76.07%, AE = 20.04%)** and the **Northern Hills (YE = 158.11%, AE = -50.26%)**. In the Northern Hills, strong productivity gains successfully compensated for a marked contraction in wheat acreage.
- In contrast, wheat output growth in the **Bastar Plateau** was overwhelmingly driven by **horizontal land expansion (AE = 128.07%)**, accompanied by a negative yield performance (YE = -42.29%), highlighting a persistent productivity deficit in the southern region.

The study concludes that while Chhattisgarh has achieved technology- and productivity-driven wheat growth overall, zone-specific policy interventions are required. Efforts in the Bastar Plateau must prioritize bridging the yield gap through enhanced irrigation and high-yielding variety (HYV) seed distribution, whereas strategies in the Northern Hills should focus on stabilizing cultivated acreage through natural resource management.

## KEYWORDS

Decomposition Analysis, Wheat Production, Agro-Climatic Zones, Minhas Model, Yield Effect, Area Effect, Chhattisgarh Agriculture, Foodgrain Growth.

## Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and serves as a staple food for nearly one-third of the global population. It plays a critical role in ensuring food and nutritional security by providing a major source of carbohydrates, proteins, vitamins, and minerals.

ISSN 1019-6609
eISSN 1853-4961

Globally, increasing wheat productivity has become a major concern due to the rising demand for food, shrinking cultivable land, climate variability, and the need for sustainable agricultural intensification. Consequently, understanding the factors contributing to changes in wheat production is essential for designing effective agricultural policies and improving productivity.

Agriculture remains the backbone of the Indian economy despite the increasing contribution of the industrial and service sectors. The sector contributes substantially to national food security, rural employment, and livelihood generation. Wheat is the second most important foodgrain crop in India after rice and occupies a significant share of the country's cropped area and foodgrain production. Over the past few decades, wheat production has increased considerably due to the adoption of high-yielding varieties, expansion of irrigation facilities, balanced fertilizer application, mechanization, and improved crop management practices. However, the relative contributions of cultivated area expansion and yield improvement have varied considerably across regions because of differences in agro-climatic conditions, technological adoption, and resource availability.

Chhattisgarh, known as the "Rice Bowl of Central India," is predominantly an agrarian state characterized by diverse agro-climatic conditions comprising the Chhattisgarh Plains, Northern Hills, and Bastar Plateau. Although rice dominates the state's agricultural landscape, wheat has emerged as an important rabi crop in irrigated areas and contributes significantly to foodgrain production and cropping system diversification. The productivity and production of wheat differ substantially among the agro-climatic zones due to variations in soil characteristics, irrigation infrastructure, rainfall distribution, input use, and technological adoption. Identifying the major drivers of wheat production growth across these regions is therefore essential for formulating region-specific strategies aimed at enhancing productivity and ensuring sustainable agricultural development.

Agricultural production growth generally results from expansion of cultivated area, improvement in crop productivity, or the combined interaction of both factors. Decomposition analysis has been widely employed in agricultural economics to quantify the relative contribution of these components. The decomposition model proposed by Minhas (1964) has become one of the most widely accepted approaches for separating production growth into area effect, yield effect, and interaction effect, thereby providing valuable insights into the underlying sources of agricultural growth.

Several researchers have applied decomposition analysis to evaluate agricultural production dynamics in different regions. Deepak (2003) reported that growth in pulse production in Maharashtra was primarily associated with expansion of cultivated area, whereas the decline in coarse cereal production was largely attributed to reduction in cultivated area despite improvements in productivity. Kakarlapudi and Kiran Kumar (2007) reviewed various decomposition techniques and emphasized their usefulness in identifying the principal sources of agricultural growth for effective policy formulation. Similarly, Shadmehri (2008) demonstrated that improvements in yield and expansion of irrigated area were the major contributors to agricultural production growth in Iran.

Studies conducted in India have consistently highlighted the dominant role of productivity enhancement in foodgrain production. Ruchi (2017) observed that increases in foodgrain production were mainly driven by improvements in crop productivity and emphasized the necessity of technological interventions because expansion of cultivated land has become increasingly constrained. Devi et al. (2017) also reported that productivity improvement contributed substantially to pulse production growth in India. Neelam et al. (2020) further confirmed that yield enhancement has become the principal driver of foodgrain production growth under conditions of limited scope for area expansion.

Research focusing on Chhattisgarh also supports the predominance of productivity effects. Anupama et al. (2019) analysed decomposition of major cereal crops across the agro-climatic regions of

ISSN 1019-6609
eISSN 1853-4961

Chhattisgarh and found that yield effect contributed more significantly than area expansion to production growth in most regions and crops. Divya and Pathak (2018) reported positive growth in area, production, and productivity of major foodgrains in the state, while Shanker et al. (2010) documented considerable inter-zonal variation in crop growth and instability, emphasizing the need for location-specific agricultural development strategies.

Although previous studies have examined decomposition of cereal and foodgrain production at the state level, comprehensive evidence on the relative contributions of area expansion and productivity improvement specifically for wheat across the different agro-climatic zones of Chhattisgarh remains limited. Given the regional disparities in natural resources, production environments, and technological adoption, understanding these differences is important for designing targeted interventions to enhance wheat productivity and strengthen regional food security.

Therefore, the present study aims to quantify the contributions of area, yield, and their interaction to wheat production growth across the agro-climatic zones of Chhattisgarh using the Minhas decomposition model. The findings are expected to provide empirical evidence for policymakers, researchers, and extension agencies in formulating region-specific strategies to improve wheat production through sustainable productivity enhancement rather than relying solely on expansion of cultivated area.

## Materials and Methods

### 1. Description of the Study Area

The study was conducted across **Chhattisgarh**, a central Indian state established on November 1, 2000, situated between 17°46' N to 24°05' N latitude and 80°15' E to 84°20' E longitude. The total geographical area of the state is approximately **13.79 million hectares**, with arable land covering around **4.68 million hectares** and forests accounting for nearly **44%** (6.35 million hectares).

### 2. Sampling Procedure

#### 2.1 Selection of Zones

Chhattisgarh comprises three distinct agro-climatic zones based on topography, climate, and soil characteristics:

1. **Chhattisgarh Plains**
2. **Northern Hills**
3. **Bastar Plateau**

All three agro-climatic zones were selected **purposively** to ensure complete regional coverage of the state.

#### 2.2 Selection of Districts

Out of the 28 districts in the state during the analysis context, all districts across the three zones were included:

- **Chhattisgarh Plains Zone:** 16 districts
- **Northern Hills Zone:** 5 districts
- **Bastar Plateau Zone:** 7 districts

**2.3 Selection of Crop**

**Wheat** was selected purposively for this investigation. It serves as a major foodgrain and Rabi crop in Chhattisgarh, accounting for approximately **12.67% of the total foodgrain area** across the state's agro-climatic zones.

**2.4 Period of the Study**

The study evaluates time-series secondary data over a 16-year duration spanning from **2002–03 to 2017–18**.

**3. Nature and Sources of Data**

The study relies entirely on **secondary time-series data** for the area, production, and yield of wheat across all selected districts and zones. Data were retrieved from official state publications, departmental reports, and government statistical releases, including:

- Department of Agricultural Statistics, Government of Chhattisgarh
- Directorate of Economics and Statistics, Chhattisgarh
- Directorate of Agriculture, Chhattisgarh
- Statistical Abstracts of Chhattisgarh State

**4. Analytical Framework**

The collected data were analyzed using simple classification and tabulation techniques to fulfill the objectives of the study. Following econometric were used to find out the growth performance, decomposition for total agricultural output growth and production projection using ARIMA Model.

**3.4.2 Decomposition of total agricultural output growth**

The contribution of area and productivity or the interaction of area and yield of the production was estimate by using the decomposition profounded by Dr. Minhas 1964, which is used to estimate the contribution of area and yield to production changes (positive/negative).

**Area Effect:** Shows percentage share of area in total production

$$AE = \frac{(A_n - A_0)Y_0}{P_n - P_0} \times 100$$

**Yield Effect:**Shows percentage share of average yield in total production

$$YE = \frac{(Y_n - Y_0)A_0}{P_n - P_0} \times 100$$

**Interaction Effect:** Shows percentage share of area and yield (simultaneous variation) interactiontowards total production.

$$IE = \frac{(A_n - A_0)(Y_n - Y_0)}{P_n - P_0} \times 100$$

Where,

ISSN 1019-6609
eISSN 1853-4961

$A_0$ = Triennium average of area in base year

$P_0$ = Triennium average of production in base year

$A_n$ = Triennium average of area in current year

$P_n$ = Triennium average of production in current year

$Y_n = P_n / A_n$

$Y_0 = P_0 / A_0$

**Results and Discussion**

**1. Output Growth and Decomposition Analysis**

To evaluate the structural drivers behind variations in wheat production across Chhattisgarh, the additive decomposition model formulated by Dr. B. S. Minhas (1964) was applied. This framework isolates total output changes into three component forces:

1. **Area Effect (AE):** Contribution driven purely by expansion or contraction of cultivated land.
2. **Yield Effect (YE):** Contribution driven purely by improvements in crop productivity per hectare.
3. **Interaction Effect (IE):** Combined contribution resulting from simultaneous changes in both area and yield.

The empirical estimates across the three distinct agro-climatic zones and for Chhattisgarh State as a whole are summarized below:

**Table 1: Decomposition of Wheat Output Growth Across Agro-Climatic Zones of Chhattisgarh**

*(Study Period: 2002–03 to 2017–18)*

| Agro-Climatic Zone / State | Area Effect (AE) (%) | Yield Effect (YE) (%) | Interaction Effect (IE) (%) | Dominant Driver |
|---|---|---|---|---|
| **Chhattisgarh Plains** | 20.04 | **76.07** | 3.90 | Yield Effect |
| **Northern Hills** | -50.26 | **158.11** | -7.85 | Yield Effect |
| **Bastar Plateau** | **128.07** | -42.29 | 14.23 | Area Expansion |
| **Chhattisgarh (State Overall)** | 7.83 | **88.93** | 3.23 | **Yield Effect** |

*Note: AE = Area Effect, YE = Yield Effect, IE = Interaction Effect.*

**2. Zone-Wise Discussion of Findings**

**2.1 Chhattisgarh Plains Zone**

- **Empirical Breakdown:** Yield Effect = **76.07%**, Area Effect = **20.04%**, Interaction Effect = **3.90%**.
- **Discussion:** In the central plain region, wheat production growth was predominantly driven by improvements in crop productivity per hectare. The positive contribution of land expansion (20.04%) and interaction (3.90%) indicates a balanced progress where yield gains were supported by a

 ISSN 1019-6609
eISSN 1853-4961

moderate increase in cultivated area. This performance reflects better access to irrigation facilities, high-yielding variety (HYV) seeds, and improved agricultural management in the central farming belt.

**2.2 Northern Hills Zone**

- **Empirical Breakdown:** Yield Effect = **158.11%**, Area Effect = **-50.26%**, Interaction Effect = **-7.85%**.
- **Discussion:** The Northern Hills zone exhibited a strong dependency on yield improvement. The Area Effect (-50.26%) and Interaction Effect (-7.85%) were negative, indicating a contraction in the physical land area allocated to wheat over the study period. However, substantial yield gains per hectare (158.11%) successfully offset the loss in acreage, resulting in net production gains. This suggests that farmers in this hilly terrain intensified production on smaller, more productive land units.

**2.3 Bastar Plateau Zone**

- **Empirical Breakdown:** Area Effect = **128.07%**, Interaction Effect = **14.23%**, Yield Effect = **-42.29%**.
- **Discussion:** Unlike the other two zones, output growth in the southern Bastar Plateau was overwhelmingly driven by horizontal land expansion (128.07% Area Effect). Conversely, the Yield Effect was negative (-42.29%), revealing that crop productivity per hectare declined or lagged behind over the study period. While total production increased due to new land brought under wheat cultivation, the zone suffers from a productivity deficit, likely due to lower input adoption, limited irrigation infrastructure, and challenging topographical conditions.

**3. Overall State Performance (Chhattisgarh)**

- **Empirical Breakdown:** Yield Effect = **88.93%**, Area Effect = **7.83%**, Interaction Effect = **3.23%**.
- **Discussion:** At the aggregate state level, wheat production growth in Chhattisgarh was overwhelmingly yield-led. Productivity gains accounted for nearly 89% of total production growth, while area expansion played a secondary role (7.83%).

These findings demonstrate that the overall growth in wheat output across Chhattisgarh was achieved through technological adoption, improved seed varieties, and expanding irrigation infrastructure, rather than relying on horizontal expansion of cultivated land.

**Extended Discussion & Policy Implications**

**1. Synthesis of Zonal Dynamics**

The empirical results from the decomposition analysis highlight clear regional variations in how wheat production growth is achieved across Chhattisgarh. Rather than following a uniform trajectory across the state, wheat output growth is driven by distinct factors in each agro-climatic zone.

**2. In-Depth Interpretation of Findings**

**2.1 Technology Adoption vs. Land Constraints in the Plains and Northern Hills**

In both the **Chhattisgarh Plains** and the **Northern Hills**, productivity gains (Yield Effect) were the primary driver of production growth.

- **Central Plains:** As the primary agricultural belt, the Plains benefit from better irrigation access, market infrastructure, and higher adoption of high-yielding variety (HYV) seeds. This allowed farmers to increase yields per hectare while expanding cultivated area.
- **Northern Hills:** The negative Area Effect (-50.26%) indicates a reduction in wheat acreage, likely due to topography, land degradation, or shifts toward competing crops. However, intensive cultivation practices and improved seed-fertilizer adoption yielded a strong positive Yield Effect (158.11%), demonstrating that vertical productivity gains can offset land constraints.

### 2.2 The Yield Deficit and Horizontal Growth in Bastar Plateau

The **Bastar Plateau** presents a contrasting dynamic, where production gains relied almost entirely on area expansion (128.07% Area Effect), while the Yield Effect was negative (-42.29%).

- Expanding land under wheat shows that farmers in the region are increasingly adopting wheat as a Rabi option.
- However, the negative yield performance underscores structural challenges, such as limited irrigation coverage, poor access to modern inputs, acidic soils, and traditional farming practices. Relying primarily on land expansion is unsustainable over the long term given land constraints and environmental concerns.

### 3. Targeted Policy Recommendations

Based on the decomposition results, policy interventions should be tailored to the specific growth drivers of each agro-climatic zone:

1. **Bastar Plateau (Yield-Boosting Interventions):**
   - **Targeted Extension Services:** Deploy localized agricultural extension programs to train tribal and smallholder farmers in modern agronomic practices.
   - **Input Access & Irrigation:** Improve the distribution of drought-tolerant and high-yielding wheat seed varieties while investing in micro-irrigation infrastructure to raise per-hectare productivity.
2. **Northern Hills (Acreage Stabilization & Resource Conservation):**
   - **Soil & Water Conservation:** Implement land treatment, terracing, and watershed development programs to stabilize cultivated wheat area.
   - **Balanced Resource Management:** Encourage crop rotations and conservation agriculture to sustain high yields without degrading land resources.
3. **Chhattisgarh Plains (Consolidating Technological Gains):**
   - **Input Efficiency:** Promote precision agriculture, efficient fertilizer use, and modern water management to maintain high yield levels.
   - **Market & Storage Infrastructure:** Strengthen cold storage, procurement centers, and supply chain logistics to maintain fair prices for farmers.

## Conclusion

### 1. Summary of Major Findings

This study evaluated the structural drivers of wheat production growth across the three distinct agro-climatic zones of Chhattisgarh (Chhattisgarh Plains, Northern Hills, and Bastar Plateau) for the period **2002–03 to 2017–18** using the additive decomposition scheme by Dr. B. S. Minhas (1964).

The empirical findings reveal clear zonal variations in how wheat output growth is achieved across the state:

1. **Statewide Growth Pattern:** At the aggregate state level, wheat production growth in Chhattisgarh was overwhelmingly driven by the **Yield Effect (88.93%)**, with Area Effect (7.83%) and Interaction Effect (3.23%) playing minor secondary roles. This indicates that overall growth was driven by vertical productivity gains rather than horizontal land expansion.

ISSN 1019-6609
eISSN 1853-4961

2. **Plains and Northern Hills (Yield Dominance):** Production growth in both the Chhattisgarh Plains (76.07%) and Northern Hills (158.11%) was dominated by yield improvements. In the Northern Hills, strong productivity gains successfully offset a substantial contraction in wheat acreage (-50.26%).

3. **Bastar Plateau (Area Dominance & Productivity Deficit):** In contrast, growth in the Bastar Plateau relied almost entirely on area expansion (128.07% Area Effect), accompanied by a negative Yield Effect (-42.29%). This highlights a persistent yield gap in the southern tribal belt.

**2. Core Takeaways & Recommendations**

- **Shift Focus from Expansion to Yield in Bastar:** Because physical land expansion is constrained over the long term, policies in the Bastar Plateau must shift focus toward bridging the productivity gap. This requires expanding micro-irrigation, introducing climate-resilient HYV seed varieties, and strengthening local extension services.

- **Stabilize Acreage in Hilly Zones:** Watershed management, soil conservation, and land treatment programs should be deployed in the Northern Hills to prevent further acreage reduction while maintaining high yields.

- **Consolidate Technological Leadership:** The central plains should continue leveraging precision farming, efficient input usage, and post-harvest infrastructure to sustain its strong productivity gains.

In conclusion, while Chhattisgarh has successfully achieved yield-led wheat production growth overall, adopting **zone-specific agricultural strategies** will be key to addressing regional disparities and ensuring sustainable foodgrain growth state-wide.

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