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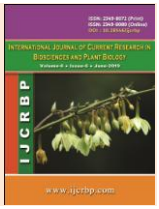

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Instability analysis of food grain production during kharif season in coastal districts of Odisha, India

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ABSTRACT

Agriculture is the backbone of the economy of Odisha. Food grain production in the state is mainly confined in the coastal areas which include Puri, Khordha, Ganjam, Kendrapada, Jagatsinghpur, Cuttack, Bhadrak and Balasore districts. Climatic and soil conditions of these areas are very much suitable for cultivation of different kharif food grain crops. Food grains include both cereals and pulses. Major cereals grown in these areas are rice, ragi, maize, wheat and bajra and major pulses grown in these areas are green gram, black gram, kulthi and arhar. To study the variation in yield of major kharif food grains, a study is made about the area and production of kharif food grains in these coastal districts from the year 1993-94 to 2014-15. This study includes test of significance of change in mean and variance of area, yield and production of kharif food grains from Period-I (1993-94 to 2002-03) to Period-II (2003-04 to 2014-15). To test the significance of change in mean and variance of area, yield and production of kharif food grains, we have to calculate the mean and variance of area, yield and production of kharif food grains from Period-I to Period-II by using Fisher's t-test and Snedecor's F-test respectively. Increase in the production of kharif food grains of Odisha after the year 2003-04 is due to adoption of new and improved technologies. High variation in mean yield and mean production of kharif food grains is marked which may be due to uneven spread of technologies. In Balasore, Bhadrak, Ganjam and Kendrapada districts change in yield variance contributes more towards change in variance of production. More variation in yield in the above districts is due to scattered land holdings by farmers.

Introduction

Odisha lies between 81.27^0 E to 87.29^0 E longitude and 17.49^0 N to 22.34^0 N latitude with an area of around 1,55,707 Square Km. Agriculture occupies the centre-stage in the overall development of Odisha's economy (Mishra, 1983). The north eastern coastal plain and east and south eastern coastal plains constitute the coastal area of Odisha. The coastal plains of Odisha stretch from the river Subarnarekha in the north to the river Rusikulya in the south. Availability of water for crop production is adequate in these areas. The coastal districts of Odisha are Puri, Khordha, Ganjam, Kendrapada, Jagatsinghpur, Cuttack, Bhadrak and Balasore. Coastal Odisha is located in eastern part of the state, which comes under agro-ecological sub region (AESR). The mean annual

rainfall is 1449 mm and more than 60-70% is received during south-west monsoon (June-September). The mean maximum summer temperature is 39°C and is mean minimum winter temperature is 11.5°C. Food grains in Odisha include cereals and pulses. Among cereals the most important crop is rice followed by ragi, maize, wheat, small millets and bajra. Rice is the principal food crop in Odisha occupying about 44.55 lakh ha. The area, yield and production of kharif food grains of Odisha in the year 2014-15 are 5012.96 thousand ha, 2010.68 Kg/ha and 10079.45 thousand MT respectively. Similarly the area, yield and production of coastal districts of Odisha in the year 2014-15 are 1235.75 thousand ha, 15668.04 Kg/ha and 2461.34 thousand MT respectively. The area under kharif food grains in coastal districts of Odisha is 24.65% of the area of the whole state and the production of kharif food grains is 24.42% of the production in the whole state in the year 2014-15. Green gram, black gram, kulthi and arhar are the major pulses grown in coastal areas (Rao and Ray, 1985). Irrigated tracts like Mahanadi delta, the Rusikulya plains and other coastal plains are the prominent food grain growing areas.Keeping in view of the above perspectives, the study has been made with the following objectives :-

1) To find out a break point in the whole period of study with respect to area, yield and production of food grains in Odisha for kharif season on basis of scatter plot of the data and then accordingly divide the entire period (1993-94 to 2014-15) of study into two periods i.e. Period-I (1993-94 to 2002-03) and Period-II (2003-04 to 2014-15).

2) To test the significance of change in mean and variance of area, yield and production of food grains from Period-I to Period-II for kharif season in coastal districts of Odisha and the state as a whole.

3) To study the contribution of various components of area and yield effect towards change in mean and variance of production of food grains for kharif season in coastal districts of Odisha and the state as a whole.

Materials and methods

The study is based on secondary data regarding area, yield and production of food grains in coastal districts of odisha and the state as a whole from various volumes of Odisha Agricultural Statistics.

The methodologies followed in the study are described in the following manner:

To find the mean area/production/yield of both the periods of study the following formula is used:

Mean, $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, where, n is the no. of observations, For period I (1993-94 to 2002-03), $n_1 = 10$; for period II(2003-04 to 2014-15), $n_2 = 12$

To test the significance of difference between the means of two periods with respect to area/yield/production of food grains, Fisher's t – test has been used.

a) Null hypothesis, H_0: $\mu_1 = \mu_2$, i.e. the two population means are identical.
b) Alternative hypothesis, H_1:$\mu_1 \neq \mu_2$ (two tailed test)

$$t = \frac{\left(\overline{x_1} - \overline{x_2}\right)}{\left[S^2\left\{\left(\frac{1}{n_1}\right) + \left(\frac{1}{n_2}\right)\right\}\right]^{\frac{1}{2}}}$$

Here S^2 is pooled variance and is given by:

$$S^2 = \frac{\left[\sum_{i=1}^{n_1}\left(x_{1i} - \overline{x_1}\right)^2 + \sum_{i=1}^{n_2}\left(x_{2i} - \overline{x_2}\right)^2\right]}{\left(n_1 + n_2 - 2\right)}$$

Variance

To find the variance (σ^2) of area/production/yield of both the periods of study the following formula is used:

$$\sigma^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}$$

To test the significance of difference between the means of two periods w.r.t area/yield/production of food grains, Snedecor's F-test has been used.

Null hypothesis; H_0: $\sigma_1^2 = \sigma_2^2$ (where σ_1^2 and σ_2^2 are the two population variances)

Alternative hypothesis; H_1: $\sigma_1^2 \neq \sigma_2^2$ (two-tailed test)

Level of significance, $\propto$ = 0.05 (5%) or 0.01(1%)

Test statistic F is given by

$$F = \frac{s_1^2}{s_2^2} \text{ (if } s_1^2 > s_2^2 \text{)}$$

Or

$$F = \frac{s_2^2}{s_1^2} \text{ (if } s_2^2 > s_1^2 \text{)}$$

s_1^2 = sample variance of period-I (1993-94 to 2002-03)

s_2^2 = sample variance of period-II (2003-04 to 2014-15)

$$s_1^2 = \frac{1}{n_1 - 1}\left\{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n_1}\right\}$$

$$s_2^2 = \frac{1}{n_2 - 1}\left\{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n_2}\right\}$$

Hazel's decomposition

Hazel decomposed the sources of change in mean production and change in production variance into four and ten components respectively. The Hazel's decomposition procedure is given below.

Let P denote production, A denote the area sown under a particular crop and Y is the yield per hectare. Then for each crop total output is P = A * Y. The variance of production, V (P) can be given by

$$V(P) = \bar{A}^2 V(Y) + \bar{Y}^2 V(A) + 2\bar{A}\bar{Y}\,\mathrm{cov}(A, Y) - \mathrm{cov}(A, Y)^2 + R$$

Where,

$\bar{A}$ and $\bar{Y}$ denote mean area and mean yield respectively;

R denote the residual term which is expected to be small.

Clearly, a change in any one of these components will lead to a change in V(P) between two periods in time (Hazell, 1982)

There are four sources of change in average production (Table 1). The first two terms, change in the mean yield and change in mean area are called as 'pure effects' which arise even if there were no other source of change. The third term is an interaction effect, which arise from the simultaneous occurrence of changes in mean yield and mean area. The fourth term represents interaction between area and yield covariance.

Table 1. Components of change in average production.

Sources of change	Symbols	Components of change
Change in mean yield	$\Delta\bar{Y}$	$\bar{A}_1\Delta\bar{Y}$
Change in mean area	$\Delta\bar{A}$	$\bar{Y}_1\Delta\bar{A}$
Interaction between change in mean yield and mean area	$\Delta\bar{A}\ \Delta\bar{Y}$	$\Delta\bar{A}\ \Delta\bar{Y}$
Change in area-yield covariance	$\Delta\,\mathrm{cov}(A,Y)$	$\Delta\,\mathrm{cov}(A,Y)$

Methods of decomposition of the changes in variance of production

In this section, we will construct a method to partition the changes in variance of production (V(P)) between the first and the second periods into its constituent parts (Table 2).

The variance of production, V(P) can be expressed

as,

$$V(AY) = \overline{A}^2 V(Y) + \overline{Y}^2 V(A) + 2\overline{A}\,\overline{Y}\,\mathrm{cov}(A, Y) - \mathrm{cov}(A, Y)^2 + R$$

Variance of production in the first period is

$$V(P_1) = \overline{A_1}^2 V(Y_1) + \overline{Y_1}^2 V(A_1) + 2\overline{A_1}\,\overline{Y}_1 \mathrm{cov}(A_1, Y_1) - \mathrm{cov}(A_1, Y)^2 + R_1 \quad \text{.....(2)}$$

And for the second period

$$V(P_2) = \overline{A_2}^2 V(Y_2) + \overline{Y_2}^2 V(A_2) + 2\overline{A_2}\,\overline{Y}_2 \mathrm{cov}(A2, Y_2) - \mathrm{cov}(A_2, Y_2)^2 + R_2 \quad \text{.....(3)}$$

Each variable in the second period can be expressed as its counterpart in the first period plus the change in the variable between the two periods, i.e.,

$$\overline{A_2} = \overline{A_1} + \Delta\overline{A}, \quad \overline{Y_2} = \overline{Y_1} + \Delta\overline{Y}$$

$$V(A_2) = V(A_1) + \Delta V(A), \quad V(Y_2) = V(Y_1) + \Delta V(Y)$$

$$\mathrm{cov}(A_2, Y_2) = \mathrm{cov}(A_1, Y_1) + \Delta\mathrm{cov}(A_1, Y_1)$$

Table 2. Components of change in variance of production.

Sources of change	Symbols	Components of change
Change in mean yield	$\Delta\overline{Y}$	$2\overline{A}_1\Delta\overline{Y}\,\mathrm{cov}(A_1, Y_1) + \{2\overline{Y}_1\Delta\overline{Y} + (\Delta\overline{Y})^2\}V(A_1)$
Change in mean area	$\Delta\overline{A}$	$2\overline{Y}_1\Delta\overline{A}\,\mathrm{cov}(A_1, Y_1) + \{2\overline{A}_1\Delta\overline{A} + (\Delta\overline{A})^2\}V(Y_1)$
Change in yield variance	$\Delta V(Y)$	$\overline{A_1}^2\Delta V(Y)$
Change in area variance	$\Delta V(A)$	$\overline{Y_1}^2\Delta V(A)$
Interaction between change in mean yield and mean area	$\Delta\overline{A}\ \Delta\overline{Y}$	$2\Delta\overline{A}\Delta\overline{Y}\,\mathrm{cov}(A_1, Y_1)$
Change in area - yield co-variance	$\Delta\mathrm{cov}(A, Y)$	$\{2\overline{A}_1\overline{Y}_1 - 2\mathrm{cov}(A_1, Y_1)\}\Delta\mathrm{cov}(A, Y) - \{\Delta\mathrm{cov}(A, Y)\}^2$
Interaction between changes in mean area and yield variance	$\Delta\overline{A}\Delta V(Y)$	$\{2\overline{A}_1\Delta\overline{A} + (\Delta\overline{A})^2\}\Delta V(Y)$
Interaction between changes in yields and area variance	$\Delta\overline{Y}\Delta V(A)$	$\{2\overline{Y}_1\Delta\overline{Y} + (\Delta\overline{Y})^2\}\Delta V(A)$
Interaction between changes in mean area and yield and changes in area-yield co-variance	$\Delta\overline{A}\ \Delta\overline{Y}\ \Delta\mathrm{cov}(A, Y)$	$(2\overline{A}_1\Delta\overline{Y} + 2\overline{Y}_1\Delta\overline{A} + 2\Delta\overline{A}\Delta\overline{Y})\Delta\mathrm{cov}(A, Y)$
Changes in residuals	ΔR	$\Delta V(AY)$ - sum of other components

Results and discussion

Study of data using scatter plot

The existing pattern in the data on area, yield and production of food grains in Odisha during kharif season is studied by plotting the scatter diagrams of these variables with respect to time 't' for the whole period of study (1993-94 to 2014-15). The value of the time variable 't' is taken as 1,2,3,...,22. Figs. 1, 2 and 3 show the scatter plot of area, yield and production of kharif food grains in Odisha for the year 1993-94 to 2014-15. From the Fig. 1, it is seen that the area under kharif food grains in Odisha declines in the first 10 years of the study i.e. from the year 1993-94 to 2002-03. In the year 2003-04, there is an abrupt increase in the area under kharif food grains in Odisha which further stabilizes for some years and starts declining in the 18th year of the study i.e. in the year 2010-11.

It is observed from the Fig. 2 that yield of kharif food grains gets stabilized in first 10 years of study period i.e. 1993-94 to 2002-03 with slight increase and decrease. After that, the yield gets declined suddenly in the 11th year of study period i.e. 2003-04 and then increased in the next year and gets stabilized till 2011-12 and after that shows an increase in the last three years of study. It is found from the Fig. 3, that production of kharif food grains gets stabilized in first 10 years of study period with slight increase and decrease. After 2002-03, the

production gets reduced in the year 2003-04 which again increases in the next year and gets stabilized thereafter up to 2011-12 and again increased in the last three years of the study period.

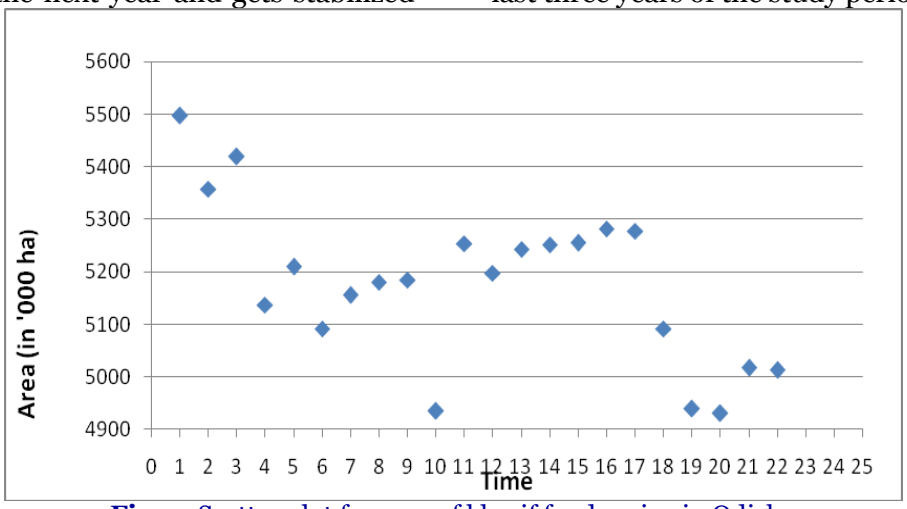

Fig. 1: Scatter plot for area of kharif food grains in Odisha

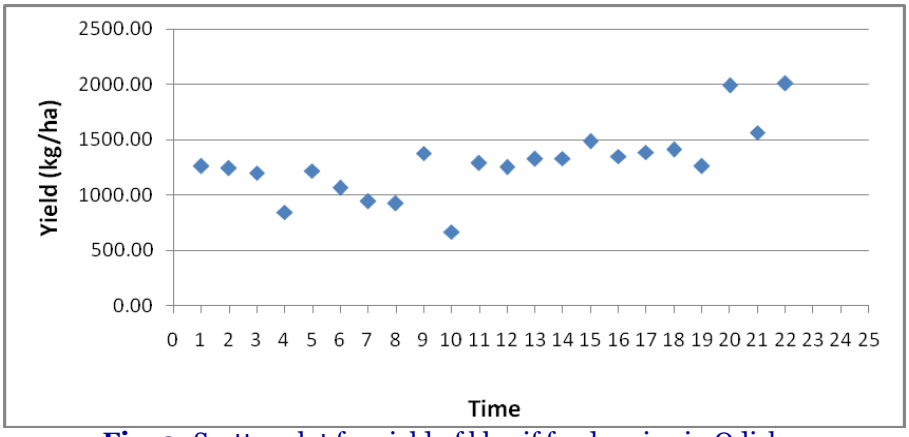

Fig. 2: Scatter plot for yield of kharif food grains in Odisha.

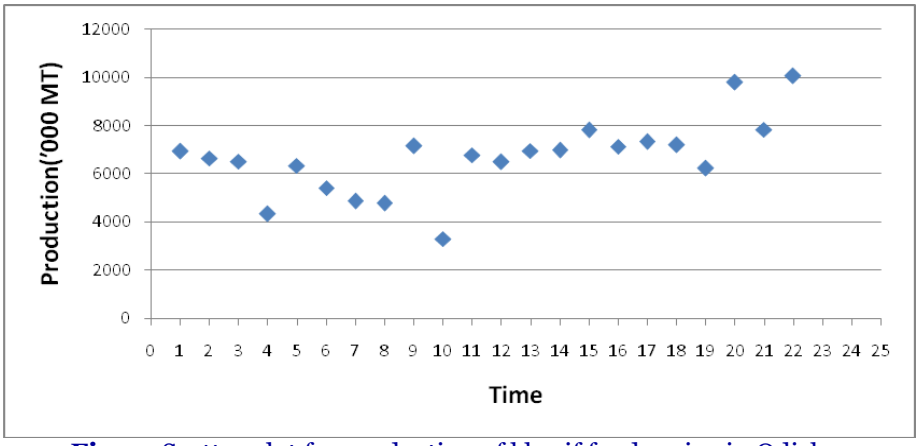

Fig. 3: Scatter plot for production of kharif food grains in Odisha.

Table 3 shows that there is no significant difference between change in mean area of kharif food grains of Odisha whereas, change in mean yield and mean production is highly significant. Among the coastal districts, Balasore, Jagatsingpur, Khurda and Puri show a highly significant difference in mean area from period-I to period-II (1993-94 to 2014-15). Mean area of

Cuttack district differ significantly from period-I to period-II. There is no significant difference in mean production in other coastal districts except Kendrapada.

Table 3. Change in mean area, yield and production of kharif food grains from period-1(1993-94 to 2002-03) to period-II (2003-04 to 2014-15) in coastal districts of Odisha and the state as a whole.

Districts	Area (in '000 ha)			Yield (in Kg/ha)			Production (in '000 MT)		
	M_1	M_2	ΔM	M_1	M_2	ΔM	M_1	M_2	ΔM
Balasore	226.34	206.62	-19.72** (5.5)	1170.96	1528.84	357.88* (151.397)	266.9	315.33	48.43 (33.954)
Bhadrak	167.26	163.9	-3.36 (3.233)	1396.86	1792.6	395.75** (128.812)	231.37	294.04	62.67** (21.379)
Cuttack	148.12	137.8	-10.32* (3.887)	1258.94	1887.56	628.62* (192.571)	185.23	259.55	74.32 (26.817)
Ganjam	364.22	359.64	-4.58 (8.252)	1238.9	1434.66	195.75 (188.960)	454.02	518.77	64.75 (74.637)
Jagatsinghpur	100.12	85.73	-14.39** (3.257)	1192.78	1994.06	801.28** (180.173)	98.86	85.73	-13.14** (14.632)
Kendrapada	135.89	135.05	-0.84 (3.544)	1052.11	1448.23	396.12* (135.288)	139.99	196.06	56.07* (19.901)
Khurdha	119.58	106.83	-12.75** (3.165)	1173.55	1609.84	436.29* (169.90)	139.02	171.36	32.35 (19.334)
Puri	133.2	116.36	-16.84** (5.448)	992.92	1369.08	376.17 (176.322)	128.37	158.1	29.72 (21.096)
Odisha	5217.06	5146.27	-70.79 (64.680)	1075.8	1472.92	397.13** (105.160)	5636.26	7560.51	1924.25** (531.483)

Values in the parentheses indicate standard error of mean.
M_1 - Mean area/production/yield of period-I**; M_2 -** Mean area/production/yield of period-II**;**
$\Delta M = M_2 - M_1$; * Significant at 5% level of significance**;** ** Significant at 1% level of significance

Table 4. Change in variance of area, yield and production of kharif food grains from Period-I (1993-94 to 2002-03) and period-II (2003-04 to 2014-15) in coastal districts of Odisha and the state as a whole.

Districts	Variance of area (in '000 ha)			Variance of yield (in Kg/ha)			Variance of production (in '000 MT)		
	V_1	V_2	ΔV	V_1	V_2	ΔV	V_1	V_2	ΔV
Balasore	127.11	195.91	68.8	152221.4	102774.1	-49447.3	8798.74	4234.25	-4564.49
Bhadrak	95.15	17.72	-77.44**	4243.12	1552.78	-2690.33*	163537.5	50415.54	-113122
Cuttack	66.91	101.14	34.23	136871.9	205573.3	68701.38	2981.65	3590.74	609.09
Ganjam	579.71	126.74	-452.97**	133644.7	253554.7	119910	24269.9	35631.41	35631.41
Jagatsinghpur	63.85	41.85	-21.99	167935.1	158645.7	-9289.34*	63.85	41.85	-21.99**
Kendrapada	85.45	21.62	-63.84**	127389.1	54222.29	-73166.8**	2183.3	1263.55	-919.75**
Khurdha	41.83	68.06	26.23	149191.9	154474.5	5282.55	2232.15	1545.86	-686.29
Puri	197.64	96.75	-100.88	120129.6	188941.4	68811.82	1774.62	2051.51	276.9
Odisha	27444.06	19035.32	-8408.74	49873.62	68866.91	18993.29	1638947	1460441	-178506

Values in the parentheses indicate standard error of variance.
V_1: Area/production/yield variance of period-I; **V_2:** Area/production/yield variance of period-II;
ΔV: $V_2 - V_1$ *: Significant at 5% level of significance; ****:** Significant at 1% level of significance.

From the Table 4, it is found that there is no significance difference in variance of area, yield and production of kharif food grains of Odisha from Period-I (1993-94 to 2002-03) to Period-II(2003-04 to 2014-15). In Balasore, Cuttack, Khurdha and Puri districts, there is also no significant difference in variance of area, yield and production of food grains. In Bhadrak, Ganjam and Kendrapada districts, variance of area shows a highly significant difference from Period-I to Period-II. Variance of yield shows significant difference from Period-I to Period-II in Bhadrak and Jagatsingpur districts. Variance of area, yield and production is highly significant in Kendrapada district. In Jagatsingpur district variance of production of kharif food grains is highly significant from Period-I (1993-94 to 2002-03) to period-II (2003-04 to 2014-15).

Table 5 reveals the contribution (in %) of various components towards change in average production of kharif food grains. Change in mean yield of kharif food grains of Odisha contributes 106.67% towards change in mean production

from Period-I (1993-94 to 2002-03) to Period-II (2003-04 to 2014-15). The contribution of change in mean area towards change in mean production from Period-I to Period-II is -3.96% where as the contribution of area-yield interaction effect and area-yield covariance towards change in mean production of kharif food grains of Odisha are -1.46% and -2.25% respectively. Among coastal districts mean yield of Puri district has highest effect towards change in mean production of kharif food grains i.e. 266.95 % where as mean yield of kharif food grains of Kendrapada district contributes lowest towards change in average production i.e. 100.47%. Contribution of mean area and area-yield interaction effect of kharif food grains towards change in mean production has negative effect for all the coastal districts of Odisha.

Table 5. Contribution of various components towards change in mean production of kharif food grains in coastal districts of Odisha and the state as a whole.

(In per cent)

Districts	Kharif			
	Yield effect	Area effect	Area-yield interaction effect	Area–yield covariance effect
Balasore	167.27	-47.69	-14.58	-5.01
Bhadrak	106.87	-6.43	-2.01	1.57
Cuttack	138.28	-26.82	-10.01	-1.45
Ganjam	116.28	-5.72	-0.71	-9.85
Jagatsinghpur	170.93	-40.35	-24.6	-5.98
Kendrapada	100.47	-1.04	-0.32	0.89
Khurdha	201.27	-73.14	-22.71	-5.42
Puri	266.95	-127.38	-34.16	-5.41
Odisha	**107.67**	**-3.96**	**-1.46**	**-2.25**

Contribution of change in area-yield covariance of kharif food grains of Odisha towards change in variance of production is highest i.e. 272.23% where as contribution of change in yield variance towards change in variance of production is lowest i.e. -289.6% (Table 6). Change in mean yield and change in yield variance have negative effect and other components of change in variance of production have positive effect on change in variance of production of kharif food grains of Odisha. Among coastal districts of Odisha contribution of change in mean yield towards change in variance of production is highest in Ganjam district i.e. 24.76% followed by Cuttack district i.e. 16.97%. In Cuttack district contribution of change in yield variance towards change in variance of production is more i.e. 280.16% where as contribution of changes in residuals is very less i.e. -44.52%. In Balasore, Bhadrak, Ganjam and Kendrapada districts change in yield variance contributes more towards change in variance of production than other components.

Table 6. Contribution of various components towards change in variance of production of kharif food grains in coastal districts of Odisha and the state as a whole.

(in per cent)

Districts	1	2	3	4	5	6	7	8	9	10
Balasore	-9.30	30.37	55.5	-2.07	0.58	28.09	-9.25	-1.46	5.4	2.16
Bhadrak	-1.02	6.02	116.04	6.96	-0.09	-20.08	-4.32	5.04	-5.78	-2.77
Cuttack	16.97	-68.53	280.16	5.83	-0.1	-43.89	-39.08	5.16	-12	-44.52
Ganjam	24.76	-6.26	237.29	-18.81	-0.11	-98.07	-2.88	-4.95	-11.6	-19.37
Jagatsinghpur	-21.04	41.25	-5.99	4.23	0.87	53.63	1.6	6.73	20.14	-1.42
Kendrapada	-5.08	0.88	89.98	6.04	0	-5.74	-0.58	4.35	-1.76	11.91
Khurdha	-8.6	44.8	17.68	-2.08	0.51	29.8	-3.76	-1.49	4.85	18.21
Puri	-13.01	66.07	-72.8	18.17	-0.6	23.26	17.44	11.05	2.45	47.97
Odisha	-70.72	22.52	-289.6	5.45	0.76	272.23	7.81	4.77	95.47	51.31

1-Change in mean yield, 2-Change in mean area, 3-Change in yield variance, 4-Change in area variance; 5:Interaction between changes in mean yield and mean area; 6-Change in area-yield covariance; 7-Interaction between change in

mean area and yield variance; 8-Interaction between change in mean yield and area variance; 9-Interaction between change in mean area and yield and change in area-yield covariance;10-Change in residuals.

Summary and conclusion

From Figs. 1, 2 and 3, it is clearly observed that there is a distinct change in the scatter plot of area, yield and production of kharif food grains of Odisha after 10th year of study period (i.e. 2002-03). Uneven decrease in the area under kharif food grains of Odisha in the first period of study (1993-94 to 2002-03) may be due to shifting of agricultural land for production of non-food grain crops, urbanization and industrialization. Increase in the production of kharif food grains of Odisha after the year 2003-04 is due to adoption of new and improved technologies. High variation in mean yield and mean production of kharif food grains is marked which may be due to uneven spread of technologies. Change in area variance is highly significant in Bhadrak, Ganjam and Kendrapada district which might be due to the shifting of food grain crops to non- food grain crops. In Kendrapada district, variance of area, yield and production of kharif food grains is highly significant from Period-I (1993-94 to 2002-03) to Period-II (2003-04 to 2014-15). Among coastal districts mean yield of Puri district has highest effect towards change in mean production of kharif food grains i.e. 266.95% which is due to availability of sufficient water for irrigation and soil is rich in organic matter and different minerals, whereas mean yield of kharif food grains of Kendrapada district contributes lowest towards change in average production i.e. 100.47%. In Balasore, Bhadrak, Ganjam and Kendrapada districts change in yield variance contributes more towards change in variance of production. More variation in yield in the above districts is due to scattered land holdings by farmers.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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