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Growth and instability of Rabi pulse production in Odisha: A Statistical Study

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Abstract
The contribution of agriculture towards economy of the state of Odisha is very vast. Cereals and pulses are the major crops of Odisha. In rabi season, pulses are the major crops grown in Odisha. Major pulses grown in Odisha are black gram, green gram, arhar, cowpea chickpea etc. Pulses are important commodity group of crops that provides high quality protein complementing cereal proteins for predominantly substantial vegetative population of the state. An attempt has been made to study the compound growth rate and variability of area, yield and production of pulses for rabi season in the districts of Odisha and the state as a whole. Then the districts of Odisha are ranked on the basis of decreasing compound growth rate and increasing instability index of area, yield and production of rabi pulses. The state of Odisha performs well with respect to area and yield of rabi pulses due to which the performance in production is also found to be good. To get more increment in growth rate of area and yield of rabi pulses along with low degree of instability more area should be brought under assured irrigation during rabi season and adopting improved cultivation practices.

Keywords: Compound growth rate, cuddy-della instability index, production, significant

Introduction
Agriculture being the chief occupation of the people of Odisha has vast contribution on the economy of the state. Major crops grown in Odisha include cereals, pulses, millets, plantation crops like coffee etc. Major pulses grown in Odisha are black gram, green gram, arhar, cowpea chickpea etc. Pulses are important commodity group of crops that provides high quality protein complementing cereal proteins for predominantly substantial vegetative population of the country. Pulses are grown in all the 30 districts of Odisha. Rusikulya plain is the most important agricultural region of Odisha and dominated by pulse crops. Odisha covers nearly about 9% area and 8% production of pulses as compared to the total area and production of pulses in India respectively. Rabi pulses area is 67% contributing 64% of the production with a productivity 481kg/ha. Twenty districts have productivity of 400-500 kg/ha, 9 districts having average yield of >500 kg/ha and one district i.e. Deogarh has productivity of < 400 kg/ha. Dash, *et al*. (2017) [1] studied the growth rate and instability of area, yield and production of food grain in Odisha using the best fit model and the model selected on the basis of scatter plot of the data.

This study helps to the policy makers to get an idea about the future requirements, enabling to take appropriate measures like selection of high yielding varieties, conducting training to farmers to improve cultural practices, adequate supply of inputs and use of latest technologies. Import and export of these pulse crops can also be planned. To study the compound growth rate and variability of area, yield and production of pulses for rabi season in the districts of Odisha and the state as a whole. Then to rank the district of Odisha on the basis of decreasing compound growth rate and increasing instability index of area, yield and production of rabi pulses. The Spearman's rank correlation between compound growth rate and instability index of area, yield and production of rabi pulses.

Keeping in view the above perspectives the study has been made regarding area, yield and production of pulses in all the 30 districts of Odisha for rabi seasons for the period from 1993-94 to 2016-17.

Material and Methods
The study is based on secondary source of data on area, yield and production of pulse crops for rabi season in the districts of Odisha from the period 1993-94 to 2016-17. The data are obtained from various volumes of Odisha Agriculture Statistic published by Directorate of Agriculture and Food Production, Government of Odisha.

Compound growth rate (CGR)
The data on area, production and yield of pulse crops for rabi season in Odisha were worked out for entire period of analysis by fitting to exponential functions as follows.

$Y_t = ab^{t}$

Where,
Y_t = Area / Production / Yield of pulse crops in years.
t = time element which takes the value 1, 2, 3,…..,n
a = intercept; b = regression coefficient

The compound growth model is established in the following manner
$\ln Y_t = \ln a + t \ln b$
$Y_t' = A' + B't$
Let $\ln Y_t = Y_t'$
$\ln a = A'$
$\ln b = B'$

The two generalised equations are

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

$$\sum_{t=1}^{n} Y_t' = nA' + B'\sum_{t=1}^{n} t \quad \text{…equation 1}$$

$$\sum_{t=1}^{n} tY_t' = A'\sum_{t=1}^{n} t + B'\sum_{t=1}^{n} t^2 \quad \text{… equation 2}$$

Solving the two equations and multiplying equation 1 by $\sum_{t=1}^{n} t$ on both sides we get

$$\sum_{t=1}^{n} Y_t' . \sum_{t=1}^{n} t = nA'\sum_{t=1}^{n} t + B'(\sum_{t=}^{n} t)^2 \quad \text{…equation 3}$$

Multiplying equation 2 by n on both sides we get

$$n\sum_{t=1}^{n} tY_t' = nA'\sum_{t=1}^{n} t + nB'\sum_{t=1}^{n} t^2 \quad \text{...equation 4}$$

By Equation 3 – Equation 4 we get

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

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

Putting the value of B′ in equation 1 we get

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

Given,
$\ln a = A'$; $a = e^{A'}$; $\ln b = B'$; $b = e^{B'}$

Compound growth rate (C.G.R.) = (b - 1) X 100
SE(CGR)= ln(b) x SE(ln b)/ln10 (Dhakre and Sharma, 2010)

Cuddy- Della Instability Index
Cuddy- Della Instability Index is most commonly used measures of instability of time series data and is universally acceptable. The indices were originally developed by John Cuddy and Della Valle for measuring the instability in time series data. This index is a better measure compared to coefficient of variation, as it is inherently adjusted for trend, often observed in time series data. This measure included as a component of instability all cyclical fluctuations present in the time series data, whether regular or irregular, as well as any component which could be defined as 'white noise'.
Cuddy-Della Instability Index (CDII) is given as,

$$CDII = CV \times \sqrt{1 - R^2}$$ (Kumar *et al.*, 2018) [3].

Where

CV= Coefficient of variation = $\frac{\sigma}{\overline{Y}} \times 100$

σ – Standard Deviation of Mean Area/Yield/Production;
$\overline{Y}$ - Mean Area/Yield/Production
R^2 - Coefficient of determination from a time trend regression adjusted for its degree of freedom

Spearman's rank correlation coefficient
Spearman's rank correlation coefficient denoted by ρ is a nonparametric measure of rank correlation. It assesses how well the relationship between two variables can be described using monotonic function.
The Spearman's correlation between two variables is equal to the Karl Pearson's correlation coefficient between rank values of those two variables and Pearson's correlation assesses linear relationships.

Spearman's formula for rank correlation coefficient,

$$\rho = \frac{1 - 6\sum_{i=1}^{n} d_i^2}{n(n^2 - 1)}$$

Where
d_i = difference between two ranks of each observations; n= number of observations

Test of significance of correlation coefficient
The significance of the correlation is tested using t- test.
Let us assume the population correlation coefficient (ρ) between Area & Production and Yield & Production be zero.
So,

H_0: ρ = 0
H_1: ρ ≠ 0
Level of significance (α) = 0.05 (5%) or 0.01(1%)
Test statistic is given by

$$t_{Cal} = \frac{r}{SE(r)}$$

$$SE(r) = \frac{1 - r^2}{n - 2}$$

Tabulated t values are obtained from t-table. Tab t values are found for 0.05 and 0.01 level of significance at (n-2) d.f as the case may be.
Let the Tabulated t value for 0.05 and 0.01 level of significance be represented by t_1 and t_2 respectively.

If $|t_{cal}| > t_2$ then we reject the null hypothesis at 1% level of significance. Here t is considered to be highly significant and correlation between Area- Production and Yield –Production of two periods differ significantly at 1% level of significance.

If $|t_{cal}| < t_1$ we accept null hypothesis. Here t is considered to be insignificant and we conclude that correlation don't differ significantly.

If $t_1 < |t_{cal}| < t_2$, then we reject null hypothesis only at 5% level of significance. Here t is considered to be significant and we conclude that correlation differs significantly at 5% level of significance.

Results and Discussion

Table 1 shows that the compound growth rate of area, yield and production of rabi pulses in Odisha is significantly positive but low. Among the districts most of them show significantly positive but low compound growth rate in area, yield and production of rabi pulses except Balasore and Malkangiri district which shows significantly negative but low compound growth rate in area under rabi pulses. The districts like Balasore, Gajapati, Bhadrak and Kalahandi show significantly negative compound growth rate in yield of rabi pulses. The compound growth rate of production of rabi pulses in Odisha is found to be significantly negative in Balasore, Cuttack and Deogarh districts.

Table 2 shows that the in Odisha Instability is highest in case of production of rabi pulses than that in area and yield. Thus the high instability in production is due to interaction effect of area and yield. The Malkangiri district has very high rate of instability in area under rabi pulses which goes above 50%. Instability in yield of rabi pulses is below 30% for all the districts of Odisha. The instability in production is also not very high for most of the districts except Boudh and Malkangiri where the instability is above 58%.

Table 3 shows that Nuapada district secured the first rank with respect to compound growth rate of area under rabi pulses followed by Sonepur. Malkangiri district has the last rank among the districts of Odisha on compound growth rate of area under rabi pulses. In case of instability of area under rabi pulses, Keonjhar occupied the first position followed by Koraput and the last position is occupied by Malkangiri. Thus Malkangiri district performs very poor in case of area under rabi pulses.

In case of compound growth rate of yield of rabi pulses as evident from table 4, Sonepuri also secured first position followed by Nuapada and last rank is occupied by Balasore. Kendrapada secured first position followed by Bargarh district and last rank is occupied by Nuapada with respect to instability in yield of rabi pulses.

Table 5 shows that in case of compound growth rate of production of rabi pulses, Nuapada district occupied the first position followed by Sonepur district and the last position is occupied by Balasore district. Gajapati secured first position followed by Bhadrak district and last rank is occupied by Boudh with respect to instability in production of rabi pulses.

Table 6 which shows the rank correlation coefficient between the compound growth rate and instability of area, yield and production of rabi pulses in Odisha, reveals that the rank correlation is significantly negative in case of area and yield, whereas, in case of production it is negative but non-significant.

Table 1: Compound Growth Rate of rabi pulses of different districts of Odisha (in per cent)

Sl. No.	Districts	Area	Yield	Production	Sl No	Districts	Area	Yield	Production
1	Anugul	0.81**	1.91**	2.74**	16	Kandhamal	0.62**	0.93**	1.56**
2	Balasore	-0.33**	-0.99**	-1.18**	17	Kendrapada	0.56**	0.23**	0.79**
3	Bargarh	3.18**	-0.06	3.12**	18	Keonjhar	0.32**	1.82**	2.16**
4	Bhadrak	-0.06	-0.36**	-2.69	19	Khurda	0.7**	0.72	1.42
5	Bolangir	2.96**	2.15**	5.18**	20	Koraput	0.23**	2.43**	2.79**
6	Boudh	1.66**	1.12**	2.81**	21	Malkangiri	-0.56**	0.64	0.06
7	Cuttack	0.46**	0.02	-0.56**	22	Mayurbhanj	1.76**	1.31	3.22**
8	Deogarh	3.29**	0.4**	3.59**	23	Nabarangpur	0.46**	1.2**	1.67**
9	Dhenkanal	0.85**	1.62**	2.5**	24	Nayagarh	0.39**	2.26**	2.67**
10	Gajapati	1.54**	-0.21**	1.23**	25	Nuapada	4.57**	3.37**	9.13**
11	Ganjam	1.45**	0.69**	2.16**	26	Puri	1.5**	2.41**	3.96**
12	Jagatsinghpur	0.43**	0.27**	0.71**	27	Rayagada	1.21**	1.67**	2.91**
13	Jajpur	0.19**	0.35	-0.55	28	Sambalpur	0.45	0.83**	1.28**
14	Jharsuguda	2.29	0.09**	2.39	29	Sonepur	4.07**	3.44**	8.54**
15	Kalahandi	2.33**	-0.31**	2.03**	30	Sundargarh	0.69**	1.13**	1.83**
	Odisha	0.4**	0.2**	0.5**					

* significant at 5% level ** significant at 1% level

Table 2: Cuddy-Della instability index of rabi pulses of different districts of Odisha (in per cent)

Sl. No.	Districts	Area	Yield	Production	Sl. No.	Districts	Area	Yield	Production
1	Anugul	8.91	26.13	31.66	16	Kandhamal	12.4	27.73	33.39
2	Balasore	14.3	13.79	26.16	17	Kendrapada	16.01	8.08	23.98
3	Bargarh	21.69	8.3	30.67	18	Keonjhar	7.65	18.56	22.92
4	Bhadrak	23.87	17.55	16.89	19	Khurda	13.94	25.78	31.8
5	Bolangir	20.72	14.77	31.58	20	Koraput	7.78	18.13	19.61
6	Boudh	20.7	15.64	63.37	21	Malkangiri	50.33	23.01	58.24
7	Cuttack	11.66	20.29	17.8	22	Mayurbhanj	24.72	5.53	36.22
8	Deogarh	30.15	17.45	19.98	23	Nabarangpur	16.03	17.97	26.61

9	Dhenkanal	17.63	21.93	30.67	24	Nayagarh	13.26	24.48	37.32
10	Gajapati	13.6	10.1	12.11	25	Nuapada	34.58	34.97	49.01
11	Ganjam	16.87	9.19	26.91	26	Puri	17.25	21.54	26.45
12	Jagatsinghpur	10.31	12.76	17.8	27	Rayagada	16.68	16.84	28.49
13	Jajpur	10.25	19.84	26.24	28	Sambalpur	29.79	12.19	28.54
14	Jharsuguda	29.12	8.9	29.89	29	Sonepur	17.95	24.23	43.06
15	Kalahandi	24.98	13.91	18.43	30	Sundargarh	16.05	17.32	21.87
	Odisha	14.52	13.62	26.37					

Table 3: Rank of the districts on basis of Compound Growth Rate (C.G.R) and Cuddy-Della Instability Index(CII) of area under pulses for rabi season

Sl. No.	Districts	Rabi		Sl. No.	Districts	Rabi	
		CGR	CDII			CGR	CDII
1	Anugul	14	3	16	Kandhamal	18	7
2	Balasore	29	11	17	Kendrapada	19	12
3	Bargarh	4	22	18	Keonjhar	25	1
4	Bhadrak	28	23	19	Khurda	16	10
5	Bolangir	5	20	20	Koraput	26	2
6	Boudh	9	21	21	Malkangiri	30	30
7	Cuttack	20	6	22	Mayurbhanj	8	24
8	Deogarh	3	28	23	Nabarangpur	21	13
9	Dhenkanal	15	18	24	Nayagarh	24	8
10	Gajapati	10	9	25	Nuapada	1	29
11	Ganjam	12	16	26	Puri	11	17
12	Jagatsinghpur	23	5	27	Rayagada	13	15
13	Jajpur	27	4	28	Sambalpur	22	27
14	Jharsuguda	7	26	29	Sonepur	2	19
15	Kalahandi	6	25	30	Sundargarh	17	14

Table 4: Rank of the districts on basis of Compound Growth Rate (C.G.R) and Cuddy-Della Instability Index(CDII) of yield under pulses for rabi season

Sl. No.	Districts	Rabi		Sl. No.	Districts	Rabi	
		CGR	CDII			CGR	CDII
1	Anugul	7	28	16	Kandhamal	15	29
2	Balasore	30	8	17	Kendrapada	23	1
3	Bargarh	26	2	18	Keonjhar	8	18
4	Bhadrak	29	15	19	Khurda	17	27
5	Bolangir	6	10	20	Koraput	3	17
6	Boudh	14	11	21	Malkangiri	19	23
7	Cuttack	25	20	22	Mayurbhanj	11	26
8	Deogarh	20	14	23	Nabarangpur	12	16
9	Dhenkanal	10	22	24	Nayagarh	5	25
10	Gajapati	27	5	25	Nuapada	2	30
11	Ganjam	18	4	26	Puri	4	21
12	Jagatsinghpur	22	7	27	Rayagada	9	12
13	Jajpur	21	19	28	Sambalpur	16	6
14	Jharsuguda	24	3	29	Sonepur	1	24
15	Kalahandi	28	9	30	Sundargarh	13	13

Table 5: Rank of the districts on basis of Compound Growth Rate (C.G.R) and Cuddy-Della Instability Index(CDII) of production under pulses for rabi season

Sl. No.	Districts	Rabi		Sl. No.	Districts	Rabi	
		CGR	CDII			CGR	CDII
1	Anugul	22	22	16	Kandhamal	17	24
2	Balasore	30	11	17	Kendrapada	24	10
3	Bargarh	6	19	18	Keonjhar	13	9
4	Bhadrak	29	2	19	Khurda	20	23
5	Bolangir	7	21	20	Koraput	9	6
6	Boudh	16	30	21	Malkangiri	28	29
7	Cuttack	25	3	22	Mayurbhanj	5	25
8	Deogarh	4	7	23	Nabarangpur	15	14
9	Dhenkanal	23	20	24	Nayagarh	10	26
10	Gajapati	18	1	25	Nuapada	1	28
11	Ganjam	19	15	26	Puri	3	13
12	Jagatsinghpur	26	4	27	Rayagada	8	16
13	Jajpur	27	12	28	Sambalpur	21	17
14	Jharsuguda	12	18	29	Sonepur	2	27

15	Kalahandi	11	5	30	Sundargarh	14	8

Table 6: Rank correlation coefficient(RCC) between Compound Growth Rate(CGR) and Cuddy Della instability index(CDII) for area, yield and production of rabi pulses of Odisha

	Area	**Yield**	**Production**
RCC	-0.483	-0.576	-0.278
SE(standard erreor)	0.165	0.154	0.181
t	-2.918	-3.73	-1.531
Highly significant/Significant/Non significant	Highly significant	Highly Significant	Non - significant

Conclusion

The performance of area and yield of rabi pulses as revealed from the study is found to be good which leads to good performance in production. Very few districts like Balasore and Malkangi show poor performance with respect to growth rate and instability in area, yield and production of rabi pulses. The performance should be enhanced to get a good increment in growth rate of area and yield of rabi pulses alongwith low degree of instability. This can be achieved by putting some more area under pulses during rabi season if possible and by adopting improved cultivation practices for increasing the growth rate and decreasing the instability of area and yield. These steps are necessary for increasing growth rate of rabi pulse production with decreased instability.

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