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Effect of Climate Variability on Yields of Major Crops Grown in Odisha, India

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ABSTRACT

This paper examines the impact of climate variables such as temperature and rainfall on the yields of selected major crops in Odisha during the period 1980-81 to 2014-15. Rice, gram, groundnut, maize, potato and sugarcane are major crops included in the study along with total cereals, total foodgrains, total oilseeds and total pulses. The study has used the Random Effect Method, Panel Corrected Standard Error, and Arellano-Bond estimation to identify the crucial determinants of crop yields on panel data of 13 districts. The regression results have reinforced that crop yields of the selected crops are susceptible to climate change. The study has shown that almost all the principal crops grown in the state are highly sensitive to changes in rainfall and temperature. Both these variables have some effects (+/-) on the yield of all crops. It is also observed that the rainfall has significant positive effects on the yields of all the selected crops under study. In case of temperature, we observed mixed results for the selected crops under study. But the extent of increase in the temperature appears to be more harmful for the crop yields. Both irrigation intensity and time trend variable appear to have significant effect on crop y6ield across districts of Odisha. Thus, the findings of the study have important policy implications.

Keywords: Agriculture, Climatic Shocks, Vulnerability, Climate Change, Odisha

JEL: D10, D81, G22, Q54, Q10

I

INTRODUCTION

Agriculture recently has become more demand-driven with a shift from staple crops to cash crops accompanied by a shift towards global integration of agricultural markets (Naylor *et al*., 1997). These changes are pushing the sector into a competitive mode without preparing it to face the concomitant and inevitable vulnerabilities. It is well acknowledged that farming is one of the riskiest economic activities. Fluctuation in farm income attributable to crop yield variability and volatility in commodity prices are significant features of agriculture. Rural households are susceptible to both ‘idiosyncratic shocks’ such as injuries, illness or yield loss, fire or theft particularly felt by an individual household but also ‘covariate shocks’ which are felt across all the households in a given area such as flood or drought or natural disaster. Climatic shocks such as excess rainfall, deficit rainfall, delayed onset of the monsoon, crop damage due to pest and insects always pose barriers to crop yields (Nepal and Shrestha, 2015). Apart from climatic shocks, fluctuation in farm income attributable to crop yield variability, volatility in

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commodity prices, policy changes in the agriculture sector are several other important issues of farming. Farm production is uneven due to its high dependence on the weather conditions. Farm incomes are vulnerable to covariate shocks such as droughts, floods, cyclones, and idiosyncratic shocks such as injuries, fire, theft, the sale of spurious seeds and several other man-made disasters.

In India, risks faced by agricultural households may be due to various reasons. First, around half of India's work force directly depends on agriculture for their livelihood. Agricultural shocks could have implications on the farm income and food security of millions apart from availability of essential raw materials. Moreover, distortions in agricultural production and supply could affect global exports and rise in prices causing inflationary situation in the country. Second is the over-dependence of our agricultural sector on weather. Climatic shocks could, therefore, affect crop production directly without proper adaptation and mitigation strategies. Third, there has been an unprecedented agricultural and agrarian crisis as evident from the spate of farmers' suicides in several regions of the country. Fourth, whether unmitigated risks could be plausibly associated with the ongoing agrarian crises or the crises might have contributed to the various risks faced by rural households, or both, is an important empirical question.

Agricultural production is highly susceptible to the distributional vagaries of weather such as climate change and inherent biological uncertainties in managing crops. Problems like erratic rainfall pattern, rising temperature, recurring climate-induced natural disasters (CINDs) such as flood and drought, high variability of onset dates of monsoon, prolonged dry-spells and unseasonal rains are the major sources of yield risk and yield uncertainty for millions of farm households in the countryside (Vaidyanathan, 1980; Bliss and Stern, 1982; Deshpande, 1985; World Bank, 2005). On the other hand, significant disease outbreak, severe pest damage, loss of crops during storage, poor soil fertility, lack of knowledge on the use of fertilisers, pesticides etc, often causing losses of great value. In the absence of effective risk management mechanisms to insure the considerable production risks on their portfolio, agricultural households in general and farmers, in particular, are exposed to the disastrous consequences of climatic variability and natural disasters. It is therefore imperative to understand the intra-seasonal variability of the monsoon for better climate change projections in these regions given the challenges of rising population, food security and poverty.

Studies carried out in many countries and regions to examine the effect of various climatic factors on crop output have singled out rainfall and temperature as the most relevant factors, the various other factors are largely temperature and rainfall dependent. Modern inputs like fertilisers being highly complementary to water, the demand for fertiliser is significantly influenced by the variations in rainfall, especially in areas inadequately served by assured sources of irrigation. Instability or amplitude of fluctuations of crop output in such areas tends to rise with growth because in a year of good rainfall, soil-moisture is adequate and ground water level is favourable, the use of fertilisers is stepped up and so the crop yields are pushed up significantly. But, in a year of deficient rainfall, crop yields go down steeply because of a significant reduction in the use of inputs, thereby widening the year to year fluctuations in yields. The consequence of this is a rise in the sensitivity or elasticity of output with respect to variations in rainfall (Rao *et al*., 1988). However, many researchers have ignored the weather factor while estimating growth rates in crop production. Although some studies have examined the relationship between rainfall and crop production at the all India level, very few analyses have been made at the regional or district level taking into consideration both rainfall and temperature.

Odisha is a coastal state situated at the head of the Bay of Bengal in the eastern coast of India. Agriculture is the largest employer in this state as a majority of its population is employed in this sector either as farmers or agricultural labourers. Like in many states of India, agriculture holds a predominant position in Odisha's economy. Odisha is an agrarian state in which about 70 per cent of the population is dependent on agriculture (Government of Odisha, 2018). Even though the quantum of rainfall in Odisha is quite high, its distribution during the monsoon period is highly uneven and erratic. As a result, flood and drought occur regularly with varying intensity. During extreme weather events, the damage to crops has been significant. Various climate events such as drought, cyclone, and flood have significantly affected Odisha's agriculture (*ibid.*). Being a coastal state, it faces cyclonic storms almost every year. Crop loss and poor productivity of agriculture often leave the farmers in this state as worst sufferers. In this background, the present study examines the impact of climate variables such as temperature and rainfall on the yields of selected major crops in Odisha during the period 1980-81 to 2014-15 using district level secondary data. This study also estimates weather-adjusted trend growth rates for crop yield for 13 districts of Odisha.

The rest of the paper has been organised as follows. Section II provides a brief condition of the impact of climate-induced natural disasters on agriculture in Odisha. Section III highlights the climate change impact on crop yields in Odisha. This section also discusses irrigation development and crop insurance. Section IV is on the data set and methodology. Empirical results and discussions are given in Section V followed by the summary and policy implications in Section IV.

II

IMPACT OF CLIMATE-INDUCED NATURAL DISASTERS ON AGRICULTURE IN ODISHA

The changes in climate by the forces of nature are the driving force behind the evolution of life on our planet. Life, general habits and sources of livelihood of people in any region have been shaped in accordance with the climate of that place. But while moving towards development and modernisation, human activities have hastened the process of climate change (Piechota and Garbrecht, 2006). The pace of atmospheric emission from industries and transport, urbanisation and deforestation has fastened and has contributed to the rise in global temperature. For the first time, the Stockholm conference recognised the necessity to address climate change. Many human activities like excessive and non-scientific industrialisation, unplanned and non-regulated land use etc. further contribute to the emission of greenhouse gases like CO_2, chlorofluorocarbons (CFCs), hydro chlorofluorocarbons (HCFCs), etc. and other pollutants which results in serious environmental problems like ozone layer depletion, global warming etc. Presently, climate change has gained momentum due to inadvertent anthropogenic disturbances (Khan *et al*., 2009). Anthropogenic greenhouse gas emissions have increased since the pre-industrial era. It has been driven largely by economic and population growth and are now higher than ever (IPCC, 2014). The threats posed by climate change have been realised across the globe. The survival of many species including humans is at stake. The frequency of geophysical disasters (earthquakes, tsunamis, volcanic eruptions, and mass movements) remained broadly constant throughout this period, but sustained rise in climate-related events (mainly floods and storms) pushed total occurrences significantly higher (CRED, 2015). The most pressing impacts of climate change are increase in mean temperature, adverse change in precipitation, rise in sea level, an erratic pattern of rainfall and the frequent occurrence of extreme climatic events or climate-induced natural disasters like drought, flood and coastal storms. Developing countries are worst hit by climate change as their major source of income like agriculture, fishery, tourism, etc. are dependent on the climatic factors.

According to the Odisha Agricultural Statistics (2013-14) agriculture and animal husbandry sub-sector contributed 13 per cent to the Gross State Domestic Product (GSDP) at 2004-05 prices. It is known that the share of the agriculture and allied sectors in the GSDP has been declining over the years. But this sector continues to be vital for the state's economy as about 60 per cent of the total population of the state draws its sustenance fully or partially from this sector. But this sector suffers from frequent natural calamities like cyclones, drought and flash floods and even animal menace, localised adverse weather events also. In Odisha, there are 10 agro-climatic zones with various types of soil like red, yellow, red-loamy, alluvial, coastal alluvial, laterite and black soil, etc. with a low and medium texture. The characteristics of different agro-climatic zones in Odisha are presented in Table 1.

TABLE 1. VARIOUS AGRO-CLIMATIC ZONES IN ODISHA AND THEIR FEATURES

Sl No. (1)	Agro-climatic zone (2)	Agricultural districts (3)	Climate (4)	Broad soil groups (5)
1)	North Western Plateau	Sundargarh, Parts of Deogarh, Sambalpur and Jharsuguda	Hot and moist	Red and yellow
2)	North Central Plateau	Mayurbhanj, Major parts of Keonjhar (except Anandpur and Ghasipura blocks)	Hot and Moist	Red loamy
3)	North Eastern Coastal Plateau	Baleswar, Bhadrak, Parts of Jajpur and hatdihi block of Keojhar	Hot and moist sub-humid	Alluvial
4)	East and South eastern Plateau	Baleswar, Khurda, Jagatsinghpur, part of Cuttack, Puri, Nayagarh, and part of Ganjam	Hot and humid	Coastal alluvial saline (near the coastal line)
5)	North Eastern Ghat	Phulbani, Rayagada, Gajapati, part of Ganjam and small patches of Koraput	Hot and moist sub-humid	Laterite and brown forest
6)	Eastern Ghat High Land	Major parts of Koraput, Nabarangpur	Warm and humid	Red, Brown
7)	South eastern Ghat	Malkangiri and Part of Keonjhar	Warm and humid	Red, mixed and yellow
8)	Western Undulating	Kalahandi and Nuapada	Warm and moist	Black, mixed red and black
9)	West Central Table Land	Bargarh, Bolangiri, Boudh, Sonepur, Parts of Sambalpur and Jharsuguda	Hot and moist	Red, Heavy textured colours
10)	Mid Central Table Land	Angul, Parts of Cuttack and Jajpur	Hot and dry sub-humid	Red loamy, Laterite mixed red and black

Source: Comprehensive District Annual Plan, 2010-11 (Government of Odisha).

To discuss the situation further the data on rainfall, crop productivity and a number of disasters in the state have been collected from various sources and discussed in Table 2 below.

TABLE 2. NATURAL CALAMITY SCENARIO AFFECTING AGRICULTURAL PRODUCTION

Year (1)	Normal rainfall (mms) (2)	Actual rainfall (mms) (3)	Per cent deviation of actual from normal rainfall (4)	*Kharif* rice production (lakh MT) (5)	Natural calamity (6)
1961	1502.5	1262.8	-15.953	36.99	
1962	1502.5	1169.9	-22.136	36.32	
1963	1502.5	1467	-2.363	42.47	
1964	1502.5	1414.1	-5.884	43.59	
1965	1502.5	997.1	-33.637	31.89	Severe drought
1966	1502.5	1134.9	-24.466	35.37	Drought
1967	1502.5	1326.7	-11.700	34.43	Cyclone and flood
1968	1502.5	1296.1	-13.737	38.48	Cyclone and flood
1969	1502.5	1802.1	19.940	38.39	Flood
1970	1502.5	1660.2	10.496	39.13	Flood
1971	1502.5	1791.5	19.235	33.76	Flood and severe cyclone
1972	1502.5	1177.1	-21.657	37.35	Drought, flood
1973	1502.5	1360.1	-9.478	41.91	Flood
1974	1502.5	951.2	-36.692	29.67	Flood, severe drought
1975	1502.5	1325.6	-11.774	42.74	Flood
1976	1502.5	1012.5	-32.612	29.58	Severe drought
1977	1502.5	1326.9	-11.687	40.5	Flood
1978	1502.5	1261.3	-16.053	41.89	Tornados, hail storm
1979	1502.5	950.7	-36.725	27.34	Severe drought
1980	1502.5	1321.7	-12.033	40.31	Flood, drought
1981	1502.5	1187.4	-20.972	36.63	Flood, drought and Tornado
1982	1502.5	1179.9	-21.471	27.07	High flood, drought, cyclone
1983	1502.5	1374.1	-8.546	47.63	
1984	1502.5	1302.8	-13.291	38.5	Drought
1985	1502.5	1606.8	6.942	48.8	Flood
1986	1502.5	1566.1	4.233	44.56	
1987	1502.5	1040.8	-30.729	31.03	Severe drought
1988	1502.5	1270.5	-15.441	48.96	
1989	1502.5	1283.9	-14.549	58.4	
1990	1502.5	1865.8	24.180	48.42	Flood
1991	1502.5	1465.7	-2.449	60.3	
1992	1502.5	1344.1	-10.542	49.76	Flood, drought
1993	1502.5	1421.6	-5.384	61.02	
1994	1502.5	1700.2	13.158	58.31	
1995	1502.5	1588	5.691	56.48	
1996	1502.5	990.1	-34.103	38.27	Severe drought
1997	1502.5	1493	-0.632	57.51	
1998	1502.5	1277.5	-14.975	48.85	Severe drought
1999	1502.5	1435.7	-4.446	42.75	Severe cyclone
2000	1502.5	1035.1	-31.108	41.72	Drought and flood
2001	1482.2	1616.2	9.041	65.71	Flood
2002	1482.2	1007.8	-32.006	28.26	Severe drought
2003	1482.2	1663.5	12.232	61.99	Flood
2004	1482.2	1273.6	-14.074	58.84	Moisture stress
2005	1451.2	1519.5	4.706	62.49	Moisture stress
2006	1451.2	1682.8	15.959	61.96	Moisture stress and flood

Contd.

TABLE 2. CONCLD.

Year (1)	Normal rainfall (mms) (2)	Actual rainfall (mms) (3)	Per cent deviation of actual from normal rainfall (4)	*Kharif* rice production (lakh MT) (5)	Natural calamity (6)
2007	1451.2	1591.5	9.668	68.26	Flood
2008	1451.2	1523.6	4.989	60.92	Flood and moisture stress
2009	1451.2	1362.6	-6.105	62.93	Flood, moisture stress and pest attack.
2010	1451.2	1293	-10.901	60.51	Drought and unseasonal rain
2011	1451.2	1327.8	-8.503	51.27	Flood and drought
2012	1451.2	1391.3	-4.128	86.81	Drought in 4 districts
2013	1451.2	1627.0	12.114	65.85	Flood and cyclone in 18 districts due to Phailin
2014	1451.2	1457.4	0.427	85.78 (Prov.)	Cyclone in 8 districts due to Hud Hud

Source: Compiled from *Status of Agriculture in Odisha,* Government of Odisha.

Table 2 provides data on the actual rainfall in mms, the natural rainfall in mms, *kharif* rice production in lakh million tonnes (MT) and the natural disasters suffered by the state from 1961 to 2014. It can be observed that in the data of 54 years, only 13 years are there where there has not been any natural disaster. Remaining 41 years have witnessed at least one natural disaster. This leaves the state with about80 per cent probability of facing natural disasters in any year. The data table can be used for further analysis of the erratic nature of rainfall, deviation of actual rainfall from normal rainfall, the relation of this deviation with the occurrence of the natural disaster and with crop productivity in each corresponding year (Senapati, 2020).

Table 2 also gives an idea that the percentage deviation of actual rainfall from normal rainfall is high, is the year with drought or severe drought. For example, the year 1965 witnessed a high negative percentage deviation of actual rainfall from normal rainfall and is the year of severe drought. Years like 1974, 1976, 1979, 1987, 1996, 1998 and 2002 witnessed severe fluctuations in the rainfall pattern and witnessed severe drought. About 23 years out of 54 years has suffered from flood situations and all these years either had a positive percentage deviation of actual rainfall from normal rainfall or very less negative deviation from normal rainfall.

Odisha which can also be termed as the disaster capital of our country faces disasters with a regularity which is evident from the above discussion. The western part of Odisha containing the major hilly segment of this state suffers from drought on a regular basis, forcing the farmers to commit suicide due to severe crop loss. The vast coastal belt of this state exposes the coastal districts to frequent cyclones and floods causing severe agricultural stress in the farming community, by making people homeless, helpless and leads to crop loss caused by nature's fury. The sensitivity of the crop outputs to the variations in the climate variables gives a picture of the extent of vulnerability to which the agricultural production is exposed. The different agro-climatic environment in the different districts of this state exposes the districts to different kinds of vulnerabilities. The sensitivity varies from district to district and from crop to crop. Despite the same technological aid and financial support in all the districts, the output sensitivity varies depending on the local climatic environment.

III

CLIMATE CHANGE IMPACT ON PRINCIPAL CROPS IN ODISHA

3.1 *Impact of Climate Change on the Agriculture Sector*

Climate change has been realised globally. Although it is not possible to definitively attribute every single episode of extreme weather to climate change, it is considered that more frequent and more severe extreme weather events are expected due to climate change (Gill, Environment Agency). Changes in climate patterns (whether cyclic or human-induced) are among the major causes of more frequent climate-related events (Delbiso *et al*., 2015). Its effects like the erratic rainfall pattern or increasing frequency of climate-induced natural disasters are not bound by geographical or economic boundaries. The developing countries are the most vulnerable to these disasters as people in these countries depend on the climatic phenomenon to maintain their livelihoods like agriculture, fishery, forestry, tourism, etc.

India, which is also a developing country, suffers from large-scale natural disasters almost every year and with climate change, the frequency of these disasters has increased. Among all the climatic stresses, Climate-Induced Natural Disasters (CINDs) like drought and flood which are mostly the result of insufficient and erratic rainfall cause havoc in the agriculture sector. The loss of life, property, and productivity leave many people working in this sector under the heap of destruction. But, the impacts of droughts and floods are often discounted or ignored in the long-term national development planning and sector-wise strategies development.[1]

According to IPPC's Fifth assessment report, "a wide range of crops shows that depressing impact of climate change on agricultural crop yield has been seen very much than its encouraging impacts" (IPCC, 2014). According to an assessment made by FAO, "during 2003-13, in 48 developing countries 78 large-scale disasters caused a loss of USD 140 billion on damage in all the sectors, out of which USD 30 billion was on the agricultural sector. So, from these developing countries, they found that agriculture absorbs around 22 per cent of the total economic impact caused by natural hazards" (FAO, 2015). Our country has an agrarian economy and the cropping pattern is sensitive to climate change. It is affected by variability in monsoon rainfall, the rising temperature, and natural disasters. Studies on climate change and vulnerability and its impact on agriculture is a high priority in India as its impact, if it follows the predictions, is expected to be widespread and severe (Khan *et al*., 2009). It affects the rain-fed cropping pattern. The increase in temperature may also due to an increase in insect and pest population and their survival, leading to crop damage. Apart from these climatic disturbances the CINDs like drought, heat waves, tropical cyclones, and floods cause huge loss of property, life and livelihood in our country. These natural disasters affect agriculture in many ways like affecting farmlands, affecting cropped areas, crop loss, production loss, loss of property, equipment, and livestock, etc. One of the major repercussions that disasters have is on agriculture. A substantial part of the rural population depends on the agriculture sector for managing their livelihood. Agricultural activity is adversely affected by any unforeseen weather changes or variations in physical conditions. This gets accentuated in the case of cyclones, floods and droughts resulting in disruption of people's livelihood and adding to the risk, damage, and stress of disasters (NAAS, 2004). In our country, recurrent droughts, floods, and cyclones threaten the livelihood of billions of people. When disasters strike, the livelihood of small farmers, pastoralists, fishers is the worst affected. Rural farmers' whose livelihoods are very much dependent on the use of natural resources are more likely to face the adverse impacts of climate change (Gbetibouo, 2009).

The vast diversity in the geography of our country makes some of the states geographically vulnerable to natural threats. Odisha situated on the eastern coast of India is one such region which has been exposed to this natural vulnerability since long and the severity of the situation has aggravated with climate change which is discussed below. The risks associated with climate change in Odisha are high variability of rainfall, leaving people with two peak periods of food shortage, drought and dry spells at an interval of every two years in Western Orissa with a major drought every 5-6 years, flash floods during the rainy season, heat waves in summer, intense coastal flooding and cyclones (OCCAP, 2010-2015). As we can see climate change manifests itself in many forms, of which change in the rainfall and temperature pattern are the subjects of the discussion below.

Climatic factors like rainfall and temperature enter into the production of a crop in a given region as exogenous variables are determined by nature whereas various controlled variables such as fertilisers, pesticides, irrigation, prices, etc which are directly controlled by the farmers differ over space and time because the magnitudes of exogenous or nature determined variables vary (Rao *et al.*, 1988). Variations in occurrence and relative magnitudes of the various climatic factors neither follow a unified pattern nor do all of them appear as constraints on agricultural output. Some fluctuate more than others and make their impact felt on production. Studies carried out in many countries and regions in order to examine the effect of various climatic factors on crop output have singled out rainfall and temperature as the most relevant factors, the various other factors are largely temperature and rainfall-dependent (Ray, 1971). The performance of the agricultural sector continues to be highly volatile mainly due to the adverse impact of natural shocks such as cyclones, droughts, and floods (Government of Odisha, 2014). In order to empirically verify the possible impact of natural shocks on the agricultural sector, researchers have used several methods such as the Ricardian cross-sectional approach, agro-economic modeling, and the production function approach in the literature. The Ricardian approach has been widely used to examine the impact of weather variables on land prices and farm revenue generation studies (as in Mendelsohn, and Dinar, 1999 and 2003; Darwin, 1999; Gbetibouo and Hassan, 2005; Mendelsohn and Reinsborough, 2007; Sanghi and Mendelsohn, 2008; Kavikumar, 2009; Palanisami *et al*., 2009). However, this approach has been severely criticised for not providing information on agricultural production and ignoring price variation and carbon fertilisation effects (Mendelsohn, 2000). However, the overall literature on Ricardian approach reported a harmful impact of climate change on the agriculture sector. On the other hand, the major studies such as Aggarwal *et al*., 1997; Aggarwal and Mall, 2002; Mall *et al*., 2006 on agronomic modeling reported again a negative impact of climate change on the agriculture sector. However, one can use panel data models with district fixed effects so as to address many aforementioned issues.

3.2 *Irrigation Development in Odisha*

The estimated water resource of Odisha is one of the highest in the country. It is of the order of 11 per cent of the country's total surface-water resources (Government of Odisha, 2011). Out of the total 6.56 million ha of cultivable land of the state, 5.9 million ha (about 90 per cent) can be brought under assured irrigation through different sources. Despite annual expansion in the created potential and capital investments on irrigation in Odisha, the area irrigated by the major, medium and minor irrigation systems have been either stagnating or declining. In many irrigation commands, an effective irrigated area has declined due to deterioration in the distribution infrastructure. The annual investment on irrigation under different five-year plans has been fluctuating. However, after liberalisation, the investment has been consistently high as shown in Table 3.

TABLE 3. INVESTMENT ON IRRIGATION DURING FIVE-YEAR PLANS IN ODISHA
(RS. CRORE AT CURRENT PRICES)

Plan periods (1)	Investment on major and medium irrigation projects (2)	Investment on minor (flow and lift) and medium irrigation projects (3)	Total investment (4)
1st Plan (1951-56)	55.28	----	55.28
2nd Plan (1956-61)	20.00	1.65	21.65
3rd Plan (1961-66)	26.22	6.22	32.44
Annual Plans (1966-69)	20.44	7.95	28.39
4th Plan (1969-74)	20.89	18.88	39.77
5th Plan (1974-78)	70.63	31.00	101.63
Annual Plans (1978-80)	67.81	28.30	96.11
6th Plan (1980-85)	360.00	85.00	445.00
7th Plan (1985-90)	623.61	177.15	800.76
Annual Plan (1990-92)	404.72	103.50	508.24
8th Plan (1992-97)	2276.00	323.40	2599.4
9th Plan (1997-02)	…..	…..	2383
10th Plan (2002-07)	2334.00	427.54	2761.54
11th Plan (2007-2012)	……	…..	2742.14
12th Plan (2012-17)	……	…..	3149.89

Source: Compiled from Paltasingh *et al*. (2012) and *Economic Survey*, Government of Odisha (various issues).

Table 4 reveals the crop-wise total cultivated area and the corresponding irrigated area. It is observed that the total irrigated potential created during 2010-11 from all sources was 44.39 lakh ha (26.62 lakh ha during *kharif* season and 14.77 lakh ha during *rabi* season). The gross irrigated area during the year is 30.39 lakh ha (20.59 lakh ha during *kharif* and 9.80 lakh ha during *rabi* season) which is 69 per cent of irrigation potential created. Among the crops, rice enjoys a bulk share of total irrigation created and utilised followed by pulses and vegetables and others. It is more in *kharif* season and less in *rabi* season. However, the point to be noted that rice covers the bulk of the total irrigation potential created and utilised. So that makes agriculture unsustainable in the sense that the entire irrigation facilities are concentrated in rice only which is affected by natural calamities quite often, but other crops get a little share (Paltasingh *et al*., 2012).

TABLE 4. IRRIGATION CONDITION IN ODISHA DURING 2010-11

(*Area in lakh ha*.)

Crops (1)	*Kharif* season: Total area (2)	Area irrigated (3)	Per cent of irrigated area (4)	*Rabi* season: Total area (5)	Area irrigated (6)	Per cent of irrigated area (7)	Total: Total area (8)	Area irrigated (9)	Per cent of irrigated area (10)
Paddy	41.00	17.28	42	2.65	2.65	100	43.65	19.93	46
Other Cereals	4.27	0.53	12	0.36	0.36	100	4.63	0.89	19
Pulses	7.51	0.45	6	13.41	1.09	8	20.92	1.54	7
Oilseeds	3.99	0.18	4	3.98	1.31	33	7.97	1.49	19
Fibres	0.88	0.06	7				0.88	0.06	7
Sugarcane				0.37	0.37	100	0.37	0.37	100
Vegetables	3.04	1.89	62	3.91	3.27	84	6.94	5.15	74
Spices	0.75	0.2	27	0.73	0.73	100	1.48	0.93	63
Others				0.03	0.03	100	0.03	0.03	100
Total	61.44	20.59	34	25.41	9.8	39	86.87	30.39	35

Source: Compiled from Odisha Agriculture Statistics, 2013-14, Government of Odisha.

3.3 *Crop Insurance in Odisha*

During *kharif* 2010-11, farmers accessing loans from institutional sources such as commercial banks, cooperatives, and regional rural banks, National Agricultural Insurance Scheme (NAIS) is compulsory thus categorised as loanee farmers whereas, in case of non-loanee farmers, it is voluntary. Here we have shown a break-up analysis of area and farmers covered according to non-loanee and loanee categories in Tables 5 and 6 for the period of *kharif* 2010-11. Here we have divided the whole districts of Odisha into four physiographical zones such as Northern Plateau, Central Table Land, Eastern Ghat, and Coastal Plain. As one can see from the above Table 5, in the case of Northern Plateau, the claim-premium ratio is very high in case of Sundargarh district and the least in the case of Deogarh district. Mayurbhanj and Jharsuguda have the highest percentage of non-loanee farmers benefitted from the crop insurance schemes. In the case of Central Table Land, Sambalpur has the Mayurbhanj and Jharsuguda have the highest percentage of non-loanee farmers benefitted from the crop insurance schemes. In the case of Central Table Land, Sambalpur has the highest claim-premium ratio as well as highest percentage of non-loanee farmers benefitted from the crop insurance schemes. In the case of Eastern Ghat, none of the districts have claimed insurance and hence benefitted from the scheme. Similarly, in the case of Coastal Plain, Balasore has the highest claim-premium ratio as well as the highest percentage of non-loanee farmers benefitted from the crop insurance schemes. On the other hand, as one can see from the Table 6, in the case of Northern Plateau, the claim-premium ratio is very high in case of Mayurbhanj district and the least in the case of Deogarh district. But, Deogarh and Jharsuguda have the highest percentage of loanee farmers benefitted from the crop insurance schemes. In the case of Central

TABLE 5. DISTRICT WISE STATISTICS OF CROP INSURANCE BY NON-LOANEE FARMERS DURING *KHARIF* 2010-11

Region ↓	Non-loanee							
Northern Plateau (1)	Farmers (Number) (2)	Area in Ha (3)	Sum insured (Rs. lakh) (4)	Premium (Rs. lakh) (5)	Claims (Rs. lakh) (6)	Claim-premium ratio (7)	Farmers benefitted (Number) (8)	Per cent of non-loanee farmers benefitted (9)
Mayurbhanj	1	1	0.1	0.004	0.1	13.75	1	100
Keonjhar	413	342	43.3	1.1	7.3	6.72	156	37.77
Sundargarh	3172	4331	458.8	11.9	202.4	16.94	3089	97.38
Jharsuguda	285	746	109.2	3.2	45.7	14.33	285	100
Deogarh	28	73	7.9	0.2	0.9	4.42	22	78.57
Total	3899	5493	619.2	16.4	256.3	15.61	3553	91.13
Central Table Land								
Bolangir	47	138	27.8	0.9	0.0	0	0	0
Sambalpur	1514	4012	748.8	22.4	391.3	17.43	1455	96.10
Bargarh	107	349	82.8	2.7	0.8	0.30	1	0.93
Dhenkanal	1	1	0.1	0.0	0.0	0	0	0
Sonepur	2463	4951	1016.4	30.4	121.7	4.00	2229	90.50
Angul	10	16	1.5	0.04	0.2	6.09	6	60.00
Boudh	106	255	42.2	1.3	4.7	3.73	59	55.66
Nawapara	226	372	84.4	3.0	0.0	0	0	0
Total	4474	10094	2004.1	60.7	518.7	9.00	3750	83.82
Eastern Ghat								
Kalahandi	889	2080	293.0	8.9	0.0	0	0	0
Others	0	0	0.0	0.0	0.0	0	0	0
Total	889	2080	293.0	8.9	0.0	0	0	0
Coastal Plain								
Balasore	1761	1629	199.5	5.0	42.3	8.47	1761	100
Cuttack	31	30	4.6	0.1	0.0	0	0	0
Ganjam	2	3	0.6	0.01	0.0	0	0	0
Khurda	48	46	6.3	0.2	0.0	0	0	0
Nayagarh	2	26	3.5	0.1	0.0	0	0	0
Others	0	0	0.0	0.0	0.0	0	0	0
Total	1844	1734	214.4	5.4	42.3	7.88	1761	95.50
State Total	11106	19401	3130.7	91.3	817.3	9.00	9064	81.61

Source: Compiled from 'Agriculture Insurance Company of India Limited', Bhubaneswar Regional Office.

TABLE 6. DISTRICT WISE STATISTICS OF CROP INSURANCE BY LOANEE FARMERS DURING *KHARIF* 2010-11

Region ↓	Loanee							
Northern Plateau (1)	No. of Farmers (lakh) (2)	Area (lakh ha) (3)	Sum insured (Rs lakh) (4)	Premium (Rs lakh) (5)	Claims (Rs lakh) (6)	Claim-premium ratio (7)	Farmers benefitted (lakh no.) (8)	Per cent of loanee farmers benefitted (9)
Mayurbhanj	0.31	0.35	6067	152	1653	10.89	0.18	58.19
Keonjhar	0.51	0.32	7113	178	297	1.66	0.04	7.88
Sundargarh	0.61	0.37	8911	223	1918	8.61	0.33	53.43
Jharsuguda	0.17	0.16	3275	82	862	10.5	0.12	69.81
Deogarh	0.11	0.07	1377	34	131	3.8	0.07	63.18
Total	1.71	1.27	26743	669	4862	7.26	0.74	43.07
Central Table Land								
Bolangir	0.23	0.29	4782	120	0	0	0.00	0

Contd.

TABLE 6. CONCLD.

Region ↓ Northern Plateau (1)	Loanee No. of Farmers (lakh) (2)	Area (lakh ha) (3)	Sum insured (Rs lakh) (4)	Premium (Rs lakh) (5)	Claims (Rs lakh) (6)	Claim-premium ratio (7)	Farmers benefitted (lakh no.) (8)	Per cent of loanee farmers benefitted (9)
Sambalpur	0.34	0.45	9034	227	2911	12.83	0.22	62.85
Bargarh	0.34	0.42	10545	264	0	0	0.00	0
Dhenkanal	0.38	0.42	6741	169	0	0	0.00	0
Sonepur	0.29	0.40	5766	144	178	1.23	0.06	19.94
Angul	0.62	0.65	10203	255	1922	8	0.35	55.65
Boudh	0.36	0.40	4970	124	357	2.87	0.12	32.36
Nawapara	0.00	0.00	0	0	0	0	0.00	0
Total	2.57	3.03	52041	1303	5368	4	0.74	28.61
Eastern Ghat								
Koraput	0.14	0.21	2156	54	0	0	0	0
Kalahandi	0.29	0.51	6984	179	0	0	0	0
Kandhamal	0.10	0.08	1468	37	0	0	0	0
Rayagada	0.18	0.35	2758	75	0	0	0	0
Gajapati	0.12	0.12	2220	56	0	0	0	0
Nowrangpur	0.26	0.36	3841	96	0	0	0	0
Malkangiri	0.10	0.13	1317	33	0	0	0	0
Total	1.20	1.76	20744	529	0	0	0	0
Coastal Plain								
Balasore	1.06	0.93	18820	470	383	0.81	0.10	9.13
Cuttack	0.36	0.22	5872	147	0	0	0.00	0
Puri	0.74	0.40	9017	225	0	0	0.00	0
Ganjam	0.80	0.80	12718	318	1719	5.4	0.28	34.75
Bhadrak	0.75	0.63	12946	324	0	0	0.00	0
Jajpur	0.24	0.13	3594	90	128	1.42	0.03	12.57
Jagatsinghpur	0.39	0.18	5007	125	0	0	0.00	0
Kendrapara	0.58	0.26	7280	182	474	2.6	0.17	28.73
Khurda	0.40	0.39	7099	177	0	0	0.00	0
Nayagarh	0.18	0.12	2261	57	0	0	0.00	0
Total	5.49	4.06	84614	2115	2704	1	0.57	10.37
State Total	10.97	10.12	184142	4616	12934	13	2.04	18.63

Source: Compiled from Agriculture Insurance Company of India Limited, Bhubaneswar regional office.

Table Land, Sambalpur has the highest claim-premium ratio as well as the highest percentage of loanee farmers benefitted from the crop insurance schemes. In the case of Eastern Ghat, none of the districts have claimed insurance and hence benefitted from the scheme. Similarly, in the case of Coastal Plain, Ganjam has the highest claim-premium ratio as well as the highest percentage of non-loanee farmers benefitted from the crop insurance schemes. The year-on-year growth rate in farmers who have obtained Pradhan Mantri Fasal Bima Yojana (PMFBY) is over 10 per cent, reaching 2.02 million farmers in 2017-18 (Government of Odisha, 2019). On the other hand, the year-on-year growth rate in case of non-loanee farmers who have obtained PMFBY is at a massive 79.27 per cent, reaching 272,909 farmers, according to the draft report. There is significant growth in non-loanee farmers accessing PMFBY.

3.4 *Conservation of Agriculture*

Soil health development and its conservation are essential for raising farm productivity. In Odisha, nearly 12.6 lakh soil health cards (SHC) have been issued to farmers in order to enhance soil health and fertility. Odisha has started Integrating Soil Health Card Portal with Integrated Fertiliser Management System (I-FMS) and promotion of site-specific nutrient management based on village/panchayat/block level soil data. The salinity of soils is an additional problem for Odisha. Excess salt in the soil impairs the productivity of crops. To address this problem, the state has started introducing salt-tolerant varieties and crop rotation techniques. For rain-fed areas, the management of surface water, groundwater, and participatory usage of common pool water resources of rainwater are important techniques so as to enhance crop productivity. The Government of Odisha has started creating and repairing farm ponds on a cluster mode.

IV

DATA AND METHODOLOGY

The present study has used panel data on yield of principal crops and weather variables such as rainfall and temperature at district levels for a 36-year period from 1980 to 2015. Since in 1980, Odisha had only 13 districts, we have selected those districts and formed them into various agro-climatic zones. The rainfall and temperature data were collected from the Indian Institute of Tropical Meteorology and www.indiawaterportal.org and district statistical handbooks for district-level data. In our study, we have considered normal rainfall and average temperature data to test the overall impact of weather variables on yield for selected principal crops in Odisha. Since Odisha is severely dependent on monsoon rains for agricultural uses, failure in monsoon leads to severe water scarcity and severe drought-like situations in rain-fed regions on one hand and heavy rainfall in some districts especially in the coastal region leads to severe flood. We will analyse the growth of crop yield for major crops in Odisha as a whole and alsoin the selected 13 districts from various agro-climatic zones. Here we have ignored the pre-green revolution period due to lack of availability of district-wise data for all these parameters. Hence, we have analysed the growth and sensitivity of crop yield from 1950-51 to 2014-15 which was further divided into three sub-periods namely First (pre-green revolution period), Second (post-green revolution period) and Third phase of technology diffusion for aggregate analysis and from 1967-68 to 2014-15 for district-wise analysis (Senapati and Goyari, 2019). The weather adjusted growth rates in crop yield were estimated based on the approach of Dev (1987) by introducing appropriate intercept and slope dummies as shown below:

The weather adjusted growth rates in crop yield were estimated by introducing appropriate intercept and slope dummies as shown below:

$$\ln Y_t = b_0 + b_1 D + b_2 T + b_3 (TD) + b_4 \ln(rt) + b_5 (D \ln rt) + b_6 \ln(tt) + b_7 (D \ln tt) \quad \ldots. (1)$$

where Y_t= Crop yield, r_t = Crop specific rainfall index, t_t= Crop specific temperature index

D = 0 for 1967-68 to 1987-88
= 1 for 1987-88 to 2014-15.

and b_2: estimated growth rate for the period 1967-68 to 1987-88, (b_2+b_3) represents estimated growth rate for the period of 1987-88 to 2014-15. b_4 represents elasticity of yield with respect to rainfall for the period 1967-68 to 1987-88, (b_4+b_5) represents elasticity of yield to rainfall variation for the period 1987-88 to 2014-15. Similarly, b_6 represents elasticity of yield with respect to temperature variation for the period of 1967-68 to 1987-88, (b_6+b_7) represents elasticity of yield to temperature variation for the period of 1987-88 to 2014-15.

Following Senapati and Goyari, 2019, Crop specific rainfall index has been calculated based on the following procedure:

Rainfall index (year x) = monthly rainfall (year x) – normal mean rainfall/s.d.

Crop specific rainfall index = rainfall index (year x) multiplied by area under particular crop cultivation. In notation:

$$\text{RI of crop}_{it} = \frac{\sum_{j=1}^{\leq 12}(\text{MR}_j - \overline{\text{m}})}{\text{S.D (MR)}} \quad \text{....(2)}$$

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.

(Crop specific rainfall index)$_t$ = (RI of crop$_{it}$) × (GCA of crop$_{it}$).

Similarly, Crop specific temperature index has been calculated based on the following procedure:

Temperature index (year x) = monthly temperature (year x) – normal mean temperature/s.d.

Crop specific temperature index = temperature index (year x) multiplied by area under crop cultivation. In notation:

$$\text{TI of crop}_{it} = \frac{\sum_{j=1}^{\leq 12}(\text{MT}_j - \overline{\text{m}})}{\text{S.D (MT)}} \quad \text{.... (3)}$$

MT = Monthly temperature of month j where monthly data of only cultivated months are considered. For example, if rice is cultivated for 8 months in a year, then n=8.

(Crop specific temperature index)$_t$ = (TI of crop$_{it}$) × (GCA of crop$_{it}$).

After highlighting the spatial and temporal distribution in weather variables, it is imperative to understand the impact of these weather variables on agriculture sector of Odisha. In this section, we have examined the impact of these weather variables on the yield of selected crops grown in Odisha. The model is:

$$y_{it} = c + \theta_t + \lambda t + \beta_1 R_{it} + \beta_2 R_{it}^2 + \beta_3 T_{it} + \beta_4 T_{it}^2 + \beta_5 \, Irint_{it} + \varepsilon_{it} \quad .... (4)$$

where y_{it} refers to yield of a particular crop in district i in year t,
θ_t represents the district fixed effects,
t represents the trend variable taken as a proxy for capturing technological change
R_{it} represents the normal rainfall in district 'i' in year 't' measured in mm.
T_{it} represents the mean temperature in district 'i' in year 't' measured in degree celsius,
$Irint_{it}$ represents irrigation intensity in district 'i' in year 't'
ε_{it} represents the error term,
c, λ, β_1, β_2, β_3, and β_4 are unknown parameters to be estimated.
In order to obtain the Panel Corrected Standard Errors i.e. PCSE estimates, let's take δ as the vector of c, β_1, and β_2 in the model. The OLS estimates and PCSE estimates are identical

$$\hat{\beta}_{ols} = \hat{\beta}_{pcse} = (x'x)^{-1} (x'y) \quad .... (5)$$

the standard error of the PCSE estimator is expressed as:

$$cov(\hat{\beta}_{pcse}) = (x'x)^{-1} (x'\Omega x) (x'x)^{-1} \quad .... (6)$$

Here x represents the vector of explanatory variables, and Ω represents the error covariance matrix.

Before we estimate our panel data model, it is always necessary to check the existence of unit roots. We have used Im *et al*. (2003) tests in our panel presented in Table 7. The results show that the null hypothesis of unit root is rejected for all variables at 1 per cent level of significance. Therefore, each variable in our panel is stationary. Now, we can estimate the panel data model without taking the first difference of the data.

TABLE 7. IM, PESARAN, AND SHIN TEST FOR PANEL UNIT ROOT

Tests (1)	t- statistics (2)
Rice yield	-2.56
Gram yield	-2.94
Maize yield	-2.22
Potato yield	-2.2
Sugarcane yield	-2.84
Groundnut yield	-2.55
Total cereals yield	-2.49
Total foodgrains yield	-2.46
Total oilseeds yield	-2.49
Total pulses yield	-2.35
Rainfall	-2.5
Temperature	-3.06
Irrigation intensity	-2.14

Note: Every value is significant at 1 per cent level of significance.

After estimating the panel data model for all the selected crops, we have also investigated the Breusch-Pagan/Cook-Weisberg test for heteroscedasticity presented in Table 8. The null hypothesis of homoscedasticity is rejected for Gram, maize, Groundnut, and total oilseeds at 1 per cent significance level whereas, for other crops, the homoscedasticity assumption is accepted. However, the above test recommends the use of a suitable method that can allow the panel heteroscedasticity of the error term. It is important to decide on the nature of the district-specific effects of the model (fixed vs. random). We have conducted Hausman test and it rejected fixed district-specific effects. In other words, the district effects cannot be fully captured by introducing dummy variables. This result prompted us to try the random-effects model, specifically the technique developed by Arellano and Bond (1991). Arellano and Bond's Generalised Method of Moments (GMM) estimator is robust to differences in the specification of the data-generating process.

TABLE 8. BREUSCH-PAGAN/ COOK-WEISBERG TEST FOR HETEROSCEDASTICITY IN YIELD RESPONSE

Variable (1)	X^2 statistics (2)	P-value (3)
Rice yield	24.52	0.0000
Gram yield	13.6	0.0002
Maize yield	31.31	0.0000
Potato yield	27.03	0.0000
Sugarcane yield	16.38	0.0001
Groundnut yield	166.07	0.0000
Total cereals yield	24.73	0.0000
Total foodgrains yield	48.21	0.0000
Total oilseeds yield	19.63	0.0000
Total pulses yield	81.53	0.0000

Notes: H_o: Homoscedasticity (constant variance) vs H_1: Heteroscedasticity (unequal variance).

V

RESULTS AND DISCUSSION

This section discusses the estimated results of equation-1 and analysed the intensity of weather-induced fluctuations in crop output. First, we will show the aggregate figure of Odisha has been worked out followed by the district-wise performance of crop output with respect to rainfall.

The main purpose of estimating weather-adjusted growth rate is to know exactly whether crop yield is sensitive to variation in weather or not. Since the adjustment for weather isolates the impact on the growth performance of rainfall conditions being better or worse, the adjusted growth rates may be taken to reflect the intrinsic performance of the state. While looking into the growth rate figure of all crops, weather adjusted growth rate of crops in Odisha was much higher in the first period as compared to the second and third periods (Table 9).

The growth rate figure for all crops changed significantly. As we can see in Table 10 while looking into the growth rate figure of all crops, our weather adjusted growth rate for all the districts was much less in the 1st period but in the 2nd period there is an improvement in the growth rate of all crops. In the 2nd period, the growth rate of all crops in almost all districts came positive except few districts where even though the figure is negative but the magnitude is less. It can be concluded by saying that our weather adjusted growth figure has been significantly improved the growth rate of various crops in almost all districts of Odisha. Thus technology diffusion plays an important role in deciding the production of various crops.

TABLE 9. WEATHER ADJUSTED GROWTH RATE OF YIELD OF MAJOR CROPS IN ODISHA DURING 1950-2015

Crops (1)	1st period (1950-51 to 1964-65) (2)	2nd period (1965-66 to 1987-88) (3)	3rd period (1988-89 to 2014-15) (4)
Rice	5.99	0.87	0.86
Wheat	6.02	5.63	-2.06
Ragi	0.96	2.21	-2.99
Jowar	2.93	4.44	-2.83
Bajra	0.41	7.13	-3.87
Maize	4.28	5.75	-0.21
Potato	12.04	-1.69	-0.26
Gram	4.03	3.96	0.26
Groundnut	6.07	6.88	-2.52
Rapeseed and mustard	0.14	5.01	-8.87
Sesamum(Til)	2.45	5.04	-4.13
Cotton	0.06	4.11	11.04
Tobacco	5.33	-0.25	-2.24
Sugarcane	3.41	2.76	-4.54
Jute	2.26	0.71	-5.16
Mesta	5.28	3.64	-3.08
Total foodgrains	5.65	1.81	-0.11
Total cereals	5.93	1.28	0.52
Total pulses	2.91	4.55	-6.03
Total oilseeds	3.96	5.37	-6.66

Source: Authors calculations based on Agricultural Statistics of Odisha (various issues).

TABLE 10. WEATHER ADJUSTED GROWTH RATE OF YIELD OF MAJOR CROPS IN 13 DISTRICTS OF ODISHA

Crop in Period 1 and Period 2 (1)	Balasore (2)	Bolangir (3)	Cuttak (4)	Dhenkanal (5)	Ganjam (6)	Kalahandi (7)	Keonjhar (8)	Koraput (9)	Mayurbhanj (10)	Phulbani (11)	Puri (12)	Sambalpur (13)	Sundargarh (14)
Rice 1	-1.34	1.24	0.24	0.87	0.33	1.78	-0.66	-0.49	1.21	1.51	0.46	0.21	0.35
Rice 2	0.37	3.56	0.75	-5.94	4.04	-1.69	2.78	2.26	0.36	2.39	0.98	-0.66	0.52
Potato 1	4.12	4.41	-7.62	-0.54	1.09	-2.27	10.87	2.24	1.26	-1.27	-2.94	-0.98	0.32
Potato 2	-0.54	0.42	-1.94	0.57	1.19	-1.34	-1.94	0.02	0.71	2.09	-1.47	-1.81	1.81
Maize 1	7.55	-1.53	6.27	2.33	1.98	3.21	1.25	-0.29	0.59	0.20	2.74	-1.43	1.55
Maize 2	-2.55	1.34	9.50	0.44	27.85	0.89	3.57	1.54	3.51	1.23	-1.58	-0.77	0.50
Groundnut 1	14.68	-1.25	6.62	5.63	-1.89	-1.45	2.02	-0.87	-3.56	1.91	-1.40	3.58	-4.45
Groundnut 2	-0.14	1.29	-2.88	5.99	6.84	1.21	2.96	0.82	2.38	-0.55	3.17	1.35	2.10
Gram 1	0.77	-0.67	0.81	-0.65	-1.70	-0.52	-4.99	-3.73	2.63	-2.35	0.77	3.44	2.92
Gram 2	-10.4	-1.49	7.02	1.88	-58.0	1.18	6.47	2.33	-0.74	4.22	-1.15	0.79	2.23
Sugarcane 1	-1.56	6.10	4.23	-0.30	10.06	2.14	-0.82	1.19	3.24	0.24	2.29	2.58	0.94
Sugarcane 2	8.91	17.17	11.44	10.37	10.10	10.07	7.25	9.85	17.95	8.00	10.44	15.19	15.09
Total food grains 1	1.37	0.77	-0.30	0.61	0.36	0.19	-0.89	0.41	0.38	1.16	-0.07	0.41	0.15
Total food grains 2	0.09	1.93	1.32	-0.75	4.54	-1.91	3.42	0.36	-0.04	2.19	1.20	0.87	0.78
Total cereals 1	1.53	0.38	0.99	0.97	0.16	0.58	-0.35	-0.94	1.45	0.53	0.48	1.05	-0.21
Total cereals 2	-0.07	1.03	1.24	2.67	3.99	-1.93	2.66	1.36	0.21	1.85	0.63	-2.22	0.95
Total pulses 1	3.81	4.30	-2.21	1.73	0.55	0.73	-1.86	-0.62	-1.25	5.66	-0.10	-3.17	1.70
Total pulses 2	-1.86	-1.00	1.40	-0.03	2.67	2.05	3.25	-2.48	1.41	0.59	-0.88	-2.42	0.62
Total oilseeds 1	9.16	0.04	3.36	0.97	-1.14	-0.66	5.21	2.36	2.86	1.31	5.67	4.11	0.38
Total oilseeds 2	0.27	-0.53	2.41	2.67	-4.10	-0.64	4.09	-3.93	-6.97	2.26	2.84	-0.33	-1.41

Source: Same as in Table 9.

Notes: Period 1 (1966-67 to 1987-88), period 2 (1988-89 to 2014-15). Rice 1 and Rice 2 refer to data for Period 1 and Period 2, respectively. It is similar for other crops.

5.1 *Sensitivity of Crop Yield to Weather Variations in Odisha*

If we employ similar development strategies and programs including investment over along a medium-term perspective then only production pattern would follow a certain path of growth under normal rainfall situation. However, if the actual rainfall situation deviates from normal, then coverage of area under the crop as well as its yield would also deviate (Bhatia, 2005). The intensity of weather-induced fluctuations in crop output in any period is the combined result of the sensitivity of output to variations in rainfall and temperature and their respective variabilities. Variability in rainfall over a short period of time may be high or low in any particular area, but over a longer period, one would not expect a marked change in this variability. However, the sensitivity of output to variations in rainfall may change depending upon the nature of technology and inputs used, and also upon the level of development in infrastructural facilities like irrigation (Rao *et al.*, 1988). Therefore, in order to study the impact of growth on instability the sensititity or elasticity of yield with respect to variations in both rainfall and temperature becomes a meaningful indicator for our purpose. The higher the sensitivity, the greater would be the fluctuations in yield. In general, this sensitivity is found to be higher at low rainfall levels and decreases as the level of rainfall increases.

Table 11 explains the elasticity of crop yield with respect to rainfall i.e. per cent deviations in yield from its trend due to 1 per cent deviation in rainfall from its normal level. In case of rice, 8 districts out of the 13 studied have experienced a significant decline in sensitivity of yield to rainfall variation in the post green revolution period except for Keonjhar, Dhenkanal, Sambalpur and Sundargarh. In case of potato, except for Bolangir, Cuttack, Ganjam, Kalahandi and Sambalpur, the rest of the districts have experienced a significant decline in the sensitivity of yield to rainfall variation in the post green revolution period. But in case of maize, all the districts except Balasore, Bolangir, Kalahandi, Keonjhar and Koraput districts have experienced a significant increase in the sensitivity of yield to rainfall variation in the post green revolution period. In case of groundnut, there has been a significant decline in sensitivity of yield in all districts except in Balasore, Bolangir, Koraput and Sambalpur to the variation in rainfall. In case of gram, a significant increase in sensitivity of yield to rainfall variation has been realised in Dhenkanal, Koraput and Puri. A mild increase was observed in Balasore, and Sambalpur and the significant decline were observed in all other districts. In case of sugarcane, a significant decline was observed in sensitivity to rainfall variation in all the districts. In case of total foodgrains, all the districts saw a significant decline insensitivity of yield to rainfall variation except for Balasore, Cuttack, Dhenkanal and Kalahandi. In case of total cereals, all the districts experienced a significant decline in sensitivity of yield to rainfall variation except in Balasore and Dhenkanal. In case of total pulses, a mild decrease in sensitivity of output to rainfall variation was observed in Balasore, Kalahandi, Keonjhar, Mayurbhanj and Sambalpur, the other districts observed a significant increase in sensitivity of output to rainfall variation. In case of total oilseeds, all the districts saw a significant decline in sensitivity to variation in rainfall except in Bolangir, Dhenkanal, Keonjhar and Sambalpur.

TABLE 11. SENSITIVITY OF CROP YIELD TO RAINFALL VARIATIONS OF MAJOR CROPS IN 13 DISTRICTS OF ODISHA

Crop in Period 1 and Period 2	Elasticity of crop output with respect to rainfall												
	Balasore	Bolangir	Cuttak	Dhenkanal	Ganjam	Kalahandi	Keonjhar	Koraput	Mayurbhanj	Phulbani	Puri	Sambalpur	Sundargarh
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Rice 1	0.11	0.56	0.36	0.96	0.68	0.71	0.76	-0.49	0.56	0.53	0.66	0.62	1.70
Rice 2	0.03	1.03	0.04	-0.04	1.24	0.06	0.12	2.26	0.05	0.31	0.42	0.90	0.75
Potato 1	0.96	0.31	1.25	-0.23	0.77	0.29	-2.50	2.24	0.31	0.22	0.04	0.38	0.40
Potato 2	0.01	0.00	1.38	0.41	-0.11	0.49	0.95	0.02	0.16	0.21	0.06	-0.01	-0.19
Maize 1	0.53	-0.23	0.76	-0.81	1.17	-0.13	0.60	0.57	0.97	0.18	-1.01	0.10	-0.22
Maize 2	0.08	0.56	0.66	0.54	1.21	-0.02	0.10	-0.40	-0.28	0.79	0.18	0.18	0.27
Groundnut 1	-0.31	1.13	-0.02	0.06	0.98	0.47	1.24	1.35	0.25	1.18	0.42	0.32	0.80
Groundnut 2	0.16	1.00	0.06	0.60	0.56	0.06	0.35	0.35	0.34	0.74	0.12	0.95	0.79
Gram 1	-0.06	0.56	0.74	0.62	0.19	0.32	0.54	1.63	0.87	0.60	-0.07	0.28	1.50
Gram 2	0.12	0.75	0.34	0.48	0.92	0.24	-0.04	0.28	9.56	0.35	0.41	0.55	0.50
Sugarcane 1	0.51	0.52	0.11	1.34	1.52	1.12	-0.04	0.64	49.84	0.99	0.80	0.30	0.27
Sugarcane 2	-0.06	-0.13	-0.01	-0.33	0.00	-0.31	-0.32	0.08	-36.8	-0.03	0.05	-0.42	-0.08
Total food grains 1	0.03	0.58	0.69	0.61	0.62	0.36	0.22	1.11	0.25	0.95	0.52	1.41	0.43
Total food grains 2	0.09	-0.09	0.19	0.65	1.30	0.10	0.31	0.29	-0.19	0.53	0.47	0.89	-0.05
Total cereals 1	0.09	0.42	0.38	1.07	0.86	0.69	0.38	1.16	0.48	0.56	0.65	0.75	0.96
Total cereals 2	0.10	-0.13	0.06	0.49	1.22	0.04	-0.13	0.20	-0.04	0.04	0.50	-0.18	0.12
Total pulses 1	0.10	0.32	0.53	0.22	0.35	-0.02	0.71	1.16	0.22	-0.08	-0.30	0.93	0.78
Total pulses 2	0.05	0.99	0.57	0.34	0.75	0.23	-0.15	0.27	0.50	-0.16	1.01	0.52	1.39
Total oilseeds 1	-0.12	0.54	0.51	-0.01	0.92	0.47	0.25	0.76	9.56	0.62	0.19	0.28	0.56
Total oilseeds 2	0.15	0.72	0.47	0.39	0.64	-0.14	1.07	0.36	59.40	0.65	0.27	-0.06	0.78

Source and Note: Same as in Table 10.

Table 12 explains the elasticity of crop yield with respect to temperature i.e. per cent deviations in yield from its trend due to 1 per cent deviation in temperature from its normal level. In case of rice, 10 districts out of the 13 studied have experienced a significant increase in sensitivity to temperature variation in the post green revolution period except for Dhenkanal, and Kalahandi. In case of potato, except for Balasore, Dhenkanal, Keonjhar, Koraput and Mayurbhanj, rest of them have experienced a significant decline in sensitivity to temperature variation in the post-green revolution period. But in case of maize all the districts except Balasore, Bolangir, Dhenkanal, Kalahandi and Koraput districts have experienced a significant decline in the sensitivity of output to temperature variation in the post green revolution period. In case of groundnut, there has been a significant decline in sensitivity in Koraput and mild decline in Bolangir, Puri, Sambalpur and Sundargarh to the variation in temperature. In case of gram, a significant increase in sensitivity of output to temperature variation has been realised in all the districts except in Balasore, Dhenkanal, Kalahandi and Puri. In case of sugarcane, a significant increase was observed in sensitivity to temperature variation in all the districts except in Balasore and Kalahandi.In case of total foodgrains, all the districts saw a significant rise in sensitivity of output to temperature variation except for Puri, Sambalpur and Sundargarh. In case of total cereals, all the districts experienced a significant rise in sensitivity of output to temperature variation except Kalahandi. In case of total pulses, a significant rise in sensitivity of output to temperature variation was observed in all the districts except in Bolangir, Ganjam, and Puri. In case of total oilseeds, all the districts saw a significant rise in sensitivity of output to variation in temperature except in Dhenkanal, Puri and Sundargarh.

TABLE 12. SENSITIVITY OF CROP YIELD TO TEMPERATURE VARIATIONS OF MAJOR CROPS IN 13 DISTRICTS OF ODISHA

	Elasticity of crop output with respect to temperature												
Crop in Period 1 and Period 2 (1)	Balasore (2)	Bolangir (3)	Cuttak (4)	Dhenkanal (5)	Ganjam (6)	Kalahandi (7)	Keonjhar (8)	Koraput (9)	Mayurbhanj (10)	Phulbani (11)	Puri (12)	Sambalpur (13)	Sundargarh (14)
Rice 1	-0.37	0.23	0.37	-0.23	0.19	0.68	0.64	-0.30	0.49	-0.59	0.24	-0.62	-0.40
Rice 2	0.61	0.04	0.81	0.01	0.10	1.12	0.43	0.00	0.64	0.36	0.79	-0.52	1.19
Potato 1	0.13	0.29	1.83	1.30	-0.04	0.77	3.95	0.38	0.48	0.25	0.89	0.24	0.56
Potato 2	0.55	0.35	-3.34	0.74	1.18	0.29	0.10	0.72	0.72	0.88	0.66	0.22	0.55
Maize 1	0.10	1.25	-0.67	1.69	-0.18	0.84	0.34	0.32	0.04	0.78	1.75	0.84	1.04
Maize 2	0.54	0.38	-0.38	0.46	0.48	0.45	1.09	0.26	1.77	0.34	0.79	0.75	-0.03
Groundnut 1	0.79	-0.13	0.20	0.45	0.23	0.64	-0.37	-0.27	0.86	-0.18	0.77	0.14	0.75
Groundnut 2	0.92	-0.35	0.12	0.72	1.09	0.86	0.66	1.08	0.81	0.38	0.68	0.10	0.74
Gram 1	0.98	0.47	0.32	0.55	0.85	0.57	0.96	-0.18	0.21	0.18	0.99	0.34	-0.12
Gram 2	0.28	0.66	1.14	0.62	0.04	0.66	0.00	0.43	1.02	0.52	0.48	0.63	0.84
Sugarcane 1	1.72	-0.44	0.40	0.15	-1.09	-0.16	0.61	0.37	-0.07	-0.30	0.07	-0.31	0.87
Sugarcane 2	0.52	1.47	0.42	0.45	0.73	0.36	0.01	0.73	0.99	0.73	0.89	1.43	1.37
Total food grains 1	0.04	0.06	0.45	-0.26	0.16	0.11	0.79	-0.11	0.66	0.04	0.78	-0.01	0.73
Total food grains 2	0.66	-0.14	0.98	0.06	0.21	1.32	0.79	0.77	0.95	0.83	0.64	-0.20	0.04
Total cereals 1	0.47	0.25	0.24	-0.06	-0.14	0.09	0.55	-0.38	0.39	0.24	0.15	-0.06	-0.09
Total cereals 2	0.66	0.01	0.94	0.77	0.32	1.59	0.38	0.38	0.83	-0.13	0.78	0.45	0.76
Total pulses 1	0.33	0.46	0.70	0.37	0.59	1.04	0.46	-0.35	0.92	0.13	1.50	0.93	0.31
Total pulses 2	0.91	0.31	0.64	0.94	1.17	-0.14	1.61	1.06	1.04	1.51	-0.04	1.16	0.86
Total oilseeds 1	0.74	0.36	0.09	0.52	0.36	0.82	0.06	-0.40	0.48	0.07	0.52	0.07	0.51
Total oilseeds 2	0.75	-0.07	0.72	1.19	-0.46	1.07	0.06	0.48	1.43	1.08	0.31	1.12	0.39

Source and Note: Same as in Table 10.

5.2 *Results of Panel Regression Model*

Table 13 reports the panel regression model for rice yield. The RGLS method shows that all variables included in the model explain 60 per cent of variations in yield. The variable rainfall is positive and significant but rainfall square is negative and significant. This result indicates that high rainfall improves crop yield up to a certain level, beyond that it is unhelpful for rice yield. The temperature has a positive but not significant impact on rice yield. The result shows that a small increase in precipitation and temperature may improve rice yield in various districts of Odisha. Irrigation intensity has a positive and significant effect on crop yield. However, there are factors other than weather variables affecting crop yield in Odisha. If we will compare RGLS results with PCSE, where rainfall and time trend variable is only significant but they have a positive effect on rice yield. The time trend variable is positive and significant showing various agricultural policy and technological changes have contributed positively to rice yield. Arellano-Bond GM model shows variables such as rainfall, rainfall square, irrigation intensity, trend, and lagged dependent variable have a significant effect on rice yield across various districts of Odisha.

TABLE 13. PANEL REGRESSION RESULTS FOR RICE

Dependent variable: Rice yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	0.84***	0.5359**	1.27***	0.84	1.41***
	(0.33)	(0.2556)	(0.33)	(0.53)	(0.33)
Rainfall^2	-0.00024***	-0.00016**	-0.003***	-0.00024**	-0.0003***
	(0.00009)	(0.00007)	(0.001)	(0.001)	(0.00009)
Temperature	-2.99	-35.56	7.64	-2.99	-14.87
	(30.55)	(50.67)	(50.75)	(21.79)	(71.05)
Temperature^2	-0.004	0.03153	-0.03	-0.004	-0.01
	(0.05)	(0.0849)	(0.08)	(0.04)	(0.12)
Irrigation intensity	7.57***		9.27***	7.57***	8.09***
	(1.37)		(2.11)	(1.43)	(2.67)
Trend	40.56***	46.066***	40.25***	40.56***	27.85***
	(2.13)	(1.1173)	(2.19)	(5.48)	(3.23)
Constant	779.51	-6740.024	-439.34	779.51	4439.92
	(4557.32)	(7571.736)	(7509.35)	(3488.76)	(10578.18)
Lagged Dependent					0.267***
					(0.04)
Observations	468	650	468	468	442
R-square	0.62	0.8	0.6	0.62	Wald-chi2: 854.93***

Source: Authors' own estimations.

Note: *** p<0.01, ** p<0.05, * p<0.1. Figures in parentheses are standard errors. OLS = ordinary least squares estimates, FGLS = feasible generalized least squares, RGLS = random-effects generalized least squares, PCSE = panel corrected standard errors, GMME = generalized method of moments estimates.

Table 14 reports the panel regression model for gram yield. The RGLS method shows that all variables included in the model explain 71 per cent of variations in yield. Both rainfall and its quadratic terms are not statistically significant. But, on the other hand, temperature found to be negative and significant while its quadratic term is positive and significant. This result indicates that high temperature deteriorates crop yield up to a certain level, below that it is always helpful for gram yield. The time trend variable is positive and significant showing various agricultural policy and technological changes have contributed positively to gram yield. If we will compare RGLS results with PCSE, the almost the same effect has been observed for gram yield. Arellano-Bond estimation results show that variables such as irrigation intensity, time trend, and lagged dependent variable have a significant effect on gram yield. Irrigation intensity has a negative and significant effect on yield whereas time trend and lagged yield has a positive and significant effect on yield.

Table 15 reports the panel regression model for groundnut yield. The RGLS method shows that all variables included in the model explain 38 per cent of variations in yield. Both rainfall and its corresponding quadratic term are statistically significant showing a significant impact on groundnut yield. This result indicates that high rainfall improves crop yield up to a certain level, beyond that it is unhelpful for rice yield. The temperature has a positive but not significant impact on rice yield. The result shows that a small increase in precipitation and temperature may improve rice yield in various districts of Odisha. Irrigation intensity also has a positive and significant effect on groundnut yield. The time trend variable is positive and significant showing various agricultural policy and

TABLE 14. PANEL REGRESSION RESULTS FOR GRAM

Dependent Variable: Gram Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	0.032	0.12575	-0.18	0.032	-0.06
	(0.15)	(0.13744)	(0.15)	(0.21)	(0.11)
Rainfall^2	-0.00005	-0.00003	0.0006	-0.00005	0.004
	(0.00004)	(0.00004)	(0.0004)	(0.00005)	(0.0003)
Temperature	-32.79***	-43.302*	-51.05**	-32.79***	-12.51
	(14.18)	(27.24)	(25.18)	(10.83)	(24.61)
Temperature^2	0.06***	0.08983**	0.094**	0.06***	0.02
	(0.02)	(0.0456)	(0.04)	(0.02)	(0.04)
Irrigation intensity	-0.27		-1.67	-0.27	-2.82***
	(0.64)		(1.01)	(0.47)	(0.95)
Trend	28.16***	16.977***	28.85***	28.16***	11.15***
	(0.99)	(0.6007)	(1.01)	(2.09)	(8.23)
Lagged Dependent					0.67***
					(0.03)
Constant	4186.58**	-483.9654	6941.65*	4186.58***	1822.98
	(2115.44)	(4070.787)	(3727.26)	(1664.5)	(3664.67)
Observations	468	650	468	468	442
R-square	0.72	0.68	0.71	0.72	Wald chi2: 2943.86***

Source and *Notes*: Same as in Table 13.

TABLE 15. PANEL REGRESSION RESULTS FOR GROUNDNUT

Dependent Variable: Groundnut Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	1.201***	0.3228	1.18***	1.201***	0.81*
	(0.48)	(0.3628)	(0.49)	(0.57)	(0.52)
Rainfall^2	-0.0003***	-0.00014	-0.0003***	-0.0003***	-0.0002*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.00014)
Temperature	12.83	-81.532	18.11	12.83	-121.33
	(44.64)	(71.92)	(61.71)	(32.35)	(116.27)
Temperature^2	-0.02	0.0939	-0.033	-0.02	0.15
	(0.07)	(0.1205)	(0.104)	(0.05)	(0.19)
Irrigation intensity	10.604***		10.64***	10.604***	4.88
	(2.01)		(2.68)	(1.85)	(4.25)
Trend	34.46***	47.025***	34.93***	34.46***	31.88***
	(3.12)	(1.5859)	(3.23)	(5.16)	(4.37)
Lagged Dependent					0.22***
					(0.046)
Constant	-2751.07	1360.087	-3084.41	-2751.07	22497.12
	(6660.05)	(10746.4)	(9146.82)	(4891.02)	(17322.24)
Observations	468	650	468	468	442
R-square	0.38	0.65	0.38	0.38	Wald chi2: 297.36***

Source and Note: Same as in Table 13.

technological changes have contributed positively to groundnut yield. The result indicates that there are factors other than these variables affecting crop yield in Odisha. If we will compare RGLS results with PCSE, where rainfall is statistically significant and has a positive impact on groundnut yield but its quadratic term has a negative impact.

Similarly, the temperature has no significant impact on groundnut yield. The time trend coefficient and irrigation intensity have a positive and statistically significant effect on yield. Arellano-Bond estimation results indicate that rainfall, its quadratic term, time trend, and lagged yield variable has a significant effect on groundnut yield.

Table 16 reports the panel regression model for maize yield. The RGLS method shows that all variables included in the model explain 45 per cent of variations in yield. Both rainfall and its quadratic terms are significant while rainfall is negative and its quadratic terms have a positive sign showing high rainfall has a negative impact up to a certain level, below that it is always helpful for maize yield. The time trend variable is positive and significant showing various agricultural policy and technological changes have contributed positively to maize yield. The result shows that a small increase in precipitation may improve maize yield in various agro-climatic zones in Odisha. However, there are factors other than these variables affecting crop yield in Odisha. If we will compare RGLS results with PCSE, all variables have a significant impact on maize yield. Arellano-Bond estimation results indicate that only the trend parameter and lagged variable have a significant effect on maize yield.

TABLE 16. PANEL REGRESSION RESULTS FOR MAIZE

Dependent Variable: Maize Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	-0.75**	-0.84196**	-0.57*	-0.75*	-0.06
	(0.33)	(0.2429)	(0.33)	(0.48)	(0.28)
Rainfall^2	0.00023***	0.00022**	0.0002*	0.00023**	0.00002
	(0.00009)	(0.00007)	(0.00009)	(0.00012)	(0.00007)
Temperature	-47.12	-60.159	-34.75	-47.12*	-28.26
	(30.58)	(48.166)	(52.23)	(25.38)	(67.28)
Temperature^2	0.074	0.07443	0.04	0.074*	0.023
	(0.051)	(0.08072)	(0.08	(0.042)	(0.11)
Irrigation intensity	-3.25***		1.45	-3.25***	3.15
	(1.38)		(2.15)	(1.17)	(2.26)
Trend	35.75***	39.856***	35.97***	35.75***	12.48***
	(2.14)	(1.0621)	(2.19)	(4.91)	(2.603)
Lagged Dependent					0.59***
					(0.04)
Constant	8415.67	-214.56	7150.55	8415.67	6483.66
	(4562.03)	(7197.167)	(7728.24)	(3949.38)	(10034.85)
Observations	468	650	468	468	442
R-square	0.5	0.75	0.45	0.5	Wald chi2: 933.97***

Source and Note: Same as in Table 13.

Table 17 reports the panel regression model for potato yield. The RGLS method shows that all variables included in the model explain 55 per cent of variations in yield. Both rainfall and its quadratic terms are significant while rainfall is positive and its quadratic terms have a negative sign showing high rainfall has a negative impact up to a certain level, below that it is always helpful for potato yield. Irrigation intensity and the time trend variable has significant and a positive impact on yield. This result indicates that there are factors other than these variables affecting crop yield in Odisha. If we will compare RGLS results with PCSE, except temperature, all variables have a significant effect on potato yield. Arellano-Bond estimation results indicate that rainfall, its quadratic term, time trend, and lagged yield has a significant effect on potato yield in Odisha.

TABLE 17. PANEL REGRESSION RESULTS FOR POTATO

Dependent Variable: Potato Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	9.09***	0.4399	4.42**	9.09***	4.06***
	(2.38)	(1.779)	(2.34)	(3.74)	(1.97)
Rainfall^2	-0.002***	-0.0004	-0.001**	-0.002***	-0.001**
	(0.00068)	(0.0005)	(0.0006)	(0.0009)	(0.0005)
Temperature	75.04	-579.96*	-120.32	75.04	-345.81
	(221.41)	(352.72)	(365.88)	(144.09)	(434.38)
Temperature^2	-0.16	0.6955	0.078	-0.16	0.35
	(0.37)	(0.5911)	(0.62)	(0.25)	(0.73)
Irrigation intensity	82.63***		55.16***	82.63***	8.01
	(9.97)		(15.12)	(9.81)	(15.71)
Trend	254.24***	334.05***	287.79***	254.24***	121.64***
	(15.47)	(7.777)	(15.65)	(38.55)	(20.28)
Lagged Dependent					0.55***
					(0.04)
Constant	-13778.66	8633.205	27354.54	-13778.66	70158.17
	(33032.5)	(52703.8)	(54135.03)	(23267.2)	(64795.46)
Observations	468	650	468	468	442
R-square	0.59	0.8	0.55	0.59	Wald chi2: 1197.15

Source and *Notes*: Same as in Table 13.

Table 18 reports the panel regression model for sugarcane yield. The RGLS method shows that all variables included in the model explain 71 per cent of variations in yield. Only the time trend variable is significant indicates that there are factors other than weather variables affecting crop yield in Odisha. If we will compare RGLS results with PCSE, only the time trend is statistically significant and has a positive impact on sugarcane yield. Arellano-Bond estimation results indicate that only time trend and lagged yield has a significant effect on sugarcane yield in Odisha.

Table 19 reports the panel regression model for total cereals. The RGLS method shows that all variables included in the model explain 61 per cent of variations in yield. Both rainfall and its quadratic terms are significant; while rainfall has a positive and its quadratic term has a negative sign. This result indicates that high rainfall improves crop yield up to a certain level, beyond that it is unhelpful for total cereals yield. Irrigation intensity also has a positive and significant effect on total cereals yield. However, the time trend variable is significant indicates that there are factors other than weather variables affecting crop yield in Odisha. If we will compare RGLS results with PCSE, except temperature, all variables have a significant impact on total cereals yield. Arellano-Bond estimation results indicate that except temperature, all variables have a significant effect on yield in Odisha.

TABLE 18. PANEL REGRESSION RESULTS FOR SUGARCANE

Dependent Variable: Sugarcane Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	3.11	19.748*	6.53	3.11	11.88
	(14.51)	(12.279)	(14.71)	(21.98)	(12.28)
$Rainfall^2$	-0.003	-0.00365	-0.004	-0.003	-0.005
	(0.004)	(0.0036)	(0.004)	(0.005)	(0.003)
Temperature	-521.37	-915.4748	-1045.66	-521.37	581.12
	(1346.47)	(2434.013)	(2358.18)	(762.72)	(2679.34)
$Temperature^2$	0.86	3.1003	1.98	0.86	-0.46
	(2.28)	(4.079)	(3.98)	(1.31)	(4.504)
Irrigation intensity	60.21		34.57	60.21	-76.84
	(60.67)		(96.71)	(46.95)	(102.06)
Trend	2679.83***	1611.278***	2662.46***	2679.83***	1082.24***
	(94.103)	(53.672)	(98.57)	(227.43)	(134.49)
Lagged Dependent					0.62***
					(0.04)
Constant	63738.42	-524584.5	117995.6	63738.42	-141635.4
	(200876.4)	(36369.7)	(348925.8)	(124463.4)	(399024.6)
Observations	468	650	468	468	442
R-square	0.72	0.73	0.71	0.72	Wald chi2: 2331.34***

Source and *Notes*: Same as in Table 13.

TABLE 19. PANEL REGRESSION RESULTS FOR TOTAL CEREALS

Dependent Variable: Total Cereals Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	1.13***	0.6622***	1.38***	1.13***	1.34***
	(0.31)	(0.2492)	(0.32)	(0.51)	(0.32)
$Rainfall^2$	-0.00033***	-0.0002***	-0.004***	-0.00033***	-0.0003***
	(0.00009)	(0.00007)	(0.00009)	(0.00012)	(0.00009)
Temperature	-18.29	-36.389	2.88	-18.29	-10.57
	(29.38)	(49.397)	(48.67)	(20.93)	(72.203)
$Temperature^2$	0.024	0.03327	-0.019	0.024	-0.014
	(0.049)	(0.08279)	(0.082)	(0.03)	(0.12)
Trend	38.37***	44.892***	38.08***	38.37***	23.51***
	(2.05)	(1.089)	(2.13)	(5.34)	(3.06)
Irrigation intensity	9.37***		10.39***	9.37***	8.62***
	(1.32)		(2.03)	(1.46)	(2.56)
Lagged Dependent					0.33***
					(0.04)
Constant	2578.46	-6373.741	-89.69	2578.46	3494.431
	(4383.68)	(7381.081)	(7202.03)	(3357.87)	(10735.58)
Observations	468	650	468	468	442
R-square	0.63	0.8	0.61	0.63	Wald chi2: 868.99***

Source and *Notes*: Same as in Table 13.

Table 20 presents the panel regressions for total foodgrains. The RGLS method shows that all variables included in the model explain 59 per cent of variations in yield. Both rainfall and its quadratic terms are significant; while rainfall has a positive and its quadratic term has a negative sign. This result indicates that high rainfall improves crop yield up to a certain level, beyond that it is unhelpful for total foodgrains yield. Both irrigation intensity and time trend variable have a significant and positive impact on total foodgrains yield. If we compare RGLS results with PCSE, where all variables are statistically significant. Arellano-Bond estimation results indicate that except temperature, all variables have a significant effect on yield in Odisha.

TABLE 20. PANEL REGRESSION RESULTS FOR TOTAL FOODGRAINS

Dependent Variable: Total Foodgrains Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	0.72***	0.1709	0.78***	0.72*	0.79***
	(0.25)	(0.2018)	(0.26)	(0.41)	(0.04)
Rainfall^2	-0.00019***	-0.00006	-0.0002***	-0.00019*	-0.0002***
	(0.00007)	(0.0005)	(0.00007)	(0.0001)	(0.00007)
Temperature	-84.33***	-35.507	-44.66	-84.33***	-1.39
	(23.93)	(40.009)	(38.18)	(18.48)	(54.71)
Temperature^2	0.14***	0.03246	0.06	0.14***	-0.025
	(0.04)	(0.06705)	(0.06)	(0.03)	(0.09)
Irrigation intensity	6.69***		9.21***	6.69***	7.48***
	(1.07)		(1.61)	(1.08)	(2.05)
Trend	29.78***	37.396***	30.11***	29.78***	18.14***
	(1.67)	(0.88224)	(1.73)	(4.49)	(2.44)
Lagged Dependent					0.36***
					(0.04)
Constant	12322.27***	-3872.724	6882.98	12322.27***	2162.6
	(3570.39)	(5978.261)	(5649.85)	(2933.44)	(8145.76)
Observations	468	650	468	468	442
R-square	0.62	0.8	0.59	0.62	Wald chi2: 907.42

Source and *Notes*: Same as in Table 13.

Table 21 presents the panel regressions for total oilseeds. The RGLS method shows that all variables included in the model explain 24 per cent of variations in yield. Irrigation intensity and time trend variables are positive and statistically significant showing that there are factors other than weather variables affecting crop yield in Odisha. If we will compare with the PCSE method, except temperature, all variables have a statistically significant impact on crop yield. Arellano-Bond estimation results indicate that except rainfall and its quadratic terms, all other variables have a significant effect on total oilseeds yield.

Table 22 presents the panel regressions for total pulses. The RGLS method shows all variables included in the model explain 27 per cent of variations in yield.. Rainfall and its quadratic terms have a statistically significant impact on total pulses yield; while rainfall has a positive and its quadratic term has a negative sign. This result indicates that high rainfall improves crop yield up to a certain level, beyond that it is unhelpful for total pulses yield. Irrigation intensity and time trend variable have a positive and significant effect on yield. There are factors other than these variables affecting crop yield in Odisha. If we will compare with PCSE results only time trend has a significant and positive effect on crop yield. Arellano-Bond estimation results indicate that except time trend variable, all other variables have a significant effect on total pulses yield in Odisha.

TABLE 21. PANEL REGRESSION RESULTS FOR TOTAL OILSEEDS

Dependent Variable: Total Oilseeds Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	0.78*	0.141	0.55	0.78*	0.08
	(0.44)	(0.3321)	(0.45)	(0.42)	(0.48)
Rainfall^2	-0.0003**	-0.00008	-0.0002	-0.0003**	-0.00005
	(0.0001)	(0.00009)	(0.0001)	(0.0001)	(0.00013)
Temperature	-23.83	-138.076**	-52.16	-23.83	-183.31*
	(41.12)	(65.844)	(57.77)	(30.88)	(102.57)
Temperature^2	0.04	0.2007**	0.08	0.04	0.27*
	(0.07)	(0.1103)	(0.09)	(0.05)	(0.17)
Irrigation intensity	15.84***		13.19***	15.84***	6.28*
	(1.85)		(2.504)	(1.75)	(3.91)
Trend	13.45***	25.5932***	15.02***	13.45***	16.89***
	(2.87)	(1.4519)	(2.97)	(3.81)	(3.85)
Lagged Dependent					0.16***
					(0.05)
Constant	2610.77	15402.97	7356.14	2610.77	30260.7**
	(6135.19)	(9838.613)	(8561.97)	(4611.11)	(15268.32)
Observations	468	650	468	468	442
R-square	0.25	0.39	0.24	0.25	Wald chi2: 95.17***

Source and *Notes*: Same as in Table 13.

TABLE 22. PANEL REGRESSION RESULTS FOR TOTAL PULSES

Dependent Variable: Total Pulses Yield (1)	OLS (2)	FGLS (3)	RGLS (4)	PCSE (5)	Arellano-Bond GMME (6)
Rainfall	0.41***	-0.1244	0.32**	0.41	0.44***
	(0.15)	(0.1159)	(0.16)	(0.26)	(0.11)
Rainfall^2	-0.00009**	0.00001	-0.00007*	-0.00009	-0.0001***
	(0.00004)	(0.00003)	(0.00004)	(0.00007)	(0.00003)
Temperature	11.92	-48.044**	-0.98	11.92	-6.51
	(14.62)	(22.973)	(22.04)	(9.14)	(23.92)
Temperature^2	-0.02	0.058	-0.002	-0.02	-0.003*
	(0.02)	(0.038)	(0.04)	(0.02)	(0.04)
Irrigation intensity	0.49		2.02**	0.49	1.52*
	(0.66)		(0.94)	(0.61)	(0.87)
Trend	8.33***	15.546***	8.37***	8.33***	1.24
	(1.02)	(0.5065)	(1.05)	(2.76)	(0.901)
Lagged Dependent					0.66***
					(0.03)
Constant	-1811.44	4540.139	417.49	-1811.44	1945.47
	(2182.13)	(3432.741)	(3263.75)	(1507.79)	(3573.33)
Observations	468	650	468	468	442
R-square	0.27	0.66	0.23	0.27	Wald chi2: 990.21***

Source and *Note:* Same as in Table 13.

VI

SUMMARY AND CONCLUSION

The present study attempts to estimate the overall impact of weather variables such as rainfall and temperature on yield data of selected crops grown in Odisha for a 36-year panel data set of major districts during 1980-81 to 2014-15. The study has used the estimation methods of the Random Effect Method, Panel Corrected Standard Error and Arellano-Bond Estimation to identify the crucial determinants of crop yields. The study results have shown that the sensitivity of crop yield to the rainfall variability has been noticeable in almost all crops in the second period (1988-89 to 2014-15)as compared to the initial phase (1966-67 to 1987-88)of the green revolution for all districts except for few crops. Crop yields in various districts of Odisha have been observed to be highly vulnerable to climate variability. The study has shown that almost all the principal crops grown in the state are highly sensitive to changes in rainfall and temperature. Both these variables have some effects (+/-) on the yield of all crops. Generally, *kharif* food crops are highly vulnerable to variation in rainfall than the *rabi* food crops. This is because normally more hazardous weather conditions prevail during the *kharif* than in the *rabi* season. The regression results have reinforced that crop yields of the selected crops are susceptible to climate changes. The study has shown that almost all the principal crops grown in the state are highly sensitive to changes in rainfall and temperature. The rainfall has significant positive effects on the yields of all the selected crops under study. In case of temperature, we have observed mixed results for the selected crops under study. But the extent of increase in the temperature appears to be harmful for the crop yields across districts of Odisha. However, the extent of increase in the temperature appears to be more harmful to the crop yields. Thus, the findings of the study have important policy implications towards agricultural development.

The central and state governments in India have taken many measures like Krishi Vikas Yojana, minimum support price system, jalanidhisubidha, disaster management plans, and watershed management programmes, etc. towards agricultural development. After all these attempts to the farmers with upgraded facilities in relation to credit, technology, irrigation and extension etc., there still is not much improvement in their conditions. So, the situation calls for different measures. Besides the national platform i.e. the legislation and policies on disaster risk reduction, farmers' adaptation to climate change and they are required to cope with natural disasters. Studies are being carried out throughout the world like in the sub-Saharan countries of Africa, in the Philippines, Bangladesh etc. and in states like Maharashtra, Tamil Nadu, Chhattisgarh, etc. in India to observe the importance of adaptation and coping in agriculture at the farm level.

The present study will be able to provide direction to the idea that different geographical areas which are prone to a different kind of CINDs require different policies and different aid. Farmers are to be trained and aided with different technology, strategy and support to deal with these adversities in different geographic zones. Policy failure or policy inadequacy is commonly found in the context of farmer adaptation to CINDS which demands geographical targeting. The necessity has aroused to see whether the most affected victim of climate change and CINDs can adapt and cope with the impacts of these stresses right where he/she faces them. Green revolution technology has contributed immensely to the increase in the productivity of Indian agriculture. But it remained confined to few states of India. Though the agrarian economy of Odisha has been directly influenced by the adoption of a scientific package of agriculture, it is not yet spread to a large extent and uniformly across the ecosystems and class of farmers.

The government of Odisha should give attention to the supply of public goods for example, land infrastructure, research and development activities for a workable agriculture in Odisha. Crop output in various districts of Odisha is highly vulnerable to climate variability. Generally, *kharif* food crops are highly vulnerable to variation in weather than the *rabi* food crops. This is because irrigation has considerably contributed towards a controlled production environment for *rabi* cultivation. Therefore it is necessary to understand the rainfall and temperature variations for an improved setting up of water resources, suggestion of the appropriate crop variety that can be grown in a particular region, better adaptation, and coping mechanisms and finally prescribing effective risk management tools to address the various issues related to agriculture and climate change. For policy makers, the present study findings can give a clear-cut message to explore the adaptation strategies and to invest more in new seed varieties for better adaptation and coping against these covariate shocks. The study findings further have emphasised to assess the importance of risk aversion attitudes of the farmers while undertaking any production decision. Farmers in a rural state like Odisha always face several risky choices while undertaking their agricultural activities. Therefore it is crucial for the policy makers and social scientists to know how risky farming environment affects farmers' production decisions. Accordingly, policies should be designed such as crop insurance, weather-based crop insurance, landscape approach to climate change, soil conservation agriculture, climate-smart farming and so on that effectively address farmers' vulnerability to extreme climatic shocks.

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NOTE

1. GFDRR: Reducing Vulnerability to Natural Hazards.

REFERENCES

Aggarwal, P.K. and R.K. Mall (2002), "Climate Change and Rice Yields in Diverse Agro-Environmentsof India: Effect of Uncertainties in Scenarios and Crop Models on ImpactAssessment", C*limatic Change,*Vol.52, No.3, pp.331-343.

Aggarwal, P.K.; M.J. Kropff, K.G. Cassman and H.F.M. Berge (1997), "Simulating Genotypic Strategies for Increasing Rice Yield Potential in Irrigated, Tropical Environments", *Field Crops Research*, Vol.51, No.1-2, pp.5-17.

Arellano, M. and S. Bond (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidenceand an Application to Employment Equations", *Review of Economic Studies,* Vol.58, No.2, pp.277-297.

Bhatia, R. (2005), Viability of Rainfed Agriculture in Semi-arid Regions. Occasional Paper - 40, Development of Economics Analysis and Research, National Bank for Agriculture and Rural Development, Mumbai.

Bliss, C. and N. Stern. (1982), Palanpur: *The Economy of an Indian Village*. Oxford: Oxford University Press.

CRED (2015), Centre for Research on the Epidemiology of Disasters Various Reports.

Darwin, R. (1999), “A Farmer's View of the Ricardian Approach to Measuring Agricultural Effects of Climatic Change”, *Climatic Change,* Vol.41, No.1, pp.371-411.

Delbiso, T.D.; J.M. Rodriguez-Llanes, A.F. Donneau, N. Speybroeck and D. Guha-Sapira (2015), Drought, Conflict and Children’s Undernutrition in Ethiopia 2000–2013: A Meta-Analysis, Department for International Development, Sustainable Livelihoods Guidance Sheets.

Deshpande, R.S. (1985), Yield Uncertainty in Maharashtra Agriculture: A Study with Special Reference to Drought Prone Areas. Unpublished Ph.D. Dissertation, Marathwada University.

Dev, S.M. (1987), “Growth and Instability in Foodgrains Production: An Inter-State Analysis”, *Economic and Political Weekly*, Vol.22, No.39, 26 September, pp.82-92.

FAO (2015), FAOSTAT, Food and Agriculture Organization of the United Nations, Rome, Italy.

Gbetibouo, G., and R. Hassan (2005), “Measuring the Economic Impact of Climate Change on Major South African Field Crops: A Ricardian Approach”, *Global and Planetary Change,* Vol.47, No.2–4), pp.143–52.

Gbetibouo, G.A. (2009), Understanding Farmers’ Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa. International Food Policy Research Institute, Discussion Paper 00849.

Government of Odisha (2019), *Draft Agricultural Policy-2019 of Odisha,* Bhubaneswar.

Government of Odisha (2014), *Odisha Economic Survey 2014-2015*, June, Planning & Coordination Department, Directorate of Economics & Statistics.

Government of Odisha (2018), *Odisha Climate Change Action Plan (For the Period 2018-23)*, Phase-II, June, Forest and Environment Department.

Government of Odisha (2011a), *Economic Survey 2010-11* (Orissa), February, Planning & Coordination Department, Directorate of Economics & Statistics.

Government of Odisha (2011b), *Comprehensive District Annual Plan*, 2010-11, Bhubaneswar.

Government of Odisha (2015a), *Odisha Agriculture Statistic*s 2013-14, June, Directorate of Agriculture & Food Production, Bhubaneswar. Bhubaneswar.

Government of Odisha (2015b), *Status of Agriculture in Odisha 2014-15*, Directorate of Agriculture & Food Production, Bhubaneswar.

Im, K.S.; M.H. Pesaran and Y. Shin (2003), Testing for Unit Roots in Heterogeneous Panels,*Journal of Econometrics*, Vol.115, No.1, pp.53–74.

Intergovernmental Panel on Climate Change (IPCC) (2014), Synthesis Report. Climate Change 2014. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Kavikumar, K.S. (2009), Climate Sensitivity of Indian Agriculture: Do Spatial Effects Matter? WorkingPaper No. 45, South Asian Network for Development and Environmental Economics (SANDEE), IUCN, Kathmandu, Nepal.

Khan, A.S.; S. Kumar, M.Z. Hussain and N. Kalra (2009), Climate Change, Climate Variability and Indian Agriculture: Impacts Vulnerability and Adaptation Strategies, Climate Change and Crops, Environmental Science and Engineering.

Mall, R.K.; R. Singh, A. Gupta, G. Srinivasan and L.S. Rathore (2006), “Impact of Climate Change on Indian Agriculture: A Review”, *Climatic Change,* Vol.78, No.2-4, pp.445-478.

Mendelsohn, R. and A. Dinar (1999), “Climate Change, Agriculture and Developing Countries: Does Adaptation Matter?”, *The World Bank Research Observer, Vol*.14, No.2, pp.277-293.

Mendelsohn, R. and A. Dinar (2003), “Climate, Water and Agriculture”, *Land Economics,* Vol.79, No.3, pp.329-341.

Mendelsohn, R. and M. Reinsborough (2007), “A Ricardian Analysis of US and Canadian Farmland”, *Climatic Change,* Vol.81, No.1, pp.9-17.

Mendelsohn, R. (2000). “Climate Change Impacts on African Agriculture”, World Bank Papers.

National Academy of Agricultural Science (2004), Policy Paper on Disaster Management in Agriculture.

Naylor, R.; W. Falcon and E. Zavaleta (1997), “Variability and Growth in Grain Yields, 1950-94: Does the Record Point To Greater Variability”, *Population and Development Review*, Vol.23,No.1, pp.41-58.

Nepal, S. and A.B. Shrestha (2015), "Impact of Climate Change on the Hydrological Regime of the Indus, Ganges and Brahmaputra River Basins: A Review of literature", *International Journal of Water Resources Development*, Vol.31, No.2, pp.201-218.

Palanisami, K.; P. Paramasivam, C.R. Ranganathan, P.K. Aggarwal and S. Senthilnathan (2009), *Quantifying Vvulnerability and Impact of Climate Change on Production of Major Crops in Tamil Nadu, India, Headwaters to the Ocean – Hydrological Change and Watershed Management*, in M. Taniguchi, W.C. Burnett, Y. Fukushima, M. Haigh and Umezawa Yu (Eds.) (2009), London: Taylor and Francis Group, pp.509–51.

Paltasingh, K.R.; P. Goyari and R.K.Mishra (2012), "Measuring Weather Impact on Crop Yield Using Aridity Index: Evidence from Odisha", *Agricultural Economics Research Review*, Vol.25, No.2, pp.200-212.

Piechota, T.C. and J.D. Garbrecht (2006), "Climate Variability and Climate Change", *Environmental and Water Resources*, Institute of the American Society of Civil Engineers, United States of America, pp.3-18.

Rao, C.H. Hanumantha; S.K.Ray and K. Subbarao (1988), *Unstable Agriculture and Droughts: Implication for Policy*, Vikas Publishing House Pvt. Ltd., New Delhi.

Ray, S.K. (1971), "Weather and Reserve Stocks for Foodgrains", *Economic and Political Weekly*, Vol.6, No.39, 25 September, pp.A131-A142.

Sanghi, A. and R. Mendelsohn (2008), "The Impacts of Global Warming on Farmers in Brazil and India",*Global Environmental Change,* Vol.18, No.4, pp.655-665.

Senapati, A.K. and P. Goyari (2019), "Growth and Instability in Agricultural Productivity in Odisha", *Agricultural Economics Research Review*, Vol.32, No.1, pp.55-65.

Senapati, A.K. (2020), "Assessing the Vulnerability of Agricultural Households to Covariate and Idiosyncratic Shocks: A Case Study in Odisha, India", *Climate and Development*, Vol.12, No.2, pp.1-15.

Vaidyanathan, A. (1980), *Influence of Weather on Crop Yields: A Review of Agro-Meteorologists' Research*, Working Paper No.109, Centre for Development Studies, Trivandrum.

World Bank (2005), Managing Agricultural Production Risk: Innovations in Developing Countries. ESW Report by the Agricultural and Rural Development Department, The World Bank, Washington D.C., U.S.A.