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Growth and instability in agricultural productivity in Odisha

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Abstract This paper analyses growth and instability in the productivity of major crops grown across the districts of Odisha, and examines its sensitivity to weather conditions during different phases of technological change. We find that except gram, the rate of growth in yield of other crops in the state is dismal. Productivity of rice, potato, maize, groundnut, and sugarcane has not only experienced deceleration but also witnessed instability over time. In Odisha, agriculture is largely rain-dependent and yield of crops is very sensitive to variations in rainfall. However, on adjusting for such variations, yield of most crops has shown an improvement. The analysis further suggests the role of irrigation and fertilizer in boosting agricultural growth and productivity and reducing variability. The composite index of agricultural development shows large inter-district variations. The districts have performed better during the sixties upto early eighties, a period coinciding with green revolution.

Keywords Crop yields, Growth, Variability, Weather uncertainty

JEL classification Q18, Q10, C5

1 Introduction

Instability is an important characteristic of agriculture. It is caused by a number of factors - natural (i.e. abrupt changes in rainfall and temperature) and man-made (i.e. technological change, quantity, and quality of inputs, irrigation etc.). Hazell (1982) argues that widespread use of modern inputs such as improved seeds, agro-chemicals and irrigation, and agronomic practices can potentially reduce instability in agricultural growth caused by changes in the weather conditions, insect-pests and diseases. Mehra (1981) and Ray (1983), on the other hand, argue that instability in agricultural growth is an outcome of widespread adoption of modern technologies. We examine this contradictory finding in the context of agriculture in Odisha. We focus on two main questions: Has agricultural growth in Odisha been accompanied by an increase in instability? Does the magnitude of instability vary across crops and regions, and what are the reasons behind it?

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The economy of Odisha is primarily agrarian, with agricultural sector contributing 24% to gross domestic product (GDP) and employing 70% of the total workforce. However, the state has lagged behind in agricultural development. A majority of the farmers are engaged in subsistence farming, cultivating low-value staple foods crops, ostensibly for their household food security. Rice is the principal crop, being cultivated mainly in the kharif season, extending from June to September, on about two-third of the total cropped area. Cropping in the rabi season (October-April) is largely restricted to irrigated tracts. In addition, maize, ragi (finger millet), arhar (pigeonpea), moong (green gram), groundnut, til (sesame), mustard, nigerseed, jute, mesta, cotton, sugarcane, and horticultural crops are cultivated in the state.

The cropping intensity in the state is close to 165%. High yielding varieties cover about 88% of the total cropped area, but the use of fertilizers and pesticides is low, at 60 kg and 0.15 kg per hectare, respectively. Crop yields are low as compared to their corresponding all-India averages. Agriculture in the state is also highly vulnerable to extreme climatic shocks of floods, cyclones and droughts that makes it highly unstable.

2 Data and methods

In this paper, we make use of long time-series of district-level data from 1967-68 to 2014-15 on crop yields and several other aspects. The data on crop yields were compiled from Agricultural Statistics of Orissa at a Glance (GoO, various years) and data on rainfall – a weather parameter were obtained from the India Metrological Department (IMD). In order to understand the behavior of growth and instability in crop yields , the entire period is divided into two sub-periods: (i) 1967-68 to 1987-88 (green revolution), and (ii) 1988-89 to 2014-15 (post-green revolution).

We estimate growth in yields employing kinked exponential (K-E) model that eliminates discontinuity between sub-periods, if any. For a generalized K-E model for m sub-periods and m-1 kinks, let $K_1,\ldots,K_{m-1}$ be the kink points and $D_1,\ldots,D_m$ be the dummies for sub-periods,t, then, an unrestricted model for joint estimation of sub-period growth rate without discontinuity can be written as:

$$lnQ_t = (a_1D_1 + a_2D_2 + ... + a_mD_m) + (b_1D_1 + b_2D_2 + ... + b_mD_m)\, t + u_t \quad \ldots(1)$$

Imposing m-1 linear restrictions, $a_i + b_ik_i = a_{i+1} + b_{i+1}k_i$ for all i = 1,…,m-1, we can estimate growth rates for sub-periods:

$$lnQ_t = a_1 + b_1 (D_1t + D_2k) + b_2 (D_2t - D_2k) + u_t \quad \ldots(2)$$

Where, Q is the yield, D_1 is the dummy for green revolution period, D_2 is the dummy for post-green revolution period, and b_1 and b_2 are the corresponding growth rates for these periods. The significance of the difference in sub-period growth rates can be tested estimating the following trend break equation:

$$lnQ_t = a_1 + b_1t + b_{*1} (D_2t - D_2k) + u_t \quad \ldots(3)$$

Where, b_1* is the difference in sub-period growth rates.

Further, we estimate instability in yield using Cuddy-Della Valley index:

$$IX = CV\sqrt{\left(1 - R^2\right)} \quad \ldots(4)$$

Where, IX is instability index, CV is coefficient of variation (%) and R^2 is coefficient of determination estimated from a time trend regression adjusted for the number of degrees of freedom.

To determine whether the difference in instability (CV) between sub-periods is statistically significant or not, we follow Anderson and Hazell (1989), where a standard normal Z-statistic is estimated as:

$$\left(CV_2 - CV_1\right)\frac{\sqrt{\left\{\left[\frac{1+2C^2}{2}\right]\left(\frac{1}{n1} - \frac{1}{n2}\right)\right\}}}{Cv} \quad \ldots(5)$$

Where, CV is the coefficient of variation for the whole period, CV_1 and CV_2 are the coefficients of variations for green revolution period and post-green revolution period, respectively and n_1, and n_2 are the number of observations for these periods, respectively.

To know whether variability differs significantly between sub-periods across districts, we estimate Kruskal-Wallis (1952) test statistic, which is based on sum of the ranks of CVs in each district for the sub-periods:

$$KW = \left[\frac{12}{n_{t(n_t+1)}} * \sum \frac{Tc^2}{n_c}\right] - 3\left(n_t + 1\right) \quad \ldots(6)$$

Where, n_c is the number of observations in each group of districts, n_t is the total number of observations in all the groups, and Tc is the rank total for each group.

Further, to see if there is a relationship between instability and growth, we estimate correlations and regressions. In order to compare the weather-adjusted and unadjusted rates of growth, we adjust kinked exponential growth with respect to rainfall. The weather-adjusted growth rate is estimated by introducing appropriate intercept and slope dummies following Dev (1987):

$$lnQ_t = a_1 + b_1 + b_2T + b_3 (TD) + b_4 \ln (rt) + b_5 (D \ln rt) + u_t \quad \ldots(7)$$

where, rt is the crop specific rainfall index[1], D is a dummy variable taking value of 1 for the post-green

[1] Crop specific rainfall index is calculated as: $RI\ of\ crop_{it} = \frac{\sum_{j=1}^{\leq 12}\left(MR_j - \bar{m}\right)}{SD(MR)} \times \text{Area under crop i}$ Where, MR = Monthly rainfall of month j where monthly data of only cultivated months are taken into account. For example, if rice is cultivated for 8 months in a year, then n=8.

revolution period, $(b_1 + b_2)$ is the growth rate during green revolution period, and; (b_2+b_3) is the growth rate during post-green revolution period. b_4 is elasticity of yield with respect to rainfall in the post-green revolution period, and (b_4+b_5) in the green revolution period.

3 Results and discussion

3.1 Disparities in agricultural development

Before addressing key research questions, we assess the level of agricultural development across districts in Odisha by constructing a composite index of agricultural development (ADI) based on the following indicators: (i) % share of cultivable land in total land area, (ii) % of cultivable area sown, (iii) % of gross cropped area (GCA) irrigated, (iv) cropping intensity in %, (v) % of GCA under high yield rice varieties (HYV), (vi) fertilizer use per hectare of GCA, (vii) road density, in km per 100 sq km, (viii) share of agricultural credit in total credit and, (ix) average yield of rice in kg/ha.

The ADI is calculated in two steps[2]; first we calculate the index for each component or variable, and then sum the component indices assigning equal weights. The component index is calculated as:

$$I_{ij} = \frac{X_{ij} - MinX_i}{MaxX_i - MinX_i} \qquad \ldots(8)$$

ADI of j^{th} district is computed as:

$$I_{ij} = \frac{\sum_{i=1}^{n} I_{ij}}{\sum_{i=1}^{n} I} \qquad \ldots(9)$$

Where, I_{ij} is the index of i^{th} variable of j^{th} district and X_{ij} is the actual value of the variable I for j^{th} district. Min X_i and Max X_i are the minimum and maximum values of i^{th} variable for the district.

The results are presented in table A1 in the appendix. The districts Balasore, Cuttack, Puri and Ganjam from the coastal belt; and Sambalpur and Bolangir from the central table belt rank higher in agricultural development. The coastal districts have better endowment of irrigation fertile lands (alluvial soils). The districts from the northern plateau zone, viz. Mayurbhanj, Keonjhar and Sundargarh; and Koraput from the eastern Ghat rank at the bottom of the index, and are agriculturally more backward. These districts are rainfed and often drought-prone.

3.2 Growth and instability

The annual growth rate in the yield of major crops during the green revolution and post-green revolution periods are compared in table 1.The growth rate of rice yield has declined significantly in several districts during the post-green revolution period, except in Kalahandi, Keonjhar and Mayurbhanj. In case of potato, Kalahandi and Phulbani are the two districts which have witnessed better yield compared to other districts. Even though, the growth rate of yield is negative in Bolangir, Cuttack, Ganjam, Mayurbhanj and Puri during the green revolution period, it improved slightly during the post-green revolution period. Interesting results came from an analysis of growth rate of maize where none of the districts gained much during the post-green revolution period despite having healthy performance during the green revolution period. Similar results are witnessed in case of groundnut, where only Phulbani district shows a positive growth rate during the post-green revolution period even though all districts have maintained positive figure during the green revolution period. The growth rate of gram yield also faced a similar trend. Except Mayurbhanj, no other district performed better during the post-green revolution period despite having a positive growth during the green revolution period. Another district Puri showed slight improvement during the post-green revolution period even though the growth rate is negative throughout period. In case of sugarcane, Cuttack, Kalahandi, Koraput which have experienced negative trend during the green revolution period increased drastically in the post-green revolution period.

We can conclude that the rate of growth in yield of major crops grown in the state has been dismal. Even though some districts performed better than others, overall performance has not been satisfactory. This could be explained by lack of technological breakthrough, poor investments in agricultural research and delivery systems, capital constraints and deterioration of soil health, relatively less use of fertilizers, and HYVs over the period.

[2] For detailed analysis, see Swain et al. (2009) and Paltasingh, et al. (2012).

Table 1. Growth in yield of selected crops from 1967-68 to 2014-15

	Balasore	Bargarh	Bolangir	Cuttack	Dhenkanal	Ganjam	Kalahandi
Rice GR	27.49	23.02	27.37	27.06	27.001	28.55	26.38
	(9.40)*	(9.21)*	(9.11)*	(9.07)*	(9.34)*	(9.59)*	(9.55)*
Rice post-GR	7.36	11.87	6.04	7.003	7.23	5.81	7.34
	(2.81)*	(5.301)*	(2.24)**	(2.62)**	(2.79)*	(2.17)**	(2.96)*
Trend break	-20.13	-11.15	-21.33	-20.05	-19.76	-22.74	-19.04
	(-4.05)*	(-4.21)*	(-3.01)*	(-3.96)*	(-4.03)***	(-4.51)*	(-4.06)*
Potato GR	27.38	25.33	26.06	26.88	27.31	25.33	23.43
	(9.06)*	(8.28)*	(8.62)*	(8.34)*	(9.14)*	(8.37)*	(7.07)*
Potato post-GR	6.42	7.02	6.51	6.51	6.59	7.003	9.75
	(2.37)*	(2.56)*	(2.41)**	(2.25)**	(2.46)**	(2.58)**	(3.28)*
Trend break	-20.95	-18.31	-19.55	-20.37	-20.72	-18.32	-13.67
	(-4.08)*	(-3.53)*	(-3.81)*	(-3.72)*	(-4.08)*	(-3.57)*	(-2.43)**
Maize GR	26.06	25.16	25.48	27.86	27.24	25.07	26.41
	(8.66)*	(9.22)*	(8.44)*	(9.51)*	(9.18)*	(9.02)*	(8.89)*
Maize post-GR	5.46	6.97	7.52	-5.02	4.68	7.33	8.18
	(2.02)*	(2.85)*	(2.77)*	(1.91)*	(1.76)***	(2.94)*	(3.11)*
Trend break	-20.6	-18.18	-17.97	-22.84	-22.55	-17.74	-18.23
	(-4.03)*	(-3.92)*	(-3.51)*	(-4.59)*	(-4.48)*	(-3.76)*	(-3.65)*
Groundnut GR	26.48	24.57	28.54	24.31	26.05	24.61	26.51
	(9.41)*	(8.57)*	(8.87)*	(8.43)*	(8.67)*	(8.96)*	(9.34)*
Groundnut post-GR	5.33	6.007	3.57	5.71	6.56	7.27	7.28
	(2.11)*	(2.34)**	(1.24)	(2.21)**	(2.44)**	(2.95)*	(2.86)*
Trend break	-21.16	-18.57	-24.97	-18.59	-19.48	-17.34	-19.24
	(-4.43)*	(-3.82)*	(-4.57)*	(-3.8)*	(-3.82)*	(-3.72)*	(-3.99)*
Gram GR	2.24	1.59	2.61	3.08	1.24	2.67	1.67
	(0.88)	(0.59)	(1.24)	(1.16)**	(0.45)	(1.04)	(0.55)
Gram post-GR	27.21	23.98	26.21	25.18	27.19	25.76	28.53
	(12.04)*	(10.01)*	(13.93)*	(10.56)*	(11.09)*	(11.14)*	(10.61)*
Trend break	24.97	22.39	23.59	22.09	25.95	23.08	26.86
	(5.84)*	(4.93)*	(6.63)*	(4.89)*	(5.59)*	(5.27)*	(5.28)*
Sugarcane GR	25.86	23.39	25.73	24.42	24.22	25.71	24.72
	(9.71)*	(8.001)*	(8.95)*	(8.08)*	(8.95)*	(8.91)*	(8.19)*
Sugarcane post-GR	18.32	20.18	19.49	18.25	18.83	19.07	20.03
	(7.67)*	(7.69)*	(7.56)*	(6.74)*	(7.76)*	(7.37)*	(7.41)*
Trend break	-7.53	-3.22	-6.24	-6.17	-5.39	-6.64	-4.68
	(-1.66)	(-0.65)	(-1.27)	(-1.20)	(-1.17)	(-1.35)	(-0.91)

	Keonjhar	Koraput	Mayurbhanj	Phulbani	Puri	Sambalpur	Sundargarh
Rice GR	25.73	27.92	26.88	28.03	26.91	27.18	26.07
	(8.95)*	(9.8)*	(9.41)*	(9.89)*	(9.02)*	(9.51)*	(9.16)*
Rice post-GR	7.55	6.84	7.001	5.89	5.99	7.11	6.52
	(2.93)*	(2.67)**	(2.73)*	(2.32)**	(2.24)**	(2.77)*	(2.55)**
Trend break	-18.17	-21.07	-19.88	-22.13	-20.91	-20.07	-19.55
	(-3.73)*	(-4.36)*	(-4.1)*	(-4.6)*	(-4.13)*	(-4.14)*	(-4.05)*

Contd...

Potato GR	26.6	27.5	25.23	25.88	26.71	25.99	25.007
	(9.25)*	(9.34)*	(8.02)*	(8.5)*	(8.21)*	(8.65)*	(8.94)*
Potato post-GR	5.85	6.31	7.44	6.36	6.64	6.63	6.05
	(2.26)**	(2.39)**	(2.64)**	(2.33)**	(2.27)**	(2.46)*	(2.41)**
Trend break	-20.75	-21.18	-17.79	-19.52	-20.07	-19.36	-18.95
	(-4.25)*	(-4.25)*	(-3.33)*	(-3.78)*	(-3.63)*	(-3.79)*	(-3.99)*
Maize GR	27.17	26.93	24.99	28.56	25.93	26.56	25.24
	(8.21)*	(9.34)*	(9.88)*	(9.75)*	(8.6)*	(8.79)*	(7.11)*
Maize post-GR	6.06	6.03	6.18	7.17	4.49	5.94	7.34
	(2.04)**	(2.33)**	(2.75)*	(2.73)*	(1.66)	(2.19)**	(2.31)**
Trend break	-21.1	-20.89	-18.81	-21.39	-21.43	-20.62	-17.89
	(-3.75)*	(-4.27)*	(-4.43)*	(-4.3)*	(-4.18)*	(-4.02)*	(-2.97)*
Groundnut GR	26.48	23.34	25.98	28.57	26.28	26.22	27.86
	(8.09)*	(7.74)*	(8.63)*	(9.68)*	(9.63)*	(9.47)*	(8.81)*
Groundnut post-GR	4.65	6.24	5.28	6.28	7.88	4.92	6.22
	(1.58)	(2.31)**	(1.95)**	(2.34)**	(3.22)*	(1.98)**	(2.19)**
Trend break	-21.83	-17.09	-20.69	-22.29	-18.39	-21.31	-21.64
	(-3.93)*	(-3.34)*	(-4.05)*	(-4.45)*	(-3.97)*	(-4.54)*	(-4.03)*
Gram GR	-0.95	6.65	-0.62	5.02	4.21	1.66	3.59
	(-0.29)	(2.92)*	(-0.22)	(1.76)***	(1.17)	(0.68)	(1.41)
Gram post-GR	31.64	19.6	28.87	16.95	17.67	24.09	26.35
	(11.02)*	(9.58)*	(11.25)*	(6.64)*	(5.46)*	(11.12)*	(11.54)*
Trend break	32.59	12.95	29.49	11.94	13.46	22.43	22.75
	(5.99)*	(3.34)*	(6.07)*	(2.47)**	(2.19)**	(5.47)*	(5.26)*
Sugarcane GR	24.1	27.1	23.75	26.61	24.43	26.62	25.95
	(9.02)*	(9.03)*	(7.93)*	(9.5)*	(8.55)*	(9.36)*	(8.48)*
Sugarcane post-GR	17.37	21.03	19.26	16.85	18.29	18.19	18.96
	(7.25)*	(7.81)*	(7.17)*	(6.71)*	(7.15)*	(7.14)*	(6.92)*
Trend break	-6.72	-6.07	-4.49	-9.75	-6.14	-8.43	-6.98
	(-1.48)	(-1.19)	(-0.88)	(-2.05)**	(-1.26)	(-1.74)***	(-1.34)

***, ** and * significant at 10, 5 and 1%, respectively

Table 2 presents coefficient of variation in yield of major crops across districts in Odisha. The instability in yield of rice, potato, maize, groundnut, and sugarcane has significantly reduced in most districts during the post-green revolution period. The yield of gram has also become more stable in all the districts except Phulbani and Puri.

To test whether there is any statistically significant difference in the variability in yield between green revolution and post-green revolution periods, we followed approach given in Anderson and Hazell (1989). The formula is slightly modified depending on availability of data. The test results confirm significant reduction in yield variability during the post-green revolution period.

Further, the K-W test statistic is found to be significant in all the crops (table 3), implying that yield variability differs significantly in the sub-periods and was higher in the green revolution period.

3.3 Relationship between growth and instability

As discussed earlier, there exists some association between growth and instability. Some of the studies have reported that instability is a consequence of growth. However, there has been a controversy regarding the linkage between growth and instability in agricultural output. Hazell (1982) has reported a positive relationship between growth and instability, while Dev (1987) has reported the reverse. Chattopadhyay (2001) has found positive as well as

Table 2. CV in yield of selected crops

	Balasore	Bargarh	Bolangir	Cuttack	Dhenkanal	Ganjam	Kalahandi	Keonjhar	Koraput	Mayurbhanj	Phulbani	Puri	Sambalpur	Sundargarh
Rice GR	168	152	163	167	161	158	151	156	156	162	155	159	158	156
Rice post-GR	11	21	22	11	17	17	12	15	13	13	10	11	15	19
CV (difference)	-157*	-131*	-141*	-156*	-144*	-141*	-139*	-141*	-143*	-149*	-145*	-148*	-143*	-137*
Potato GR	161	160	160	164	160	157	202	160	162	164	163	167	164	164
Potato post-GR	14	10	11	06	08	10	16	09	08	07	19	09	10	16
CV (difference)	-147*	-150*	-149*	-158*	-152*	-147*	-186*	-151*	-154*	-157*	-144*	-158*	-154*	-148*
Maize GR	159	155	161	153	164	169	162	178	170	153	158	159	153	160
Maize post-GR	15	15	14	09	27	11	17	18	23	09	14	08	18	18
CV (difference)	-144*	-140*	-147*	-144*	-137*	-158*	-145*	-160*	-147*	-144*	-144*	-151*	-135*	-142*
Groundnut GR	164	159	175	162	171	157	172	165	161	168	182	160	160	165
Groundnut post-GR	12	14	14	17	16	11	11	21	17	11	15	18	15	11
CV (difference)	-152*	-145*	-161*	-145*	-155*	-146*	-161*	-144*	-144*	-157*	-167*	-142*	-145*	-154*
Gram GR	11	26	10	12	7	15	15	21	06	17	162	225	20	7
Gram post-GR	28	44	23	42	37	36	43	36	49	65	39	46	38	31
CV (difference)	17	18	13	30**	30**	21	28***	15	43**	48**	-123*	-179*	18	24
Sugarcane GR	164	156	168	167	150	166	162	161	166	153	167	167	166	159
Sugarcane post-GR	33	41	33	33	36	36	45	36	74	35	42	47	39	40
CV (difference)	-131*	-115*	-135*	-134*	-114*	-130*	-117*	-125*	-92*	-118*	-125*	-120*	-127*	-21

Note: Figures are in the percentage form calculated by the help of Cuddy-Della Valley index. *, **, and *** shows Z-statistics is significant at 1%, 5%, and 10% level of significance.

Table 3. Kruskal-Wallis test

	K-W test statistic	Tc1	Tc2
Rice	20.27586207	301	105
Potato	20.27586207	301	105
Maize	19.83673469	301	103
Groundnut	20.27586207	301	105
Gram	9.489795918	132	272
Sugarcane	20.95038705	301	108

Note: Authors calculation based on ASO data. Tc1, & Tc2 are the rank total for GR, &Post-GR period respectively. Chi-squared statistic D.F: 1(2-1), $\chi^2_{0.01=}$ 6.63, $\chi^2_{0.05}$= 3.84, & $\chi^2_{0.1}$= 2.71.

Table 4. Correlation between instability and growth in crop yields

	GR	Post-GR
Rice	0.41*	0.35*
Potato	-0.64*	0.19*
Maize	0.11*	0.27*
Groundnut	0.73*	-0.13*
Gram	0.37*	-0.13*
Sugarcane	0.61	0.53

Note: Authors calculation based on ASO data. * shows statistically significant at 5% levels of significance.

negative relationship between growth and instability. We have tested the relationship between instability and unadjusted growth rates in yield across districts of Odisha based on correlation coefficients and regression. The estimated correlation coefficients are reported in table 4. Except for potato, there correlation coefficient between instability and yield growth is positive during the green revolution period, except for groundnut and gram. The regression coefficients in table 5 also demonstrated these observations.

In order to evaluate performance of districts in terms of growth and instability, we have classified districts into four different groups - AA, AB, BA, and BB on the basis of unadjusted rates of growth and levels of instability during the period from 1967-68 to 2014-15. We have found four different types of association as shown in table 6 - AA represents increase in growth and decline in instability, AB represents increase in growth as well as instability, BA represents decline in growth and decline in instability, and BB represents decline in growth and increase in instability. From development perspective, AA is the desirable situation, while BB is the other extreme. Results show that in case of rice, potato, maize, groundnut, and sugarcane, all the districts fall in category BA. In case of gram, Phulbani and Puri fall in AA whereas all other districts fall in the AB category.

Table 5. OLS estimates of the relationship between instability and growth of selected crops

	GR	Post-GR
Rice	1.57	0.91
	(1.58)	(1.29)
Potato	-6.25*	0.81
	(-2.9)	(0.69)
Maize	0.73	0.46
	(0.39)	(1.006)
Groundnut	3.35*	-0.36
	(3.71)	(-0.46)
Gram	12.31	-0.32
	(1.401)	(-0.47)
Sugarcane	2.96**	4.98**
	(2.64)	(2.14)

Note: Authors calculation based on ASO data. It=C+Gt+ut: OLS Estimation, where It: Instability, Gt: Growth rate & ut: error term. *,**, and *** represents statistically significant at 1%, 5%, and 10% level respectively and the figures in brackets are t-statistic values.

4 Rainfall and fluctuations in crop yields

Rainfall is one of the crucial factors that determine variability in agricultural production. Inputs like fertilizers are complementary to the availability of water to crops. The demand for fertilizers is significantly influenced by variations in rainfall, especially those lack assured sources of irrigation. The amplitude of fluctuations in crop output in such areas tends to rise with the growth as in a year of good rainfall the soil-moisture is adequate and levels of ground water is favorable. But, in a year of deficit rainfall, crop yields go down steeply because of significant reduction in the use of inputs. In other words, crop yields, in absence of irrigation, are highly sensitive to variations in rainfall (Rao et al. 1988). Yet, weather factor is ignored in several studies that have estimated growth rates in crop production. We estimate weather-adjusted growth rates

Table 6. Association between growth and instability in yield of major crops in Odisha

Types of Association	AA	AB	BA	BB
Rice	None	None	All	None
Potato	None	None	All	None
Maize	None	None	All	None
Groundnut	None	None	All	None
Gram	Phulbani, & Puri	Balasore,Bargarh,Bolangir,Cuttack,Dhenkanal, Ganjam,Kalahandi, Keonjhar,Koraput, Mayurbhanj, Sambalpur & Sundargarh	None	None
Sugarcane	None	None	All	None

Note: Author's Own Classification. AA represents increase in growth and decline in instability, AB represents increase in growth as well as instability, BA represents decline in growth and decline in instability, and BB represents decline in growth and increase in instability.

in crop yields to know exactly whether crop output/ yield is sensitive to variations in rainfall.

As shown in table 7, the weather-adjusted growth rates for all crops are significantly different than the unadjusted growth rates. For all crops, the weather-adjusted growth rates in all the districts are more than the unadjusted rates of growth during the green revolution as well as post-green revolution periods. In order to understand the impact of growth on instability, we have also examined sensitivity or elasticity of yield with respect to variations in rainfall. Table 8 shows elasticity estimates. Crop yields have become more sensitive to rainfall in the post-green revolution period. In case of rice, almost all the districts (except Bargarh, Ganjam and Keonjhar) have experienced a significant rise in the sensitivity of yield to variations in rainfall. On the other hand, potato yield has become less sensitive to variation in rainfall during the post-green revolution period in most of the districts. Also, there is a decline in elasticity in case of maize in several of the districts. Groundnut became more sensitive in several of the districts. A similar story unfolds for gram and sugarcane.

5 Causes of low rate of growth of yield

Growth in yield of most crops has been sluggish on account of several factors. To begin with, irrigation shows a depressing picture. The gross cropped area irrigated that was 18.6% in 1980 increased to 30.3% in 1990, declined to 26.1% in 1995 and eventually increased to 36.5% in 2011. Area under HYV paddy, although increasing but shows about 33% in 2001, 35% in 2005 and further to 40% in 2010. Use of fertilizers, a key factor that augments yield increased only after 2005, and remained abysmally low. Chand et al. (2011) have also reported deceleration in growth rate in fertilizer consumption in Odisha at an annual rate of 5.1% during 1985-95 and 2.84% during 1996-2003. Furthermore, consumption of electricity in agriculture was 59 million units (kwh) in 1980-81, increased to 305 million units by 1990-91, but declined afterwards to 155 million units in 2009-10.

6 Conclusions and implications

To conclude, growth is a necessary condition for development of agricultural sector. A moderate and significant growth in production/yield accompanied by a low level of instability is desirable for sustainable development of agriculture. This is important as the arable land in Odisha will decline over time due to urban development and industrialization. The government should provide more resources for agricultural research to boost agricultural growth in the state. Further, for sustainable growth the focus should be on varietal improvements of minor crops that can be cultivated in rainfed areas. This is likely to reduce instability also. For accelerating agricultural growth, public investments in agriculture need to be stepped up substantially. Emphasis should be on provision of rural infrastructure and services. Irrigation facilities should be extended to dry land and rain-fed areas. Other infrastructural facilities like rural roads, transport, power supply, marketing and storage should

Table 7. Weather-adjusted growth rate of yield of selected crops in 14 districts of Odisha

	Balasore	Bargarh	Bolangir	Cuttack	Dhenkanal	Ganjam	Kalahandi	Keonjhar	Koraput	Mayurbhanj	Phulbani	Puri	Sambalpur	Sundargarh
Rice GR	20.001	15.79	18.65	19.3	20.62	21.5	16.95	19.15	23.44	19.43	13.99	19.82	21.64	19.2
Rice post-GR	1.87	6.97	1.32	1.42	3.67	-0.48	1.45	1.81	0.95	1.67	1.55	0.96	2.71	1.44
Potato GR	19.95	29.35	21.9	27.4	20.57	21.17	18.95	16.52	20.11	18.98	23.32	18.66	17.21	19.35
Potato post-GR	-0.11	-0.21	0.29	-0.003	0.85	0.52	-0.48	0.53	0.64	-0.78	0.73	0.2	-1.46	0.59
Maize GR	21.3	-2.2	26.18	24.35	41.74	55.54	55.8	32.58	47.5	21.95	48.36	21.45	21.12	51.39
Maize post-GR	2.58	-0.08	1.69	-1.71	2.44	2.09	2.38	-2.21	2.47	0.46	2.09	-1.65	-2.02	-0.31
Groundnut GR	38.04	13.86	-4.36	53.47	14.44	-11.33	25.45	-9.6	13.41	13.89	7.92	64.26	-16.94	17.44
Groundnut post-GR	0.5	1.37	3.97	3.31	4.28	2.57	1.28	3.47	2.41	-0.8	1.34	3.45	-0.51	1.08
Gram GR	0.8	-1.46	0.84	-1.42	-0.9	0.38	-1.92	-5.04	3.57	-2.58	-2.25	-0.96	2.73	1.86
Gram post-GR	23.46	19.47	16.03	5.24	14.22	9.54	21.71	21.06	5.05	28.85	5.97	14.74	8.34	10.88
Sugarcane GR	27.35	13.97	23.35	17.67	18.69	17.59	18.36	28.87	20.14	14.67	23.82	15.75	23.45	16.98
Sugarcane post-GR	13.95	19.92	16.14	15.07	16.12	16.11	13.52	14.76	18.03	8.69	16.95	16.17	16.98	16.83

Table 8. Sensitivity of crop yield to rainfall variations of selected crops in 14 districts of Odisha

	Elasticity of crop yield with respect to rainfall													
	Balasore	Bargarh	Bolangir	Cuttack	Dhenkanal	Ganjam	Kalahandi	Keonjhar	Koraput	Mayurbhanj	Phulbani	Puri	Sambalpur	Sundargarh
Rice GR	-0.006	0.14	5.62	-0.8	0.5	0.3	5.1	1.65	-2.26	-1.21	3.85	-0.45	-1.16	1.01
Rice post-GR	0.08	0.07	0.64	0.06	0.44	-0.26	-0.23	-0.2	-0.13	-0.42	0.18	0.17	0.13	0.16
Potato GR	0.75	-1.14	0.73	1.49	1.47	1.16	0.67	0.58	0.3	0.59	1.01	0.03	0.05	-0.13
Potato post-GR	-0.08	-0.07	0.09	0.06	0.05	0.06	0.13	0.04	0.009	0.09	0.09	-0.02	0.05	0.007
Maize GR	-0.67	1.26	-2.68	-0.78	-2.52	-3.44	-4.71	-1.87	-3.59	-0.75	-3.17	-1.002	-0.46	-5.55
Maize post-GR	0.34	-0.1	0.26	-0.08	0.65	-0.17	0.08	0.11	0.48	0.16	-0.12	-0.02	-0.2	-0.201
Groundnut GR	-0.75	0.26	5.43	-2.61	-0.55	3.67	-0.49	2.12	3.19	0.95	2.98	-2.95	7.07	0.22
Groundnut post-GR	0.26	0.39	0.18	0.21	0.41	0.01	-0.05	0.59	0.17	4.06	0.17	-0.07	0.004	0.36
Gram GR	-0.04	0.07	0.1	0.24	-0.04	-0.02	0.13	0.35	0.05	-0.19	0.16	1.44	-0.34	-0.09
Gram post-GR	-0.27	-2.19	-1.18	-1.78	1.82	-1.11	-2.12	-3.74	-0.89	-2.26	-0.46	0.28	-1.56	-0.35
Sugarcane GR	-1.44	0.77	-0.67	-0.87	-0.1	0.47	-1.65	-2.37	0.29	-1.64	-1.2	1.29	-0.64	-1.12
Sugarcane post-GR	-0.14	0.36	-0.12	0.13	0.02	-0.11	-0.58	-0.04	0.03	-0.33	0.11	-0.08	0.05	0.16

Table 9. Inputs-use and other factors in Odisha

Year	Net sown area ('000ha)	Gross cropped area ('000 ha)	Cropping intensity	Gross irrigated area ('000 ha)	Net irrigated area ('000 ha)	Fertilizer-use (NPK) (kg/ha)	Power-use (million units)	Rice area under HYVs ('000 ha)	Land for non-agricultural uses ('000 ha)
1980-81	6130	8746	142.68	1624	1181	9.68	59	…….	…….
1985-86	6323	9260	146.45	2054	1542	15.2	75	1652.4	688
1990-91	6304	9642	152.95	2918	1925	20	305	2042.6	746
1995-96	6221	9631	155.04	2510	2090	23	491	2481.5	858
2000-01	5829	7878	135.15	2512	1335	41	186	2628.3	999
2005-06	5691	8928	156.88	2691	1846	46	137	3102.3	1015
2009-10	5574	9074	162.79	3308	2158	60	155	3451.5	1298
2010-11	5407	8565	158.41	……	……	62.8	158	3407.6	1300

Source: Compiled from various issues of Agricultural Statistics of Odisha and Economic Survey, Govt. of Odisha

be improved. Agricultural inputs - quality seeds, chemical fertilizers and pesticides should be made available to farmers as per their requirement at reasonable prices.

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Table A1. Agricultural development index (ADI) of Odisha

Sl No.	Zone/District	1980-81		1990-91		2000-01		2008-09	
		ADI	Rank	ADI	Rank	ADI	Rank	ADI	Rank
I	Northern Plateau								
1	Mayurbhanj	0.2868	8	0.2222	12	0.3415	6	0.4875	5
2	Kendujhar	0.1135	13	0.2452	8	0.2874	8	0.3214	8
3	Sundargarh	0.1326	12	0.229	11	0.2359	10	0.2123	11
II	Central Table Land								
4	Bolangir	0.4133	6	0.4645	6	0.3256	7	0.4521	6
5	Sambalpur	0.5452	4	0.6618	2	0.4325	5	0.5542	4
6	Dhenkanal	0.2101	10	0.2895	7	0.2435	9	0.2984	9
III	Eastern Ghat								
7	Koraput	0.1712	11	0.2142	13	0.2324	11	0.2142	10
8	Kalahandi	0.2605	9	0.2305	10	0.1954	13	0.2015	12
9	Phulbani	0.3477	7	0.2429	9	0.1995	12	0.1985	13
IV	Coastal Plain								
10	Balasore	0.5049	5	0.6136	3	0.6874	2	0.5842	3
11	Cuttack	0.6963	1	0.4986	5	0.6524	3	0.6125	2
12	Puri	0.5656	3	0.5785	4	0.7142	1	0.6554	1
13	Ganjam	0.6961	2	0.7208	1	0.5235	4	0.4231	7
	C.V (%)	54.06		48.19		49.26		42.27	

Note: the figures for first two years are adopted from Planning Commission Report 2003-04 and the rest of the figures are being computed using the same methodology and same variables from various issues of Agricultural Statistics 2000-01 and 2008-09.