Sources of Growth and Instability in Agricultural Production in Western Odisha, India

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ABSTRACT

This paper analyzes the nature and sources of agricultural instability in the Bolangir district of Western Odisha, India. The nature of instability in agricultural production is examined by determining the agricultural instability index (AII) of variables such as area, production and yield of food grains and paddy, irrigation coverage, and annual rainfall. The period covered by the study (1984–2009), which is characterized by greater technology dissemination, is categorized into two sub- periods: (1984–1993) and (1994–2009). The effects of a change in major inputs on the variability of crop productivity are assessed using a double-log model. The yield decomposition analysis is used to examine the role of drought risk factors and the amount and productivity of inputs in crop yield growth. The extent of instability in agricultural production and productivity in the region is found to be quite high on account of the high level of rainfall variability and the low irrigation coverage. The level of instability in food grain production is much larger during the second sub-period. The decomposition analysis reveals that about 84.4 percent of the total change in paddy yield growth is due to drought risk factors such as rainfall failure, rainfall variability, high temperature, and drought-induced pest attack, while the remaining change in paddy yield is due to the change in amount and productivity of major agricultural inputs such as labor, fertilizer, pesticides, and irrigation.

Keywords: drought, agricultural instability, yield decomposition, Western Odisha
JEL classification: Q54, Q12, C51, C88

INTRODUCTION

Agriculture is considered as the backbone of the Indian economy notwithstanding the fact that its share in the nation's GDP has declined to about 14 percent in 2011–2012 (Government of India [GOI] 2012). It is the major source of livelihood for about half of India's population, and it is a source of raw material for a large number of industries (GOI 2013). Stability and growth in agriculture are vital for providing food and nutrition security to the burgeoning population of more than 1.2 billion in the country. A decent agricultural growth is therefore a prerequisite for achieving inclusive growth, reducing poverty levels, developing the rural economy, and enhancing farm incomes. An impressive growth in agriculture is also necessary to attain the overall GDP target of 8 percent as stated in the country's 12th Five-Year Plan (GOI 2013).

However, instability in agricultural production is on the rise due to several factors such as erratic rainfall pattern, low irrigation coverage, and increase in frequency and severity of natural disasters, among others. Furthermore, the weak institutional setup and the poor coping capacity of most farm households have considerably increased the vulnerability to agricultural risks in various parts of the country (Jodha 1991; Samal and Jena 1998; Bokil 2000; Ramaswamy et al. 2004; Swain 2010). Instability in agricultural production has affected price stability and the consumers, and has increased the vulnerability of low-income households to market forces (Acharya 2001). This instability has also had adverse effects on the food management and macroeconomic stability in the country (Chand and Raju 2009). Given these realities, it is incumbent upon the Indian government to confront the challenge not only of promoting agricultural growth but also that of reducing instability in agricultural production.

The nature and sources of growth and instability in agriculture in India have been debated upon since the introduction of new technology during the so-called Green Revolution period. Many studies reveal that the level of instability in agricultural production was higher during the period when Green Revolution technology was adopted (late 1960s, 1970s, and 1980s) compared to the pre-Green Revolution period (Mehra 1981; Hazell 1982; Ray 1983; Rao et al. 1988). Growth and instability in agricultural production have moved in parallel directions during this period that saw the adoption of new technology. However, a study by Mahendradev (1987) reveals that instability in food grain production during the Green Revolution declined marginally country-wide but exhibited mixed results at the state level. Agricultural production during the period of wider technology dissemination (1990s and 2000s) was much more stable compared to the pre-Green Revolution and the first two decades of Green Revolution in the country (Sharma et al. 2006; Chand and Raju 2009).

In spite of marginal decline in the level of instability during the 1990s and 2000s, it has remained a matter of policy concern in the country across states. Very high risk is involved in food grain production in the states of Maharashtra, Tamil Nadu, Odisha, Madhya Pradesh, Rajasthan, and Gujarat (Chand and Raju 2009). In the eastern part of India, drought, flood, and cyclone are the major climatic risks, which are mostly responsible for the growing instability in agricultural production. Odisha, one of the states located in the eastern part of the country, is known as the 'disaster capital' of India since the state is considerably affected by some kind of natural disaster every year (Mahapatra 2001). Coastal districts of the state are more prone to tropical cyclones and floods whereas the western part of the state is more affected by frequent droughts (Roy et al. 2004). In addition to the frequent occurrence of natural disasters, other factors such as low irrigation coverage and widespread poverty have significantly contributed to spatial and temporal variations in agricultural production in the western parts of the state (Swain et al. 2009).

In this context, this paper makes an attempt to analyze the nature and causes of agricultural instability in Western Odisha. The short-term and long-term behavior of rainfall and drought probability and intensity, and their implications on crop output variability are examined. Attempt is made to assess the influence of rainfall variability and other agricultural inputs like irrigation and fertilizer use on the variability of crop output and productivity. The growth of crop yield is decomposed to find out how much change in crop yield is due to drought risk factors and how much is due to a change in the amount and productivity of inputs.

The paper contains six sections. The next section briefly discusses the data and methodology. Section 3 highlights the major features and importance of the study region. Section 4 discusses the extent, nature, and causes of agricultural instability in Bolangir. Section 5 discusses the major sources of crop output variability at the household level, and Section 6 concludes with some policy suggestions.

DATA AND METHODOLOGY

A multi-stage purposive sampling method is applied in this study. At the first stage, the Bolangir district, which is located in the western part of Odisha, is deliberately chosen for the study because it is found to be the most vulnerable to drought among all districts of Odisha (Roy et al. 2004). Also, the entire district has been declared as drought-prone by the Government of India. At the second stage, out of the total of 14 blocks in the Bolangir district, three blocks are selected on the basis of degree of drought vulnerability, namely: Saintala (most vulnerable), Patnagarh (moderately vulnerable), and Titlagarh (least vulnerable).[1] Detailed analysis is carried out for these three study blocks. At the third stage, three villages—one from each of the selected blocks—are selected purposively considering their suitability for the study purpose and the degree of their representation for respective blocks in terms of socioeconomic and biophysical factors. Finally, households are sampled from each of the selected villages through a stratified random sampling method covering cultivator and non-cultivator households. Out of a total of 139 sample households, 92 are cultivator households which are considered for analyzing agricultural instability at the household level.

Agricultural instability in Bolangir district, Odisha state is analyzed in terms of the following variables: area, production and yield of food grains and paddy, irrigation coverage, and annual rainfall. The period of study is 1984–2009 which is characterized by wider technology dissemination. The whole period is divided into Sub-period I (1984–1993) and Sub-period II (1994–2009). The second sub-period, which coincides with trade liberalization, experienced the occurrence of repeated droughts.[2] The agricultural instability

1 The degree of drought vulnerability is calculated on the basis of the composite drought vulnerability index (CDVI) which is constructed using 19 key drought vulnerability factors out of which six are biophysical factors (i.e., drought probability, drought intensity, long-term rainfall variability, available water holding capacity of soil, land slope, and ground water table) and 13 are socioeconomic factors covering irrigation, major crop production, poverty, land use pattern, and major social and institutional factors. (For details, see Swain 2010).

2 The study region, along with the major parts of the state and the country, was severely affected by drought in 1996, 1998, 2000, 2001, and 2002 (Swain 2010).

index (AII), as developed by Ray (1983) and used by Chand and Raju (2009), is used to study the nature of agricultural instability in the study district and the Odisha state, as a whole. The AII is defined as the standard deviation of natural logarithm (Y_{t+1}/Y_t) where Y_t is the area / production / yield in the current year and, Y_{t+1} is for the next year. This index is unit-free and very robust, and it measures deviations from the underlying trend. This is a very simple measure of instability given by standard deviation in annual growth rates. The method satisfies such properties like instability based on detrended data and comparability.

A double-log regression analysis is carried out to analyze the determinants of yield variability and agricultural instability in the study region. The decomposition analysis is performed at household level to analyze the role of drought risk factors and the amount and productivity of inputs in influencing the growth of crop yield in the region.

Since the variability of rainfall is found to considerably influence the agricultural instability in the study region, a detailed analysis is carried out by using daily rainfall data for a period of 18 years (1986–2003), besides using annual rainfall data for the period 1901–2003. The weekly rainfall analysis is carried out at block level mainly on three selected study blocks. With the help of the standard package written in FORTRAN 77, the long-term frequency behavior of dry and wet spells is examined. The initial and conditional probabilities of dry and wet weeks are defined as follows:

$$P(D) = \frac{F(D)}{N}; \; P\left(D/_D\right) = \frac{F\left(D/_D\right)}{F(F)}$$

where:

$P(D)$=probability of a week being dry;
$F(D)$=total number of dry weeks;
$P(D/D)$=conditional probability of a dry week preceded by another dry week;
$F(D/D)$=total number of dry weeks which are also preceded by dry weeks; and
N=total number of weeks taken for analysis.

In this study, the Indian Meteorological Department (IMD) definition of meteorological drought is used to define drought probability and intensity. Accordingly, a particular year is considered as a drought year if the annual rainfall is less than 75 percent of the long-term normal amount. The criteria followed for defining the intensity of drought are shown in Table 1. Based on the available rainfall data, the percentage departure (PD) has been calculated using the following formula:

$$PD = \frac{(R_i - \bar{R})}{\bar{R}} \times 100$$

where:

R_i=actual rainfall for the year (mm)
$\bar{R}$ = long period average (LPA) rainfall (mm) for 1951–2000.

Table 1. IMD criteria for defining drought intensity

Classification	Percentage Deviation (D_i)	Intensity of Drought
M0	> 0	No drought
M1	0 to –25	Mild drought
M2	–26 to –50	Moderate drought
M3	< –50	Severe drought

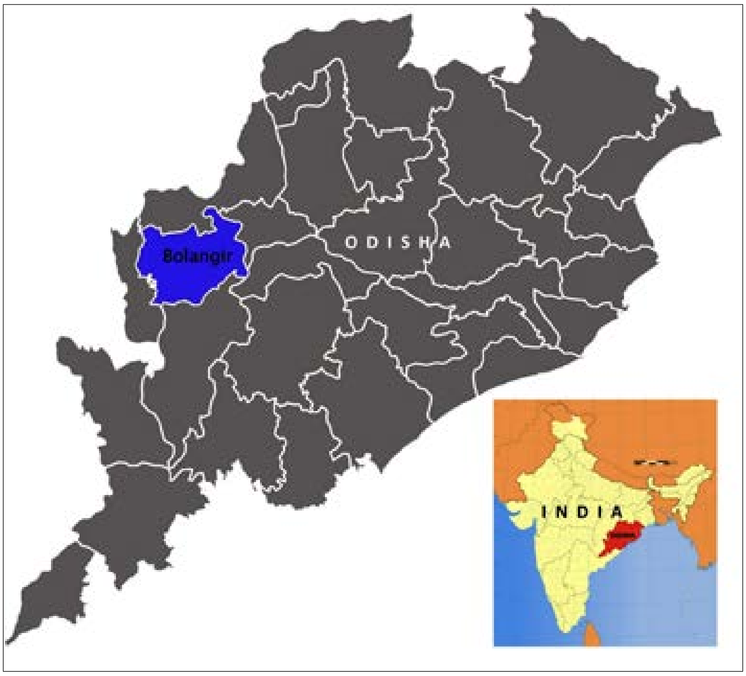
Source: Indian Meteorological Department (IMD), Pune

THE STUDY REGION

The Bolangir district of Western Odisha (Figure 1) is one of the constituent districts of the Kalahandi-Bolangir-Koraput (KBK) region of Odisha.[3] Bolangir has an area of 6,575 square kilometers and a population of about 1.38 million (GOI 2001). The proportion of the rural population is much higher (88.46%) not only in the district but in the entire KBK region. The proportion of scheduled castes (SC) and scheduled tribes (ST) in the total population is around 16.9 percent and 20.6 percent, respectively.

The district (and the entire KBK region, as well) has attracted the attention of international media several times because of the prevalence of chronic poverty, malnutrition, hunger and starvation death, periodic outmigration, and unusually high day temperature (Pattnaik 1998). About 201,310 families, comprising 61.1 percent of the total, are below the poverty line (BPL) in the district, as per the BPL survey conducted in 1997 (Government of Odisha 2002). Agriculture is the predominant source of livelihood for the people in the district. About 52.7 percent of its total main workers are agricultural laborers (GOI 2001). Drought is a recurring, and the single most insidious, phenomenon which is largely accountable for the chronic backwardness of the district (Pattnaik 1998; Mahapatra 2001; Roy et al. 2004). The district has been affected by droughts of different intensities in 20 out of the last 50 years (1962–2012). Furthermore, the intensity and frequency of the drought episodes appear to increase with each passing year (Swain 2010).

Figure 1. The study region: Bolangir, Odisha, India



3 The KBK region was originally composed of three districts namely: Kalahandi, Bolangir, and Koraput.It was later divided into eight districts in 1992-93. The eight districts are Kalahandi, Nuapara, Bolangir, Sonepur, Koraput, Rayagada, Nowrangpur, and Malkanagiri.

NATURE AND DETERMINANTS OF AGRICULTURAL INSTABILITY IN BOLANGIR

Agriculture in the study area is heavily dependent on the monsoon, given that about 77 percent of cultivable area is rainfed (Table 2), for which the level of output variability is found to be considerably high (Figure 2). Some measures of growth and instability in paddy and total food grains are presented in Table 2. The instability index values are much higher in the case of the production and productivity of food grains and paddy. The standard deviation of growth rates or AII of paddy production and productivity was as high as 78.2 percent and 78.8 percent, respectively, during the whole period (1984–2009). The instability in yield of food grains and paddy was more than six times the instability in area during the corresponding period. It may be observed that the average production and productivity of both food grains and paddy were much less during the second sub-period (1994–2009) compared to the first sub-period (1984–1993), whereas the extent of their variability in terms of coefficient of variation (CV) and AII was much larger during the second sub-period. The value of the AII of production and productivity of food grains has increased from 26.8 percent and 23.6 percent, respectively, during Sub-period I to 82.5 percent and 76.3 percent, respectively, during Sub-period II. Moreover, the fluctuation in area, production, and yield of food grains and paddy is considerably larger during both periods in the district compared to that in the state. The AII of production and productivity of food grains was 65.2 percent and 60.2 percent, respectively, in the district compared to 26.8 percent and 22.5 percent, respectively, at the state level during the whole period (1984–2009). Due to the frequent occurrence of drought during the second period, the agricultural production in the district as well as in the state has declined, alongside the increased level of agricultural instability.

Figure 2. Fluctuations in area, production, and yield of total food grains and paddy in Bolangir district, India (1984-2009)

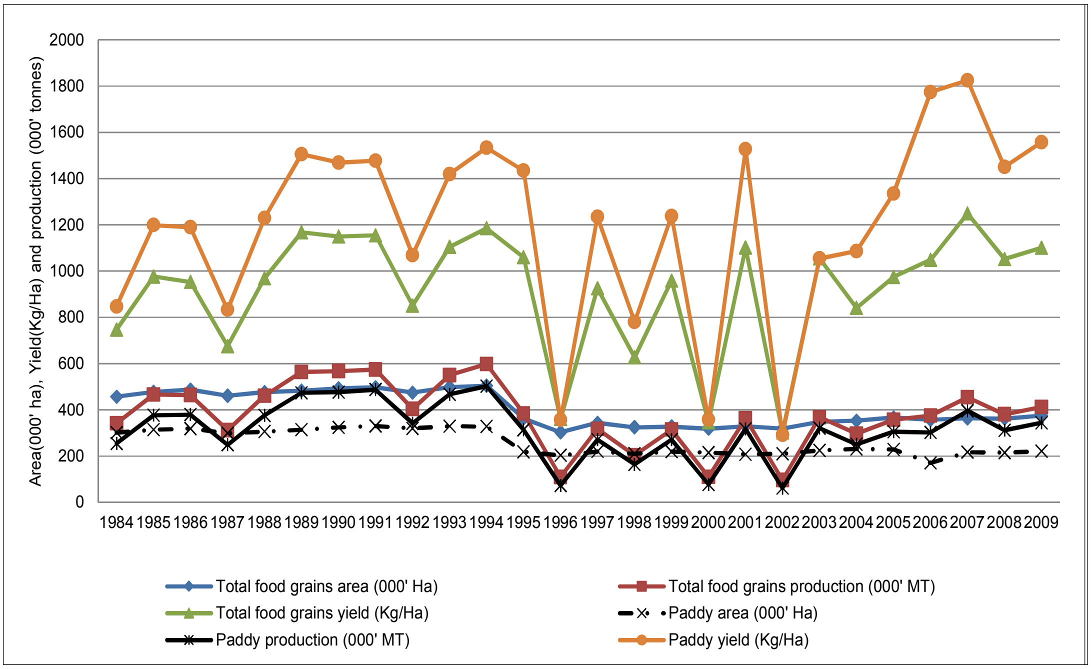


Table 2. Some measures of growth and instability in Bolangir and Odisha agriculture (1984–2009)

Variables	Sub-period I (1984–1993)				Sub-period II (1994–2009)				Whole Period (1984–2009)			
	Mean	CV (%)	AAGR (%)*	AII (%)**	Mean	CV (%)	AAGR (%)*	AII (%)**	Mean	CV (%)	AAGR (%)*	AII (%)**
Bolangir												
Area under food grains (000' ha)	480.4	3.0	0.9	3.5	353.6	12.8	-1.9	11.0	402.4	18.0	-0.8	8.8
Production of food grains (000' ton)	470.3	20.3	4.8	26.8	321.3	42.0	-2.3	82.5	378.6	37.0	0.7	65.2
Yield of food grains (kg/ha)	974.7	17.9	3.9	23.6	886.8	34.7	-0.5	76.3	920.6	28.7	1.5	60.1
Area under paddy (000' ha)	315.6	3.5	0.9	3.3	221.1	14.3	-2.5	15.1	257.5	20.7	-1.2	11.9
Production of paddy (000' ton)	388.1	22.8	6.1	28.6	267.6	45.0	-2.4	99.6	314.0	39.1	1.2	78.2
Yield of paddy (kg/ha)	1229.7	45.7	9.3	44.7	1210.1	41.1	0.0	96.6	1219.3	46.1	3.9	78.8
Gross cropped area (000' ha)	634.7	4.2	1.2	13.4	447.0	6.2	0.5	8.8	519.2	18.7	-0.8	10.7
Gross irrigated area (000' ha)	181.2	9.5	2.9	9.3	83.5	40.5	-5.0	26.3	121.1	46.3	-1.9	21.3
Odisha												
Area under food grains (000' ha)	6975.5	2.7	0.8	3.2	6683.1	4.7	-0.2	5.9	6795.6	4.5	0.2	4.9
Production of food grains (000' ton)	6939.6	15.3	3.8	19.1	7341.4	19.5	0.5	31.5	7186.9	18.0	1.7	26.8
Yield of food grains (kg/ha)	992.3	13.2	3.0	16.6	1093.3	16.6	0.7	26.3	1054.5	16.0	1.5	22.5
Area under paddy (000' ha)	4377.6	3.3	0.6	3.8	4462.5	1.6	-0.1	2.6	4429.8	2.5	0.1	3.1
Production of paddy (000' ton)	5322.4	19.2	4.6	24.3	6097.5	19.7	0.6	34.2	5799.4	20.3	2.0	30.1
Yield of paddy (kg/ha)	1210.8	16.7	4.1	20.9	1366.4	35.3	0.8	40.8	1309.2	34.9	2.0	33.7
Gross cropped area (000' ha)	9358.9	3.4	1.1	2.8	8756.5	6.0	-0.4	7.1	8988.2	6.0	0.1	5.7
Gross irrigated area (000' ha)	2286.8	8.1	2.0	5.4	2611.2	16.5	1.3	17.3	2486.4	15.5	1.5	13.6

Sources: Government of Odisha (2011a; 2011b) and earlier issues

Notes: CV=coefficient of variation; AAGR=annual average growth rate; AII=agricultural instability index; *AAGR=((Ln(value year end)–Ln(value year begin))/number of years)x100; **(AII)=standard deviation of natural logarithm (Y_{t+1}/Y_t) where Y_t is the indicator value in the current year and, Y_{t+1} is for the next year

Besides the erratic pattern and frequent occurrence of rainfall, the access to other complementary inputs such as irrigation, chemical fertilizer, and plant protection chemicals also contributes to the variability in crop output. To determine the effects of the change in supply of agricultural inputs on yield variability, a double-log regression model is estimated for food grains and paddy separately for the whole period (1984–2009). The relative contribution and significance of three major inputs such as rainfall, irrigation, and fertilizer to agricultural instability in the Bolangir district is examined. Our regression model follows a log-linear functional form due to two reasons. First, the agricultural production function is normally assumed to follow a Cobb-Douglas type that requires a log-linear transformation for the estimation of input coefficients. Second, based on Sargan's criterion (Sargan 1964) for choosing between linear and log-linear specifications, the appropriate choice for our model is a log-linear specification. Sargan's criterion is computed as:

$$S = \frac{[\delta u]^N}{[g\delta v]^N}$$

where:

g=the geometric mean of the dependent variable of the linear model

δu =the residual sum of squares of the linear model

δv =the residual sum of squares of the model with log-linear specification

N=the number of observations.

The result of Sargan's criterion for paddy is given below in Table 3. According to Sargan's criterion, if S is less than 1, the linear model is preferred; if it is greater than 1, then the model with log-linear specification is to be preferred. Since our estimation result showed that S was greater than 1, we opted for a log-linear specification. The Sargan's criterion also favored a log-linear specification for food grains.

Thus the estimable equation is as follows:

$$\ln Y_i = \ln A_i + \alpha \ln RF_i + \beta \ln FC_i + \gamma \ln IR_i + \mu_i.$$

The summary of regression results is shown in Table 4. The coefficient values of all three explanatory variables as the major determinants of crop yield in the study area have positive signs as expected. Rainfall (*RF*) and the percentage of gross cropped area that is irrigated (*IR*) have a highly significant influence on the variation in yield of food grains and paddy in the study district. The per hectare fertilizer consumption (*FC*) though is found to have significant influence only on food grain yield, but not on paddy yield. The distribution of per hectare consumption of fertilizer is widely skewed in favor of large and medium farmers in the district. The marginal and small farmers, who together constitute the majority among the farmer categories in the region, do not have enough resources to invest in purchasing fertilizer and pesticides. The extent of fertilizer application is also considerably reduced because of drought occurrence (Swain 2010). The irrigation development in the region is also poor. Only about 23 percent of the gross cropped area is irrigated through various sources which are again mainly accessible to large and medium farmers in the region. The extent of irrigation coverage is largely insufficient to fulfill the irrigation requirement of the farmers in the region.

Since our model has log-linear specification, the coefficients can be interpreted as elasticity. For example, we may say that the food grains yield would increase by 0.409 percent for every 1 percent increase in the irrigation area. If rainfall increases by 1 percent up to a certain level, the food grains yield would increase by 0.851 percent. It may be noted that the rainfall elasticity of paddy yield is considerably higher compared to that of total food grains. This is because paddy consumes more water and is, therefore, more dependent on rainfall. Rainfall

Table 3. Result of Sargon's Test for paddy

g	δu	δv	N	S
1815.63	17539705.87	4.52	26	(2137.995) 26

Table 4. Description and results of the double-log models

Variables	Description	Food Grains			Paddy			VIF
		Coefficients	*t*-values	*p*-values	Coefficients	*t*-values	*p*-values	
RF	Annual actual rainfall (mm)	0.851***	4.715	0.000	0.939***	2.716	0.013	1.132
FC	Per hectare fertilizer consumption	0.228**	2.427	0.024	0.268	1.485	0.152	1.352
IR	% GCA irrigated	0.409**	2.621	0.016	0.640**	2.139	0.044	1.338
A (Constant)	–1.227	–0.994	0.331	–1.934	–0.818	0.422		
Dependent variable (Y)	Food grains yield	Paddy yield						
Durbin-Watson statistic 'd'	2.44	1.449						
R^2	0.674	0.4516						
F observed	15.191	6.039						
No. of observations (N)	26	26						

Notes: *, **, *** means significant at 10%, 5%, and 1% level, respectively; VIF stands for variable inflation factor is the most significant variable for augmenting food grains production in the study district which enjoys adequate rainfall; its average annual rainfall (1,230 millimeters [mm]) is more than the state and national averages. The fragile state of agriculture in the region could have been significantly benefited, had a part of such vast quantity of rainfall been captured through water harvesting structures which are largely feasible in the hilly terrain of the district.

Nature of Rainfall Pattern and Drought Occurrence

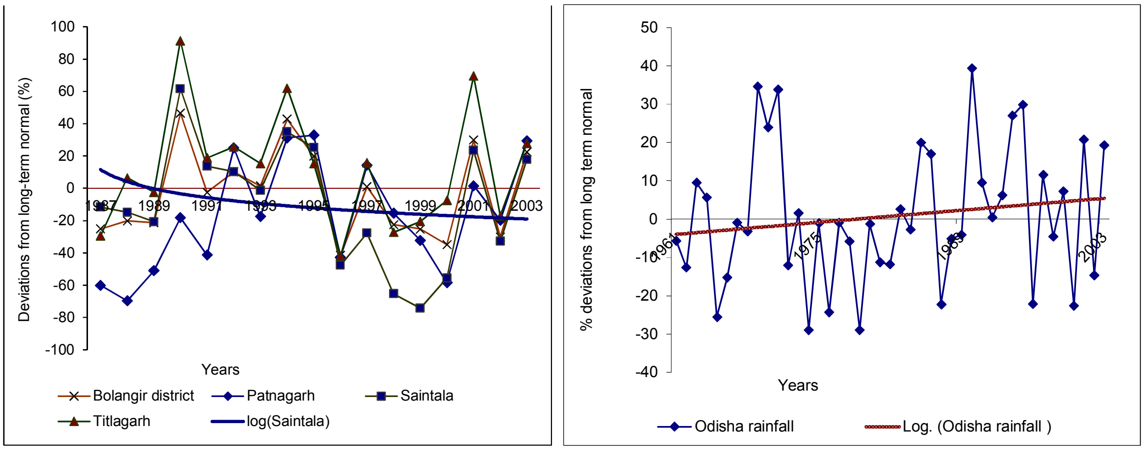
A fairly larger proportion (about 77%) of gross cropped area in the Bolangir district is rainfed (Table 2). Thus the variability of rainfall and frequent drought occurrence play a critical role in raising the level of agricultural instability in the study region. One of the most disappointing features of the rainfall pattern in Bolangir is the gradual decline in average annual rainfall over the years. The annual normal rainfall for the period 1901–1950 in Bolangir (1st long period average [LPA]) was 1,443.5 mm which declined to 1,230 mm in 1951–2000 (2nd LPA) and further to 1,211 mm during the period 1986–2003 (3rd LPA). The drop from the 1st LPA (1901–1950) to the 2nd LPA (1950–1991) is 14.8 percent while that from the 1st LPA to 3rd LPA shows a further decline of 16.1 percent (Table 5). While the annual rainfall in the state as a whole has depicted an increasing trend, rainfall in the most vulnerable Saintala block of the Bolangir district exhibits a declining trend as revealed by the log rainfall graph for the period 1986–2003 (Figure 3). Notably, the total average annual rainfall of the Bolangir district is not a cause of concern since it is even higher than the state and national average. It is the decline in the long-term average annual rainfall that poses a serious problem, since it indicates the gradual desertification of the area and makes agricultural work more risky. Aside from the decline in the long-term average rainfall, the erratic rainfall pattern is also a significant threat to the agrarian economy of Bolangir. The rainfall variability in the study region, with CV at 27.7 percent, has reached a disturbingly high level. The variability in annual rainfall is more pronounced at the block level. Among all 14 blocks of Bolangir district, the CV of rainfall is highest (40.6%) in

Table 5. Rainfall variation in Bolangir district of Odisha

Month	Average Rainfall (1901–1950)	Average Rainfall (1951–2000)	Average Rainfall (1986–2003)	% Change between Col. 2 and Col. 3	% Change between Col. 2 and Col. 4	% Change between Col. 3 and Col. 4
1	2	3	4	(3–2)/2*100	(4–2)/2*100	(4–3)/3*100
January	13.9	6.7	9.9	–51.8	–28.8	47.8
February	18.2	16.3	11.2	–10.4	–38.5	–31.3
March	13.9	9.8	10.1	–29.5	–27.3	3.1
April	18.7	20.0	15.3	7.0	–18.2	–23.5
May	29.1	27.0	38.4	–7.2	32.0	42.2
June	233.7	217.5	200.5	–6.9	–14.2	–7.8
July	391.7	338.4	340.3	–13.6	–13.1	0.6
August	407.1	321.0	335.0	–21.1	–17.7	4.4
September	232.0	191.0	176.1	–17.7	–24.1	–7.8
October	65.6	60.5	50.7	–7.8	–22.7	–16.2
November	15.9	20.1	20.4	26.4	28.3	1.5
December	3.7	1.7	3.1	–54.1	–16.2	82.4
Total	1443.5	1230.0	1211.0	–14.8	–16.1	–1.5

Source: Computed from the rainfall data collected from the Office of the District Collectorate, Bolangir

Figure 3. Rainfall variability in Bolangir and Odisha



Saintala (the most vulnerable block), the least vulnerable Titlagarh experienced the lowest CV of 28.1 percent, and the moderately vulnerable Patnagarh experienced a significantly high level of CV of 40.5 percent.

In addition to the higher variability in annual rainfall over the years, the significant level of intra-regional and seasonal fluctuations in rainfall in the region has been found to hinder agricultural growth. The deficient rainfall in any of the months during the *kharif* (June to October) season may lead to a drought situation in the region. The average rainfall (1986–2003) in the blocks of Bolangir district during June, July, and August was 200.5 mm, 340.3 mm, and 335.0 mm, respectively, which are considered as healthy levels for agricultural operations. On average, 86.9 percent of total rainfall occurred from June to September. However, the average monthly rainfall received during the important kharif months of June, July, and August in the Bolangir district during the period 1986–2003 declined by 14.2 percent, 13.1 percent, and 17.7 percent over the long-term normal of 1901–1951 (Table 5).

The analysis on the behavior of weekly rainfall reveals that the mean, earliest, and latest week of monsoon arrival in the most vulnerable Saintala block are the 24th, 20th, and 28th week, respectively, while the corresponding weeks for the Patnagarh block are the 25th, 23rd, and 28th week, respectively (Table 6). In the case of Titlagarh, the mean, earliest, and latest week the monsoon arrives are the 27th, 24th, and 31st standard meteorological weeks, respectively. The monsoon ends normally in the 37th week at Saintala; however, the earliest week of its termination occurred in the 32nd week in 2000, a drought year. The average duration of monsoon at Saintala is 13.2 weeks; however, it experienced the minimum duration of only seven weeks of monsoon during the two drought years 1996 and 1998. Notably, the variation in commencement, end, and duration of monsoon was greater in the most drought-prone Saintala block with standard deviation of 2.1, 3.5, and 5.0, respectively, during the period 1986–2003. In contrast, the other study blocks experienced lesser variations in commencement, ending, and duration of monsoon. Since the extent of variation was greater in Saintala, the block was found to be more vulnerable to recurrent drought. Both early and late droughts occurred more in this block since the monsoon arrived here a little late and terminated early.

Since a significant proportion of cultivated land in Bolangir is under rainfed agriculture, the variability in the date of onset

Table 6. Monsoon behavior at study blocks in Bolangir (1986– 2003)

Year	Saintala			Patnagarh			Titlagarh		
	Start	End	Duration	Start	End	Duration	Start	End	Duration
1986	25	37	12	25	34	9	25	40	15
1987	23	40	17	27	41	14	23	37	14
1988	25	38	13	26	33	7	25	40	15
1989	24	37	13	24	34	10	25	40	15
1990	22	45	23	25	41	16	20	45	25
1991	23	38	15	24	41	17	23	41	18
1992	25	35	10	25	36	11	25	36	11
1993	24	38	14	24	36	12	24	38	14
1994	20	38	18	23	37	14	24	38	14
1995	20	45	25	25	38	13	26	38	12
1996	27	34	7	27	35	8	27	37	10
1997	26	39	13	26	44	18	24	43	19
1998	26	33	7	27	42	15	17	42	17
1999	26	35	9	24	39	15	22	35	13
2000	24	32	8	24	33	9	24	36	12
2001	24	35	11	23	34	11	23	35	12
2002	24	35	11	24	37	13	24	38	14
2003	28	39	11	28	41	13	27	40	13
Mean	24.2	37	13.2	25.1	37.6	12.5	24.2	38.8	14.6
Earliest	20	32	7	23	33	7	20	35	10
Latest	28	45	25	28	44	18	27	45	25
Std.Dev	2.1	3.5	5	1.5	3.5	3.1	1.7	2.8	3.5

Source: Computed from the rainfall data collected from the Office of the District Collectorate, Bolangir

of effective monsoon, and the higher initial and conditional probability of dry weeks are critical factors responsible for the increase in drought vulnerability and risk in the region. For example, in the case of the Saintala block, the initial probability of dry week *P*(*D*) until the 24th meteorological week was found to vary from 0.65 to 1. The probability of dry weeks continued to increase from the 37th week, reached 0.67 in the 38th week, and thereafter continued to increase until the end of the year. Moreover, the probability of occurrence of a dry week preceded by another dry week, referred to as *P*(*D*/*D*), was very high until the 24th week and thereafter fluctuated heavily around 0.64 in the 28th week which was a crucial time for agricultural activities (Figure 4). With such a variable rainfall pattern, the rainfed agriculture in the region becomes a highly risky venture.

The probability of occurrence of a drought in the Bolangir district (considering the database of daily rainfall from 1986–2003) is found to be 33.8 percent. The frequency of occurrence of mild drought, moderate drought, and severe drought in the district is 23.4 percent, 16.3 percent, and 17.5 percent, respectively (Table 7). Data show that the study region has been affected by a maximum number of mild droughts. Among the study blocks, Patnagarh faced the maximum drought probability of 44.4 percent while Titlagarh experienced a lower level of drought probability of 22.2 percent. It may be noted that Saintala faced about 38.9 percent drought years of which 22.2 percent were severe in intensity. The Patnagarh block was affected by severe droughts in 33.3 percent years, while Titlagarh was affected by the severe intensity of drought only in 5.6 percent of years between 1983 and 2003. This was mainly because the Titlagarh block was endowed with better irrigation infrastructure compared to other study blocks.

Figure 4. Conditional probability of weekly rainfall at Saintala block (1986–2003)

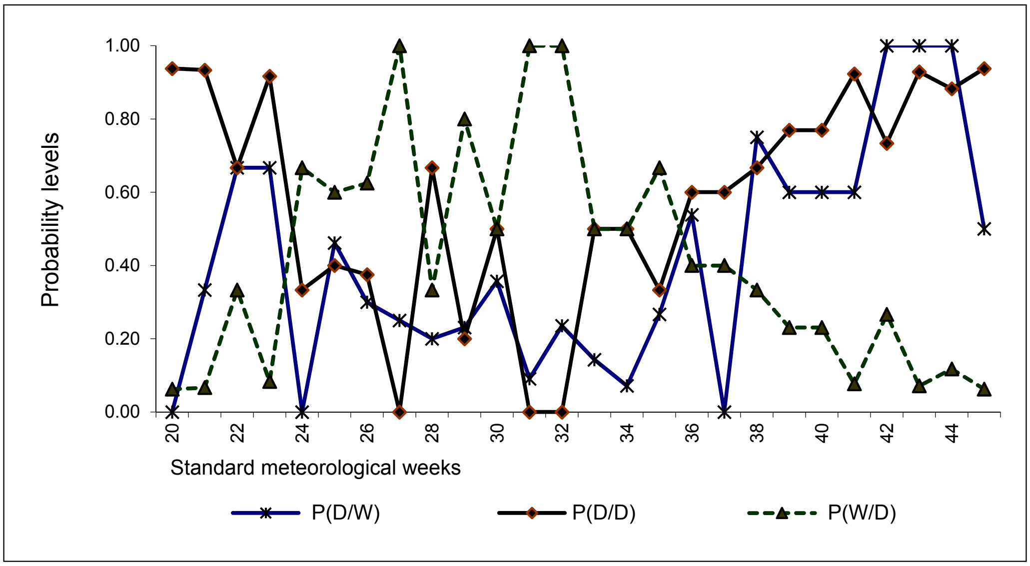


Table 7. Probability of occurrence of drought and variability in annual rainfall, 1986–2003

Blocks of Bolangir	Mild Drought	Moderate Drought	Severe Drought	Probability of Drought Occurrence	Average Annual Rainfall	Coefficient of Variation in Rainfall (%)
Agalpur	16.7	33.3	11.1	44.4	1188.2	32.5
Bangomunda	16.7	22.2	16.7	38.9	1227.3	38.9
Belpara	27.8	16.7	27.8	44.4	1116.1	39.6
Bolangir	27.8	16.7	5.6	22.2	1330.8	29.6
Deogaon	22.2	0.0	22.2	22.2	1245.0	30.6
Khaprakhol	27.8	5.6	44.4	50.0	957.6	38.8
Loisinga	11.1	27.8	5.6	33.3	1220.0	25.3
Tentulikhunti	11.1	16.7	5.6	22.2	1495.8	37.7
Patnagarh	22.2	11.1	33.3	44.4	1016.7	40.5
Muribahal	16.7	16.7	27.8	44.4	1183.1	39.0
Saintala	22.2	16.7	22.2	38.9	1116.5	40.6
Titlagarh	22.2	16.7	5.6	22.2	1376.7	31.6
Puintala	33.3	11.1	5.6	16.7	1362.2	28.1
Tureikala	50.0	16.7	11.1	27.8	1058.5	23.0
Bolangir District	23.4	16.3	17.5	33.8	1206.7	27.7

Source: Computed from the rainfall data collected from the Office of the District Collectorate, Bolangir

It may be noted that the correlation coefficient (r) between the probability of drought occurrence and the CV (%) in rainfall for the period 1986–2003 is 0.601 which implies that there is a strong positive association between rainfall variability and drought occurrence in the region. On the other hand, the deficiency in annual rainfall is not a problem in the study region, as far as drought and agricultural instability is concerned, since it is more than the state average. It is the erratic pattern of rainfall that poses a considerable threat to stability in agricultural output and income in the region.

Besides the erratic pattern of rainfall, there are some other factors which have contributed to agricultural instability in the region. These are the neglect of water harvesting structures (WHS); the promotion of high-yielding varieties (HYV) which replace indigenous crop varieties; the depreciation of agro-biodiversity; deforestation; the poor institutional setup; and the lack of transparency and accountability in the governance system (Selvarajan, Roy, and Mruthyunjaya 2002; Nayak 2004; Swain 2010).

SOURCES OF YIELD VARIABILITY AT HOUSEHOLD LEVEL

The determinants of changes in crop output and yield in the drought-prone areas in a certain year are numerous and thus may be categorized into two major groups: (1) the change in amount and productivity of agricultural inputs such as labor, fertilizer, pesticides, and irrigation; and (2) the exposure to weather-related risks and other exogenous risks such as dry spell, drought, and pest attack, among others. In this section, the percentage contributions of the different effects to the change in crop productivity in the drought year are measured and analyzed.

We have used a decomposition method first used by Oaxaca (1973) and Blinder (1973) to explain wage differentials. Singh and Asokan (2000), Broack and Durlauf (2001), and Selvaraj and Ramaswamy (2006) have used this method to decompose the agricultural output growth in different agro-climatic environments. By applying this method, we have estimated how much change in crop yield was due to drought risk factors and how much change was due to change in the amount and productivity of inputs. Since paddy was the major staple crop grown in the larger proportion of lands in the study area, we used the decomposition analysis for finding out the effect of drought and other relevant factors on the productivity of paddy in the region.

The agricultural production function at farm level is assumed to follow a Cobb-Douglas type that may be stated as $Y = AL^B F^C P^D I^E$ (Equation 1). With logarithm transformation and adding the error term U, the production functions for drought year and normal year (Equation 2) may be stated as follows:

$$\begin{aligned}\ln Y_d &= \ln A_d + B_d \ln L_d + C_d \ln F_d \\ &\quad + D_d \ln P_d + E_d \ln I_d + U_d \cdots \\ \ln Y_n &= \ln A_n + B_n \ln L_n + C_n \ln F_n \\ &\quad + D_n \ln P_n + E_n \ln I_n + U_n \cdots\end{aligned}$$

where:
d = stands for drought year (2002);
n = refers to normal year (2003);
Y = paddy yield (kg/acre);
L = labor use (man-days/acre);
F = fertilizer consumption (kg/acre);
P = plant protection chemicals (INR/acre)[4]
I = percent irrigated of net sown area; and
U = error term.[5]

We distinguish three specific effects that influence the change in agricultural production.

4The input values have been deflated by an average price, the average of two reference years' prices.

5 The error term is the sum of a household fixed effect and a random variable with zero mean and constant variance.

They are (1) the change in amount of inputs; (2) the change in input productivity; and (3) drought-risk factors such as rainfall failure, dry spell, and insect infestation. The household-specific fixed effect that captures time-invariant household heterogeneity such as farmer ability is assumed not to affect the change in paddy productivity.

By first-differencing the production function over two periods d and n and adding some terms and subtracting the same terms, we get Equation 3 below:

$$\begin{aligned}\ln Y_d - \ln Y_n &= (\ln A_d - \ln A_n) \\ &+(B_d \ln L_d - B_n \ln L_n + B_d \ln L_n - B_d \ln L_n) \\ &+(C_d \ln F_d - C_n \ln F_n - C_d \ln F_n + C_d \ln F_n) \\ &+(D_d \ln P_d - D_n \ln P_n - D_d \ln P_n + D_d \ln P_n) \\ &+(E_d \ln I_d - E_n \ln I_n - E_d \ln I_n + E_d \ln I_n)\end{aligned}$$

First-differencing allows us to effectively control for household fixed effects so that the change in the paddy yield is explained by the change in the constant term implying changes due to exogenous factors like drought, pest attack, change in the productivity of inputs, and change in amount of inputs used. By rearranging Equation 3, we get Equation 4:

$$\begin{aligned}\ln Y_d - \ln Y_n = {} & [(\ln A_d - \ln A_n)] \\ & + [(B_d - B_n) \ln L_n \\ & + (C_d - C_n) \ln F_n \\ & + (D_d - D_n) \\ & + (E_d - E_n) \ln I_n]\end{aligned}$$

Equation 5 below is Equation 4 rewritten as:

$$\begin{aligned}\ln \frac{Y_d}{Y_n} = {} & \left[\ln \frac{A_d}{A_n}\right] + [(B_d - B_n) \ln L_n \\ & + (C_d - C_n) \ln F_n + (D_d - D_n) \\ & + (E_d - E_n) \ln I_n] \\ & + \left[B_d \left(\ln \frac{L_d}{L_n}\right) + C_d \left(\ln \frac{F_d}{F_n}\right)\right. \\ & \left. + D_d \left(\ln \frac{P_d}{P_n}\right) + E_d \left(\ln \frac{I_d}{I_n}\right)\right]\end{aligned}$$

Equation 5 involves decomposing the natural logarithm of the ratio of paddy productivity during the drought year and normal year. The bracketed expression in the left side of Equation 5 is a measure of percentage change in paddy output in the drought year in relation to the normal year. The first bracketed expression in the right-hand side of the decomposition equation is the measure of percentage change in output due to shift in scale parameter (A) of the production function. The change in constant term (A) represents the change in the total factor productivity (TFP) which is a joint effect of both technology change and weather-related shocks. Since we have taken into consideration the agricultural production function for two consecutive years, we have assumed the constant state of technology.[6] So the change in scale parameter represents the change in crop yield due to weather-related shocks (i.e., different intensities of drought and drought risk factors).[7] This is one component of change in yield due to drought. Let's denote it as *C1*.

The second bracketed expression is the sum of differences in coefficients or output elasticities during the drought and the normal year, each weighted with the natural logarithm of the volume of respective input used in the normal year. This gives the measure of changes in paddy yield due to a change in factor-specific productivity represented by a shift in the slope parameters of the model. This coefficient component may be denoted as *C2*.

The third bracketed expression is the sum of natural logarithms of the ratio of input use, each weighted with the respective drought year's input coefficient. This change in explanatory variable represents the change in paddy yield due to changes in the amount of

6 From our sample data, there is no evidence of significant change in technological adoption by farmers between these two consecutive years, 2002-2003 and 2003-2004.

7 Most kinds of shocks that households face are induced by crop failure due to drought directly or indirectly. With a very low level of irrigation coverage, the rainfed agriculture is the major source of shocks for the households in the study region.

per acre quantities of human labor, fertilizer, pesticide, and irrigation water. This component of decomposition may be termed as 'input use component' and denoted as *C3*.

Since we use the OLS estimation method which imposes that the mean of the error term is zero, the mean of change in paddy yield is perfectly predicted as the mean of all explanatory variables. So averages are taken of all the explanatory variables and then multiplied by the estimation coefficients. After dividing each component by the mean of change in paddy yield, they add up to one that has been shown in percentage term by multiplying by 100.

Table 8 shows the sample descriptive statistics of the variables used in our model. From the figures in the table, we can immediately conclude that, on average, the paddy yield has drastically decreased in the drought year compared to the normal year, as discussed in the previous section. Among different agricultural inputs, the amount of all inputs fell except pesticides. The higher per acre use of pesticide was due to an increase in insect infestation in the drought year. Apparently, the farmers were very anxious to save the small amount of crops that were left after being affected by rainfall deficiency. So they put all their efforts into preserving their future yield by applying more plant protection chemicals to combat pest infestation during the drought year. The higher incidence of pest attack in the drought year resulted from the decreased level of resistance of plants due to moisture stress. The paddy plants were weakened by moisture stress, making them highly vulnerable to different kinds of pests.

Table 9 shows the extent by which the change in paddy yield is influenced by different components such as the change in the amount of agricultural inputs and drought-induced factors. It may be noted that most of the results from the regression are robust. With regard to *C1*, the total factor productivity that represents the impacts of drought, dry spell, and pest attack has negatively and significantly affected the yield growth of paddy. The strength of the effect is very strong as revealed by a very low *p*-value. On the other hand, the impacts of the change in amounts of all agricultural

Table 8. Descriptive statistics of the selected variables (*n*=92)

Variable	Mean	Standard Deviation	Maximum	Minimum
Normal Year				
Kharif paddy yield (quintal/acre)	10.3	3.4	16	2.5
Labor use (man-days/acre)	40.2	9.9	61	30
Fertilizer use (kg/acre)	102.9	29.5	155	54
Pesticide cost (INR/acre)	102.5	105.6	400	0
% of GCA Irrigated	29.9	11.4	36.7	0
Drought Year				
Kharif Paddy yield (quintal/acre)	4.1	2.6	10	0
Labor use (man-days/acre)	30.6	12.4	62	10
Fertilizer use (kg/acre)	65.9	22.4	105	30
Pesticide cost (INR/acre)	124.9	112.7	405	0
% of GCA Irrigated	24.4	10.8	30.3	0

Source: Field survey

Table 9. Explaining the change in paddy productivity

Parameters	Coefficient	p-value	Sample Mean
C1: Drought risk component	–34.38***	0.006	1.00
Constant term $\left[\ln \frac{A_d}{A_n}\right]$			
C2: Change in input productivity			
Labor ($\ln L_n$)	0.17	0.289	3.96
Fertilizer use ($\ln F_n$)	–0.76**	0.016	4.59
Pesticide use ($\ln P_n$)	0.08***	0.002	5.02
Irrigation coverage ($\ln I_n$)	–1.07	0.842	3.11
C3: Change in amount of inputs			
Labor $\left[\ln \frac{L_d}{L_n}\right]$	0.26***	0.007	–0.32
Fertilizer use $\left[\ln \frac{F_d}{F_n}\right]$	1.00***	0.005	–0.47
Pesticide use $\left[\ln \frac{P_d}{P_n}\right]$	–0.26	0.722	0.16
Irrigation coverage $\left[\ln \frac{I_d}{I_n}\right]$	0.03*	0.090	–0.16
Dependent variable: ln (paddy yield growth)			
F value =	13.68		
R^2 =	0.5154		

Note: *, **, *** means significant at 10%, 5%, and 1% level, respectively

inputs, except pesticides, remain positive but not all of their effects were significant. Only labor and fertilizer inputs could significantly affect the change in paddy yield. Moreover, it is surprising to see that both the amount of irrigation and irrigation productivity are found to be insignificant in affecting the yield growth in the study area. This is basically due to the weak irrigation infrastructure and the very low level of irrigation coverage in the region. Notably,fertilizer and pesticide inputs are found to positively influence the change in the paddy yield. This is due to the fact that farmers in the region do rely on these inputs for enhancing the paddy yield although the most essential input, irrigation facility, is not adequate in the region.

The final step in the analysis was to decompose total change in paddy yield into the different effects that have played a role in it. Therefore, the mean value of each regressor was multiplied with its respective estimated coefficient and then divided by the mean growth of paddy yield. The results are shown in Table 10.

It may be noted that the total attributable change in paddy yield is –40.7 percent, which implies that the paddy yield declined by 40.7 percent due to various reasons during the drought year. The productivity of agricultural inputs as a whole reduced the growth of paddy yield by 5.8 percent and the change in amount of inputs reduced the paddy yield growth by only 0.6 percent. It is noteworthy that about 8.6 percent reduction in paddy yield was due to the decline in fertilizer productivity and another 8.1 percent was due to the reduction in irrigation

Table 10. Percentage contribution of different effects to the change in paddy productivity

Parameters	Sources of Change (%)	% Contribution of Components
Change in paddy yield	–40.73	100.00
C1: Drought risk component		
Change in constant term	–34.38	84.41
C2: Change in input productivity	–5.75	14.13
Labor	0.67	–1.63
Fertilizer use	–3.51	8.61
Pesticide use	0.41	–1.00
Irrigation coverage	–3.32	8.14
C3: Change in amount of inputs	–0.60	1.47
Labor	–0.08	0.20
Fertilizer use	–0.47	1.15
Pesticide use	-0.04	0.10
Irrigation coverage	0.00	0.01

productivity. The major share of change in the yield was due to change in the drought risk factors that are represented by the change in scale parameter. The change in paddy yield due to the drought component was 34.4 percent. In other words, 84.4 percent of total change in paddy yield (–40.7) was due to drought risk factors such as rainfall failure, rainfall variability, high temperature, and drought-induced pest attack. Thus, drought has played a significant role in the resulting variation in crop yield compared to changes in the amount of input use or changes in input productivity in the drought year.

CONCLUSIONS AND POLICY OPTIONS

On account of the high variability in annual, monthly, and weekly rainfall, and the deficiency in irrigated area, the extent of instability in agricultural production in the region is quite high. To reduce the level of instability, it is necessary to cover more cultivable area under assured irrigation. There is a huge scope for increasing irrigation in the district by developing micro-level water resources. The traditional tanks (locally known as *kata, bandha, chahala,* etc.) have proven to be extremely useful not only in normal years but also in water-scarce years. An analysis of irrigation status and existing water harvesting structures (WHS) reveals that minor irrigation is the largest source of irrigation in Bolangir and the share of dug wells stands highest among all sources of minor irrigation (Swain 2006). Small-size WHS are advantageous over medium and large irrigation projects in Bolangir due to the area's uneven and hilly topography. Most of the biophysical factors like rainfall, soil, and topography are conducive for developing WHS in the region, which was previously irrigating about a third of its gross cropped area. Therefore, instead of going for big dams that have already consumed a lot of time and resources but have not yet been completed, efforts should be made to increase the irrigation coverage through the erection of WHS such as dug wells, check dams, and tanks, as well as the renovation of the existing defunct WHS. Though WHS are quite feasible in the region, their sustainability is hampered by such factors as poor economic standards of majority of farmers, erratic power supply, political negligence, and weak institutional setup. The financial constraints may be eased by encouraging the community mobilization of resources, the provision of incentives, and effective institutional support. Continuous and concerted efforts should be made to increase farmers' participation and their adopti on which is essential for the sustainability of WHS.

The study also found that the risk in production was quite high due to deficient or erratic rainfall pattern. The agricultural production risks may be lowered by increasing the crop insurance coverage (quite low at about 4.1%) in the region. Credit-linked insurance may be promoted on a larger scale to reduce the risk level of the farmers. Since the rainfall pattern in this drought-prone region is highly erratic, the timing of investment becomes extremely crucial. Thus, the timely supply of agricultural credit should be the priority of rural financial institutions. Repayment schedules should also be made flexible and suited to different categories of farmers because the time required for a deficit farmer to repay the loan is not usually the same as in the case of a surplus farmer with a larger farm size. Institutional credit policy should be in favor of encouraging the adoption of the recommended cropping pattern, keeping in mind the nature of rainfall deficiency and variability. This would reduce the risk level for the farmers, in turn, increasing the agricultural productivity and stability in the drought-prone region. Increased stability in agricultural production would increase the credit-worthiness of the farmers and reduce the proportion of defaulters.

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