International Journal of Tropical Agriculture
Volume 43, Numbers (1-2) • 2025 : pp. 49-54
ISSN: 0254-8755

Assessing Instability in Onion Cultivation, Production, and Yield in India: A Modified Cuddy-Della Approach"

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Abstract: The present study analyzes the instability in onion cultivation, production, and yield across major states of India from 1985 to 2022 using secondary data sourced from www.indiastat.com and *Agricultural Statistics at a Glance*. The study employs the Cuddy and Della (1978) instability index, with modifications to account for non-linearity in time series trends. The analysis is conducted over three distinct periods: Period I (1985–2003, traditional technology), Period II (2004–2022, modern technology), and Period III (1985–2022, entire study period). The findings reveal significant variability in onion cultivation, with Maharashtra exhibiting the highest instability in area under onion during the modern technology phase, while Madhya Pradesh and Karnataka displayed relatively lower instability. At the national level, instability in onion area increased from 7.628 in Period I to 11.160 in Period II, reflecting regional fluctuations. Production instability followed diverse patterns, with Maharashtra experiencing a substantial increase in instability, whereas Madhya Pradesh saw improved output stability. Yield instability exhibited mixed trends, with Gujarat showing a decrease while states like Madhya Pradesh and Karnataka recorded an increase. The study highlights that modern technology has influenced instability differently across states, emphasizing the need for region-specific policy interventions to ensure sustainable onion cultivation.

Keywords: Area**,** Coefficient of Variation, Cuddy Della Valla Index, Onion, Production, Instability, Yield

INTRODUCTION

Onion (*Allium cepa L.*) is a globally cultivated vegetable of immense economic and nutritional importance. As a staple ingredient in diverse cuisines, it is valued for its distinct flavor, culinary versatility, and health benefits. Onions are rich in essential nutrients, including vitamin C, B-complex vitamins, flavonoids, and sulfur-containing compounds, which exhibit strong antioxidant, anti-inflammatory, and antimicrobial properties (Mahajan *et al.,* 2014). Regular consumption of onions has been associated with reduced risks of cardiovascular diseases, improved immune function, and enhanced digestive health (Patil *et al.,* 2024). Beyond its dietary significance, onion cultivation plays a crucial role in farm income generation, rural employment, and agricultural trade, positioning it as one of the most significant horticultural crops worldwide.

Onion is cultivated across various agro-climatic regions worldwide, with major production hubs in Asia, Europe, and North America. According to the Food and Agriculture Organization (FAO), the global area under onion cultivation stood at approximately 5.30 million hectares in 2022, with an annual production exceeding 106.00 million metric tonnes and an average yield of 20.00 tonnes per hectare (FAO, 2023). The top five onion-producing countries include China,

Article History: Received: 20 January 2025; Revised: 10 February 2025; Accepted: 16 February 2025; Published: 30 June 2025

India, the United States, Egypt, and Turkey, collectively contributing over 65% of the world's onion supply. Among these, China and India alone account for nearly 50% of global production. The increasing global demand for onions, driven by expanding food industries and international trade, underscores the crop's strategic importance.

India is the second-largest producer of onions globally, with a cultivated area of 1.91 million hectares, producing 31.12 million tonnes in the 2022-23 agricultural year. This marks a substantial increase from 26.64 million tonnes in the previous year, reflecting a 16.81% growth in production (Ministry of Agriculture & Farmers Welfare, 2023). The average onion yield in India stands at 16.30 tonnes per hectare, which, despite steady improvements, remains lower than the global average. Onion cultivation in India is concentrated in a few key states, which contribute significantly to national production. The top five onion-producing states in India are Maharashtra, which accounts for approximately 35% of total production, followed by Madhya Pradesh (17%), Karnataka (11%), Gujarat (9%), and Rajasthan (7%). These states dominate onion production due to favorable agro-climatic conditions, established marketing infrastructure, and robust research and extension support (Sable *et al.*, 2021).

India plays a crucial role in the global onion trade. In the 2023-24 period, India exported approximately 1.72 million metric tonnes of fresh onions, generating revenue of ₹3,922.78 crores (USD 473.72 million). The primary export destinations include Bangladesh, Malaysia, Sri Lanka, the United Arab Emirates, Nepal, and Indonesia (APEDA, 2024). However, onion exports often face policy restrictions due to domestic price fluctuations and supply shortages, leading to periodic export bans to stabilize local markets. Conversely, despite being a major producer, India occasionally imports onions, especially during off-season periods and production shortfalls, from countries such as Egypt, Afghanistan, and Iran to regulate domestic supply and control price volatility.

Despite the significant expansion in onion cultivation, production instability remains a major challenge. Variability in weather conditions, pest and disease outbreaks, fluctuating market prices, inadequate storage facilities, and policy interventions have contributed to production volatility over the years. The instability in agricultural production is typically assessed using various statistical techniques. Chand and Raju (2008) proposed an advanced instability index that refines the Cuddy-Della Valle index by adjusting for long-term trends, making it more suitable for measuring variability in crop production. This method has been widely applied in agricultural research to evaluate the extent and causes of instability in different crops, including onions. The assessment of instability in onion area, production, and yield across major producing states in India is essential for identifying risk factors and formulating policies to enhance resilience in the onion sector.

Given the economic significance of onion production and the associated instability concerns, the present study aims to analyze the trends in onion area, production, and yield at national and state levels, assess the extent of instability in onion cultivation using a modified Cuddy-Della Valle approach, identify the key factors contributing to production fluctuations across major onion-growing states, and evaluate policy measures aimed at stabilizing onion production while suggesting strategic interventions for long-term sustainability. This study is expected to provide empirical insights into production variability and offer policy recommendations to enhance the resilience, sustainability, and profitability of onion cultivation in India.

MATERIALS AND METHODS

The collected information are purely secondary. The information on Area, Production and

Yield of Onion for the period 1985-2022 were collected from www.indiastat.com and *Agricultural Statistics at a Glance.*

INSTABILITY AND ITS MEASURES

India has gone through several phases of agricultural productivity since gaining its freedom. Significant changes have occurred in weather, technology, and other production-related aspects during the process. As a result, the dimensions of production growth, stability, etc., vary depending on the era. Agricultural growth and development behave differently at each of these stages (Shabana and Madhulika, 2018). For obvious reasons, three distinct phases have been analyzed independently in the majority of studies pertaining to the expansion and development of Indian agriculture. As such in this study is divided into three periods viz. , period- I from 1985 to 2003, period-II from 2004 to 2022 and period III from 1985-2022 during the study of instability. In majority of the literature one can found extensive used coefficient variation as measure of instability along with variance.

For measuring the instability in production the index given by Cuddy and Della (1978) and used by **Srivastava *et al.*, 2022:** CV_t = (CV) $x\sqrt{1-R^2}$ where, $C.V. = \frac{\sigma}{\bar{X}} x100$

Where σ = Standard Deviation

$\bar{X} = Mean$

R^2 = coefficient of determination of the linear trend model of the variable concerned.

CV_t = CV around trend

Using the standard CV value is a more generic option, but it cannot sufficiently account for the intrinsic trend component in a time series when there is a trend (Hasan *et al.,* 2008). Consequently, it is assumed that the Cuddy and Della (1978) approach is better than the traditional CV. Consequently, the trend's CV, or CVt, was determined in this study. One of the problems with the Cuddy and Della (1978) approach is that it assumes a linear progression. However, when working with time series data that covers a long period of time, it is quite challenging to find a linear trend. The coefficient of determination obtained from the best-fit models is used to calculate the CVt values for different series, and the nonlinearity in trend models has been included in this work. We call this study model the modified Cuddy and Della measures. As a result, the R^2 can differ between the Cuddy and Della model and the current study's modified Cuddy and Della model. Comparing CVts based on various R^2 value types is extremely challenging if different series display distinct nonlinear form trend models. This is one limitation of the approach.

RESULTS AND DISCUSSION

Instability Analysis

In major states and India, the Cuddy and Della (1978) approach was used to determine the instability in onion area, production, and yield. A more general alternative is to use the CV value, but in the presence of a trend variable in time series properly use the CV value (Hasan *et al.,* 2008). Cuddy and Della's (1978) method is based on the assumption of a linear pattern. However, when dealing with long-term time series data, finding a linear trend is difficult. In this analysis, we had to integrate nonlinearity into the trend model, and the coefficient of determination obtained from such a best fitting model was used to calculate the CV_t value for various sequences, which we call modified Cuddy and Della measure, thus the R^2 used in Cuddy and Della model and the present study modified Cuddy and Della. The research used the Cuddy and Della (1978) measure for non linearity in the trend model against only the Cuddy and Della model's linearity assumption. As a result, the R^2 in the Cuddy and Della model and the modified Cuddy and

Della model can differ. During the analysis of instability, the de trend coefficient of variation is measured in three periods: period 1 from 1985 to 2003 (traditional technology), period 2 from 2004 to 2022 (modern technology), and period 3 (the entire period) from 1985 to 2022. The results of such an exercise will be discussed in the following subsection.

Instability of Onion

Analysis of instability in onion is presented in table 1; which clearly indicates wide range of instability over the periods and over the states. Area under onion shows high instability in the period of modern technology in Maharashtra. From the data it is clearly shown that during the period of modern technology adoption, area under onion in Maharashtra has increased by fluctuation, thereby causing instability in area during the period. In Madhya Pradesh area under onion shows low instability in the period II; but it witnesses small increase during rest of the period; may be because of the impact of the introduction of high input intensive modern technology. Similarly in Karnataka, area under onion shows low instability (5.251) in the period II. Instability in area under onion is higher in period II than the period I in Gujarat, and Rajasthan. Instability in onion area is quite high in whole India during the second phase of our study period from 7.628 in Period I to 11.160 in Period II, reflecting broader variability across different regions. This clearly indicates two things: a) there has been frequent change in area under onion crop in India during the traditional and modern technology adoption period b) most probably the expansion in area under onion during period II could not be sustained afterwards, as a result there has been year to year changes in area under onion in India.

The production instability exhibited diverse patterns. In Maharashtra, there was a substantial increase from 8.114 in Period I to 18.851 in Period II, indicating the influence of technological advancements and shifts in the market. Madhya Pradesh, as shown in table 4.2, saw a drop in production instability from 15.729 in Period I to 12.648 in Period II, showing an improvement in output stability. Karnataka's production instability decreased slightly from 30.579 in Period I to 30.027 in Period II, whereas Rajasthan suffered a large decline from 26.377 in Period I to 21.253 in Period II. In Gujarat, there was a modest increase in production

Table 1: Instability in area of onion in major states of India

States or Country	*Statistics*	*Period I (1985-2003)*	*Period II (2004-2022)*	*Period III (1985-2022)*
Maharashtra	R^2	0.214	0.877	0.711
	CV	22.644	63.486	104.753
	CV_t	20.067	22.211	56.307
Madhya Pradesh	R^2	0.708	0.973	0.761
	CV	23.441	59.430	98.838
	CV_t	12.662	9.737	48.309
Karnataka	R^2	0.111	0.690	0.718
	CV	33.838	41.741	65.227
	CV_t	31.897	23.259	34.635
Gujarat	R^2	0.593	0.195	0.631
	CV	43.764	37.082	56.706
	CV_t	27.915	33.275	34.445
Rajasthan	R^2	0.834	0.481	0.706
	CV	27.195	45.741	73.782
	CV_t	11.078	32.953	40.008
India	R^2	0.838	0.928	0.823
	CV	18.927	41.667	68.169
	CV_t	7.628	11.160	28.646

instability from 36.860 in Period I to 36.535 in Period II. Production instability at the national level dropped somewhat from 8.790 in Period I to 8.085 in Period II.

Table 2: Instability in production of onion in major states of India

Components	*Statistics*	*Period I (1985-2003)*	*Period II (2004-2022)*	*Period III (1985-2022)*
Maharashtra	R^2	0.923	0.908	0.747
	CV	29.332	62.034	104.568
	CV_t	8.114	18.851	52.599
Madhya Pradesh	R^2	0.637	0.967	0.732
	CV	26.115	69.233	121.695
	CV_t	15.729	12.648	63.032
Karnataka	R^2	0.312	0.635	0.739
	CV	36.855	49.684	92.205
	CV_t	30.579	30.027	47.142
Gujarat	R^2	0.294	0.232	0.581
	CV	43.854	41.683	61.559
	CV_t	36.860	36.535	39.843
Rajasthan	R^2	0.810	0.824	0.815
	CV	60.485	50.650	91.422
	CV_t	26.377	21.253	39.319
India	R^2	0.895	0.970	0.833
	CV	27.175	47.067	83.745
	CV_t	8.790	8.085	34.268

In Maharashtra, there was a modest decline in yield per unit area from 15.028 in Period I to 17.518 in Period II, indicating some level of stabilization despite an overall rise in variability. In Madhya Pradesh, there was a rise in yield volatility from 8.300 in Period I to 11.996 in Period II. The yield instability in Karnataka rose from 19.678 in Period I to 25.050 in Period II, suggesting a greater level of inconsistency throughout the implementation of contemporary technologies. In contrast, Gujarat demonstrated a positive trend in yield instability, as indicated by a decrease in values from 11.949 in Period I to 9.706 in Period II. The yield instability in Rajasthan increased from 18.847 in Period I to 23.334 in Period II. At the national level, the degree of yield instability remained essentially constant, with a minor decrease from 7.273 in Period I to 7.140 in Period II.

Table 3: Instability in yield of onion in major states of India

Components	*Statistics*	*Period I (1985-2003)*	*Period II (2004-2022)*	*Period III (1985-2022)*
Maharashtra	R^2	0.634	0.221	0.074
	CV	24.837	19.845	22.423
	CV_t	15.028	17.518	21.577
Madhya Pradesh	R^2	0.021	0.773	0.752
	CV	8.390	25.173	35.420
	CV_t	8.300	11.996	17.654
Karnataka	R^2	0.296	0.238	0.631
	CV	23.452	28.704	41.779
	CV_t	19.678	25.050	25.376
Gujarat	R^2	0.420	0.160	0.001
	CV	15.691	10.592	13.197
	CV_t	11.949	9.706	13.188
Rajasthan	R^2	0.745	0.154	0.649
	CV	37.359	25.361	39.630
	CV_t	18.847	23.334	23.495
India	R^2	0.573	0.539	0.862
	CV	11.126	10.519	20.018
	CV_t	7.273	7.140	7.426

Overall, clearly indicates the varying impacts of modern technology on the instability of onion cultivation, production, and yield across different states and the entire country. Indeed, state level measures of instability are probably more meaningful for policy implementation activities that focus on local areas.

CONCLUSION

The instability analysis of onion cultivation, production, and yield across major states of India underscores the dynamic nature of agricultural variability influenced by technological advancements. The study finds that while modern technology has expanded onion cultivation, it has also introduced fluctuations in production and yield. The instability in onion area increased significantly in states like Maharashtra and Rajasthan, suggesting rapid expansion but also challenges in sustaining cultivated areas. Conversely, Madhya Pradesh and Karnataka witnessed relatively lower instability in area and production, indicating a more stable adoption of modern techniques. The national-level

findings suggest that while production and yield stability have improved in some regions, fluctuations persist, necessitating targeted policy measures. Addressing these instabilities requires state-specific interventions focusing on improved input management, market stabilization policies, and the promotion of resilient agricultural practices. Future research should explore the role of climate variability, input costs, and market dynamics in influencing onion production instability to develop more comprehensive policy frameworks.

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