IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 18, Issue 6 Ser. 1 (June. 2025), Pp 24-30
www.iosrjournals.org

Growth, Instability and Crop Diversification of Cereals (A Study in Guntur District of Andhra Pradesh)

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Abstract
Cereals are edible grains that belong to the grass family (Poaceae) and are widely cultivated for their carbohydrate-rich seeds, which serve as staple foods for a large portion of the global population. The present study aims to know the growth, instability and crop diversification of Cereals as they are most significant food crops which are grown in large extent and yielding more income to the farmers in Guntur district of Andhra Pradesh with the secondary data for a period of 20 years. This study calculated Linear Growth Rates (LGR), Coefficient of Variation (CV), and Cuddy-Della Valle Index (CDVI) and Herfindahl Index (HI)to analyze the growth, instability and crop diversification of Cereals. The study observed fluctuated growth in production and increasing trend in case of yield, moderate instability in area and yield but low instability in production and moderate crop diversification over the study period.

Key words*: Cereals, Stable Food, Instability, Coefficient of Variation, Cuddy-Della Valle Index, Herfindahl Index, Crop Diversification*

Date of Submission: 11-06-2025 Date of Acceptance: 24-06-2025

I. Introduction:

Guntur district plays a crucial role in Andhra Pradesh state's agricultural growth, contributing significantly to its overall output. Known for its fertile soils, diverse cropping patterns, and extensive irrigation infrastructure, Guntur is one of the most agriculturally vibrant regions of the state. The district mirrors the state's broader growth trends while also exhibiting unique patterns in the cultivation of key crops. Cereals are edible grains that belong to the grass family (Poaceae) and are widely cultivated for their carbohydrate-rich seeds, which serve as staple foods for a large portion of the global population. They provide essential nutrients, including carbohydrates, proteins, fiber, vitamins, and minerals, making them a crucial component of a balanced diet. Over the years, Guntur has been a key contributor to the state's cereal production, primarily cultivating Paddy, Maize, Jowar, Bajra, varagu and Ragi

II. Review of Literature:

Asha Devi et al. (2024) studied the production and utilization of minor millets in Madhya Pradesh, focusing on farmers' challenges and market dynamics and concluded that reviving millet cultivation requires government support, research in varietal development, price stabilization, and awareness campaigns to promote value-added millet products. **Verma et al. (2024)** analyzed the growth performance of major food grain and oilseed crops in Rajasthan in the context of food security. **Krishnan Kutty and Sajeev (2022)** analyzed the growth trends, structural stability, and area under cultivation of food grains in India.

Shafeer et al. (2021) analyzed trends and instability in paddy area, productivity, and production across districts in Andhra Pradesh using secondary data. **Nyiawung et al. (2019)**study examined changes in land under cereal production, cereal yield, and overall production levels **Das et al. (2024)**study employed Compound Annual Growth Rate (CAGR) and Cuddy-Della Valle Instability Index to assess trends in area, yield, and production of twenty major crops. **Faldu et al. (2024)** study covered ten major rice-producing states and five districts in Gujarat, employing CGR, Cuddy-Della Valle Index, Nerlovian Lag Model, and ARIMA for analysis

Dalal et al. (2024) study employed Compound Annual Growth Rate (CAGR) for growth analysis, Coefficient of Variation (CV), Instability Index, and Cuddy Della Valle Index for instability assessment, and regression analysis for trend estimation. **Yamuna et al. (2024)** study applied Compound Growth Rate (CGR), Coefficient of Variation (CV), and Cuddy-Della Valle Index (CDVI) to assess growth trends and instability. **Ralte (2023)** analyzed the growth and instability in the area, production, and productivity of cereals in India using secondary data. Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV), Cuddy-Della Valle Index (CDI), and Coppock's Instability Index (CII) were used for trend and instability analysis.

Ansari and Ansari (2023) study, they used Compound Annual Growth Rate (CAGR) and Cuddy Della Valle Instability Index (CDVI) to assess trends and fluctuations across three sub-periods.**Aiswarya et al. (2024)** analyzed crop diversification trends in the midland region of Kerala, the study employed Simpson Index, Modified Entropy Index, and Markov Chain Analysis to assess diversification patterns. **Meena et al. (2023)** analyzed the nature and extent of crop diversification across districts of Rajasthan. **Areef et al. (2021)** examined income diversification and its determinants among agricultural households in the South Coastal region of Andhra Pradesh. **Singh and Pawariya (2021)** employed the Crop Diversification Index (CDI), Entropy Index, and multiline regression analysis to assess the scope and factors influencing diversification. **Kumar and Gupta (2015)** study concentrated on the Simpson Index of Diversification (SID) and panel regression analysis.

III. Research Methodology:

Objectives of the Study:

This study aims to analyse the growth, instability and crop diversifications of cereals (Paddy, Maize, Jowar, Bajra, Varagu and Ragi) for the period of twenty years from 2002-03 to 2021-22. During this period the superior technology evolved, emerged as the result of evolution of irrigation - fertilizer responsive varieties of crops. Large scale adoption of high yielding varieties enhances the agriculture productivity and production in the state. The study accessed, the production in all type of cereal crops has been increasing year by year because the technology and scientific methods in agriculture are being implemented in agriculture. Thus, the study focuses on area, production and yield, growth and instability and crop diversifications of cereals at Guntur district of Andhra Pradesh.

Tools of Analysis:

(i) Growth Model:

To fulfil the aim and objective of the present research, the following s Linear Regression Model has been considered to analyze area, output and yield growth of cereals crops for aggregate data analysis

$$\mathbf{Y = a + bT}$$

Here:

Y = Area / Production / Yield.

a is the intercept of the function and

b is the coefficient of independent variable of time 't'

T= Independent variable time

The Linear Growth Rate in percent is calculated as

$$\mathrm{L.G.R} = \frac{\hat{b}}{\bar{Y}} * 100$$

$\hat{b}$is the estimated value of 'b' and tested by student 't'-test statistic

$$\mathrm{t} = \frac{\hat{\hat{b}}}{S.E\ (\hat{b})}$$

Were,

$$\mathrm{S.E}(\hat{b}) = \sqrt{\frac{\sum(\mathrm{Y} - \bar{\mathrm{Y}})^2}{\mathrm{N}}}$$

To determine the Instability in area, output and yield of the selected crops, the Co-efficient of Variation (CV) was calculated by the formula, $\mathbf{C.V.} = \frac{\boldsymbol{\sigma}}{\bar{\mathbf{Y}}}\ \mathbf{x\ 100}$

Where: σ = Standard Deviation (SD)

$\bar{Y}$ = Mean value of Area / Production / Yield

(ii)Instability Model:

The Cuddy Della Valle (CDVI) Index is a statistical measure used to quantify the instability of a time series data, particularly in agricultural studies. The use of Co - efficient of Variation (CV) as a measure to show the Instability in time series data has some limitations. If the time series data show a trend, the Coefficient of Variation (CV) captures the variation, meaning a higher CV value indicates greater instability. By taking into account the trend of the data, where a higher CDVI value indicates greater instability in the series; it is calculated by multiplying the coefficient of variation (CV) by the square root of (1 - adjusted R-squared) from a trend regression analysis.

This study incorporates the following **CDV Index** measure to assess instability.

$$\textbf{CDV Index} = \mathbf{C.V} * \sqrt{\mathbf{1 - R^2}}$$

Where, CV is the Coefficient of Variation in percent, and R^2 is the coefficient of determination from time trend regression adjusted by the number of degrees of freedom. The CDV Index value shows, if less than 15 low instability, 15-30 moderate instability and above 30 high instability.

(iii) Crop Diversification Model:

The present study considered Herfindahl Index for crop diversification analysis and is to be calculated by taking sum of squares of acreage proportion of each crop in the total cropped area. The formula for the Herfindahl Index is as follows.

$$H.I = \sum_{i=1}^{N} P_i^2$$

Where, N is total number of crops and P_i is acreage proportion of the i-th crop in total cropped area. The Herfindahl Index would decrease. This index takes a value one when there is a complete specialization and approaches zero as N gets large, that is, if diversification is 'perfect'. It means, Herfindahl Index values range from 0 (perfect diversification, equal proportion of all crops) to 1 (complete specialization, only one crop grown). Higher Herfindahl Index indicates a higher concentration on a single dominant crop, signifying less crop diversity. Lower Herfindahl Index indicates a more diverse cropping system with a wider range of crops. Thus, the present study considered if the obtained value ranged between 0 to 0.33 considered to be complete diversification. If the value lies between 0.34 to 0.66 it indicates moderate diversification and if the value found between 0.67 and 1.0 then it considered as crop specialization. This Index is also called as inverse index of diversification.

IV. Data Analysis:

(i) Growth of Area, Production and Yield of Cereals

In this subsection, the growth trends of cereals cultivated in Guntur district from 2002-03 to 2021-22 have been analyzed across five periods. The 20-year period from 2002-03 to 2021-22 has been divided into four sub-periods: the first period from 2002-07, the second period from 2007-12, the third period from 2012-17, and the fourth period from 2017-22. Additionally, the entire 20-year period has been considered as the total period. The growth trends in the area, production, and yield for Period 1, Period 2, Period 3, Period 4, and the total period have been examined and presented in Table 4.1. Linear Growth Regression function has been used to analyze the growth trends in area, production, and yield of cereals.

Period -1 (2002-03):

Table 4.1 depicts that the estimated value of area is 35603.80, indicating an increase in the cultivated land for cereals at a growth rate of 0.975% per year. It indicates the area of cereals increased by 35603.80hectares every year at 0.975per cent of growth rate during the study period. The estimated value of production is 2001.20, which shows that cereal production increased at a rate of 0.842% per year. It is also observed that the estimated value of yield is 146084.60, and the yield growth rate is 0.848% per year, implying that productivity improvements contributed to the increase in production.

Table: 4.1. Linear Growth Regression of Area, Production and Yield of Cereals in Guntur District of Andhra Pradesh

Period	Area	Production	Yield
Period – 1 (5 Years) 2002-2007	A=-71089032.600+35603.800*t	P=-3996682.400+2001.200*t	Y=-291885164.800+146084.600*t
Period – 2 (5 Years) 2007-2012	A=-2460762.000+1421.300t	P= -2009882.800+1009.900*t	Y= -40022706.200+20808.400t
Period – 3 (5 Years) 2012-2017	A=72393299.600-35776.400*t	P= -1344103.200+677.200*t	Y= 132764459.300-65131.900*t
Period – 4 (5 Years) 2017-2022	A=-27241717.000+13649.400*t	P= 1041537.400-503.800*t	Y= 117414722.000-57131.000*t
Total Period – (20 Years) 2002-2022	A=-431553.974+379.227t	P= -1016484.026+515.030*t	Y= -102220265.432+51581.550*t
Liner Growth Rates (LGR) of Cereals			
Period – 1 (5 Years) 2002-2007	0.975*	0.842*	0.848*

Period – 2 (5 Years) 007-2012	0.081	0.837*	0.150
Period – 3 (5 Years) 2012-2017	0.621*	0.488*	0.364*
Period – 4 (5 Years) 2017-2022	0.952*	0.414*	0.593*
Total Period – (20 Years) 2002-2022	0.034	0.805*	0.693*

Source: Author's calculations
Note: * denotes significant at5% probability level

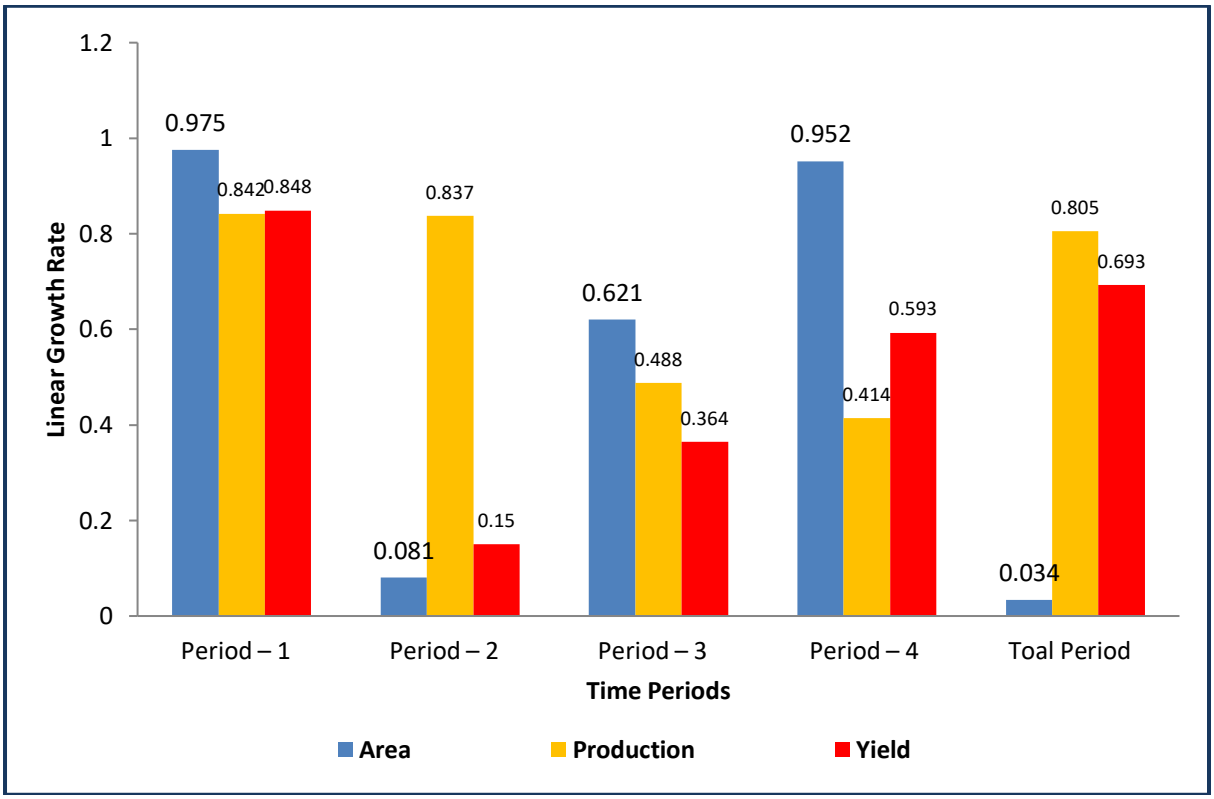

Figure: 4.1. Period-wise growth trends in Area, Production and Yield of Cereals

Period – 2 (2007-2012)
From Table 4.1, it is evident that the estimated value of area is 1421.30, which is significantly lower than in the previous period, indicating stagnation in the expansion of cultivated land. The growth rate of the area is 0.081% per year, showing minimal change. The estimated value of production is 1009.90, with a growth rate of 0.837% per year, reflecting a continued but slower increase in output. However, the estimated value of yield is 20808.40, with a growth rate of 0.150% per year, indicating a significant decline in productivity improvements compared to the previous period.

Period – 3 (2017-2022)
Table 4.1 depicts that the estimated value of area is 13649.40, and the area growth rate is 0.952% per year, indicating a renewed expansion in cultivated land. However, the estimated value of production is negative (-503.80) and its growth rate is 0.414% per year, showing a continued decline in production growth. The estimated value of yield is also negative (-57131.00)in this period, and its growth rate is 0.593% per year, suggesting that productivity improvements remained inconsistent. Despite an increase in the area under cereals, the slower growth in production indicates declining yield efficiency.

Total Period (2002-2022)
For the entire study period, the estimated value of area is 379.227, with an overall growth rate of 0.034% per year, indicating negligible expansion in cultivated land. The estimated value of production is 515.030, and the growth rate of 0.805% per year suggests that production has grown over time, primarily due to yield

improvements rather than area expansion. The estimated value of yield is 51581.550, and its growth rate is 0.693% per year, confirming that productivity played a crucial role in sustaining cereal production.

(ii) Instability in Area, Production and Yield of Cereals:

In this subsection, the variability in area, production and yield of cereals cultivated in Guntur district from 2002-03 to 2021-22 is analyzed in five periods. The variability in area, production, and yield of cereals for Period 1, Period 2, Period 3, Period 4, and the total period was examined and presented in Table 5.1. The coefficient of variation (CV), coefficient of determination (R^2), and CDV volatility index were calculated to analyze the variability in area, production, and yield of cereals.

The instability in the area, production, and yield of cereals over different periods has been analyzed using the Coefficient of Determination (R^2), Coefficient of Variation (CV), and CDV Index.

Period 1 (2002-2007)

During this period, the R^2 values for area, production, and yield were 0.952, 0.708, and 0.718, respectively, indicating a strong relationship between time and area, production, and yield. The CV values for area, production, and yield were 19.46, 23.91, and 26.86, respectively. The CDV Index values were 4.26, 13.02, and 14.26, suggesting low instability in all three parameters.

Table: 4.2. Instability in area, production and yield of Cereals

Period	R^2			CV			CDV Index		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Period – 1 2002-2007	0.952	0.708	0.718	19.46	23.91	26.86	4.26*	13.02*	14.26*
Period – 2 2007-2012	0.007	0.701	0.022	6.97	9.53	12.19	6.95*	5.21*	12.05*
Period – 3 2012-2017	0.385	0.238	0.133	30.03	10.72	18.56	23.55**	9.35*	17.28**
Period – 4 2017-2022	0.907	0.172	0.352	6.87	8.06	7.53	2.09*	7.33*	6.06*
Total Period – 2002-2022	0.001	0.648	0.480	19.86	18.91	27.75	19.86**	11.21*	20.01**

Source: Author's calculations

(* Low Instability, ** Moderate Instability, *** High Instability)

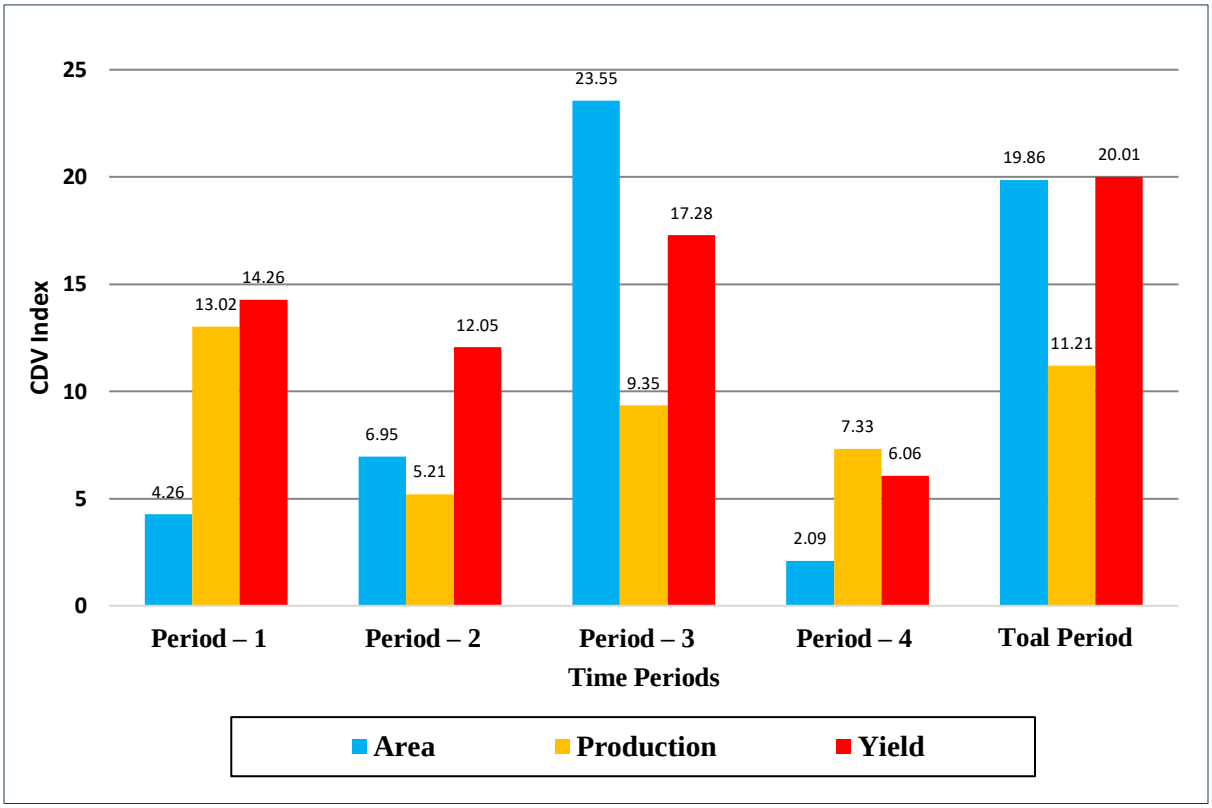

Figure: 4.2Instability in area, production, and yield of Cereals

Period 2 (2007-2012)

The R^2 values for area, production, and yield during this period were significantly lower (0.007, 0.701, and 0.022), indicating weaker trends. The CV values for area, production, and yield were 6.97, 9.53, and 12.19, respectively. The CDV Index values were 6.95, 5.21, and 12.05, all of which indicate low instability in this period.

Period 3 (2012-2017)

In this period, the R^2 values for area, production, and yield were 0.385, 0.238, and 0.133, respectively. The CV values were 30.03, 10.72, and 18.56, reflecting increased variability in the area. The CDV Index values were 23.55 for area (moderate instability), 9.35 for production (low instability), and 17.28 for yield (moderate instability). This period showed moderate instability in area and yield, while production remained relatively stable.

Period 4 (2017-2022)

The R^2 values were 0.907, 0.172, and 0.352, indicating a strong trend for area but weaker trends for production and yield. The CV values were 6.87, 8.06, and 7.53, showing minimal variation. The CDV Index values of 2.09 (area), 7.33 (production), and 6.06 (yield) confirm low instability in all three parameters.

Total Period (2002-2022)

For the entire study period (2002-2022), the R^2 values for area, production, and yield were 0.001, 0.648, and 0.480, respectively, suggesting weak long-term trends in area but stronger relationships for production and yield. The CV values for area, production, and yield were 19.86, 18.91, and 27.75, respectively. The CDV Index values were 19.86 for area (moderate instability), 11.21 for production (low instability), and 20.01 for yield (moderate instability). These results indicate moderate instability in area and yield but low instability in production over the entire study period.

(iii) Crop Diversification in Area of Cereals:

In this subsection, the crop diversification in area of cereals cultivated in Guntur district from 2002-03 to 2021-22 is analyzed in five periods. The crop diversification in area of cereals for Period 1, Period 2, Period 3, Period 4, and the total period was examined and presented in Table 4.3. As shown in table 4.3 during the first period-1 (2002-2007), the Herfindahl Index (HI) was 0.76, indicating crop specialization since the value above 0.67. These values indicate that cereal cultivation in Guntur district was highly concentrated during this period and little effort was made towards diversification.

Table: 4.3 Crop Diversification Index for Cereals

Period	Period- 1(2002-2007)	Period- 2 (2007-2012)	Period- 3 (2012-2017)	Period- 4 (2017-2022)	Total Period(2002-2022)
Herfindahl Index (HI)	0.76*	0.66**	0.60**	0.57**	0.65**

Source: Author's calculations

* Indicates crop specialization, **Indicates moderate crop diversification

The calculated index values are 0.66, 0.60 and 0.57 for the period- 2, period-3and period-4 respectively and the entire study period the calculated crop diversification value is 0.65. These indexed values show moderate crop diversification of cereals, from year 2002-03 to 2021-22, reflecting, the farmers are aware on their cropping pattern and practicing crop rotation for better yield, income towards sustainable cultivation of cereals in Guntur district of Andhra Pradesh.

V. Conclusions:

The study observed fluctuated growth in production and increasing trend in case of yield, moderate instability in area and yield but low instability in production and moderate crop diversification over the study period. The analysis of diversification indices across different time periods highlights a gradual but steady shift from crop specialization to moderate diversification in Guntur district, reflecting, the farmers are aware and practicing crop rotation for better yield, income towards sustainable cultivation of cereals in Guntur district of Andhra Pradesh.

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