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Analysing the Growth and Instability of Cereal Crop Production Across Kharif and Rabi Seasons in Western Odisha, India

Ravi Ranjan Kumar [a], Moumita Baishya [b*], Anupam Panigrahi [c] and Kakali Das [b]

[a] Department of Agricultural Statistics, College of Horticulture and Research Station, Saja, Bemetara, 491993, India.
[b] The Graduate School, ICAR-Indian Agricultural Research Institute, New Delhi-110 012, India.
[c] College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar-751003, Odisha, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Over the past decade, agricultural development in India has evolved significantly due to a range of influencing factors. In Odisha, the agricultural sector is particularly susceptible to risks and uncertainties, making it crucial to assess growth and instability. This study provides an in-depth analysis of the compound growth rate and Coppock's Instability Index for four major cereal crops-rice and maize for both Kharif and Rabi seasons, as well as ragi and wheat, each in their respective

**Corresponding author: E-mail: moumitabaishya1194@gmail.com;*

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seasons. Utilizing secondary data spanning from 1993-94 to 2022-23, the research evaluates and compares the growth and instability of production of these crops across districts in Western Odisha. The study also ranks districts based on these metrics, offering a detailed comparison between Kharif and Rabi seasons. The results highlight differences in growth trends and instability levels among the crops, providing valuable insights into the agricultural patterns and challenges faced by the region. The final findings reveal that rice tends to have lower growth rates but greater stability in the kharif season compared to the rabi season, while maize shows overall positive growth. Ragi struggles with negative growth during the kharif season, and wheat experiences declining growth in the rabi season.

Keywords: Compound growth rate; coppock's instability index; growth rate; CGR; temporal analysis.

1. INTRODUCTION

Agriculture plays a pivotal role in the economic landscape of Odisha, contributing approximately 17% to the state's Gross State Domestic Product (GSDP) and 18% to India's overall Gross Domestic Product (GDP). Beyond its substantial impact on state income, agriculture is vital for food security and employment, engaging around 60% of Odisha's workforce and directly or indirectly involving about 70% of its population. With a total geographical area of 155.71 lakh hectares, Odisha's cultivated land spans 61.80 lakh hectares, with 53.31 lakh hectares dedicated to crops, representing 34% of the state's land area **(**Odisha Economic Survey Reports**).** The state's agricultural sector is distinguished by its significant rice production, contributing nearly 10% of India's total rice output, supported by favourable climatic conditions and fertile soils. Despite these advantages, Odisha's agriculture faces considerable challenges. Natural calamities and fluctuating rainfall patterns often disrupt crop production, leading to variability and instability in growth rates and economic outcomes. For instance, the food grain production peaked at 114 lakh metric tons in 2012-13 but suffered setbacks due to adverse conditions like Cyclone Phailin and heavy rains in 2013-14. Nonetheless, Odisha's agriculture sector has demonstrated resilience, meeting food demands and adapting to population growth through a combination of infrastructure, technology, policy support, and political will. Cereal crops, particularly rice, maize, and ragi, are central to the state's agricultural economy. Rice, along with wheat and maize, provides about 60% of the dietary energy and protein derived from plant sources, with rice alone supplying 40% of protein in the Asian diet. Maize, the third most important food crop in India, contributes significantly to the agricultural GDP and employment, with potential for value-added products such as quality protein maize (QPM) and baby corn.

Instability in agricultural production poses a critical challenge, influencing market fluctuations and price volatility. These instabilities can adversely affect both consumers, who face fluctuating food prices, and farmers, who may misallocate resources due to unpredictable prices. Understanding and addressing these variabilities is essential for effective agricultural planning and sustainable development. While previous studies have explored agricultural growth and instability in regions such as Tamil Nadu, there remains a need for comprehensive research on the instability of cereal crops in Odisha, particularly focusing on the district level. Previous research has contributed significantly to understanding the patterns of agricultural growth and instability. For instance, Baishya and Kumar [1] used the GARCH model to forecast onion price volatility, while Bhatnagar and Saxena [2] estimated wheat production in Haryana. Studies by Dash et al. [3], Ghosh and Sahu [4] and Kachroo et al. [5] investigated food grain growth and instability in Odisha, rice in West Bengal, and maize in Jammu and Kashmir. Dhakre and Amod [6] analyzed maize growth in Nagaland, and Jha and Khare [7] alongside Kumar and Kumar [8] examined chickpea production in Madhya Pradesh and India. Gupta and Chandran [9] and Prajneshu and Chandran [10] offered insights into compound growth rates in agriculture. Kumar and Baishya [11] forecasted potato prices using ARIMA, while Kumar and Singh [12] studied sugarcane trends in Haryana. Mander and Sharma [13] and Singh and Chandran [14] explored cereal crop performance in India and Madhya Pradesh, and Lal et al. [15] assessed resource productivity in Bihar. Mazumdar and Das [16] focused on pulse production in Assam, and Patel and Sharma [17] analyzed maize instability in Uttar Pradesh. Shankar et al. [18] compared kharif and rabi crops in Chhattisgarh, and Singh et al. [19] looked at cereal crop stability across different regions. Singh and Rao [20] studied sugarcane in Maharashtra, and Singh and Srivastava [21] examined it in Uttar Pradesh. Other significant studies include Vani and Vyasulu [22] on Karnataka's cereal crops, Toncheva et al. [23] on wheat yield variability in Bulgaria, and Prasher and Bahl [24] on Himachal Pradesh agriculture. Purbia [25] and Shete et al. [26] provided detailed analyses of trends in Rajasthan and Maharashtra, respectively. This diverse body of research offers a comprehensive view of agricultural dynamics, capturing both regional and crop-specific nuances. This study aims to fill this gap by analysing the compound growth rates and instability of key cereal crops in Western Odisha, providing valuable insights for enhancing agricultural stability and development in the region.

2. MATERIALS AND METHODS

2.1 Data Collection

This study undertakes a comprehensive analysis of key cereal crops in Western Odisha, with a specific focus on rice, maize, ragi, and wheat. The analysis spans from the agricultural years 1993-94 to 2022-23, providing a broad temporal perspective on the trends and patterns associated with these crops. To capture seasonal variations and their impact, the study incorporates data from both the kharif and rabi seasons. By examining these two distinct cropping periods, the research aims to offer a detailed understanding of how seasonal factors influence the growth, production, and yield of these major cereal crops in the region.

2.2 Data Sources

The data for this research were acquired from secondary sources provided by the Directorate of Agriculture and Food Production, Government of Odisha. In particular, the study relies on the comprehensive datasets available in the Odisha Agriculture Statistics volumes. These volumes offer detailed and extensive information on the production levels of selected cereal crops, systematically compiled from various districts throughout Western Odisha. This robust dataset forms the foundation for analyzing agricultural trends and performance in the region.

2.3 Analytical Methods

2.3.1 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:

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

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:

$$log\, Yt = Log\, a\, +\, tLog\, b \quad (2)$$

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

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

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

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

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

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

Calculation of Compound Growth Rate

Compound Growth Rate $= (Antilog\, B - 1) \times 100$

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.

3. RESULTS AND DISCUSSION

3.1 Compound Growth Rate and Instability Index of Production of Rice during Kharif and Rabi Season

The analysis of rice production data in Western Odisha from 1993-94 to 2022-23 reveals varying compound growth rates (CGR) across districts during the kharif and rabi seasons. In the kharif season, Sonepur recorded the highest CGR at 0.864% per annum, while Jharsuguda exhibited a negative CGR of -0.290%. Sambalpur and Bargarh also showed positive growth, but their rates were significantly lower than Sonepur's. The Coppock's Instability Index (CII) for kharif rice production varied widely, with Balangir having the highest CII at 28.255%, indicating significant production fluctuations, while Sonepur had the lowest at 15.035%. In the rabi season, the state-level CGR was 0.701%, with Kalahandi achieving the highest CGR of 4.153% per annum, whereas Deogarh, Jharsuguda, and Sundargarh experienced negative growth rates. Deogarh exhibited the highest CII at 78.463%, reflecting considerable instability in production. Variability in rice production across both seasons appears to be influenced by climatic factors, particularly rainfall.

3.2 Compound Growth Rate and Instability Index of Production of Maize during Kharif and Rabi Season

In the kharif season, all districts in Western Odisha exhibited a positive Compound Growth Rate (CGR) in maize production, with Kalahandi recording the highest CGR at 3.334% per annum, indicating robust growth. Sundargarh had the lowest CGR at 0.644% per annum, followed by Bargarh (1.266%) and Deogarh (1.406%). The Coppock's Instability Index (CII) revealed a state-level variability of 11.509%, with Sonepur experiencing the highest instability (CII of 15.908%) and Balangir the lowest (CII of 13.226%) [27]. This variability may be attributed to climatic factors, including rainfall. For the rabi season, maize production showed a positive CGR across the region, except for Deogarh, which recorded a negative CGR of -0.304%. The state-level CGR for maize during this season was 2.262%, with Kalahandi achieving the highest CGR at 4.090%. The CII for the rabi season was 13.063%, with Kalahandi exhibiting the highest instability at 19.135%. This instability is likely influenced by similar climatic factors.

3.3 Compound Growth Rate and Instability Index of Production of Ragi during Kharif and Wheat in Rabi Season

Ragi production during the kharif season exhibited a predominantly negative compound growth rate (CGR) across most districts of Western Odisha. Notably, the districts of Sonepur and Sundargarh deviated from this trend, recording positive growth rates. Sundargarh achieved the highest CGR of 0.548% per annum, while the districts of Sambalpur and Jharsuguda experienced the lowest CGRs of -2.797% and -2.380% per annum, respectively. The Coppock's Instability Index (CII) for ragi production across the state was calculated at 12.490%, reflecting the overall variability in production. Among the districts, Nuapada displayed the highest instability, with a CII of 27.442%, indicating significant production fluctuations. Conversely, Kalahandi reported the lowest variability, with a CII of 14.713%, suggesting relatively stable production levels [28]. The observed variability in ragi production across these districts may be largely attributed to fluctuations in rainfall and other climatic factors. For wheat production during the rabi season, a negative compound growth rate was observed across Odisha and most districts of Western Odisha, with the exception of Kalahandi, which demonstrated positive growth. The state-level CGR for wheat was -0.532% per annum. Within Western Odisha, Kalahandi exhibited the highest growth rate at 1.433% per annum, while Jharsuguda recorded the lowest CGR at -1.810% per annum. Other districts, including Deogarh (-1.434%) and Balangir (-1.353%), also experienced negative growth rates. The Coppock's Instability Index for wheat production

Table 1. Compound growth rate and coppock's instability index for production 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	0.758	28.255	1.602	20.239
Bargarh	0.302	15.712	0.840	11.902
Deogarh	0.569	18.645	-1.329	78.463
Jharsuguda	-0.290	20.875	-0.505	24.031
Kalahandi	0.532	18.224	4.152	23.909
Nuapada	0.701	21.725	2.951	62.534
Sambalpur	0.205	16.810	0.967	17.660
Sonepur	0.864	15.035	1.336	12.163
Sundargarh	0.652	17.073	-0.651	21.393
Odisha	**0.365**	**14.188**	**0.701**	12.938

Table 2. Compound growth rate and coppock's instability index for production 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	2.259	13.226	2.022	14.905
Bargarh	1.266	15.226	1.139	14.075
Deogarh	1.406	13.735	-0.304	14.768
Jharsuguda	2.200	15.817	0.680	16.470
Kalahandi	3.334	13.345	4.090	19.135
Nuapada	2.390	13.799	3.188	18.838
Sambalpur	1.955	14.996	1.908	16.546
Sonepur	2.013	15.908	1.662	15.930
Sundargarh	0.644	13.378	1.104	15.671
Odisha	1.733	11.510	2.262	13.063

in the rabi season was found to be 13.255% for the state. Jharsuguda displayed the highest instability, with a CII of 27.402%, indicating substantial production variability. This heightened instability may be attributed to variations in rainfall and other climatic factors impacting wheat production stability [29].

3.4 Rank Classification of the Districts of Western Odisha According to the Growth Rate and Instability Index of Major CerealCrops

Table 4 highlights district rankings in Western Odisha for rice production based on compound growth rate (CGR) and Coppock's Instability Index (CII) for both kharif and rabi seasons. In the kharif season, Sonepur ranks highest in CGR (Rank 1) and lowest in CII (Rank 9), indicating robust growth and stability. Conversely, Balangir, while second in CGR (Rank 2), shows the highest instability with a CII rank of 1. For the rabi season, Kalahandi leads in CGR (Rank 1) but has a moderate instability (CII rank 4). Sonepur ranks fourth in CGR and eighth in CII, reflecting strong stability and performance.

Table 5 shows Kalahandi leads in maize production growth (rank 1) but faces high instability (rank 9). Balangir, with a CGR rank of 3, is more stable (rank 8), while Sonepur exhibits significant production instability. For the rabi season, Kalahandi ranks 1st in both CGR and CII, indicating high growth and instability. Deogarh, ranked 9th in both metrics, demonstrates lower growth with greater stability.

Table 3. Compound growth rate and coppock's instability index for production of ragi in kharif and wheat in rabi seasons for the districts of western Odisha and the state as awhole

Districts	Ragi (Kharif)		Wheat (Rabi)	
	CGR	CII	CGR	CII
Balangir	-2.228	16.392	-1.353	14.387
Bargarh	-0.226	16.498	-1.265	17.208
Deogarh	-2.379	15.684	-1.434	24.762
Jharsuguda	-2.797	17.614	-1.899	27.402
Kalahandi	-1.029	14.713	1.433	20.598
Nuapada	-0.452	27.442	-0.415	16.212
Sambalpur	-2.797	17.614	-0.425	15.866
Sonepur	0.081	15.189	-0.831	13.178
Sundargarh	0.548	15.774	-0.486	13.829
Odisha	-0.085	12.490	-0.532	13.255

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 productionunder rice in kharif and rabi seasons

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

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 productionunder maize in kharif and rabi seasons

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

3.4.1 Ragi production in kharif season

Table 5 reveals that Sundargarh leads in the kharif season with the highest compound growth rate (CGR) for ragi production (Rank 1). However, its Coppock's Instability Index (CII) rank is 6, indicating substantial growth but moderate production stability. Conversely, Nuapada, ranked 4th for CGR, exhibits the highest instability with a CII rank of 1, reflecting significant variability in ragi production despite favorable growth.

3.4.2 Wheat production in rabi season

In the rabi season, Kalahandi ranks highest (Rank 1) for CGR in wheat production, yet it holds a CII rank of 3, suggesting notable instability despite superior growth. Jharsuguda, with a CGR rank of 9, demonstrates exceptional stability with the top CII rank of 1, indicating consistent production but less pronounced growth.

3.5 Study of Comparison of CGR and Instability Index of Rice and Maize between Kharif and Rabi Seasons

Fig. 1 reveals that the Compound Growth Rate (CGR) for rice production during the kharif season is generally lower than in the rabi season at the state level. This pattern is mirrored in districts such as Balangir, Bargarh, Kalahandi, Nuapada, Sambalpur, and Sonepur. However, Deogarh, Jharsuguda, and Sundargarh diverge

Table 6. 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 productionunder ragi in kharif and wheat in rabi seasons

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

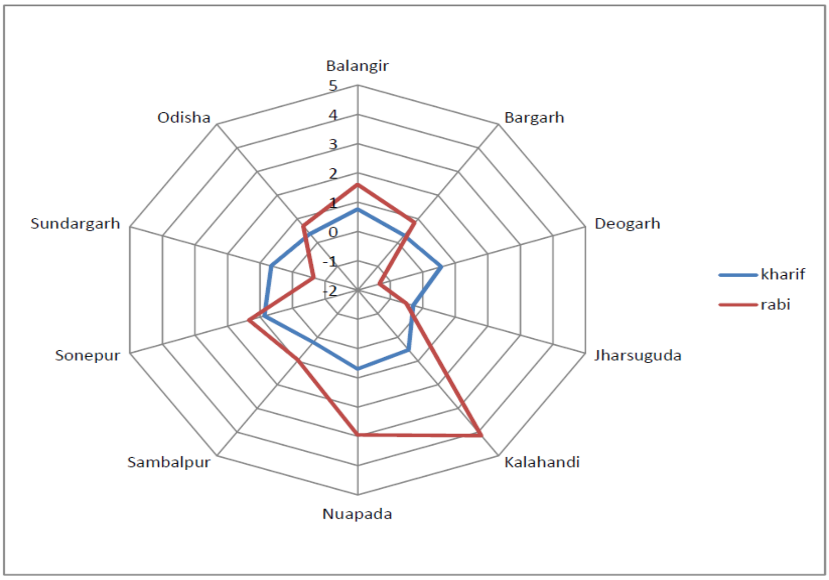

Fig. 1. Radar graph showing compound growth rate of production under rice crop during kharif and rabi season for the districts of Western Odisha and thestate as a whole

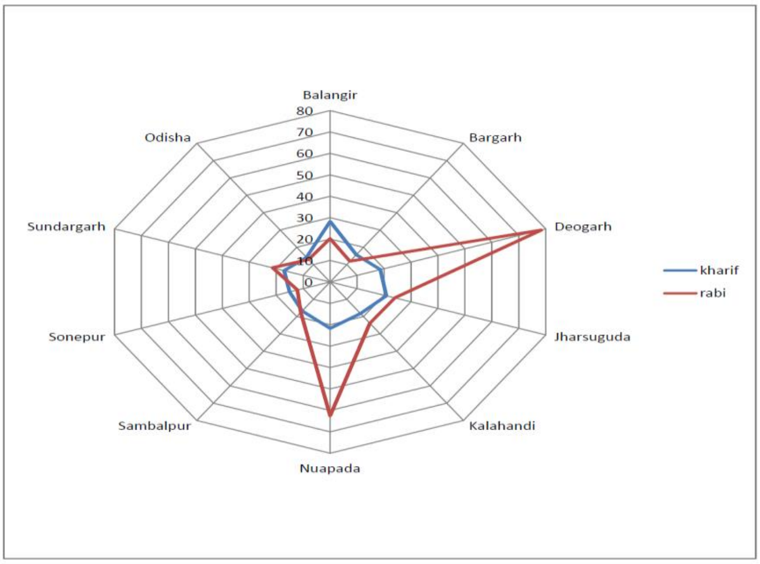

Fig. 2. Radar graph showing coppocks instability Index of production under rice crop during kharif and rabi season for the districts of Western Odisha and thestate as a whole

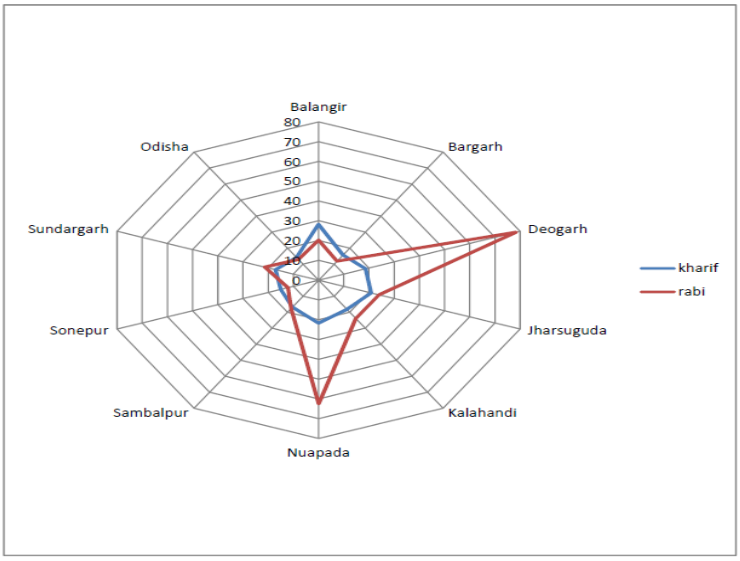

Fig. 3. Radar graph showing Coppocks Instability Index of production under maize cropduring kharif and rabi season for the districts of Western Odisha and the state as a whole

from this trend, exhibiting higher CGRs during kharif compared to rabi. Significantly, Kalahandi and Nuapada show pronounced disparities in CGR between the two seasons, underscoring the impact of seasonal variability on rice production in these regions.

Fig. 2 illustrates a pronounced increase in rice production instability during the rabi season compared to the kharif season at the state level. This pattern is evident in districts like Balangir, Bargarh, and Sonepur, where the rabi season experiences higher instability than the kharif season. Conversely, districts such as Deogarh, Jharsuguda, Kalahandi, Nuapada, Sambalpur, and Sundargarh exhibit greater instability during rabi than kharif. Notably, Deogarh and Nuapada demonstrate significant variations in production between the two seasons, emphasizing considerable fluctuations in production stability. This variation underscores the impact of seasonal and regional factors on rice production instability.

Fig. 3 indicates a general decrease in production instability for maize during the rabi season compared to the kharif season at the state level. This trend is evident in districts like Balangir, Bargarh, and Sonepur, where maize production is more stable in rabi than in kharif.

Conversely, districts such as Deogarh, Jharsuguda, Kalahandi, Nuapada, Sambalpur, and Sundargarh show increased instability in rabi season maize production compared to kharif. Deogarh and Nuapada, in particular, exhibit significant fluctuations between the two seasons, with a pronounced rise in instability during rabi.

These findings underscore the differential impact of seasonal and climatic factors on maize production stability across districts [30].

4. CONCLUSION

The comprehensive analysis of cereal crop production in Western Odisha reveals distinct seasonal and district-specific trends. For rice, the kharif season generally exhibits lower growth rates and greater stability compared to the rabi season, where instability is pronounced despite higher growth rates in certain districts like Kalahandi. Maize production displays overall positive growth, but instability varies, with high instability in Kalahandi during the rabi season due to erratic weather. Ragi faces negative growth in the kharif season, likely due to adverse climatic conditions such as inadequate rainfall. Wheat shows declining growth in the rabi season, except in Kalahandi, where better conditions help offset some negative impacts. These findings underscore the significant impact of seasonal and climatic factors on production stability. Future research should focus on optimizing agricultural practices and resource management to mitigate instability and enhance growth, particularly by tailoring strategies to district-specific climatic conditions and seasonal variations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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