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Assessment of Agricultural Vulnerability to Climate Change in Manipur: A District Level Analysis

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ABSTRACT

Climate-change vulnerability profiles are developed at the district level of Manipur by constructing a vulnerability index. The index was based on several sets of indicators and each indicator was aggregated to obtain normalised score or vulnerability index. The normalised vulnerability indices were categorized across vulnerability classes *viz.* less vulnerable, moderately vulnerable and highly vulnerable. Results indicate that most of the hill districts fell in the highly vulnerable category except Senapati and Ukhrul, which were moderately vulnerable districts. The hill districts were found to be more vulnerable in comparison to valley districts. Mean annual rainfall and mean annual maximum temperature were positively related with vulnerability while mean annual minimum temperature, per cent of gross irrigated to gross area sown, per cent of small farmers and per cent of small female farmers, population density, literacy rate, cropping intensity, livestock density and fertilizer consumption per unit gross cropped area were negatively related with vulnerability in which gross irrigated area, small farmers, small female farmers, population density and cropping intensity are significant. The assessment and identification of vulnerable districts would assist the planners, decision-makers and development agencies to identify the most vulnerable regions for adaptation interventions in the state.

Keywords: Adaptation, Assessment, Identification, Normalised score, Vulnerability Index

INTRODUCTION

Climate change is a change in weather conditions over a period of 25-30 years. The change in weather condition is indicated by changes in temperature, rainfall, relative humidity, wind, etc. and any changes in their pattern, if any. A number of studies found that average global temperature is increasing and there is a shift in rainfall pattern. The rainfall has become more erratic in nature. The number of extreme climatic events has gone up in recent years. The yield of C_3 plants such as rice and wheat are expected to become low and for the C_4 plants *viz.* maize, initially the yield may increase but after a certain point the yield will decrease.

Any change in climatic factor will have an impact on agriculture, especially for the countries like ours where we still depend on rainfall for agriculture. The regions which practice cereal based agriculture will be worst affected if the monsoon delays or does not occur at all. The hill states of north east Himalaya are mainly rice-growing states and lack irrigation facility. Moreover, the region is ecologically fragile and soil runoff is high. Hence, agriculture in this region is at risk. The food security of the region may be jeopardized if attention is not paid to scientific interventions in agriculture of the region. Given the strong dependence of the population of North East India on agriculture, which in turn depends strongly on climatic suitability, even slight unfavourable shifts in its climate (rainfall and temperature, in particular) can potentially endanger the food and livelihood security of the people of north east India (Kumar et al. 2011). So, climate-

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change vulnerability assessments will be the key tools for the development of climate-change adaptation strategies where it stands for, the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. They are being assessed to help in setting management and planning priorities, assist in informing and crafting adaptation strategies and enable more efficient allocation of scarce resources.

Agriculture being the main occupation of the people of Manipur, it has an important place in the economy of the state. The sector contributes a major share to the total state domestic product and provides employment to about 52.19 % of the total workers in Manipur. Cropping system in the state is predominantly rice based. However, the performance of agriculture in the state mainly depends on timely rainfall and weather conditions, but the rainfall of the state is highly variable due to its topography. The rise in temperature, change in rainfall patterns has been affecting Manipur's agricultural sector and eventually the farmers. The production of rice, potato, chilly and even pineapple and oranges has been severely affected due to = climate change and subsequent human pressure. Rice, being the staple food crop grown both in hill and plain areas, the effect of rainfall will take into account for its area and productivity for the mentioned periods.

What is vulnerability?

Vulnerability assessment describes a diverse set of methods used to systematically integrate and examine interactions between humans and their physical and social surroundings. The field of climate vulnerability assessment is important to know how much a community of a district is vulnerable so as the communities will adapt to changing environmental conditions. Various researchers have tried to bridge the gap between the social, natural, and physical sciences and contributed new methodologies that confront this challenge. Fourth assessment report of the IPCC and some other global studies indicate a probability of up to 40 per cent loss in crop production in India with the increase in temperature during the last quarter of this century (Parry et al. 2004; Fischer et al. 2002). The North Eastern region of India is expected to be highly prone to the consequences of climate change. Environmental security and sustainability of the region are and will be greatly challenged by these impacts. In the absence of operational irrigation facilities in North East India, farmers are facing a totally disastrous condition due to lack of adequate rainfall for paddy cultivation that otherwise faces a perennial problem of flood during the monsoon season (Das et al. 2010). The high relative variability and inter-annual variability of rainfall have created increased occurrence of droughts and floods in the recent times, leading to uncertainty in yield and increased agricultural vulnerability. The majority of the districts of North East India are subject to climate induced vulnerability currently and in the near future (Ravindranath et al. 2011). So, an attempt has been made for giving rank to districts of Manipur based on vulnerability index values, which will help in identifying and prioritizing the most vulnerable districts and at the same time identifying adaptation interventions.

METHODOLOGY

Secondary data available from various sources such as different census reports and State Government published databases like Statistical Abstract 2008-09, data on climatic variables collected from Directorate of Agriculture and IFCD Manipur for the most recent available time point were used. Some of the indicators which were suitable for calculating the vulnerability index of climate change in Manipur were selected for the assessment of current vulnerability. The indicators are grouped into three components of vulnerability as exposure, sensitivity and adaptive capacity.

Exposure can be interpreted as the direct danger (i.e. the stressor), and the nature and extent of changes to a region's climate variables (e.g. temperature, precipitation, extreme weather events). Average annual rainfall, average annual maximum temperature and average annual minimum temperature are considered as the indicator for exposure. It is also assumed that relative variability of climatic factors *viz*. rainfall, maximum and minimum temperature enhances vulnerability.

Sensitivity describes the human–environmental conditions that can worsen the hazard, ameliorate the hazard, or trigger an impact. Percentage of the gross irrigated area to net sown area, percentage of small female farmers to total farmers, small farmers to total farmers and population density per sq. km. (Census 2001), are considered as indicators of sensitivity. It is expected that higher the percentage of the gross irrigated area lesser will be the vulnerability. While, the per cent of small female farmers and small farmers are expected to be directly proportional to vulnerability, small female farmers and small farmers have less access to resources, which makes them less adaptive to changes in climate. Population density is hypothesized to be directly proportional to vulnerability.

Adaptive capacity represents the potential to implement adaptation measures that help avert potential impacts. Literacy rate (Census 2001), cropping intensity (2011-12), livestock population (Census 2007) and fertilizer consumption per unit of the gross cropped area (2011-2012) are indicators of adaptive capacity where the indicators are inversely proportional to vulnerability. If literacy rate is high in the area, it indicates higher potential to cope with climate change impacts due to awareness. High cropping intensity and livestock population indicates less vulnerablilty to climate change since farmers income can be supplemented from it.

For aggregation purposes, each indicator is normalized to render it as a dimensionless measure or number. Indicator sets for each sector are aggregated to obtain the vulnerability index, VI.

$$Si_{normalized} = \frac{Si - Si\ min}{Si\ max - Si\ min}$$

where Si is the ith indicator value.

The normalised vulnerability indices are categorized across vulnerability classes (less vulnerable, moderately vulnerable and highly vulnerable) using the Mean ± Standard Deviation method. The assignments of vulnerability scales across the index values are as follows: Less vulnerable: < 0.3388,

Moderately vulnerable: 0.3388- 0.6724,

Highly vulnerable: > 0.6724

RESULTS AND DISCUSSION

1. Trends in rainfall and temperature

The trends in rainfall in different districts of Manipur are presented in Fig. 1 to Fig. 8. The distribution of rainfalls over months during the year 2002-03, 2003,04, 2004-05, 2005-06, 2006-07, 2007-08 and 2008-09 which had a direct bearing in the *kharif* crops of the agricultural year 2002-03, 2003-04, 2004-05, 2005-06, 2006-07, 2007-08 and 2008-09 respectively are shown in the following figures.

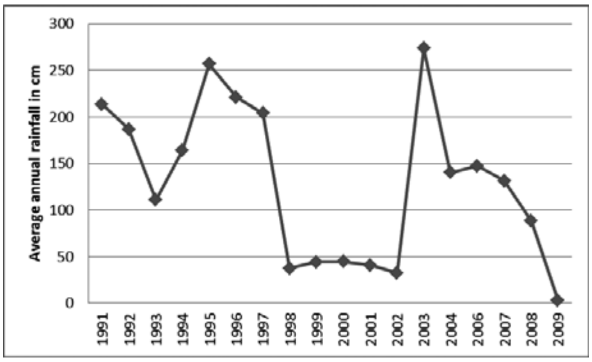

Fig. 1: Average annual rainfall for Senapati district

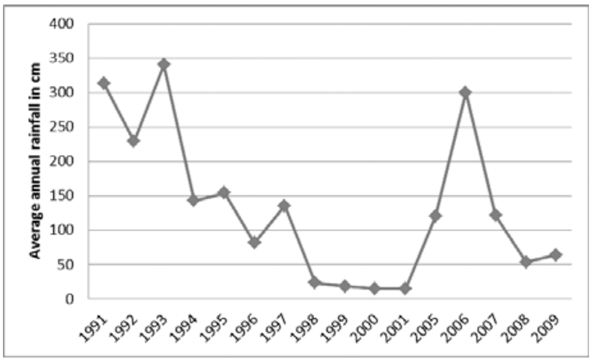

Fig. 2: Average annual rainfall for Tamenglong district

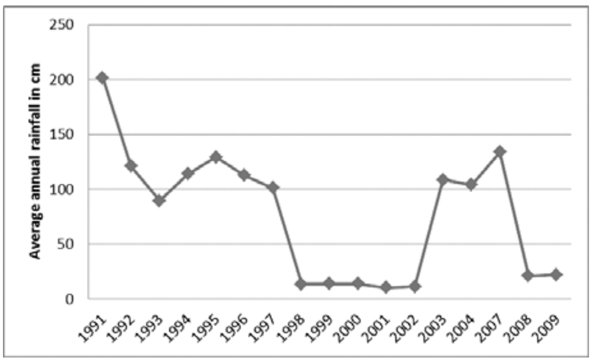

Fig. 3: Average annual rainfall for Churachandpur district

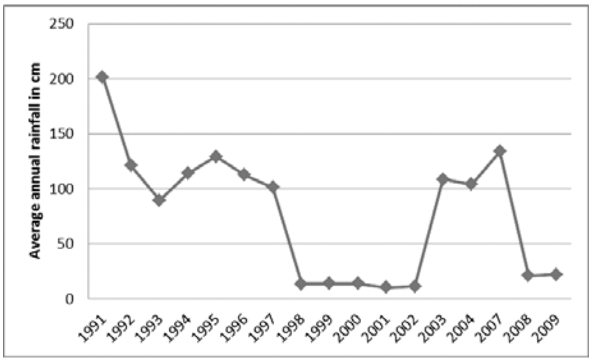

Fig. 4: Average annual rainfall for Ukhrul district

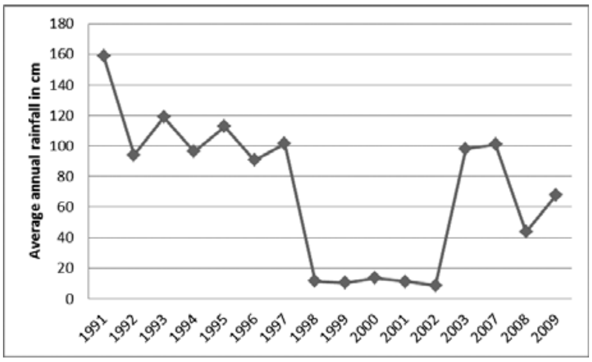

Fig. 8: Average annual rainfall for Thoubal district

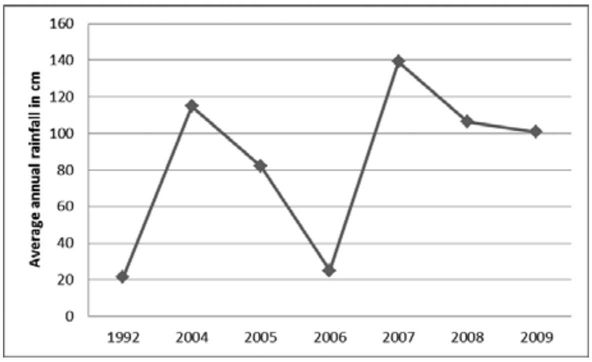

Fig. 5: Average annual rainfall for Imphal East district

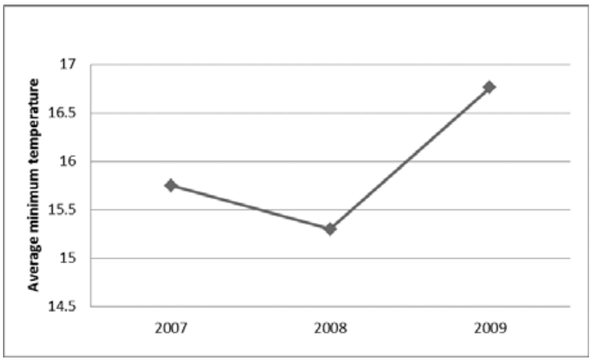

Fig. 9: Average minimum temperature for Senapati district

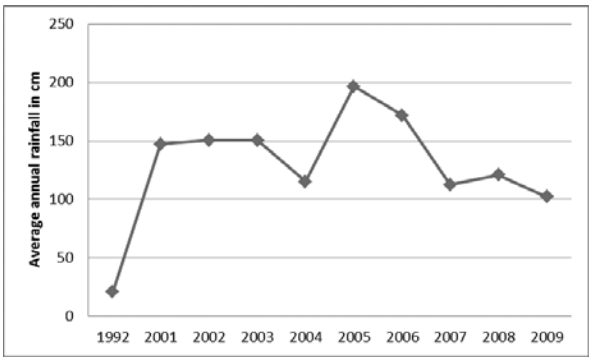

Fig. 6: Average annual rainfall for Imphal West district

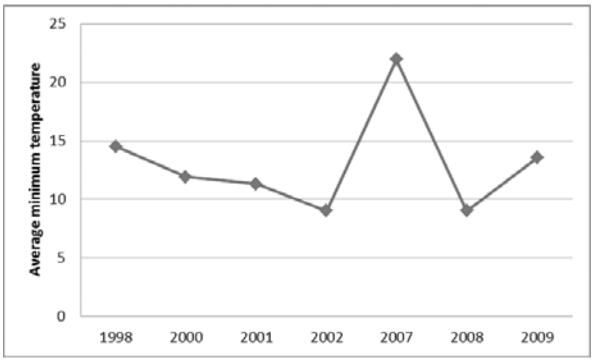

Fig. 10: Average minimum temperature for Tamenglong district

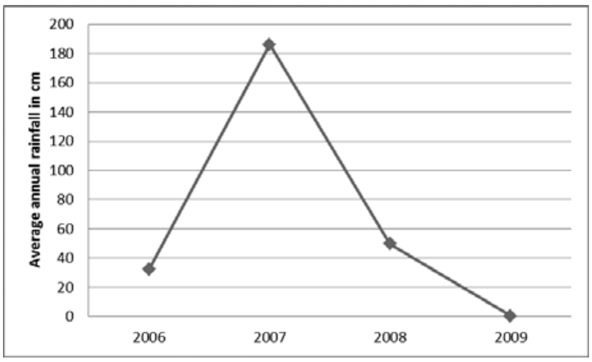

Fig. 7: Average annual rainfall for Bishnupur district

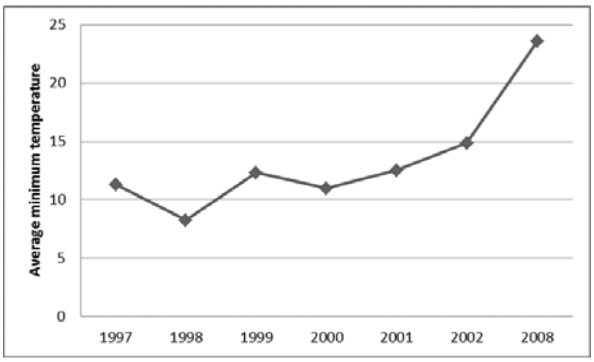

Fig. 11: Average minimum temperature for Churachandpur district

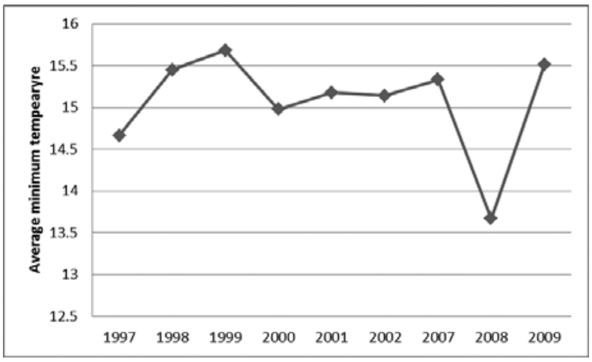

Fig. 12: Average minimum temperature for Imphal West district

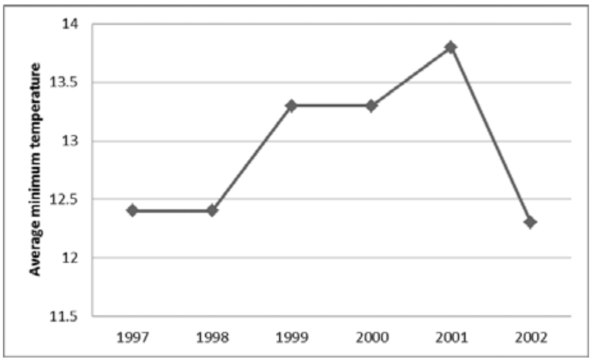

Fig. 13: Average minimum temperature for Thoubal district

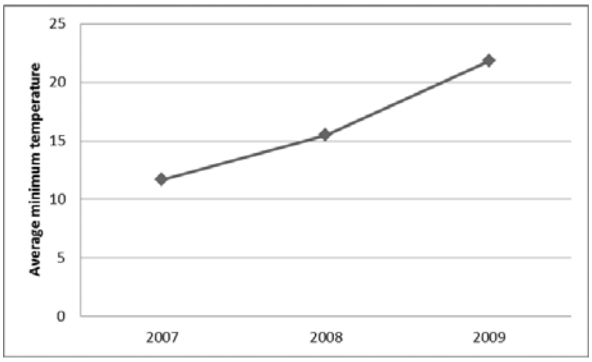

Fig. 14: Average minimum temperature for Bishnupur district

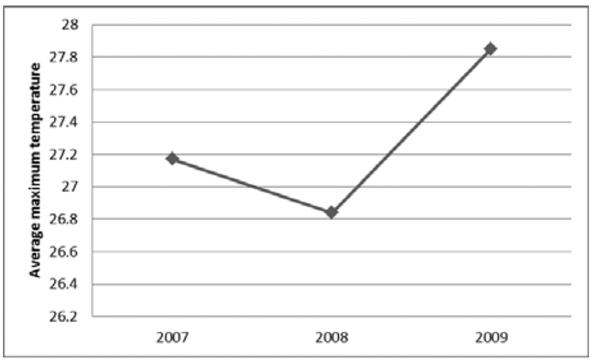

Fig. 15: Average maximum temperature for Senapati district

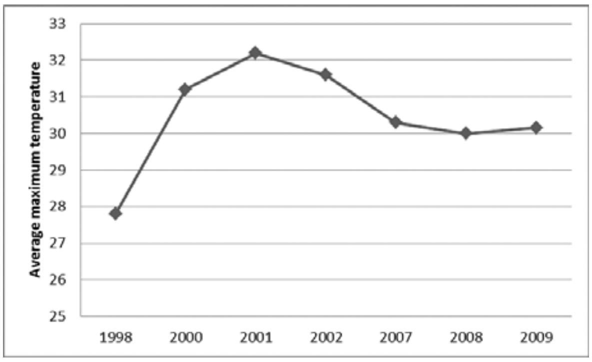

Fig. 16: Average maximum temperature for Tamenglong district

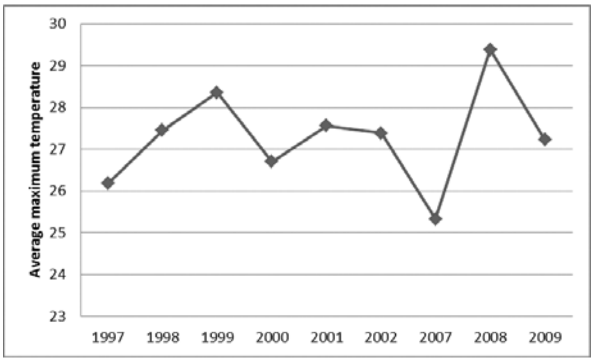

Fig. 17: Average maximum temperature for Imphal West district

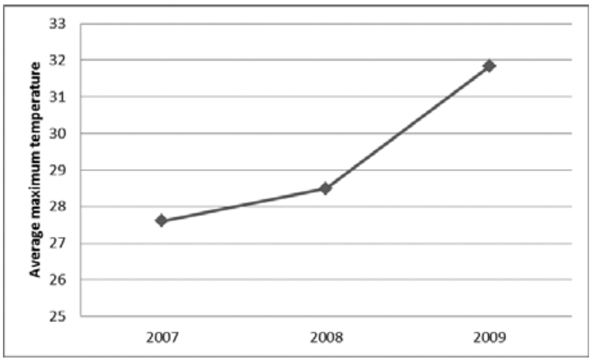

Fig. 18: Average maximum temperature for Bishnupur district

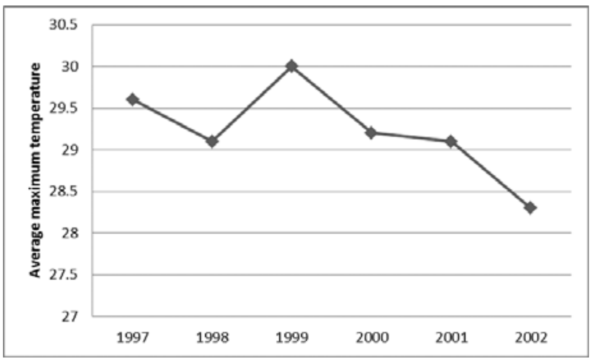

Fig. 19: Average maximum temperature for Thoubal district

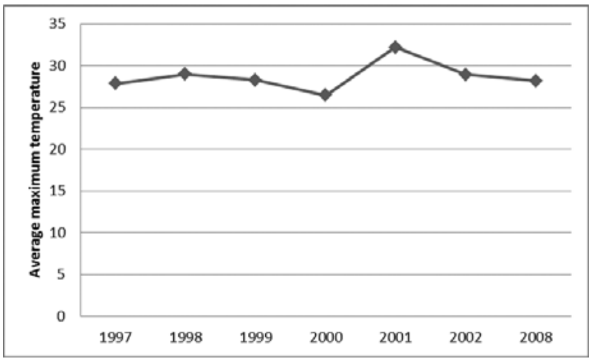

Fig. 20: Average maximum temperature for Churachandpur district

Fig. 1 depicts the annual rainfall pattern of Senapati district of Manipur for the period of 18 years (1991-2009). During the period of 1998 to 2002 the district received even less than 50 cm rainfall per annum. The rainfall was maximum (273.58 cm) during the year 2003; followed by 1995 (256.74 cm). The area under paddy has also increased during the same year which might be the reason of adequate rainfall. However, the annual rainfall has declined from 2003 to 2009. Fig. 2 indicates that the trend in mean annual rainfall of Tamenglong district for the period of 15 years. It has experienced a drastic decrease in annual rainfall up to the year 2001. The annual rainfall data for the period of 2002, 2003 and 2004 were unavailable. The annual rainfall significantly increased during the year 2006 up to 300 cm. The estimated area under paddy at the same year also increased for the district up to 9.58 thousand hectares. Similar trend was observed for most of the districts during the year 2009. The annual rainfall pattern reveals that rainfall is quite erratic in nature in all the districts of Manipur, which make the farmers of the state more vulnerable as the agriculture in the state mainly depends on rainfall.

Analysis of long-term temperature data for different districts shows that the average minimum temperature is increasing in Churachandpur. The available data shows that the minimum temperature increased during 2009 in Senapati and Bishnupur districts and during 2007 in Tamenglong district whereas it declined in 2008 in Senapati, Tamenglong and Imphal West districts. The average maximum temperature shows an increasing trend for all the districts.

2. *Vulnerability indices*

The districts based upon the vulnerability indices were grouped into three vulnerability category: i) less vulnerable, ii) moderately vulnerable and iii) highly vulnerable and presented in Table 4. The variables for the vulnerability assessment include the per cent gross area irrigated to gross area sown, per cent small female farmers, per cent small total farmers, population density per sq.km, literacy rate, cropping intensity, livestock population per ha, fertilizer consumption per unit of gross cropped area, mean annual rainfall, mean minimum and maximum temperature for different districts of Manipur. Table 1 reveals that per cent of gross area irrigated to gross area sown is highest in Senapati district among the hill districts and Bishnupur among the valley districts. But the irrigation capacity is very low in case of Ukhrul and Thoubal districts. It is expected that the district with better irrigation facility will be less vulnerable to change in climate. Per cent of small female farmers are higher in Tamenglong and Ukhrul districts than other districts. The higher the percentage of small and female farmers, more the community will be vulnerable. The coefficient for population density turned out to be negative, which is contrary to our hypothesis. The populations in the state are much lower (122 /sq.km^2) than the national level (382 /sq.km$^{2)}$. Moreover, the population density of valley districts such as Imphal West, Thoubal and Imphal East are mainly contributing to the overall state's population density. Whereas, the hill districts have a fragile ecosystem, hence are more vulnerable to climate, but they have low population density. This may be the root for opposite finding to the assumed hypothesis. The literacy rate, on the other hand, is lowest in Chandel district indicating less potential to cope with climate-change impacts. If the literacy rate is higher, the community may be able to adapt better to the climate change with proper technological intervention. The livestock population per hectare is highest in Senapati district, which can supplement the farmer's income thereby they may be less vulnerable to climate impacts. The population is lower in Bishnupur and Ukhrul districts. Application of fertilizers can be found mainly in valley districts whereas agriculture is organic in nature in case of hill districts. Fertilizer consumption is maximum in Thoubal district.

Table 1: Descriptive statistics of the indicators used to construct vulnerability index.

District	EXPOSURE (EXP)			SENSITIVITY (SEN)				ADAPTIVE CAPACITY (ADC)			
	Average annual rainfall (cm)	Average annual max. temp. (° C)	Average annual min. temp. (° C)	% of gross area irrigated to gross area sown	% of small farmers	% of small female farmers	Popula -tion density (per sq. km)	Literacy Rate (%)	Cropping Intensity (%)	Livestock Popula- tion /Ha (no.)	Fertilizer consump- tion per unit of gross cropped area (in tonnes)
Hill districts											
Senapati	128.65	27.29	15.94	84.91	23.82	17.67	87	59.8	138.84	74.08	9
Tamenglong	132.86	30.47	13.03	NA	30.86	33.12	25	59.2	123.43	28.76	1
Churachadnpur	184.79	28.68	13.39	NA	20.95	17.42	50	70.6	119.14	38.99	2
Chandel	156.1	28.81	14.12	NA	23.89	21.49	36	56.2	141.39	33.7	2
Ukhrul	85.31	28.81	14.12	2.24	26.27	28.4	31	73.1	157.88	27.92	3
Valley districts											
Imphal East	84.247	28.6	14.77	25.91	7.42	3.7	557	75.4	126.9	38.33	34
Imphal West	128.804	29.31	15.07	19.09	6.62	4.15	856	80.2	152.21	42.49	29
Bishnupur	67.03	27.28	16.33	65.59	10.38	5.45	420	67.6	175.3	27.46	35
Thoubal	71.26	29.22	12.92	13.74	17.03	12.35	708	66.4	175.56	44.33	65
Manipur	115.45	28.73	14.36	35.25	18.58	15.97	307.77	67.6	145.63	39.57	20
CV	72.24	3.43	8.45	92.26	46.96	66.33	107.83	11.94	14.52	36.37	11.05

Except Ukhrul, all the hill districts received very high rainfall whereas low rainfall in case of valley districts except Imphal West. Other districts received rainfall less than the state average. Average minimum temperature is lowest in Thoubal district, and maximum temperature is highest in Tamenglong indicating that the increase in the variability of these climatic indicators would increase the vulnerability of the districts to climate change. The districts with less variability in climatic factors are expected to be less vulnerable to climate change. The results of vulnerability indices analysis

Table 2: Normalized scores and vulnerability indices for different districts

District	EXP1	EXP2	EXP3	SEN1	SEN2	SEN3	SEN 4	ADC1	ADC2	ADC3	ADC 4	Vulnerability Index	Rank
Senapati	0.1430	0.0000	0.0074	0.0000	0.7095	0.4748	0.0746	0.8500	0.6508	0.0000	0.8750	0.3533	7
Tamenglong	0.2790	0.0624	0.7504	1.0000	1.0000	1.0000	0.0000	0.8750	0.9239	0.9729	1.0000	0.7343	1
Churachandpur	1.0000	0.1001	0.9136	1.0000	0.5912	0.4661	0.0301	0.4000	1.0000	0.7532	0.9844	0.6772	2
Chandel	0.0972	1.0000	0.5306	1.0000	0.7122	0.6045	0.0132	1.0000	0.6057	0.8669	0.9844	0.6726	3
Ukhrul	0.0395	1.0000	0.5306	0.9736	0.8104	0.8396	0.0072	0.2958	0.3133	0.9908	0.9688	0.6114	4
Imphal East	0.0000	0.9928	0.5557	0.6949	0.0330	0.0000	0.6402	0.2000	0.8624	0.7674	0.4844	0.4573	5
Imphal West	0.0072	0.1643	0.0000	0.7752	0.0000	0.0154	1.0000	0.0000	0.4138	0.6782	0.5625	0.3276	9
Bishnupur	0.1305	0.0390	1.0000	0.2275	0.1532	0.0595	0.4753	0.5250	0.0046	1.0000	0.4688	0.3823	6
Thoubal	0.0075	0.0021	0.0012	0.8382	0.4292	0.2939	0.8219	0.5750	0.0000	0.6387	0.0000	0.3344	8

Table 3: Correlation between vulnerability index and different indicators

Indicators	Average annual rainfall (cm)	Average annual max. temp. (° C)	Average annual min. temp. (° C)	% of gross area irrigated to gross area sown	% of small farmers	% of small female farmers	Popula -tion density (per sq. km)	Literacy Rate (%)	Cropping Intensity (%)	Livestock Popula- tion /Ha (no.)	Fertilizer consump- tion per unit of gross cropped area (in tonnes
	0.55 (0.122)	0.477 (0.195)	-0.56 (0.113)	-0.67* (0.499)	-0.69* (0.399)	-0.76* (0.017)	-0.77* (0.015)	-0.36 (0.331)	-0.60* (0.085)	-0.51 (0.159)	-0.75* (0.019)

*Correlation is significant at the 0.05 level.

for the districts of Manipur showed that among the hill districts, Tamenglong, Churachandpur and Chandel are highly vulnerable districts whereas, Senapati and Ukhrul are moderately vulnerable districts. None of the valley districts fell in the highly vulnerable category. Imphal East and Bishnupur are moderately vulnerable and Imphal West and Thoubal are found to be in less vulnerable category. Mean annual rainfall and mean annual maximum temperature were positively related with vulnerability while mean annual minimum temperature, per cent of gross irrigated to gross area sown, per cent of small farmers and per cent of small female farmers, population density, literacy rate, cropping intensity, livestock density and fertilizer consumption per unit gross cropped area were negatively related with vulnerability where gross irrigated area, small farmers, small female farmers, population density and cropping intensity are significant.

Table 4: Categorization of districts according to vulnerability

Category	Vulnerability index	Hill districts	Valley districts
Less vulnerable	<0.3388		Imphal West and Thoubal
Moderately vulnerable	0.3388-0.6724	Senapati and Ukhrul	Imphal East and Bishnupur
Highly vulnerable	>0.6724	Tamenglong, Churachandpur and Chandel	

CONCLUSION

Climate variability and climate change could impact agricultural sector in Manipur of North Eastern Region. In the present study, an attempt was made to assess the vulnerability of the sector to climate variability and climate change. Vulnerability profiles were developed for the current climate scenario using the index method, and all the districts of Manipur were ranked according to the vulnerability index. Tamenglong, Churachandpur and Chandel fell in highly vulnerable category whereas; Senapati and Ukhrul fell in moderately vulnerable category. The hill districts are found to be more vulnerable in comparison to valley districts. The ranking of the districts based on the vulnerability index would assist planners, decision-makers and development agencies to identify the most vulnerable regions for adaptation interventions. Vulnerability index development was limited by the availability socio-economic data but by utilizing the available data, the present study demonstrates the utility of an index based approach for identifying the most vulnerable regions and to identify and prioritize adaptation interventions. Hence, a scientific intervention is essential from both Government and local tribal communities so as to develop a climate resilient sustainable system.

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