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Vulnerability to Agricultural Drought in Western Orissa: A Case Study of Representative Blocks[§]

Mrutyunjay Swain[a]* and Mamata Swain[b]

[a]Agro-Economic Research Centre, Sardar Patel University, Vallabh Vidyanagar-388 120, Gujarat
[b]Department of Economics, Ravenshaw University, Cuttack- 753 003, Orissa

Abstract

The nature of vulnerability to agricultural drought in three study blocks of Bolangir district in western Orissa has been analysed. The indexing and vulnerability profile method have been used for assessing the nature of drought vulnerability, coping capacity and risk. The study has revealed that the three most influential biophysical factors of drought vulnerability are: rainfall variability, drought intensity and shortage of available waterholding capacity of soil and the three most influential socioeconomic factors are: low irrigation development, poor crop insurance coverage and smaller forest area. It is found that while drought risk varies widely across the study blocks and drought vulnerability and physical exposure to drought vary moderately, the coping capacity of study blocks differ marginally. However, the level of coping capacity has been found significantly lower than the level of drought risk and vulnerability in the study blocks.

Key words: Drought, Drought vulnerability, Composite drought vulnerability index, Physical exposure index, Drought risk index

JEL Classification: Q54, Q58, C43, O13

Introduction

Droughts produce a complex web of impacts that span many sectors of the economy and reach well beyond the area experiencing the physical drought. Agriculture being the major livelihood activity in the rural areas, is severely affected by droughts. The nature and intensity of drought impacts vary from location to location, depending on relative influence of various agro-climatic, geophysical and socio-economic factors. Rainfall variability, soil type, land topography, groundwater availability and utilization, irrigation coverage, economic strength and institutional support system are some of the key factors that determine the nature and extent of drought vulnerability in a region. It is also influenced by the coping capacity of inhabitants characterized by their resource endowments and entitlements. Some exogenous factors like climate change do influence the level of risk and vulnerability of different livelihood groups in a region (UNDHA, 1992; Blaikie *et al*., 1994). It is noteworthy that increasing occurrence of climate-induced natural disasters (CINDs) like drought, flood, and cyclone is the major outcome of the intensification of climate change (IPCC, 2001). Among these CINDs, drought is considered by many to be the most complex but least understood phenomenon affecting more people than by any other hazard (Hagman, 1984). More than half of the world population is susceptible to drought every year (Kogan, 1997). In the coming decades, the extent of drought risk and vulnerability is expected to increase, irrespective of the changes in drought exposure mainly

* Author for correspondence,
Email: mrutyunjay77@gmail.com

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due to development pressure, population increase, and environmental degradation (ISDR, 2002). Keeping in view the changing circumstances, appropriate policy needs to be formulated for adapting to increasing vulnerability and a precautionary approach at different levels is essential. It is because the benefit of risk management is larger than the cost of repeated crisis management (Anderson, 1990; Dzeiegielewski, 2000), which in turn, brings much more stability to diversified livelihood systems and puts the rural economy on an upward trajectory.

The attention towards drought risk mitigation and planning has dramatically increased in recent years due to unexpected rise in the magnitude of drought losses worldwide (Wilhite, 2002). One of the main aspects of any drought mitigation and planning strategy is the 'vulnerability assessment' (Wilhelmi *et al.*, 2002), which requires identification of who and what are most vulnerable and why.

This paper has assessed the nature and determinants of drought risk and vulnerability experienced by selected blocks of drought-prone Bolangir district in western Orissa. It has examined the relative influence of different socio-economic and biophysical factors on the levels of drought vulnerability in the study blocks. The major events or processes that increase the extent of drought risk and vulnerability in the study region have also been studied.

Data and Methodology

The Bolangir district was deliberately chosen for the study. At the second stage, three blocks Saintala (most vulnerable), Patnagarh (moderately vulnerable), and Titlagarh (least vulnerable) were selected on the basis of degree of drought vulnerability. Following UNEP (2001), drought vulnerability was taken as the composite of conditions and exposure to adverse processes that increase the susceptibility level of populations and their habitations to drought. A composite drought vulnerability index (CDVI) was constructed using indexing and vulnerability profile method. Nineteen key drought vulnerability factors were taken into consideration for deriving the CDVI; of these 19 factors, six were biophysical factors and thirteen were socio-economic factors, as given in Table 1. Data on different biophysical and socio-economic indicators of drought adaptability, physical exposure, and drought risk were used to generate aggregate indices such as composite drought adaptability index (CDAI), physical exposure index (PhyExpo) and drought risk index (DRI) for each block under study.

A normalization procedure was adopted for adjusting indicator values to take the values between 0 and 1 using formula (1):

$$V_{ij} = [(X_{ij} - \text{Min } X_i)/ (\text{Max}_i - \text{Min}_i) \quad \ldots(1)$$

where, V_{ij} is the normalized value of drought vulnerability indicator, X_{ij} is the value of ith drought vulnerability indicator in the jth block, 'Min X_i' and 'Max X_i' denote to the minimum and maximum value of the ith drought vulnerability indicator across blocks. The DVI and CDVI indices are given by:

Drought Vulnerability Index (DVI) =

$$1/m \left(\sum_{i=1}^{m} K_i \ V_{ij}\right) \times 100 \quad \ldots(2)$$

Composite Drought Vulnerability Index (CDVI) =

$$1/n \left(\sum_{i=1}^{n} W_i \ DVI_i\right) \times 100 \quad \ldots(3)$$

where, K_i is the weight attached to ith normalized drought vulnerability indicator with the value of i varying from 1 to m. The scalar m is the number of drought vulnerability indicators considered for a particular DVI. The value of m is different for different DVIs. In addition, n is the number of DVIs considered for computing the CDVI. The weights attached to vulnerability indicators were decided in consultation with agricultural experts and key informants. Three types of CDVI were constructed: (i) as simple average, (ii) with equal weights, and (iii) with unequal weights. The blocks were ranked by the type of CDVI that ranked Bolangir district around middle of its blocks. Suitable cut-off points were assigned for classifying blocks into different vulnerability zones.

The risk associated with drought episodes was considered as the product of drought hazard and drought vulnerability, relative (i.e., divided by) to a variable that proxies coping capacity based on an indexing procedure termed as composite drought adaptability index (CDAI) and was calculated using the same procedure as was followed for deriving CDVI. The physical exposure to drought (PhyExpo) was taken as the product of probability of drought occurrence and the extent of human population exposed. At the block level, the

Table 1. Indicators of drought vulnerability used for constructing CDVI

Sl No.	Indicators	Proxy for indicator	Data period	Study blocks of Bolangir: Saintala (most vulnerable)	Study blocks of Bolangir: Patnagarh (moderately vulnerable)	Study blocks of Bolangir: Titlagarh (least vulnerable)	Bolangir district	Orissa state
Bio-physical indicators of drought vulnerability								
1	Drought frequency	Drought frequency (%)	1986-2003	61.1	66.7	44.4	56.8	38.9
2	Drought intensity	Decrease in rainfall from long-term normal in drought years (%)	1986-2003	40.3	43.7	17.5	27.6	11.0
3	Rainfall	Average annual rainfall variability (CV %)	1986-2003	40.6	40.5	31.6	27.7	17.7
4	Soil	Available waterholding capacity of soil (Rank*)	1998	4	1	2	1	1
5	Land topography	Land slope (%)	1998	3.2	4.2	2.4	3.3	2.0
6	Ground water table	Decline in post monsoon water level in drought year compared to normal (%)	1998-2002	25.2	13.3	22.3	21.9	9.9
Socio-economic indicators of drought vulnerability								
7	Irrigation	Area without any irrigation potential (%)	2001	96.4	93.8	86.8	94.4	59.9
8		Unirrigated area to total cultivable area (%)	1991	95	94.3	87.3	96	80.2
9	Major crop production	Paddy area variability (CV %)	1986-2003	17.1	5.6	6.0	16.3	2.7
10		Paddy yield variability (CV %)	1986-2003	35.4	44.7	36.2	41.0	15.6
11	Poverty	Households below poverty line (%)	1997	81.0	64.0	55.0	61.0	47.2
12	Social factors	Landless and marginal labourers to total main workers (%)	2001	47.7	50.3	58.8	48.8	35.0
13		People illiterate (%)	1991	64.2	62.3	72.5	61.4	59.2
14		People living in rural area (%)	2001	100	100	97.6	88.5	85.0
15		Population density (per sq km)	2001	206.5	168.2	292.7	203.3	236.0
16	Land-use pattern	Geographical area not covered under forest (%)	2001	92.7	87.1	97.6	93.3	62.7
17		Barren uncultivable and other fallows (%)	2001	13.5	24.3	12.6	16.7	5.4
18	Institutional factors	Farmers not covered under crop insurance (%)	2001	97.4	97.2	98.3	96.2	93.7
19		People not benefited by IRDP (%)	1991	96.9	97.0	98.3	97.6	91.0

Notes: (1) CV stands for co-efficient of variation; IRDP stands for Integrated Rural Development Programme.
(2) * 1 stands for medium available waterholding capacity (AWC) of soil, 2 for medium to low, 4 for low to medium, and 6 for low to very low AWC

Sources: Authors computation from data collected from various source such as Office of the District Collectorate, Bolangir; Office of the Junior Agriculture Officers, Respective block offices, Bolangir; DES (2001); Census of India (1991; 2001); CGWB (1997); Sarkar *et al.* (1998).

population exposed was expressed in two ways — as percentage of population living in rural areas and as population density. The variables for constructing CDVI, CDAI and PhyExpo were chosen considering their strength of influence on respective outcomes. The care was taken to ensure that the values or magnitudes of the variables moved in the same direction with respect to drought vulnerability and adaptability. For example, if the value of certain variable of CDVI increases *ceteris paribus* the level of drought vulnerability also increases.

Nature of Drought Vulnerability and Risk

The drought risk level for different blocks of Bolangir district depended on varying levels of their vulnerability, physical exposure to drought and adaptive capacity. Data on indices of drought risk, drought vulnerability and coping capacity are given in Table 2. A perusal of Table 2 revealed as follows: (i) the drought risk level varied widely across the blocks, (ii) the extent of drought vulnerability and physical exposure to drought varied moderately, and (iii) the coping capacity of different blocks differed only slightly. It was also observed that in some study blocks, the biophysical factors had contributed more to their drought vulnerability while in some other blocks, socio-economic factors had played a dominant role in making them more vulnerable to recurrent droughts.

The status of the study blocks with respect to different factors of drought vulnerability has been illustrated in Table 1. When these factors were indexed to form CDVI, out of 14 blocks, Saintala was found to be the most vulnerable block with maximum CDVI value (CDVI-3) of 0.776, while Titlagarh was observed to be the least vulnerable with index value of 0.437. Patnagarh experienced a moderate degree of drought vulnerability with index value of 0.675 (Table 2). As regards relative contribution of different biophysical factors to drought vulnerability, it was observed from the vulnerability radar (Figure 1) that the available water holding capacity (AWC) of soil, rainfall variability and drought intensity were posing significant threat to the most drought vulnerable block Saintala. However, the maximum number of biophysical factors, viz. land slope, drought frequency and intensity and long-term rainfall variability were affecting the moderately drought vulnerable block Patnagarh more compared to Saintala.

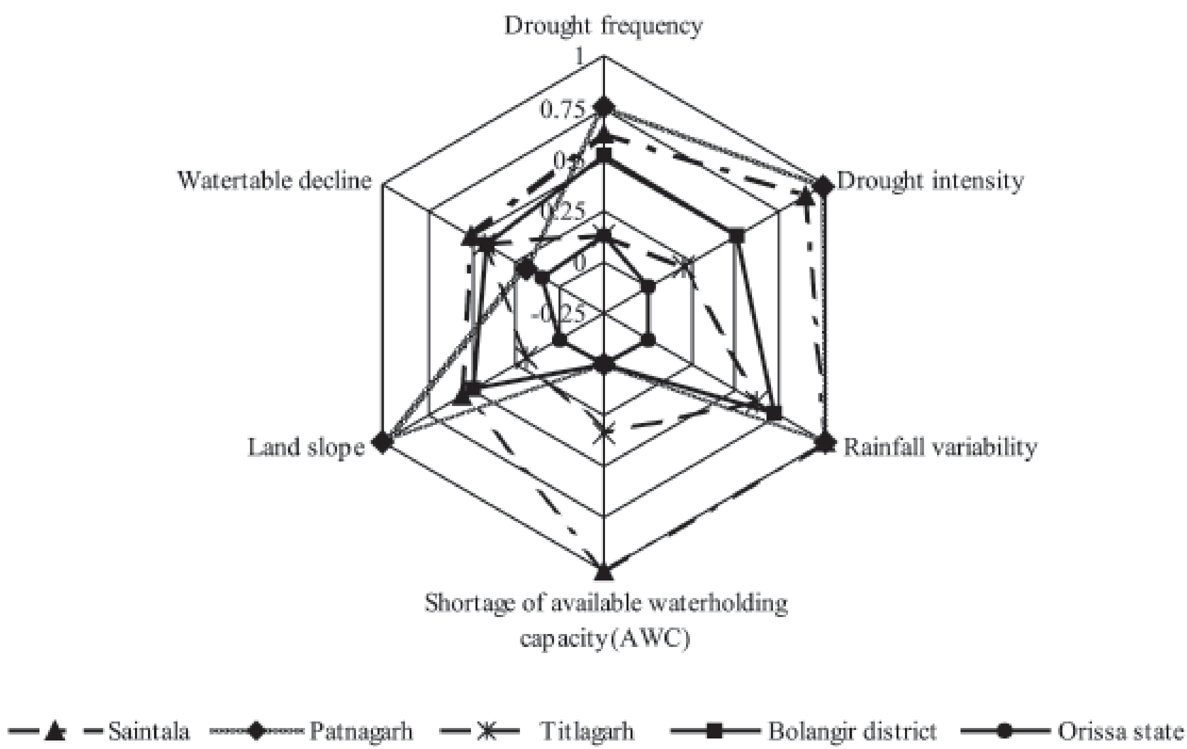

Figure 1. Relative influence of biophysical factors in drought vulnerability across study blocks in Bolangir district of Orissa

Table 2. Computation of drought risk index (DRI) in the study blocks of Bolangir district

Blocks of Bolangir district	Physical exposure		Composite drought vulnerability index			Composite drought adaptability index			Drought risk index
	PhyExpo-1 (Prob* RuralPop)	PhyExpo-2 (Prob* PopDen)	CDVI-1 (simple average)	CDVI-2 (weighted with equal weights)	CDVI-3 (weighted with unequal weights)	CDAI-1 (simple average)	CDAI-2 (weighted with equal weights)	CDAI-3 (weighted with unequal weights)	DRI (PhyExpo-1 × CDVI-3/ CDAI-1)
Saintala	0.627	0.439	0.701	0.716	0.776	0.505	0.565	0.676	0.963
Patnagarh	0.751	0.296	0.616	0.626	0.675	0.478	0.531	0.604	1.062
Titlagarh	0.109	0.313	0.537	0.476	0.437	0.557	0.613	0.746	0.086
Bolangir district	0.250	0.190	0.531	0.505	0.561	0.538	0.601	0.728	0.260
Orissa state	0.000	0.089	0.077	0.066	0.058	0.959	0.901	1.214	0.000

Notes: 'Prob' stands for probability of drought; 'RuralPop' stands for rural population; and 'PopDen' stands for population density.
Source: Computed from data collected from secondary sources as mentioned in Table 1.

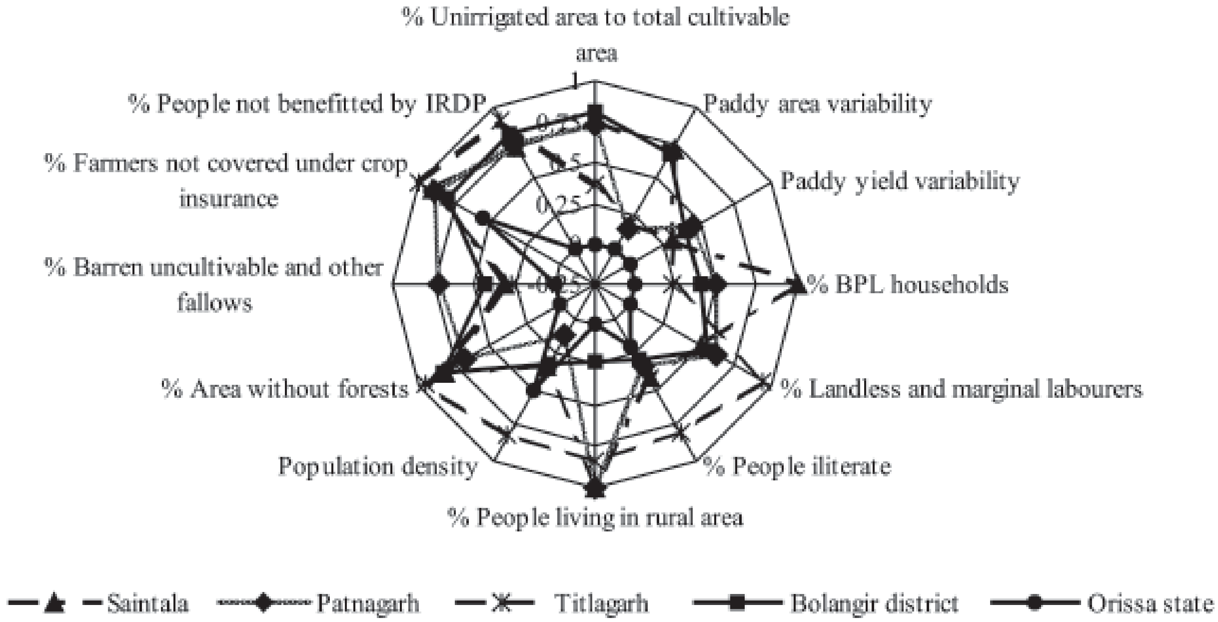

Figure 2. Relative influence of socio-economic factors in drought vulnerability across study blocks in Bolangir district of Orissa

Among major socio-economic factors of concern for Saintala, the most significant was its poverty with 81 per cent of its households living below the poverty line (Figure 2). It was followed by percentage of people living in the rural areas, percentage of unirrigated area, percentage of geographical area covered under forest and poor crop insurance coverage. Titlagarh which ranked best among the study blocks also suffered on fronts like percentage of people not covered under crop insurance, percentage of people not benefited by IRDP, percentage of landless and marginal farmers and percentage of area without forest. The block, which is locally known as '*tatala garh' (*means hot town), has recorded the maximum temperature in India many times. Therefore, the temperature variability was the second most important climatic threat (next to drought) affecting the livelihood activities in the region.

All the study blocks depicted an erratic rainfall pattern along with a declining long-term mean rainfall. While the growth of annual rainfall in Orissa state as a whole has depicted increasing trend (Swain, 2006), the Saintala block has exhibited a steady fall, as revealed by the log rainfall graph for this period of 1986-2003 (Figure 3). As a result of the declining trend of annual rainfall coupled with a high degree of variability, frequency of drought is rising with time. The probability of occurrence of a drought[1] was maximum in Patnagarh, followed by Saintala and Titlagarh (Table 3).

Since a significant proportion of cultivated land (96%) in Bolangir is under rainfed agriculture, the variability in date of onset of effective monsoon, higher initial and conditional probability of dry weeks are crucial factors for increasing drought vulnerability and risk in the region[2]. For example, in the case of Saintala block, the initial probability of dry week 'P (D)' until the 24th meteorological week has been found to vary from 0.65 to 1. The probability of dry weeks continues to increase

[1] To define the drought intensity, the percentage departure (PD) was calculated using the formula: $PD = \frac{(Ri - \overline{R})}{\overline{R}} X100$ where, R_i = Actual rainfall for the year (mm) and $\overline{R}$ = Long period average (LPA) rainfall (mm) for 1951-2000. If the rainfall departure was less than 25 per cent, then the drought intensity was considered as mild. If the rainfall departure was between 25 per cent and 50 per cent, it was taken as moderate drought and if the rainfall departure was more than 50 per cent, the severe drought was said to have occurred.

[2] With the help of standard package written in FORTAN, the long-term frequency behaviour of dry and wet spells was examined by Markov Chain Probability Model, taking into consideration the block level daily rainfall data for the period 1986-2003.

Table 3. Probability of occurrence of drought and variability in rainfall in the study blocks: 1986-2003

Blocks of Bolangir district	Mild drought (%)	Moderate drought (%)	Severe drought (%)	Frequency of drought occurrence (moderate+ severe)	Average annual rainfall (mm)	Coefficient of variation in rainfall (%)
Saintala	22.2	16.7	22.2	38.9	1116.5	40.6
Patnagarh	22.2	11.1	33.3	44.4	1016.7	40.5
Titlagarh	22.2	16.7	5.6	22.2	1376.7	31.6
Bolangir district	23.4	16.3	17.5	33.7	1206.7	27.7

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

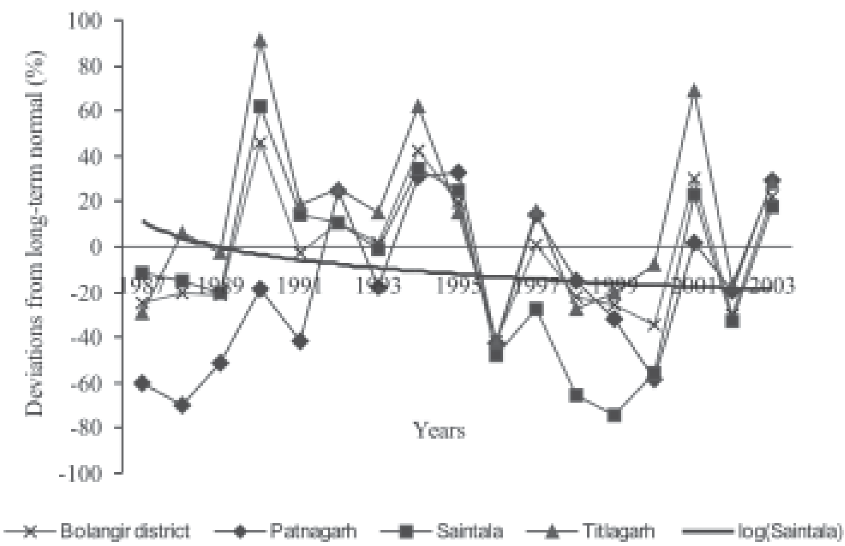

Figure 3. Rainfall variability across study blocks in Bolangir district of Orissa (Database: 1986-2003)

from the 37th week, reaches 0.67 in the 38th week and thereafter continues to increase until the end of the year. Moreover, the probability of occurrence of a dry week preceded by another dry week, referred to as P (D/D), is very high until the 24th week and thereafter fluctuates heavily around 0.64 in the 28th week which is a crucial time for agricultural activities. With such a variable rainfall pattern, rainfed agriculture is a highly risky venture.

An analysis of the adaptive capacity of different study blocks[3] revealed that the most- vulnerable block Saintala had the moderate degree of drought coping capacity with CDAI (CDAI-1) value of 0.505. The moderately-vulnerable block Patnagarh had a lower coping capacity with CDAI value of 0.478, while the least-vulnerable Titlagarh had a better coping capacity with CDAI value of 0.557 (Table 2). The factors contributing to make Titlagarh a better drought coping block were its better status with regard to cultivable lands under irrigation (12.7%), forest area (10.1%) and people benefited by IRDP (2.7%). The probability of no drought was also maximum for Titlagarh (77.8%). On the other hand, the probability of no drought was only 61.1 per cent for Saintala, which occupied the lowest rank with regard to irrigation coverage (5.2%), forest area (2.4%) and long-term average paddy yield (9.2 q/ha). All these factors had reduced the drought coping capacity of the Saintala block.

[3] The relative adaptability was classified as follows: If CDAI value was lower than 0.4, it denoted low level of adaptability; if CDAI value was 0.5 or above, it denoted high level of adaptability; if CDAI value lied between 0.4 and 0.5, it denoted a moderate level of adaptability.

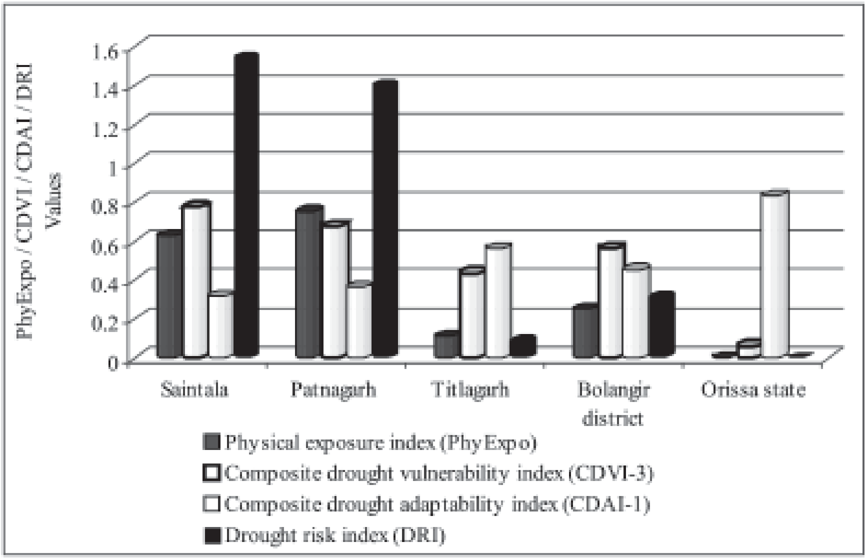

Figure 4. Drought vulnerability, adaptability and risk across study blocks in Bolangir district of Orissa

Among the study blocks, Titlagarh faced the least physical exposure to drought with the exposure score (PhyExpo-1) of 0.109, while Patnagarh faced maximum exposure with PhyExpo value of 0.751 and Saintala remained in between with PhyExpo value of 0.627. The physical exposure to drought varied basically due to the variation in the level of drought probability and the proportion of people living in the rural area in those blocks. As regards drought risks[4] for different blocks, Saintala and Patnagarh blocks were under moderate drought risk zone. Titlagarh was under low drought risk zone (Figure 4). The DRI values for Saintala and Patnagarh were 0.963 and 1.062, respectively (Table 2). In the case of Saintala, it was the relatively lower degree of physical exposure and moderate level of coping capacity that pulled down its risk level to somewhat moderate level. The drought risk for Titlagarh was significantly reduced due to the low level of physical exposure and lower vulnerability since, among the study blocks, it had the highest irrigation coverage, lowest barren and uncultivable and other fallows, lowest average paddy yield variability and more importantly, lowest percentage of population under poverty.

The two most influential biophysical factors of drought vulnerability were rainfall variability and drought intensity in the case of moderately-vulnerable block Patnagarh. In the case of most vulnerable Saintala block, the rainfall variability and the shortage of available waterholding capacity of soil were found to be two most important biophysical factors of drought vulnerability. In the case of least-vulnerable block Titlagarh, two most influential biophysical factors were rainfall variability and decline in the groundwater table. Regarding the most influential socioeconomic factors of drought vulnerability, poverty and proportion of people living in the rural area were found to be the two most influential socioeconomic factors in case of most-vulnerable Saintala block. The two most influential socioeconomic factors of drought vulnerability of Patnagarh block were higher proportion of people living in rural area and low level of crop insurance coverage. In the case of least-vulnerable Titlagarh, the poor crop insurance coverage and the area not covered under forest were found to be two major socioeconomic factors of drought vulnerability.

Conclusions

The analysis of the nature of vulnerability to agricultural drought in study blocks of Bolangir district in Orissa has revealed that while the drought risk level vary widely across the blocks and the extent of drought vulnerability and physical exposure to drought vary moderately, the coping capacity of study blocks varies marginally. The level of coping capacity has been found

[4] The relative level of drought risk was classified as follows: If DRI value was below 0.4, it denoted a low level of drought risk. If DRI value was above 0.8, it denoted a high level of drought risk. If DRI value lied between 0.4 and 0.8, it denoted a moderate level of drought risk.

significantly lower than the level of drought risk and vulnerability in the study blocks. This implies that there is a need for strengthening the coping capacity for effectively dealing with drought risk that seems to be rising in the region along with the process of climate change and desertification.

There are many areas where coping capacity can be strengthened with effective policy interventions. Firstly, expansion of irrigation facility has to be given due importance. There is a huge scope for increasing irrigation in the district through developing micro level water resources. Most of the biophysical factors like rainfall, soil characteristics and topography are conducive for developing water harvesting structures in the region which was previously irrigating about a third of its gross cropped area. Shortage of power coupled with poor economic condition of farmers have been found preventing large-scale use of energized dug-wells and tube-wells and drawing of groundwater even though groundwater is abundantly available in the study region.

The institutional support system is required to be strengthened for improving the socio-economic conditions of drought afflicted households in the region. The crop insurance coverage hovers around 4 per cent that needs to be increased for reducing the level of drought risk of the farmer community. Huge deficiency is also felt on the marketing front. Local produces including paddy are hardly sold at a reasonable price. The lack of proper marketing facilities coupled with the problem of credit availability from institutional sources and shortage of power supply have forced many prospective farmers to avoid cultivating highly remunerative cash crops like sugarcane and cotton.

Furthermore, the higher incidence of poverty, declining forest vegetation, increasing variability in yield and area of major crops due to promotion of HYVs and disappearance of drought-resistant indigenous crop varieties have increased the level of vulnerability to agricultural drought in the study blocks of Bolangir district. The Governments of India and Orissa have been implementing a number of special programs like Drought Prone Area Programme (DPAP), Western Orissa Rural Livelihood Programme (WORLP), Revised Long Term Action Plan (RLTAP) for development and renovation of community based water harvesting structures (WHSs), developing common property resource base, strengthening rural socio-economic infrastructures like education, health, communication networks and financial institutions, etc. However, the implementation of these programmes so far has not been done in a manner that would truly benefit the people. There is an urgent need to make the governance system more transparent and accountable so that these programmes would help to reduce the vulnerability of the people. Safeguarding indigenous crop varieties, sustained R&D efforts for developing drought resistant crop varieties and revival of traditional water harvesting structures require urgent policy attention for reducing the extent of drought vulnerability and risk in the study area.

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