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RESEARCH PAPER

Assessing the Influence of Seasonal Variations on Cereal Crop Yield: A Case Study in Western Odisha

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ABSTRACT

In the past decade, agricultural development in India has undergone significant changes influenced by various factors. The agricultural sector in Odisha, in particular, faces considerable risks and uncertainties, making the assessment of growth and instability crucial. This study provides a comprehensive analysis of the compound growth rate and Coppock's Instability Index for four major cereal crops: rice and maize in the *Kharif* season, and ragi and wheat in the *Rabi* season. Leveraging secondary data from 1993-94 to 2022-23, the research evaluates and compares the growth and instability in crop yield across districts in Western Odisha. Additionally, the study ranks districts based on these metrics, offering a comparative analysis between the *Kharif* and *Rabi* seasons. The results highlight differences in yield trends and instability levels among the crops, delivering valuable insights into the agricultural patterns and challenges in the region.

HIGHLIGHTS

- The results highlight differences in yield trends and instability levels among the crops, delivering valuable insights into the agricultural patterns and challenges in the region.

Keywords: Compound Growth Rate, Coppock's Instability Index, Growth Rate, CGR, Temporal Analysis

Agriculture is a vital sector in Odisha's economy, contributing approximately 17% to the state's Gross State Domestic Product (GSDP) and 18% to India's Gross Domestic Product (GDP). It is essential for ensuring food security and providing employment, with around 60% of Odisha's workforce engaged in agriculture and about 70% of the population involved either directly or indirectly. The state covers a total geographical area of 155.71 lakh hectares, with 61.80 lakh hectares under cultivation and 53.31 lakh hectares specifically for crops, making up 34% of the land area. Odisha is notable for its significant rice production, accounting for nearly 10% of India's total rice yield, thanks to its favorable climate and fertile soil conditions.

However, Odisha's agricultural sector faces several challenges, such as natural disasters and irregular rainfall, which can lead to variability and instability in crop yields. For instance, the state experienced a peak in food grain yield at 114 lakh metric tons during 2012-13, but subsequent adverse conditions, including Cyclone Phailin and excessive rains in 2013-14, caused disruptions. Despite these hurdles, Odisha's agriculture sector has demonstrated adaptability and resilience through infrastructure enhancements, technological advancements, and supportive policies. Cereal crops, particularly rice, maize, and ragi, are integral to the agricultural framework of the state. Rice, wheat and maize, supplies about 60% of the dietary energy and protein from plant-based sources, rice alone providing 40%

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of protein in the Asian diet. Maize, the third most significant food crop in India, contributes notably to the agricultural economy and employment, with potential for value-added products like quality protein maize (QPM) and baby corn.

Instability in crop yields presents a crucial challenge, affecting market stability and price fluctuations. Such variability impacts consumers through unstable food prices and can lead to inefficient resource allocation by farmers. Understanding and addressing these yield instabilities is essential for effective agricultural planning and sustainable development. While research on agricultural growth and instability has been conducted in regions such as Tamil Nadu, there remains a need for detailed studies on yield instability for cereal crops in Odisha, especially at the district level. This study aims to bridge this gap by analyzing the compound growth rates and instability of key cereal crop yields in Western Odisha, providing valuable insights to improve agricultural stability and development in the region.

MATERIALS AND METHODS

Data Collection

This research conducts a thorough examination of key cereal crops in Western Odisha, with a particular emphasis on rice, maize, ragi, and wheat. Spanning the agricultural years from 1993-94 to 2022-23, the study provides a comprehensive temporal analysis of trends and patterns associated with these crops. To account for the influence of seasonal variations, the research incorporates data from both the *kharif* and *rabi* seasons. By exploring these two distinct cropping periods, the study seeks to offer a nuanced understanding of the effects of seasonal factors on the growth, production, and yield of these essential cereal crops in the region.

Data Sources

The data utilized in this research were obtained from secondary sources provided by the Directorate of Agriculture and Food Production, Government of Odisha. The study primarily relies on the detailed datasets found in the Odisha Agriculture Statistics volumes, which offer extensive information on the production of selected cereal crops, meticulously compiled from various districts across Western Odisha. This comprehensive dataset serves as the foundation for the analysis of agricultural trends and performance in the region.

ANALYTICAL METHODS

Compound Growth Rate (CGR)

Model Specification:

The compound growth rate (CGR) of production for each cereal crop was estimated using an exponential growth model. The model is represented as:

$$Y_t = ab^t \quad \ldots(1)$$

where, Y_t represents the production of the cereal crop in year

t is the time element which takes the value 1,2,3……,n

a is the intercept,

b is the growth rate coefficient.

Logarithmic Transformation: To linearize the exponential growth model, a logarithmic transformation was applied:

$$log\ Y_t = Log\ a + tLog\ b \quad \ldots(2)$$

By defining

$Log\ Yt = Yt'$

$Log\ a = A'$

$Log\ b = B'$

the transformed equation becomes: $Yt' = A' + B't$

Estimation of Parameters:

The parameters A' and B' were estimated using the least squares method. Two key equations were derived for this purpose

$$\sum_{t=1}^{n} Yt' = nA' + B' \sum_{t=1}^{n} t \quad \ldots(3)$$

$$\sum_{t=1}^{n} tYt' = A' \sum_{t=1}^{n} t + B' \sum_{t=1}^{n} t^2 \quad \ldots(4)$$

Solving these 4 equations and multiplying equation 3 by on both sides and multiplying equation 4 by $\sum_{t=1}^{n} t$ on both sides we get,

$$B' = \frac{n\sum_{t=1}^{n} tY_t' - \sum_{t=1}^{n} Y_t' \sum_{t=1}^{n} t}{n\sum_{t=1}^{n} t^2 - \left(\sum_{t=1}^{n} t\right)^2}$$

and

$$A' = \sum_{t=1}^{n} Y_t' \left(\sum_{t=1}^{n} Y_t' - B' \sum_{t=1}^{n} t\right)/n$$

Compound Growth Rate = (Antilog B – 1) × 100

Coppock's Instability Index

Coppock's instability index was used to assess the variability or instability in the production of cereal crops. Coppock's Instability Index = $Antilog\left(\sqrt{vlog} - 1\right) \times 100$

where, $vlog = \left(\sum_{t=1}^{n} log\frac{X_{t+1}}{X_t} - m\right)^2$, X_t denotes the production in year t and m is the mean of the logarithm of X_t.

RESULTS AND DISCUSSION

1. Compound Growth Rate and Instability Index of yield of Rice during *Kharif* and *Rabi* season

Table 1: Compound Growth Rate and Coppock's Instability Index for yield of rice in*kharif* and *rabi* seasons for the districts of western Odisha and the state as a whole

Districts	*Kharif*		*Rabi*	
	CGR	CII	CGR	CII
Balangir	0.852	27.098	0.845	12.202
Bargarh	0.335	15.624	0.569	11.478
Deogarh	0.628	18.511	0.591	13.231
Jharsuguda	-0.067	20.476	0.236	12.533
Kalahandi	0.657	17.928	0.993	12.314
Nuapada	0.793	21.477	1.058	13.885
Sambalpur	0.205	16.636	0.575	11.480
Sonepur	0.716	15.016	0.847	11.427
Sundargarh	0.810	16.711	0.663	11.826
Odisha	0.499	14.038	0.603	10.915

Table 1 highlights that during the study period (1993-94 to 2015-16), rice yields in Odisha and Western Odisha's districts generally exhibited positive compound growth rates in both *kharif* and *rabi* seasons, with exceptions. In the *kharif* season, Balangir led with the highest growth rate of 0.852% per annum, while Jharsuguda had a negative growth rate of -0.067%, the lowest among all districts. Similarly, in the *rabi* season, Nuapada showed the highest growth rate at 1.058% per annum, and Jharsuguda again had the lowest at 0.236%. The variability in rice yields, assessed using Coppock's Instability Index, was notable, with Balangir showing the highest variability (27.098%) in the *kharif* season, and Nuapada leading in the *rabi* season with 13.885%. These fluctuations may be linked to rainfall variability or other climatic factors.

Compound Growth Rate and Instability Index of yield of Maize during *Kharif* and *Rabi* season

Table 2 reveals that maize yields in Western Odisha exhibited a positive compound growth rate during the *kharif* season from 1993-94 to 2015-16, with Kalahandi leading at 1.749 percent per annum and Bargarh trailing at 0.372 percent. The variability in maize yield, assessed using Coppock's Instability Index, was 11.213 percent statewide, with Bargarh showing the highest variability at 13.878 percent and Sonepur the lowest at 11.642 percent, likely due to rainfall fluctuations.

Table 2: Compound Growth Rate and Coppock's Instability Index for yield ofmaize in *kharif* and *rabi* seasons for the districts of western Odisha and the state as a whole.

Districts	*Kharif*		*Rabi*	
	CGR	CII	CGR	CII
Balangir	14.603	12.333	1.298	12.156
Bargarh	0.372	13.878	0.124	11.579
Deogarh	0.473	12.102	0.303	12.228
Jharsuguda	0.646	13.626	0.184	11.402
Kalahandi	1.749	12.076	1.697	12.757
Nuapada	0.938	13.501	1.076	12.619
Sambalpur	0.451	12.991	0.322	11.957
Sonepur	1.251	11.642	1.201	11.227
Sundargarh	0.416	12.607	0.614	14.101
Odisha	1.011	11.213	1.277	11.374

In the *rabi* season, maize yields also demonstrated a positive compound growth rate, with the state average at 1.277 percent per annum. Within Western Odisha, Kalahandi had the highest growth rate of 1.697 percent, while Bargarh had the lowest at 0.124 percent. Variability during the *rabi* season

was 11.374 percent statewide, with Sundargarh exhibiting the highest variability at 14.101 percent, possibly due to rainfall or other climatic factors.

Compound Growth Rate and Instability Index of yield of Ragi during *Kharif* and Wheat in Rabi season

The analysis in Table 3 reveals that ragi yields in Odisha experienced a positive compound growth rate during the *kharif* season, with notable increases in districts such as Sonepur, Nuapada, Kalahandi, Balangir, and Sundargarh from 1993-94 to 2015-16. Kalahandi recorded the highest growth rate at 0.783% per annum, while Sambalpur and Jharsuguda showed the lowest at -0.344% per annum, with Bargarh and Deogarh also exhibiting negative growth. The variability in ragi yields, assessed using Coppock's Instability Index, was 11.798% for the state. Sundargarh had the highest variability at 14.060%, while Balangir had the lowest at 12.241%, which may be attributed to fluctuations in rainfall.

Table 3: Compound Growth Rate and Coppock's Instability Index for yield of ragi in *kharif* and wheat in *rabi* seasons for western Odisha and the state as a whole

Districts	Ragi (*Kharif*)		Wheat (*Rabi*)	
	CGR	CII	CGR	CII
Balangir	0.371	12.241	0.371	11.282
Bargarh	-0.184	12.731	-0.101	11.263
Deogarh	-0.190	12.578	-0.110	12.468
Jharsuguda	-0.344	13.628	-0.110	12.111
Kalahandi	0.783	13.206	0.765	12.536
Nuapada	0.409	13.370	0.529	12.943
Sambalpur	-0.344	13.628	0.139	11.492
Sonepur	0.669	13.231	0.559	11.773
Sundargarh	0.017	14.060	0.147	11.479
Odisha	0.227	11.799	0.160	10.587

For wheat, Table 3 indicates that yields during the *rabi* season displayed a positive compound growth rate in most districts of Western Odisha, excluding Jharsuguda, Deogarh, and Bargarh. The overall growth rate for wheat yields in the state was 0.160% per annum. Kalahandi led with a growth rate of 0.765% per annum, while Jharsuguda and Deogarh had the lowest at -0.110% per annum, followed by Bargarh at -0.101%. The variability in wheat yields, measured using Coppock's Instability Index, was 10.578% for the state, with Nuapada exhibiting the highest variability at 12.943%, potentially due to climatic factors or rainfall variations.

2. Rank classification of the districts of Western Odisha according to the growth rate and instability index of major cerealcrops

Table 4 illustrates the district rankings based on compound growth rate and Coppock's instability index, highlighting their performance across seasons. In the *kharif* season, Balangir ranks highest in both compound growth rate and Coppock's instability index (rank 1), indicating strong rice yields but with high instability, as the performance varies annually. In contrast, Sonepur, with a compound growth rank of 4 and an instability index rank of 9, shows both high stability and solid performance. During the *rabi* season, Nuapada also ranks highest in both metrics (rank 1), reflecting excellent yields but significant instability. Conversely, Sonepur ranks 3rd in compound growth rate and 9th in instability, showcasing stability and good performance. Sonepur's instability is consistent across both seasons, indicating stable yields, while Nuapada's high rankings in both measures during *rabi* season highlight notable yield instability. Sambalpur maintains a uniform ranking (rank 7) for both metrics in the *rabi* season.

Table 4: Classification of the districts of western Odisha on the basis of their ranks with respect to Compound Growth Rate and Coppock's Instability Index for yield under rice in *kharif* and *rabi* seasons

Districts	*Kharif*		*Rabi*	
	Rank of the districts according to CGR	Rank of the districts according to CII	Rank of the districts according to CGR	Rank of the districts according to CII
Balangir	1	1	4	5
Bargarh	7	8	8	8
Deogarh	6	4	6	2
Jharsuguda	9	3	9	3
Kalahandi	5	5	2	4
Nuapada	3	2	1	1
Sambalpur	8	7	7	7
Sonepur	4	9	3	9
Sundargarh	2	6	5	6

Table 5 presents a comparative ranking of districts based on their compound growth rate and Coppock's instability index. In the *kharif* season, Balangir ranks highest (rank 1) for the compound growth rate of rice area but is lower (rank 6) in Coppock's instability index, indicating good performance in rice yield but higher instability in maize. In contrast, Bargarh shows high instability with minimal growth in rice area. During the *rabi* season, Kalahandi ranks first for the compound growth rate of maize yield and second for instability, reflecting strong performance but with some instability. Sundargarh, however, has a lower growth rank (rank 5) and the highest instability (rank 1), showing significant variability. Sonepur displays high instability in both seasons, highlighting considerable yield variability in maize.

Table 5: Classification of the districts of western Odisha on the basis of their ranks with respect to Compound Growth Rate and Coppock's Instability Index for yield under maize in *kharif* and *rabi* seasons

Districts	*Kharif*		*Rabi*	
	Rank of the districts according to CGR	**Rank of the districts according to CII**	**Rank of the districts according to CGR**	**Rank of the districts according to CII**
Balangir	1	6	2	5
Bargarh	9	1	9	7
Deogarh	6	7	7	4
Jharsuguda	5	2	8	8
Kalahandi	2	8	1	2
Nuapada	4	3	4	3
Sambalpur	7	4	6	6
Sonepur	3	9	3	9
Sundargarh	8	5	5	1

Table 6 indicates that in the kharif season, Kalahandi ranks highest (rank 1) for the compound growth rate of ragi yield but is 6th for Coppock's instability index, reflecting strong yield performance with some instability. In contrast, Sambalpur is ranked 9th for growth rate and 3rd for instability, showing considerable performance instability. In the rabi season, Kalahandi leads with the highest compound growth rate for wheat (rank 1) but is 2nd for Coppock's instability index, suggesting unstable performance despite high growth. Nuapada, however, ranks 3rd for growth rate and 1st for instability, indicating high instability in wheat yield. Notably, Kalahandi and Balangir maintain consistent rankings for compound growth rate, with Kalahandi at rank 1 and Balangir at rank 4, across both seasons and crops.

Table 6: Classification of the districts of western Odisha on the basis of their ranks withrespect to Compound Growth Rate and Coppock's Instability Index for yield under ragi in *kharif* and wheat in *rabi* seasons

Districts	ragi (*Kharif*)		wheat (*Rabi*)	
	Rank of the districts according to CGR	**Rank of the districts according to CII**	**Rank of the districts according to CGR**	**Rank of the districts according to CII**
Balangir	4	9	4	8
Bargarh	6	7	7	9
Deogarh	7	8	8	3
Jharsuguda	8	2	9	4
Kalahandi	1	6	1	2
Nuapada	3	4	3	1
Sambalpur	9	3	6	6
Sonepur	2	5	2	5
Sundargarh	5	1	5	7

3. Study of Comparison of CGR and Instability index of rice andmaize between *kharif* and *rabi* seasons

Fig. 1 reveals that the Compound Growth Rate of rice yield is generally lower in the *kharif* season compared to the rabi season across Western Odisha districts such as Bargarh, Jharsuguda, Kalahandi, Nuapada, Sambalpur, and Sonepur. Balangir, however, shows no notable difference in growth rates between the two seasons. In contrast, Deogarh and Sundargarh exhibit a higher growth rate during *kharif* than *rabi*. Sambalpur, in particular, demonstrates a significant variation in growth rates between *kharif* and *rabi* seasons.

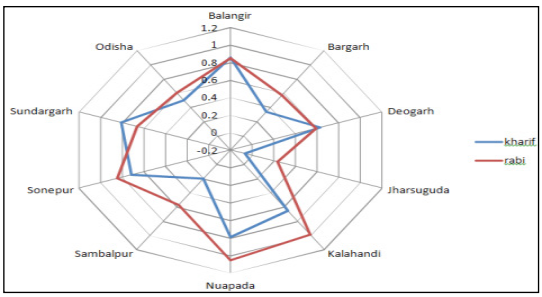

Fig. 1: Radar graph showing Compound Growth Rate of yield under rice crop during *kharif* and *rabi* season for the districts of Western Odisha and the stateas a whole

Fig. 2 indicates that rice yield instability is notably higher during the *kharif* season across the state compared to the *rabi* season. This trend is evident in districts like Balangir, Bargarh, and Sonepur, where *kharif* yields show more instability. However, districts such as Deogarh, Jharsuguda, Kalahandi, Nuapada, and Sundargarh experience greater instability during the *rabi* season. Among them, Deogarh and Nuapada exhibit significant yield variation between kharif and rabi seasons.

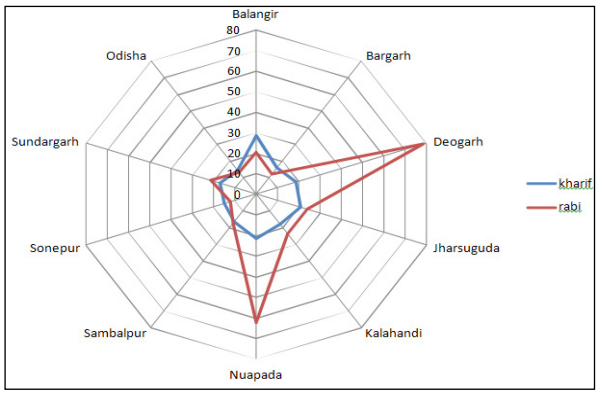

Fig. 2: Radar graph showing Coppocks Instability Index of yield under rice crop during *kharif* and *rabi* season for the districts of Western Odisha and thestate as a whole

Fig. 3 shows that the Compound Growth Rate of maize yield is lower during the *kharif* season compared to the *rabi* season across the state, a trend observed in districts of Western Odisha such as Balangir, Bargarh, Kalahandi, Nuapada, Sambalpur, and Sonepur. These districts all exhibit reduced maize yield growth in *kharif* relative to *rabi*. Conversely, districts like Deogarh, Jharsuguda, and Sundargarh display a higher Compound Growth Rate of area in *kharif* than in *rabi*. Additionally, Kalahandi and Nuapada show a notable variation in the Compound Growth Rate of area between the two seasons.

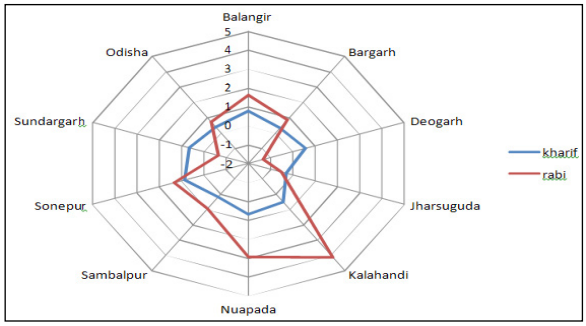

Fig. 3: Radar graph showing Coppocks Instability Index of yield under maize cropduring *kharif* and *rabi* season for the districts of Western Odisha and the state as a whole.

Fig. 4 shows that maize yield instability is lower in the *rabi* season compared to the *kharif* season across the state. This pattern is evident in districts like Balangir, Bargarh, and Sonepur, where *rabi* season yields are more stable. However, in districts such as Deogarh, Jharsuguda, Kalahandi, Nuapada, Sambalpur, and Sundargarh, instability increases in *rabi* relative to *kharif*. Deogarh and Nuapada, in particular, display significant fluctuations in maize production between the two seasons.

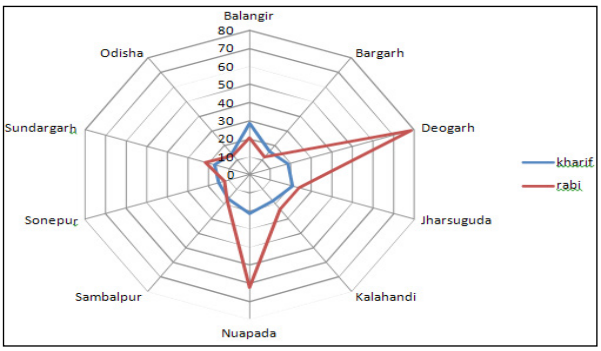

Fig. 4: Radar graph showing Coppocks Instability Index of yield under maize cropduring *kharif* and *rabi* season for the districts of Western Odisha and the state as a whole

Fig. 5 shows that the Compound Growth Rate (CGR) of maize production is lower in the *kharif* season compared to the *rabi* season across the state. This pattern is observed in Western Odisha districts such as Balangir, Bargarh, Kalahandi, Nuapada, Sambalpur, and Sonepur, where maize production growth is higher in *rabi*. In contrast, districts like Deogarh, Jharsuguda, and Sundargarh display the opposite trend, with greater CGR in kharif. Furthermore, Kalahandi and Nuapada exhibit a significant variation in CGR for maize area between the two seasons.

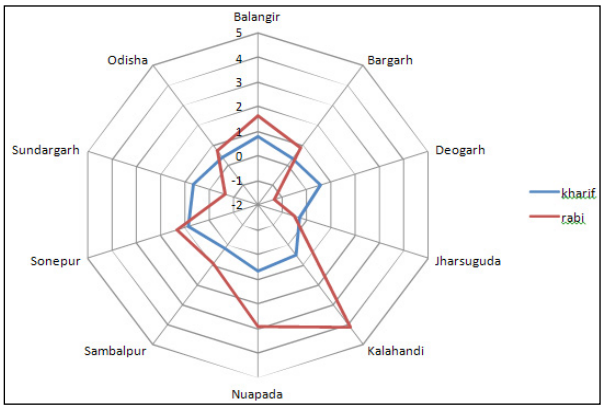

Fig. 5: Radar graph showing Compound Growth Rate of yield under maize crop during *kharif* and *rabi* season for the districts of Western Odisha and the stateas a whole.

Fig. 6 illustrates that maize production instability is lower during the *rabi* season compared to the *kharif* season across the state. This pattern is evident in districts such as Balangir, Bargarh, and Sonepur, where maize production is more stable in *rabi*. However, in districts like Deogarh, Jharsuguda, Kalahandi, Nuapada, Sambalpur, and Sundargarh, instability increases during *rabi*. Particularly, Deogarh and Nuapada show significant variations in maize production between the two seasons.

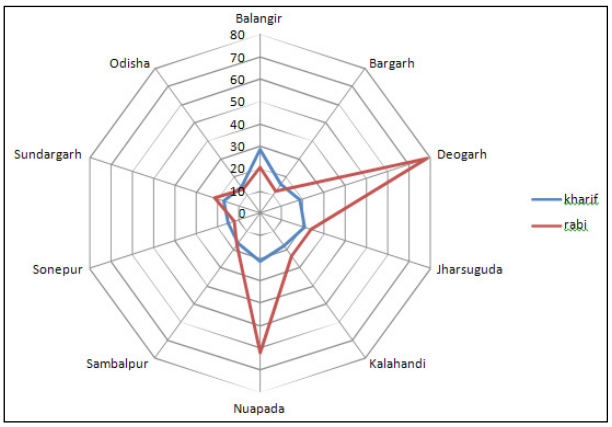

Fig. 6: Radar graph showing Coppocks Instability Index of yield under maize cropduring *kharif* and *rabi* season for the districts of Western Odisha and the state as a whole

CONCLUSION

The study indicates that rice yields in Western Odisha exhibited positive compound growth rates across both *kharif* and *rabi* seasons, with Balangir and Nuapada showing the highest growth rates in *kharif* and *rabi* seasons respectively, while Jharsuguda consistently exhibited the lowest growth rates. Instability, as measured by Coppock's Instability Index, was generally higher in the kharif season for rice, though districts such as Deogarh and Nuapada experienced greater instability in the *rabi* season. Maize yields also demonstrated positive growth rates in both seasons, with Kalahandi leading in kharif and Nuapada in *rabi*, though instability was lower in *rabi* for most districts, including Balangir and Sonepur. For ragi, Kalahandi achieved the highest growth rate in kharif but faced significant instability, while wheat yields showed a positive growth rate in *rabi* with Kalahandi leading, albeit with considerable instability. Rankings revealed that high growth rates often corresponded with high instability, with districts like Kalahandi and Nuapada showing significant variations across seasons. These findings highlight the substantial seasonal variability in crop yields and instability, which are influenced by regional and climatic factors.

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