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Climate Vulnerability Assessment of Loktak Lakeshore Villages, Manipur

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Abstract

As the impacts of climate change on society and the ecosystem become visible, the need for responding to this challenge through effective policymaking is now more urgently felt. Central to such a policy response is to understand the factors that generate vulnerabilities of society at multiple spatial scales. This paper is an attempt to examine the relative importance of the factors generating climate vulnerabilities at two Loktak lakeshore villages (Khoijuman and Toubul) of Manipur. In this study, vulnerability is conceptualized as the function of exposure, sensitivity and adaptive capacity of the villages. The results suggest that the two villages, although moderately vulnerable to climate change, are differentially exposed with varying degrees of sensitivity and adaptive capacity, an interesting finding considering the proximity of their location. These findings make it imperative that climate change policies must be informed by in-depth research, and also precludes the formulation of uniform policies applicable across communities.

Introduction

Modern climate change poses one of the greatest threats to humanity as its impacts are felt on society, economy and natural ecosystems, with the potential to reduce the society's ability to sustain itself. The distribution of the adverse consequences associated with the change, however, will not be uniform across regions, social groups and economy. Societies and regions that have made minimal contributions to the modern climate change are also poor and dependent on climate-sensitive sectors and hence are expected to bear the disproportionate share of its effects (IPCC, 2014). Consequently, climate change has become a significant policy challenge to countries, like India, as nations move into the 21st century with the agenda of achieving sustainable development goals (Panda, 2009). Mitigation policy-involving curtailing human activities that produce greenhouse gases to reduce their concentration in the atmosphere and, adaptation policy that aims to enhance human capacity to cope with adverse effects of climate change, are the two important policy options available. As the human struggle to achieve mitigation goals, global warming-induced climate change and effects will continue to occur in the future, thereby, making adaptation a necessity (Burton et al., 2002).

The vulnerability has emerged as an integrating concept in the climate change research field (Adger, 2006). It means the potential to experience harm to a system under consideration of hazards including climate change. A system can be a country, sector, ecosystem or a community. A hazard may be a perturbation (discontinuous change) or stress (continuous change) in the environment (Turner et al., 2003). Climate change qualifies in both the categories as it can produce discontinuous spikes like extreme hot days or continuous change in the temperature with time. The diverse methodologies that seek to systematically integrate and examine interactions between humans and their physical and social surroundings are known as vulnerability assessment (Fussel and Klein, 2006). It aims to quantify different facets of the interaction by employing indicators as proxies. Vulnerability assessments are conducted for both academic and policy considerations, although, the overarching goal for every assessment is to inform policies that will facilitate adaptation. In resource-poor and dependent society like India, vulnerability assessments can help resource allocation and prioritization of people, place and sectors that need immediate institutional attention.

The Conceptual Evolution of Vulnerability

The current understanding of vulnerability has been derived from a diverse set of knowledge domains-sustainable livelihoods, risk-hazard health studies, etc. (Tanmoy et al., 2014)). As a result, no common methodological framework for vulnerability assessment has evolved. Three common conceptual models of vulnerability are found in the literature, each of which has informed our current understanding of vulnerability. First is the *biophysical model,* which conceptualizes vulnerability in risk- hazard framework, and vulnerability is understood only as a function of exposure and sensitivity of the system to climate change. Climate vulnerability assessment applying this concept paid central focus to exposure and sensitivity of the exposed entity neglecting the system's capacity to enhance or reduce impacts of the change (Turner et al., 2003). Most significantly, the role of social structures and institutions in producing differential exposure and consequences is not addressed. The second concept understands vulnerability in a *social constructivist framework,* which regards it as a pre-existing condition within the society at the household or community level, and is generated primarily by unequal resource access (Cutter et al.,2000)). Here, major attention is paid to the conditions of society that make exposure unsafe, and to the causes creating these conditions (Kimberley et al. 2018). Assessment employing this concept attempts to explain differences in vulnerability among social groups when similarly exposed to hazards. The third model incorporates adaptive capacity in the concept of vulnerability. This recognizes the importance of human agency in terms community's ability to respond to and cope with external changes. In other words, a system's vulnerability is regulated by its adaptive capacity by modulating exposure and sensitivity (Engle, 2011)).

The Intergovernmental Panel on Climate Change (IPCC) has drawn on past research on vulnerability and defines climate vulnerability as a function of exposure, sensitivity and adaptive capacity. Where, adaptive capacity is the system's ability to adjust to climate stresses determined by wealth, technology, education, information, skills, and infrastructure, access to resources and stability and management capabilities. Sensitivity, on the other, is the degree to which a system will respond to a change in the climate, positively or negatively. The degree of climate stress upon a particular unit of analysis is referred to as exposure (IPCC, 2001).

Climate Vulnerability Assessment

The field of climate vulnerability assessment has emerged to address the need to quantify how communities will adapt to changing environmental conditions (Hahn et al.2009). Different scholars working in this field have used various methods in the attempt to bridge the gaps between different disciplinary boundaries-social, natural, and physical- however, all such studies fall under two common approaches. To-down approach, that typically uses results of climate models to examine how the future change in climate characteristics might pass through biophysical systems at the regional or local level (Desai and Hulme, 2004)). Such studies suffer from multiple pitfalls when applied at community levels: uncertainty involves in the projections; used of secondary and most importantly, the scale of the projection is still not sufficiently detailed to be relevant at the local level, where all adaptation policies take place. Indicator based vulnerability assessment (IBVA), on the other hand, has been extensively used (Tanmoy et al.2014.) as it is amenable to the incorporation of biophysical and socio-economic components of vulnerability and the ease with which vulnerability can be assessed. This approach involves the creation of a composite vulnerability index obtains by combining many indicators. The index captures multiple dimensions of vulnerability in a single figure which makes it easy to communicate to the public and policymakers (Hahn et al.2009). Vulnerability indices are constructed for three major purposes. First, it can help evaluate development policy by examining the framework under which it was developed. Second, indices can provide information for developing adaptation and mitigation plans. Third, indices can act as a means of standardization of vulnerability assessment, facilitating comparison of different contexts (Kalim et al.2013).

Framework for the Study

This study adopts IPPC defined concept of climate vulnerability and uses an indicator-based approach as a framework to assess sustainable livelihood vulnerability to climate change at two Loktak lakeshore villages. The selection of indicators for the study is guided by the understanding of sustainable livelihood use in sustainable livelihood approach(SLA). A livelihood is sustainable, according to SLA, if it is able to cope with and recover from shocks and maintain or enhance its capabilities and assets, while not undermining the natural resources base(Chambers and Conway,1992.*).* This approach suggests that the sustainable livelihood of a household as a function of five assets: natural, social, financial, physical and human capital. These can be measured by indicators of exposure to natural disaster and climate variability(NDCV); socio-demographic profile(SD), livelihood strategies(LS) and social networks(SN) for adaptive capacity of households; and health (H), food (F), housing(Ho) and water (W) resource attributes that determine sensitivity to climate change effects (Hahn,2009).

Objective

This paper seeks to assess the factors that generate differential climate vulnerabilities at two Loktak lakeshore villages viz. Khoijuman and Toubul, Manipur by comparing composite vulnerability indices prepared through livelihood vulnerability approach.

Methodology

Vulnerability is a multidimensional concept whose determinants include socio-economic and biophysical factors. Indicator based vulnerability assessment involves the preparation of a composite index formed by combining indicators reflecting different factors of vulnerability. The eight components viz. natural disaster and climate variability (NDCV); socio-demographic profile(SD), livelihood strategies(LS) and social networks(SN); and health (H), food (F), housing(Ho) and water (W) resource, of livelihood vulnerability are represented by sub-component indicators(Pandey and Jha, 2011). Since the sub-components or indicators are measured in different scales, they are required to be standardized before major component values are obtained. An index, formed by the formulae, given below, is devised for standardized values of the sub-component.

$$Index_{SV} = \frac{S_v - S_{min}}{S_{max} - S_{min}}$$

Where, S_V is the sub-component or indicator value for a village and S_{min} and S_{max} are the minimum and maximum value of sub-component

The values of major components are calculated after standardization of sub-component by another index, in which every sub-component contributes equally (UNDP,2007). The formula for major component index is given below:

$$MC_v = \frac{\sum_{i=1}^{n} Index_{Svi}}{n}$$

Where, MC_v is the value of a major component of the IPCC defined climate vulnerability index. $Index_{sv}$ is the i^{th} sub-component, belonging to major component MC_v for v^{th} village the number of sub-components in the major component.

After grouping the major components into respective categories of the three contributing factors of climate vulnerability (Table 1), the climate vulnerability index is composed. In the calculation of values for each contributing factor, the balanced weighted average approach is utilized, where irrespective of the difference in the number of sub-component, each major component is regarded to contribute equally to the CF values. This is because no presumption is made about the importance of each indicator or main component in the overall total. Each of the eight components is viewed as contributing equally to a community's vulnerability (Sullivan et al.2002). The following formula is used to calculate exposure, sensitivity and adaptive capacity.

$$Exposure_{index} = \frac{W_{el}NDCV}{W_{e1} + W_{e2}}$$

Where, W_1 and W_2 is the weight for the major component, equal to the number of sub-components.

$$Sensitivity_{index} = \frac{W_{s1}H + W_{s2}F + W_{s3}W_a + W_{s4}H_o}{W_{s1} + W_{s2} + W_{s3}}$$

Where, W_{s1}, W_{s2} and W_{s3} are the weights for the major component, equal to the number of sub-components.

$$AdaptiveCapaciy_{index} = \frac{W_{ac1}SD + W_{ac2}LS + W_{ac3}SN}{W_{ac1} + W_{ac2} + W_{ac3}}$$

Where, W_{ac1}, W_{ac2} and W_{ac3} are the weights for the major component, equal to the number of sub-components.

IPPC defined Climate vulnerability of a village is found by:

$$CV_{IPCCV} = (E_v - AC_v) \times S_v$$

Where CV_{IPCCV} is the IPCC climate vulnerability composite value of village, E_v is the exposure score of village, Ac_v is the calculated adaptive capacity value for village and S_v is the obtained sensitivity score of village .The value was scaled from -1.0 (most vulnerable) to +1.0 (most vulnerability) (Shah, 2013).

The Study Area

The study area i.e. Toubul and Khoijuman villages lie on the western part of the Loktak Lake, the largest freshwater lake of northeast India. The geographical coordinate is 24°37'29"N to 24°37'31"N and 93°47'29"E to 93°47'31"E(Fig.1).

Administratively, the villages belong to Bishnupur District on the southern parts of Imphal valley. The terrain is flat but is interspersed by rivulets descending swiftly from the western hills that flank the area. Climate is a sub-tropical monsoon type with maximum rainfall occurring in June to September season.

The population of the area practices agriculture that involves the cultivation of both food and horticultural crops largely on a commercial basis. Soil is fertile alluvium and that responds well to the application of fertilizers allowing it to support a variety of crops. Agriculture is the mainstay of the local economy although other livelihoods closely linked to the lake are also present.Despite being located on the lakeshore, agriculture is mostly rainfed with limited development of irrigation infrastructure. All the villagers are linked to the lake in either a direct or indirect manner for their livelihoods. Most of the livelihoods, thus, belong to climate-sensitive sectors (Ravindranath et at., 2011; MAPCC,2013).

Data Collection

The strength of the approach used in this study is that it uses primary data from household surveys to construct the index, reducing the drawbacks of using secondary data and less reliant on climate models whose projections are coarse scale (Hahn et al.2009). Fifty households in each village were randomly surveyed by administering a structured questionnaire. Questions were structured to include the three contributing factors of climate vulnerability (exposure, sensitivity and adaptive capacity). The head of the household was interviewed in most cases. Preparation of the questionnaire was preceded by informal discussions with village elders and important personalities of the villages to informed the content of the questionnaire and make it context-specific. The meteorological data used for calculating climate variability was of Imphal, Tulihal station(station no.42623), procured from Climate Data Centre(CDC), IMD, Pune. The station is located only 30kms. North-east of the villages. The field survey data was tabulated, cleaned and analyzed using MS excel.

Results and Discussion

The results of the vulnerability data analysis are presented in two parts. The first part is concerned with the assessment of individual major components along with the respective sub-components(Table-2), and the second part deals with various contributing factors with an estimated value of CV_{IPCC} (Table -3) in Toubul and Khoijuman Villages.

As evident from Table -2 and further illustrated in Fig.2, for the two villages under study, the values of eight major components exhibit both within and between variations. Food component score of 0.70 is the highest for the former and 0.76 is the highest for the latter. For both the villages, the vulnerability of food is high due to dependence on farm income and relying mostly on self farm food. Concerning natural disaster and climate variability, Khoijuman village scores 0.48 and Toubul Village 0.31 suggesting that Khoijuman village has higher vulnerability owing to experiencing a greater number of floods in the last few years. Health vulnerability (0.42) of Khoijuman is very similar to Toubul value (0.41) indicating similar health vulnerabilities of the villages. Differential contributions of each component to overall vulnerability is a notable finding of this study despite the villages being situated in close proximity to each other.Fig.2 further suggests that there is no marked difference in the score of socio-demographic, livelihood strategies, social networks, housing, and water components between the villages. However, there exists a large differential vulnerability between the villages mainly contributed by differences in food and natural disaster component values.

Climate vulnerability indices of Khoijuman and Toubul villages are functions of exposure, sensitivity, and adaptive capacity scores, and is presented in Table - 3 and illustrated in Fig.3. Overall, Khoijuman village has a climate-vulnerable index value of 0.09 in the scale -1.0 to +1.0, from least vulnerable to most vulnerable as mentioned earlier, while Toubul village scores 0.01 in the same scale. Khoijuman village, therefore, is more climate-vulnerable compare to Toubul village.

Both the villages can be said to be moderately vulnerable to climate. But on closer examination, it becomes apparent that there is marked variation in the values of contributing factors between the villages. Consequently, the difference in overall climate vulnerability indices can be better explained and appreciated by understanding the variations in the values of the three contributing factors. There is a sharp difference in contributing factor score with respect to sensitivity values, Toubul is 0.31 and Khoijuman's 0.48. While adaptive capacity scores of 0.29 and 0.31 respectively show a less significant difference, suggesting similar ability to adjust and withstand the effects of climate change in both the villages. In terms of sensitivity, Khoijuman (0.53) again scores marginally higher than Toubul (0.49). The higher exposure and sensitivity scores of Khoijuman makes it relatively more vulnerable to Toubul Villages despite having a marginally higher value of adaptive capacity.

The in-depth village level climate vulnerability study presented here has shown that many interrelated factors operating at community levels shape vulnerability despite being situated in a seemingly similar physical setting. Such knowledge can be of value to policymakers in identifying opportunities to reduce vulnerability and enhance adaptive capacity to current and future climate risks (Ford et al., 2010). With low scores in all the three contributing factors, both the two villages need policy intervention in terms of the plan to strengthen coping capacities and reduction in sensitivity by providing provisions of institutional irrigation facilities.

Conclusion

The climate vulnerability of two villages located at Loktak Lakeshore was assessed based on the sustainable livelihood approach by preparing climate vulnerability indices. It was found that the two villages were moderately vulnerable to climate change, with Khoijuman village relative more vulnerable than Toubul village due to greater exposure value. Manipur being a climate-vulnerable and resource-poor state, the findings presented here can help prioritize sectors and places while allocating resources for climate adaptation. In-depth local level vulnerability studies represent a valuable step towards framing effective adaptation policies that are informed by local context and realities in resource-limited settings. In light of this study, it is proposed that initiatives for systematic vulnerability studies of important places in representative socio-ecological systems of the state should be initiated on a priority basis.

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Table-1: IPPC Vulnerability contributing factors and its major components

Exposure	**Sensitivity**	**Adaptive capacity**
Natural disasters and climate variability(NDCV)	Health(H) Food(F) Water(W) Housing(Ho)	Socio-demographic profile(SD) Livelihood strategies(LS) Social networks (SN)

Table-2: Livelihood Vulnerability Sub-component values, minimum and maximum sub-component values and major component values for Khoijuman and Toubul villages, Manipur

Main Component	**Sub- component**	**Khoijuman Village** (n=50) Actual	Standardised	**Toubul Village** (n=50) Actual	Standardised	Max /Min values in villages
Socio-demographic profile		**0.21**		**0.25**		
	Households: members need care (%)	20.00	0.20	20.75	0.20	100 / 0
	Households: head with no formal education (%)	22.44	0.22	30.18	0.30	100 /0
Livelihood strategies		**0.54**		**0.47**		
	Households: No members working outside the community (%)	63.26	0.63	66.03	0.66	100/0
	Households: main income from agriculture /fishing (%)	40.81	0.40	47.16	0.47	100/0
	Households: without non agricultural livelihood income contribution (%)	59.18	0.59	30.18	0.30	100 /0
Social networks		**0.08**		**0.07**		
	Mean Borrow : Lend ratio	2.66	0.16	2.63	0.15	6 /2
	Households: for Govt. assistance in last 12 months (%)	0	0.00	0.00	0.00	100/0
Health		**0.42**		**0.41**		
	Avg. time to health facility (mins.)	27	0.48	22	0.34	45/10
	Households: members suffering from chronic illness (%)	20.40	0.20	20.75	0.20	100 /0
	Households: members missing work/ school in last 2 weeks due to illness (%)	6.12	0.60	7.54	0.70	100/0
Food		**0.70**		**0.34**		
	Households: do not sell food produce (%)	40.81	0.40	22.64	0.22	100/0
	Households: dependent on farming for income (%)	61.22	0.61	47.16	0.47	100/0
Water		**0.66**		**0.76**		
	Households without tap water (%)	100	1.00	100	1.00	100/0
	Households using natural water (%)	61	0.61	71.69	0.71	100/0
	Households: dependent on commercial water (%)	38.77	0.38	58.49	0.58	100/0
Housing and land Tenure		**0.34**		**0.36**		
	Households: with weak storm resistant construction (%)	68.38	0.68	73.49	0.73	100/0
	Households: without ownership of the lands they live on (%)	0	0.00	0	0.00	0/0
Natural disasters and climate variability		**0.48**		**0.31**		
	Avg. floods/droughts in the past 2 years	1	0.33	2	0.66	3
	Households: lost physical assets due to flooding (%)	0	0.00	0	0.00	100
	Households: suffered injury/death to members due to climate events (%)	0	0.00	0	0.00	100
	C.V. of monsoon months precipitation for the last three decades (%)	18.12	0.61	18.12	0.61	25.56 /6.3

Source: Computed from field survey data and meteorological data obtained from CDC,Pune

Table -3 Vulnerability contributing factors scores and over all climate vulnerability values for Khoijuman and Toubul Villages

Climate vulnerability contributing factors and major components	Khoijuman village	Toubul village
Exposure	**0.48**	**0.31**
Natural disasters and climate variability	0.48	0.31
Sensitivity	**0.53**	**0.49**
Health	0.42	0.41
Water	0.66	0.76
Food	0.70	0.34
Housing and land tenure	0.34	0.36
Adaptive capacity	**0.31**	**0.29**
Socio-demographic profile	0.21	0.25
Livelihood strategies	0.54	0.47
Social networks	0.08	0.07
$CV_{IPCCv}=(E_v-AC_v)xS_v$ vulnerability scores	**0.09**	**0.01**

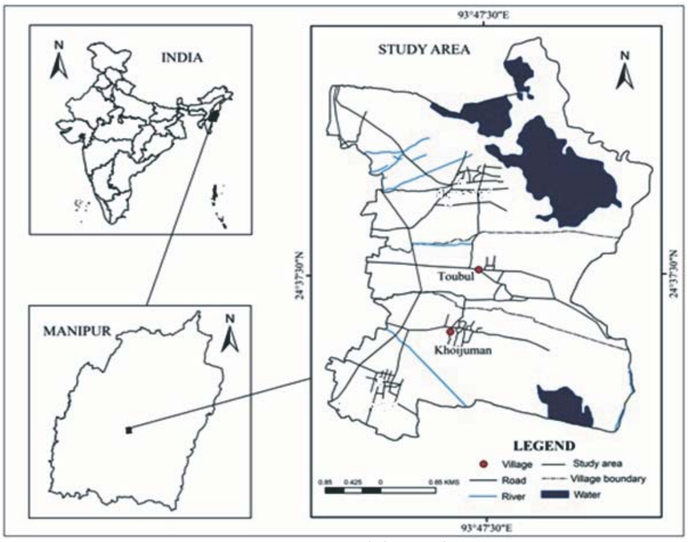

Fig. 1. Location map of the study area

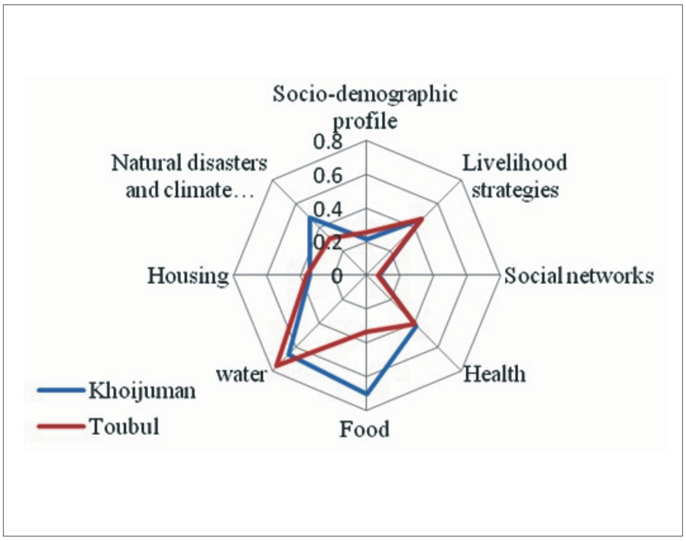

Fig. 2 Major Component Values of Khoijuman and Toubul Villages

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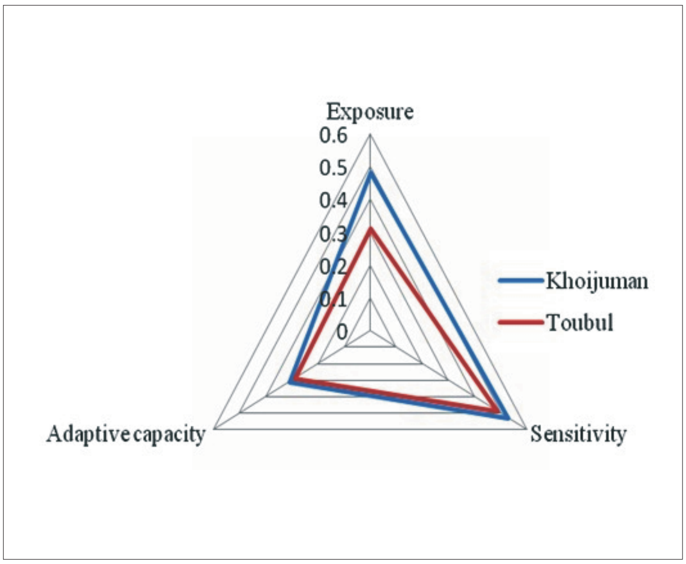

Fig.3 Exposure, Sensitivity and Adaptive Capacity Indices of the two Villages