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Long-Term Trends and Instability in Cropping Intensity and Foodgrain Production in Odisha

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Abstract:

Agricultural resilience depends on both sustained output growth and stability in land utilisation patterns. This study investigates long-term growth and instability in Cropping Intensity, Total Foodgrain Production, and Rice Production in Odisha over the period (2004-2005) to (2023–2024). Growth trends are estimated using the compound annual growth rate (CAGR), while instability is measured through the Cuddy–Della Valle Index (CDVI) after adjusting for deterministic time trends. Empirical findings indicate a structural divergence in the state's agricultural trajectory. Cropping Intensity declined at -1.66 per cent annually, reflecting weakening land-use intensification. Conversely, Total Foodgrain and Rice Production grew at 1.52 per cent and 1.45 per cent per annum, respectively, suggesting productivity-led expansion. Instability estimates reveal moderate volatility in Cropping Intensity (10.49 per cent) and relatively low instability in production variables. The evidence points to a shift from area-driven growth to productivity-based stabilisation. Nonetheless, declining land-use intensity may signal emerging structural vulnerabilities with implications for sustainability and agrarian welfare. The study provides empirical insights into Odisha's agricultural transformation and contributes to broader debates on growth–instability dynamics in developing agrarian economies.

Keywords: Cropping intensity; Agricultural growth; Production instability; Cuddy–Della Valle Index; Compound annual growth rate

1. Introduction

Agriculture continues to play a pivotal role in India's economy, contributing approximately 18–20 per cent to the Gross Value Added (GVA) and employing nearly 45 per cent of the workforce (Government of India, 2023). In eastern states such as Odisha, the dependence on agriculture is even more pronounced, with a substantial proportion of rural households relying on crop cultivation as their primary source of livelihood (Government of Odisha, 2023). Rice dominates the cropping pattern in the state, accounting for nearly two-thirds of the gross cropped area, thereby making agricultural stability closely linked to foodgrain performance. Over the past two decades, Indian agriculture has experienced a structural shift from area-led expansion to productivity-driven growth (Bhalla & Singh, 2009). However, growth alone does not ensure resilience. Agricultural sustainability depends equally on the stability of output and efficient utilisation of land resources. Cropping intensity, defined as the ratio of gross cropped area to net sown area, serves as an important indicator of land-use intensification and resource optimisation (Chand et al, 2007). A declining trend in cropping intensity may reflect irrigation constraints, climatic variability, rising input costs, or soil degradation. Odisha's agriculture is particularly vulnerable to climatic shocks, including frequent droughts and floods, which influence both production stability and land-use decisions (Birthal et al, 2015). While improvements in seed technology, irrigation expansion, and minimum support price mechanisms have contributed to production growth, concerns regarding long-term sustainability and farmer welfare persist. Despite the importance of these issues, a comprehensive assessment integrating long-term growth and instability in cropping intensity and foodgrain production in Odisha remains limited. Understanding these dynamics is crucial for evaluating agricultural resilience and its implications for agrarian stability.

Agricultural growth and instability have long been central themes in development economics. Early studies emphasised that variability in agricultural output significantly affects farm income and rural welfare (Hazell, 1982). Instability in agricultural production can undermine income security and increase vulnerability among small and marginal farmers.

Research on growth patterns in Indian agriculture has shown a gradual transition from area expansion to productivity-led growth (Bhalla & Singh, 2009). This structural transformation suggests that technological improvements and input intensification increasingly drive output growth rather than the expansion of cultivated area.

Several scholars have examined cropping intensity as a determinant of agricultural performance. Increased cropping intensity has been associated with irrigation development and improved infrastructure (Chand et al, 2007). However, declining or stagnant cropping intensity may indicate constraints in resource availability and sustainability challenges.

Instability measurement in agricultural studies has evolved. The Cuddy-Della Valle Index has been widely used to measure instability after adjusting for trend effects (Cuddy & Della Valle, 1978). This index corrects the limitations of the simple coefficient of variation by accounting for deterministic growth trends.

Recent studies on Indian states highlight regional disparities in agricultural growth and vulnerability, particularly in rain-fed and resource-constrained regions (Birthal et al, 2015). However, many analyses focus either on growth or instability separately, rather than examining both simultaneously within a long-term framework.

Despite the importance of Odisha in eastern India's agricultural landscape, systematic empirical analysis combining growth and instability of cropping intensity and foodgrain production over an extended period remains relatively underexplored.

The existing literature provides substantial insights into agricultural growth, productivity enhancement, and output instability at the national and regional levels. However, three major gaps emerge: Limited integration of growth and instability analysis within a unified framework. Insufficient focus on cropping intensity alongside production variables. Lack of updated long-term analysis for Odisha covering recent structural changes in agriculture. Most studies either examine output growth without addressing instability or focus on instability without adequately linking it to land-use intensity. Furthermore, empirical evidence specific to Odisha over the last two decades remains fragmented. Therefore, a comprehensive analysis combining growth and instability of cropping intensity, total foodgrain production, and rice production over 2004–2024 is warranted.

The present study aims to: Examine the long-term growth trends in Cropping Intensity, Total Foodgrain Production, and Rice Production in Odisha during 2004–2024. Measure the extent of variability and instability in these variables using appropriate statistical tools. Analyse the structural relationship between land-use intensity and production performance. Draw implications for agricultural sustainability and farmer welfare in Odisha.

2. Data source and Methodology

Odisha, located in eastern India, has a predominantly agrarian economy with nearly 45 per cent of the workforce engaged in agriculture (Government of Odisha, 2023). The state is characterised by a diverse cropping pattern, dominated by rice, which occupies about two-thirds of the gross cropped area. Agriculture in Odisha is highly dependent on monsoon rainfall, making the sector vulnerable to climatic fluctuations and resource constraints. This study uses secondary time-series data for Odisha from 2004 to 2024, obtained from official sources including the Directorate of Economics and Statistics, Government of Odisha, and Ministry of Agriculture & Farmers'

Welfare, Government of India. The analysis focuses on the following variables: Net Sown Area (NSA) – area cultivated during a year, Gross Sown Area (GSA) – total area sown, including multiple crops

Cropping Intensity (CI) – calculated as:

$$\text{CI (\%)} = \frac{\text{Gross Sown Area}}{\text{Net Sown Area}} \times 100$$

Total Foodgrain Production (TFP) – total annual production of foodgrains (in lakh tonnes) Rice Production (RP) – annual rice production (in lakh tonnes). These variables capture both land-use intensity and output performance, providing a comprehensive picture of agricultural growth and stability.

Growth Estimation: The compound annual growth rate (CAGR) of cropping intensity was estimated using a semi-log linear trend model. The semi-log specification was preferred as it captures exponential growth patterns over time and provides a direct estimate of the average proportional change.

The functional form of the model is expressed as:

$$\ln(Y_t) = \alpha + \beta t + \varepsilon_t$$

where $Y_t$represents the cropping intensity in the year t, α is the intercept term, $\beta$is the trend coefficient indicating the instantaneous growth rate, $t$denotes time in years, and $\varepsilon_t$is the random error term. The parameter β was estimated using Ordinary Least Squares (OLS). The compound annual growth rate (CAGR) was computed from the estimated coefficient as:

$$\text{CAGR} = (e^{\beta} - 1) \times 100$$

where e denotes the base of the natural logarithm. The statistical significance of the growth rate was tested using the t-statistic associated with the estimated coefficient β. A positive, statistically significant coefficient indicates sustained growth over the study period, whereas a negative, statistically significant coefficient suggests a declining trend.

Variability Analysis: The Coefficient of Variation (CV) is computed to measure relative fluctuations:

$$\text{CV (\%)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

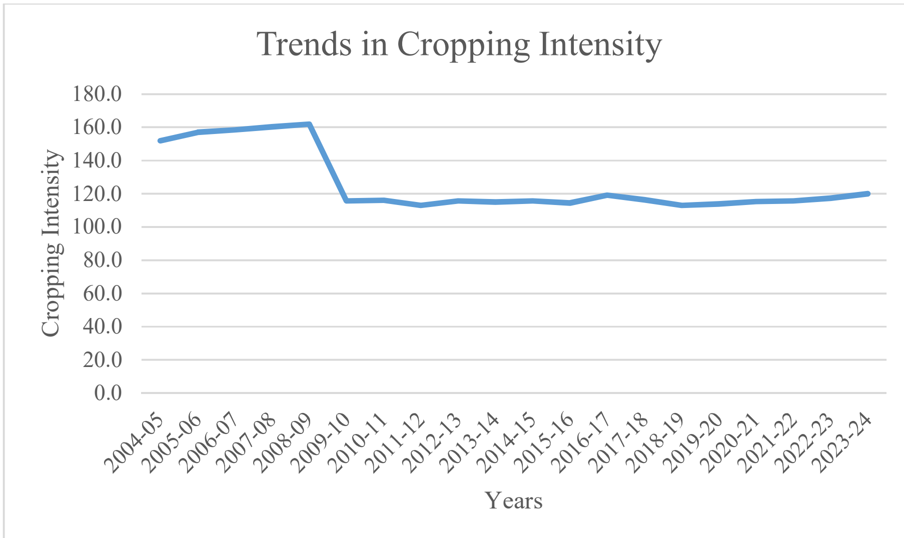
It provides an overview of variability in cropping intensity and production over the study period.

Instability Analysis: Simple dispersion measures overstate variability in trending data. To extract instability net of deterministic trend effects, the Cuddy–Della Valle Index (Cuddy & Della Valle, 1978) was employed:

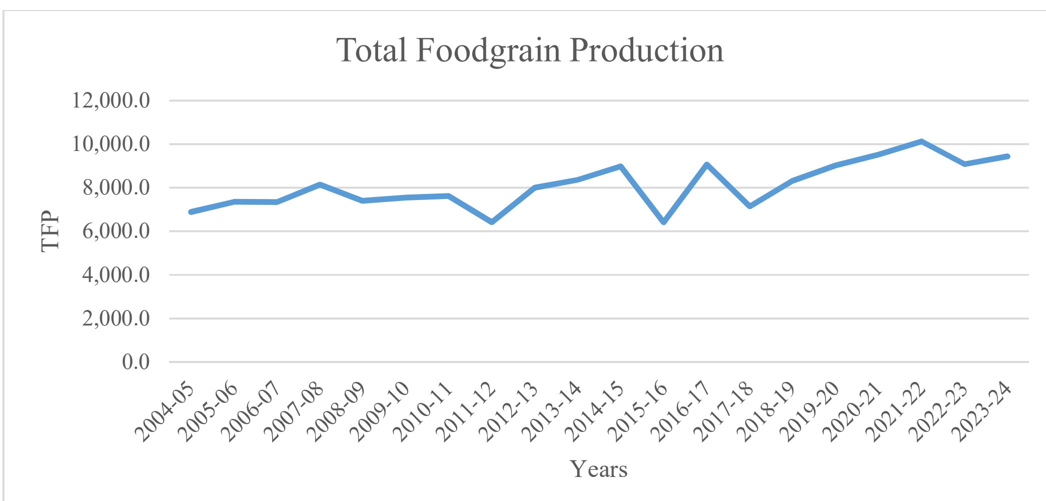
$$\text{CDVI} = CV \times \sqrt{1 - R^2}$$

where $CV$is the coefficient of variation and $R^2$is obtained from the linear time trend regression. This adjustment ensures that variability attributable to systematic growth is excluded.

3. Trends of Cropping Intensity, Total Food Production and Rice Production.



Source: Authors own work from Reserve Bank of India, Handbook of Statistics on Indian States.



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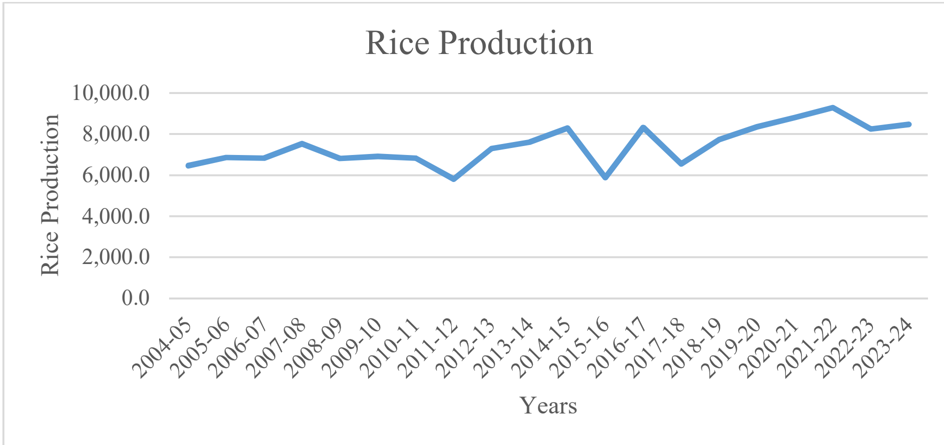

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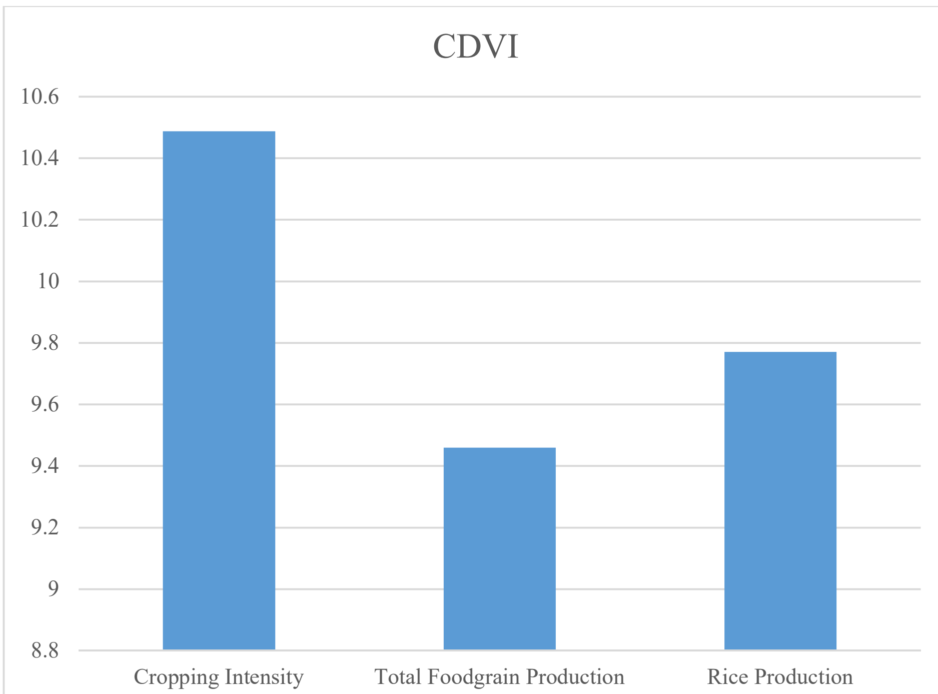

Source: Authors own work from Reserve Bank of India, Handbook of Statistics on Indian States.

Table 1: Descriptive Statistics (2004-05 to 2023-24)

Variable	Mean	Standard Deviation	CV (%)
Cropping Intensity	126.28	18.89	14.96

Total Foodgrain Production	8109.49	1069.98	13.19
Rice Production	7446.71	977.49	13.13

Table 2: Compound Annual Growth Rate (CAGR) using Log-Linear Method

Variable	CAGR (%)
Cropping Intensity	-1.66
Total Foodgrain Production	1.52
Rice Production	1.45

Source: Authors own work from Reserve Bank of India, Handbook of Statistics on Indian States.

Table 3: Linear Trend Regression Results (Original Series)

Variable	R^2
Cropping Intensity	0.5084
Total Foodgrain Production	0.4859
Rice Production	0.446

Source: Authors own work from Reserve Bank of India, Handbook of Statistics on Indian States.

Table 4: Cuddy–Della Valle Instability Index (CDVI)

Variable	CV (%)	R^2	$\sqrt{(1-R^2)}$	CDVI
Cropping Intensity	14.96	0.5084	0.7011	10.49
Total Foodgrain Production	13.19	0.4859	0.717	9.46
Rice Production	13.13	0.446	0.7443	9.77

Source: Author Calculation from Reserve Bank of India - Handbook of Statistics on Indian States.

4. Result and Discussion

The trend analysis reveals distinct structural patterns in cropping intensity (CI), total foodgrain production (TFP), and rice production (RP) in Odisha over the study period. Cropping intensity exhibited a sharp structural shift during the period. Between 2004–05 and 2008–09, CI increased steadily from 151.9 per cent to 161.9 per cent, indicating intensive utilisation of agricultural land. However, a significant decline occurred in 2009–10, when CI dropped abruptly to 115.7 per cent. Thereafter, cropping intensity remained largely stagnant within a narrow band of 113–120 per cent, with only a modest recovery toward the end of the period (120 per cent in 2023–24). The negative CAGR of –1.66 per cent confirms a long-term declining trend in land-use intensity. This suggests structural constraints such as climatic variability, irrigation limitations, or changes in cropping patterns that reduced multiple cropping practices in the state. In contrast, total foodgrain production shows a positive long-term trajectory despite periodic fluctuations. Although production declined in certain years, notably 2011–12 and 2015-16, the overall movement is upward, reaching a peak of 10,125.2 thousand tonnes in 2021-22. The CAGR of 1.52 per cent indicates steady growth over time. Similarly, rice production, being the dominant component of foodgrain output, mirrors this pattern. Despite temporary shocks, rice production increased consistently, registering a CAGR of 1.45 per cent and reaching 9,290.8 thousand tonnes in 2021–22. This indicates that improvements in yield, technological adoption, and policy interventions may have compensated for the decline in cropping intensity. The descriptive statistics further highlight variability patterns. Cropping intensity recorded the highest coefficient of variation (14.96 per cent), followed by total foodgrain production (13.19 per cent) and rice production (13.13 per cent). This indicates that land-use intensity fluctuated more than output levels. The linear trend regression results show moderate explanatory power of time, with R^2 values of 0.508 for CI, 0.486 for TFP, and 0.446 for rice production, suggesting that nearly half of the variation in these variables is explained by time trends, while the remaining variation may be attributed to climatic shocks, market conditions, and policy factors. The Cuddy-Della Valle Instability Index (CDVI) refines this analysis by adjusting variability for trend effects. Cropping intensity recorded the highest instability (10.49), followed by rice production (9.77) and total foodgrain production (9.46). This confirms that land-use intensity is more unstable than production, while rice production exhibits slightly higher instability than aggregate foodgrain output. Overall, the results suggest a structural transformation in Odisha's agriculture: production growth has been achieved despite declining cropping intensity, indicating a shift toward productivity-driven rather than area-driven growth. However, the moderate instability levels highlight continued vulnerability to climatic and structural shocks, with potential implications for farmer income stability and long-term sustainability.

5. Conclusion and Policy Implications

The analysis demonstrates that Odisha's agricultural expansion over the past two decades has been characterised by productivity-led output growth amid declining land-use intensity. While total foodgrain and rice production have increased steadily, cropping intensity has contracted and remains comparatively unstable. This structural shift indicates diminishing reliance on multiple cropping and increasing dependence on yield enhancement.

Policy intervention must therefore prioritise irrigation deepening, particularly micro-irrigation and minor irrigation networks, to restore cropping intensity. Simultaneously, strengthening climate-resilient seed dissemination, extension services, and risk management instruments such as crop insurance will reduce volatility. Diversification beyond rice monoculture can mitigate systemic production risk and enhance income stability. Ensuring sustainable agricultural growth in Odisha requires balancing productivity gains with land-use resilience. Without addressing instability in cultivation intensity, long-term agricultural sustainability may remain fragile despite positive output growth.

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