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State level agricultural vulnerability to climate change in North-eastern region of India

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ABSTRACT

The difficult terrain, fragile hill ecology, poor infrastructure and resource endowments, low level of productivity make the agriculture vulnerable to climate change in North-eastern (NE) region of India. The small and marginal land holdings add to the inability to cope up with the climatic stress. There are every possibilities that failing to achieve the goal of climate action (Goal 13) may become obstacle in the path of achieving the goal of zero hunger (Goal No 2) that underlie the sustainable development goal envisaged by UNDP. Hence, this paper assessed the agricultural vulnerability of the different eight states in the NE region by constructing a vulnerability index using secondary data. The three dimensions of vulnerability *viz.* exposure, sensitivity and adaptive capacity includes a number of indicators. Manipur was agriculturally the most vulnerable state due to high exposure to change in climatic factors and lower adaptive capacity, whereas Tripura was the least vulnerable due to higher level of adaptive capacity. About 50% of the states were medium to highly vulnerable. Hence, increasing the cropping intensity, irrigation facility, extending the credit facility may help the states to cope up with the climate changes; hence decreasing their vulnerability.

1. Introduction

Vulnerability to agriculture possess a threat to livelihood of the peasants and progress of any region, state or country, when the major chunk of the population depends on agriculture which is a risky enterprise due to its exposure to and direct dependence on the climatic factors *viz.* rainfall and temperature (Hiremath and Shiyani, 2013). The same is true for the states in the North Eastern (NE) region of India. The concept of vulnerability is highly debated or contested (Moss *et al.,* 2001). This concept is in use in different literature of Developmental Sciences to refer to a section of the society or a geographic region with specific characteristics. The concept, off-late, came in use in climatic studies too; linking a group of people to the physical-environmental dimension *i.e.* the hazard caused by the climate change. In a broader sense scholar agree that it is 'the capacity of system to get harmed'. Blaikie *et al.* (1994) defined vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with and recover from the impacts of natural hazards". Vogel (1994) extending this felt that it may be viewed along a continuum from resilience to susceptibility. Exposure to climatic hazard was component of the vulnerability definitions of Cutter (1996) and Downing (1999). Cutter states "It is the interaction of the hazards of place (risk and mitigation) with social profile of the communities"; which implies that geographical location or place is the fundamental unit of analysis. She also included the concept of coping or adaptive capacity for social response to hazard. According to the Intergovernmental Panel on Climate Change (IPCC) vulnerability is the extent to which climate change has the ability to damage or harm a system and this depends not only on a system's sensitivity, but also on its ability to adapt to the changing conditions (IPCC 2001). There are every possibilities that failing to achieve the goal of climate action (Goal 13) may become obstacle in the path of achieving the goal of zero hunger (Goal No 2) that underlie the sustainable development goal envisaged by UNDP.

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Hence, understanding the fact that who (geographic or socioeconomic groups) and how much is sensitive to climatic hazard to develop appropriate policy measures to address the causes rather than the symptoms Ribot (1995). Assessment of vulnerability is a core element for developing adaptation strategy and for disaster risk management. This has the direct implication for policy development (Fussel and Klein 2005). Identification of the factors that affect these components of vulnerability is of paramount importance for reducing the vulnerability of a state or country. The states in NE India are dependent on agriculture with average 21.88 per cent share on agriculture GDP in total GDP in 2011-12 and the region has been experiencing change in climate. Dash *et al.* (2007) reported that the maximum temperature of NE region has increased at a rate of 1°C/decade and minimum temperature experienced a sharp drop by 1.4°C during 1955-1972. Nongbri (2016) observed that the high sensitivity and low adaptive capacity of farm households in Nagaland make them vulnerable to drought. The different level of climatic exposure and difference in resource endowment across the states will lead to different level of vulnerability. Ravindranath *et al.* (2011) conducted a comprehensive district level assessment of vulnerability in NE region covering the agriculture, water and forest sectors. They reported that majority of the districts in the region are vulnerable to climate change in the present and in the near future as well. In another study, Feroze *et al.* (2014) assessed the vulnerability of different districts of Manipur and found that hill districts were more vulnerable in comparison to the valley districts. But state is the primary unit of decision-making (Vincent 2004), and it became crucial for agricultural policy decision especially with respect to investment decisions. Investment on planned adaption measures is critical to tackle vulnerability of the agriculture sector. Therefore, the present study is an attempt to assess quantitatively the agricultural vulnerability of states in the NE region of India.

2. Data and Methodology

Study area

The NE region is a biodiversity hotspot and its fragile ecosystem makes it highly susceptible to climate change. Also the poor infrastructure in these states adds to its susceptibility; therefore, all the eight states of NE region *i.e.* Arunachal Pradesh (AR), Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura were selected for this study. The NE region of India is stretched between 89.46 degree to 97.30-degree East longitude and 21.57 degree to 29.30-degree North latitude covering an area of 262179 sq. km. which is only 8% of country's geographical area. The region is connected with the rest of the country by a stretch of 'Chicken's Neck' of 22 km land corridor through Siliguri of West Bengal. It has 4,500 km long international border with five foreign countries namely Bangladesh, Bhutan, Myanmar, China and Nepal. NE is home for 45.49 million people, which is only 3.76 per cent of the country's total population; out of which about 56.11% belongs to 221 ethnic groups and still 72.05% of the population leaves in the rural areas. The population density is 159 persons per sq km. as in 2011. The sex ratio is 954 females per 1000 males and the literacy rate is 79% (Census 2011).

The region can be physiographically categorized into the Eastern Himalaya, the Patkai and the Brahmaputra and the Barak valley plains. About two third of the region is hilly and the altitude varies from almost sea-level to over 7,000 m above mean sea level. Brahmaputra-Barak river and their tributaries are the major river system in the region. It has a predominantly humid sub-tropical climate with hot, humid summers, severe monsoons, and mild winters. About 61.63% of the total geographical area is covered by forest. The high rainfall supports diverse flora and fauna. The economy of the region is primarily agriculture based and depends upon Central Government grants.

Measuring vulnerability

Much of the studies dealt vulnerability and adaptation in the form of case studies. These studies covered the events of hazards *viz.* flood, drought, sea level rise et.; their impacts and how the local community or administration cope up and adapt to these or fail to do so Chen (1991), Adger and Kelly (1999). Assessing vulnerability is highly interdisciplinary. Model the effect of climate change including society as a variable and including the society’s ability to cope up is challenging as social and economic structures are not static. Downing (1991, 1992) recognized the multivariate nature of societal vulnerability by including social, economic and political structures. In this study vulnerability is taken as a function of three components: exposure, sensitivity, and adaptive capacity (Palanisami *et al.* 2009; Ravindranath *et al.* 2011; Feroze *et al.* 2014; Nongbri *et al.* 2016). As these concepts are not all together objective rather many a time subjective, it is necessary to identify proxy variables or indicators for use in modeling (Moss *et al.* 2001)

Vulnerability index

An index was constructed for the quantitative assessment of the agricultural vulnerability of different NE states. The indicators of vulnerability were selected based on the previous works (Watson *et al*., 1998; O'Brien and Leichenko, 2000; Fischer *et al*., 2002; Palanisami *et al.,* 2009; Ravindranath *et al*., 2011; Hiremath and Shiyani, 2013; Feroze *et al*., 2014), availability of data and personal judgement. The indicators were grouped into three dimensions of vulnerability *i.e*. Exposure, Sensitivity and Adaptive capacity (Table 1). Data were normalized to make the indicators unit free (UNDP, 1990) and bring them under the range of 0-1 (Feroze *et al*., 2014). Primarily three methods were used to assign weights to the indicators by different researchers, *viz.* i) equal weight (Feroze *et al*., 2014), ii) Iyengar and Sudarshan's (IS) method (Nongbri *et al*., 2016) which ensures that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter regional comparisons (Iyengar and Sudarshan, 1982) and iii) Principal Component Analysis (PCA) method (Feroze and Chauhan, 2010; Ravindranath *et al*., 2011) in which weights were given to the indicators by the factor loadings of the first principal component.

Table 1. Indicators used to construct vulnerability index

Proxy variable/indicators	Year	Source	Expected relationship with the respective dimension	Expected relationship with vulnerability
A. Exposure				
Percentage change in rainfall	2002-12	(0.25° X 0.25°) IMD, Pune	Positive	Positive
Frequency of excess rainfall years (No.)				
Frequency of deficit rainfall years (No.)				
Standard deviation in rainfall				
Annual change in maximum temperature (trend)		(0.1° X 0.1°) IMD, Pune		
Annual change in minimum temperature (trend)				
B. Sensitivity				
Population density (person/sq. km)	2011	Census, 2011	Positive	
% of female farmers	2011	www.indiastats.com		
% of gross area irrigated to gross area sown	2011		Negative	
Groundwater availability (%)	2010			
Area under rice ('000 ha)	2011	www.dacnet.nic.in	Positive	
Cropping intensity (%)	2012	www.indiastats.com	Negative	
Rice yield(kg/ha)	2011	www.dacnet.nic.in		
C. Adaptive capacity				
Population (Below poverty line (%)	2011	Census, 2011	Negative	Positive
Literacy rate (%)			Positive	Negative
Livestock density (no. per capita)				
Average farm size (ha)		www.indiastats.com		
Share of agricultural GDP in total GDP (%)		GoI, 2015		
Fertilizer consumption (kg/ha)	2010	Fertilizer statistics 2010		
Rice yield(kg/ha)	2011	www. dacnet.nic.in		
Milk availability (g/capita)	2013	Department of Animal Husbandry, Dairying & Fisheries, , GoI		
Household using banking services (%)	2012	www.rbi.org.in		
Number of Primary Agricultural Cooperatives (PAC)		www.rbi.org.in		
Kisan Credit Card (KCC) amount sanctioned (` billion)		www.rbi.org.in		

All these three methods of assigning weights were used in the present study so as to avoid the risk of omission of any of the vulnerable state. The weights were then multiplied with their respective normalized indicator values and summed them up to get the indices. The vulnerability indices for each of the states were calculated by adding the exposure and sensitivity indices and then deducting the adaptive capacity index (Feroze *et al*., 2014).

3. Results and Discussion

3.1 Exposure to change in climatic factors

Exposure is the nature and degree to which a system is exposed to the variations in its climatic conditions (IPCC, 2001). Scale effects are important in measuring physical-environmental changes and timescale of century is appropriate climate change but it becomes irrelevant to decision makers dealing with issues that are near term or local (Moss *et al.,* 2001). The study of different rainfall indicators revealed its erratic nature in all the NE states (Table 2) which increases the vulnerability of agriculture as primarily rainfed agriculture is practised in the region. The high percentage change in rainfall in Assam (+) and Meghalaya (-) during 2002-12 increased their exposure to climatic change. Though the magnitude of change in rainfall was low in Manipur but the frequency of excess and deficit rainfall was very high. The state received excess rainfall in 4 years out of 11 years and 5 years were rainfall deficit years. Meghalaya and Nagaland were the other two states where the extreme events were more frequent.

The inter year variations in rainfall was comparatively higher in Manipur and Meghalaya which is evident from high value of calculated standard deviations. Manipur has registered the highest annual change in the maximum temperature (0.081C), followed by Assam and Nagaland. The highest annual change in minimum temperature (0.091C) was observed in AR, followed by Manipur and Nagaland (Table 1). The overall exposure index reveals that Manipur, Assam and Nagaland were highly exposed to the climatic variations among the different NE states (Table 6).

3.2 Sensitivity to climate change

Sensitivity of a system can be defined as its degree to which it is affected either adversely or beneficially by climate related stimuli (IPCC, 2001). Assam and Tripura were comparatively the most population dense states while Nagaland, Sikkim, Manipur and Mizoram have larger number of female farmers than the NE average which make these states comparatively sensitive to climatic change (Table 3). Assam, Tripura and Manipur have comparatively larger area under rice cultivation which increased the risk of crop failure during the climate change scenario but comparatively higher level of rice productivities in Tripura (2.70 MT/ha) and Manipur (2.64 MT/ha) reduced the sensitivities of these states to climatic changes. The percentage of irrigated land in NE (19.52%) is much lower than the national average of 44.9 per cent (GoI, 2015). Irrigation supplements water requirement of crops during low rainfall or drought situations. States like Sikkim, Assam and Mizoram have extremely low percentage of irrigated land making them more susceptible to climate change. The higher availability of groundwater in Assam reduced its sensitivity but it was reverse for other NE states.

Table 2. Descriptive statistics for the exposure indicators

State	Percentage change in rainfall	Frequency of excess rainfall years	Frequency of deficit rainfall years	Standard deviation in rainfall	Annual change in max temp (°C)	Annual change in min temp (°C)
AR	1.59	2	2	182.87	0.007	0.091
Assam	43.36	4	3	205.13	0.077	0.050
Manipur	2.31	4	5	389.46	0.081	0.064
Meghalaya	34.84	2	3	342.04	0.043	0.024
Mizoram	0.71	2	3	184.06	0.060	0.034
Nagaland	14.51	4	4	228.74	0.069	0.064
Sikkim	7.59	2	2	188.83	0.048	0.002
Tripura	11.86	3	3	152.76	0.055	0.025
NE	14.60	2.88	3.13	234.24	0.055	0.044

Table 3. Descriptive statistics for the sensitivity indicators

State	Population density (per sq km)	% of female farmers	% of gross area irrigated to gross area sown	Groundwater availability (%)	Area under rice ('000 ha)	Yield of rice (kg/ha)
AR	17	39.49	20.29	2.56	123.50	2064.80
Assam	398	23.69	3.77	27.23	393.62	1780.02
Manipur	128	42.73	22.03	0.38	212.68	2640.00
Meghalaya	132	34.97	21.66	1.15	108.27	2330.00
Mizoram	52	41.86	11.58	0.04	40.68	1410.90
Nagaland	119	52.26	20.40	0.36	181.39	2110.00
Sikkim	86	44.63	0.85	0.08	12.14	1729.90
Tripura	350	26.28	35.25	2.19	264.559	2700.40
NE	160.25	38.24	19.52	4.25	167.11	2095.76

About 4 to 6 states in the NE region turn out to be medium to highly sensitive across different methods (Table 5). Assam was the most sensitive state to climate change (EW and IS method) due to its high population density, larger area under rice with very low level of irrigation facility and low level of rice productivity; whereas, Nagaland is the most sensitive state in PCA technique due to large number of female farmers and low level of ground water availability (Table 6). Mizoram, Sikkim, Tripura and Manipur were the other sensitive states across the different methods.

3.3 Adaptive capacity of different states

Adaptive capacity of a system is its ability to adjust itself during any climatic variations to cope up with its consequences and further risks. The literacy rates in Mizoram, Tripura and Sikkim were much higher than the national average of 64.8 per cent (Census, 2011) which indicate their potential to adjust in climate change regime by taking advantage of any possible opportunities from the government agencies and taking up proper technological interventions. On the other hand, states like Manipur, AR and Assam have quite a high percentage of people *i.e.* 36.90%, 34.70% and 32.0%, respectively living below poverty line (BPL) making them less adaptable to the changing situation. While Tripura and Manipur have higher level of rice productivity, fertilizer consumption and cropping intensity was highest in Assam indicating higher adaptive capacity. The number of livestock per capita was higher in states like AR, Nagaland, Sikkim and Meghalaya which supplements farmer's income through milk and meat production.

The financial support in terms of penetration of bank branches and disbursement of agricultural loans is crucial for adaptation. The percentage of households (78.2%) using banking services was largest in Tripura and the number of agricultural cooperatives was higher in Nagaland and Assam. The highest loan through Kisan Credit Card (KCC) was sanctioned in Assam making easier the cash constraints of the farmers and encouraging them to adopt new technologies and purchase necessary agricultural inputs. The adaptive capacity was high for only 3 to 4 states out of the 8 states (Table 5). Tripura, Nagaland and Assam turned out to be having better adaptive capacities among the states under the study. Manipur's capacity to adapt to climate change is low due to low level of cropping intensity, low level of penetration by formal financial institutions, high percentage of BPL population; Mizoram and AR are the other two states with very low level of adaptive capacities (Table 6).

3.4 Vulnerability of the Northeast states

Four to five states were under medium to high vulnerability category (Table 4). Manipur turns out to be the most agriculturally vulnerable state due to higher level of exposure to climatic change and low adaptive capacity which warrants immediate planned interventions. Assam and Mizoram too turned out to be highly vulnerable in IS and EW methods whereas, Nagaland was vulnerable in PCA method. These states have high exposure (except Mizoram in PCA), high sensitivity and low adaptive capacity (except Nagaland in PCA) (Table 6). Tripura was the agriculturally least vulnerable state due to its high level of adaptive capacity.

Table 4. Descriptive statistics for the adaptive capacity indicators

State	Cropping intensity (%)	Fertilizer consumption (kg/ha)	Literacy rate (%)	Number of livestock per capita	Average farm size (ha)	% of share agricultural GDP	Yield of rice (kg/ha)	Milk availability (g/capita)	BPL (%)	Banking services (%)	No. of PAC	KCC Amount sanctioned (Rs billion)
AR	131	3.00	65.38	0.909	3.51	31.06	2064.80	93.00	34.70	43.1	34	0.20
Assam	148	69.50	72.19	0.444	1.10	27.31	1780.02	69.00	32.00	38.3	766	7.80
Manipur	100	27.50	76.94	0.357	1.14	24.77	2640.00	80.00	36.90	23.5	204	0.10
Meghalaya	119	14.90	74.43	0.523	1.37	18.06	2330.00	84.00	11.90	28.2	179	0.70
Mizoram	102	58.90	91.33	0.257	1.14	18.79	1410.90	40.00	20.40	35.9	133	0.30
Nagaland	125	3.50	79.55	0.681	6.02	24.99	2110.00	95.00	18.90	23.1	1719	0.40
Sikkim	117	0.00	81.42	0.555	1.42	10.84	1729.90	200.00	8.20	63.5	169	0.10
Tripura	137	54.00	87.22	0.397	0.49	19.25	2700.40	95.00	14.00	78.2	268	1.40
Northeast	122	28.91	78.56	0.515	2.02	21.88	2095.75	94.50	22.12	41.72	434	1.37

Table 5. Number of NE states under different categories across different vulnerability dimensions

Equal weight method					
Category	Range	Exposure index	Sensitivity index	Adaptive capacity index	Vulnerability index
Low	≤0.330	4	2	2	3
Medium	0.331-0.660	1	2	3	1
High	≥0.661	3	4	3	4
IS method					
Low	≤0.330	4	4	2	3
Medium	0.331-0.660	1	3	2	2
High	≥0.661	3	1	4	3
PCA method					
Low	≤0.330	4	4	2	4
Medium	0.331-0.660	1	1	3	3
High	≥0.661	3	3	3	1

Conclusions

In this study, agricultural vulnerability level of different states of NE was assessed by constructing vulnerability index. It was found that halve of the states were medium to highly exposed to the changes in climate due to high variation in the rainfall. Most of the states are sensitive to climate change due to lack of irrigation facility, low level of ground water and large areas under rice. Due to lack of resources and other sources of income, adaptive capacity was found to be low for about half of the states. The high exposure and sensitivity and low adaptive capacity has led the states to be under high vulnerability conditions. Increasing the area under irrigation, cropping intensity, increasing yield by introducing stress resistant varieties, crop diversification, extending credit facility may be the way to reduce the vulnerability of these states.

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Table 6. Rank of different NE states according to different dimensions of vulnerability

	Exposure			**Sensitivity**			**Adaptation capacity**			**Vulnerability**		
States	EW	IS	PCA	EW	IS	PCA	EW	IS	PCA	EW	IS	PCA
AR	7	7	8	6	6	7	5	5	5	7	6	8
Assam	2	2	3	1	1	4	3	4	3	3	2	3
Manipur	1	1	1	5	5	3	7	7	8	1	1	1
Meghalaya	4	4	5	8	8	8	6	6	6	6	5	6
Mizoram	6	6	6	3	2	6	8	8	7	2	3	5
Nagaland	3	3	2	2	3	1	2	2	1	4	4	2
Sikkim	8	8	7	4	4	5	4	3	4	5	7	7
Tripura	5	5	4	7	7	2	1	1	2	8	8	4

Note: EW = Equal weight method, IS = Iyenger and Sudarshan method, PCA = Principal component method

Annexure I

Exposure, sensitivity, adaptation capacity and vulnerability indices for different ne states

States	**Exposure**			**Sensitivity**			**Adaptation capacity**			**Vulnerability**		
	EW	IS	PCA	EW	IS	PCA	EW	IS	PCA	EW	IS	PCA
AR	0.072	0.088	0.000	0.368	0.279	0.053	0.501	0.531	0.560	0.194	0.227	0.560
Assam	0.820	0.786	0.767	1.000	1.000	0.504	0.834	0.806	0.775	0.738	0.917	0.775
Manipur	1.000	1.000	1.000	0.630	0.298	0.726	0.139	0.181	0.000	1.000	1.000	0.000
Meghalaya	0.465	0.476	0.318	0.000	0.000	0.000	0.366	0.358	0.335	0.277	0.397	0.335
Mizoram	0.174	0.202	0.193	0.876	0.616	0.076	0.000	0.000	0.186	0.771	0.820	0.186
Nagaland	0.770	0.751	0.793	0.992	0.602	1.000	0.884	0.967	1.000	0.682	0.560	1.000
Sikkim	0.000	0.000	0.062	0.781	0.420	0.147	0.535	0.836	0.583	0.353	0.075	0.583
Tripura	0.293	0.278	0.372	0.272	0.182	0.819	1.000	1.000	0.920	0.000	0.000	0.920