RAPID, COST EFFECTIVE AND HIGH RESOLUTION ASSESSMENT OF CLIMATE-RELATED VULNERABILITY OF RURAL COMMUNITIES OF SIKKIM HIMALAYA, INDIA

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ABSTRACT

With impacts of climate change becoming increasingly visible locally, identification of areas vulnerable to climate change risks is emerging as an urgent policy need. This assessment responds to this requirement by identifying the most vulnerable villages using a rapid, cost effective and high resolution methodology. We provide a preliminary, village level, climate related vulnerability assessment of the rural communities in the Sikkim state of India. We found that climate change impacts have resulted in a reduction in the temporal spread of rainfall; increase in the intensity; with a marked decline in winter rain. We show that the subtropical villages (less than 1000m) especially in the drought prone zone are more vulnerable due to an increased outbreak of pest, disease and weeds. Spring water sources are drying up and preservation of seeds during the warm winter is becoming risky. A high variation was found in the sensitivity and adaptive capacity due to the diverse developmental profile of the villages. Hence while climate change adaptation related developmental interventions need to have a diverse sectoral profile, however they must geographically target areas with specific interventions. We expect that this study will provide a scientific basis for designing climate change adaptation policy and programs.

KEYWORDS: *Exposure, Sensitivity, Adaptive capacity, Coping mechanism, Policy*

Rabi crops are specially susceptible to winter droughts

Begagaon Dhara is the spring water source in Soreng, West Sikkim

Sikkim is the least populous and the second-smallest state of India. Despite its small area, it is geographically diverse due to its location in the Himalayas, with a high variation in elevation ranging from 300 to 8598 m. Mt. Khangchendzonga, the world's third-highest peak, is the guardian deity of the state. It is not only the highest but also the steepest landscape in the country since the width of the Himalaya across its entire length is narrowest here (Schaller 1977). It is a part of the Eastern Himalaya global biodiversity hotspot with 47% forest cover (Mittermeier et al. 2004; FSI 2007). In terms of country-level vulnerability to climate change, India ranks very high globally. Within India, Sikkim state shows high resilience as compared to the other states (Malone & Brenkert 2005). The relative climate change vulnerability rank of Sikkim amongst the mountain ecosystems in the Eastern Himalayas was found to be 51 out of 89 (Tse-ring et al. 2010).

The two basic responses to the threats posed by climate change are mitigation and adaptation. While mitigation has been the main focus of the climate change debate, now adaptation strategies are also getting the desired attention. Adaptation to climate change is necessary, in addition to mitigation of climate change, to avoid unacceptable impacts of anthropogenic climate change (IPCC 2007). First-generation vulnerability assessments focused on climate change related drivers (temperature, rainfall, submergence etc) and off late second-generation assessments are being explored, which adopt a multi-disciplinary approach where non-climatic drivers (economic, education, infrastructure etc) are also taken into consideration (Fussel & Klein 2006). Like in other developing countries, there is a lack of spatially disaggregated meteorological records. Long term, reliable data is available only for one station - Gangtok. Climate change related studies based on the analysis of the data for this station month-wise, season wise and annually from 1957 to 2005 indicates a trend

Table 1: Percentage variation of monthly rainfall, maximum and minimum temperature averaged for the years 2006 to 2009, in comparison with long period average (LPA) for the period 1957-2005 (Adapted from Seetharaman 2008)

Month	Rainfall	Max Temp	Min Temp
Jan	-73%	-0.1%	2.1%
Feb	-19%	0.3%	2.0%
Mar	-25%	-0.3%	1.5%
Apr	7%	-0.6%	1.4%
May	-26%	0.1%	1.4%
Jun	-8%	-0.4%	0.9%
Jul	-10%	-0.2%	1.4%
Aug	0%	-0.3%	1.0%
Sep	2%	-0.2%	1.0%
Oct	-40%	-0.3%	1.5%
Nov	-24%	-1.0%	1.6%
Dec	-39%	-0.7%	2.1%

towards warmer nights and cooler days, with increased rainfall except in winter. The maximum temperature in Gangtok has been rising at the rate of 0.2 ^{0}C per decade and the annual rainfall is increasing at the rate of nearly 50 mm per decade (Seetharaman 2008; Ravindranath et al. 2006; IISc 2010). Comparison of long term meteorological data available for Gangtok station (1957 to 2005) with the trend over the last few years (2006-09), shows an acceleration of these patterns, with winters becoming increasingly warmer and drier now (Table 1). With the impacts of climate change becoming more and more visible especially over the last few years and with increased media coverage, there is a pressure on governments now to act fast and invest in this sector. The National Action Plan on Climate Change which incorporates the country's vision on climate change was prepared in 2008 (Anon 2008). The above factors have created a need for reliable and high resolution vulnerability assessment reports, which can act as decision support systems for developmental planning.

The state is administratively divided into four districts, namely North, East, South and West. Climate change related vulnerability studies taken up in the state at the district level have found the South and West districts to be the most vulnerable (IISc 2010; WWF-India 2010). Inspite of being a small state, there is a high variation in exposure (temperature and rainfall), sensitivity (water, livelihoods and health) and adaptive capacity (poverty, literacy, environment and connectivity) indicators over short distances. So far only macro studies had been conducted, and there is an absence of studies at the village level. For the first time a micro scale study was taken up to address the issue of high variability typical of mountain areas.

The purpose of this study was to undertake a comparative preliminary assessment of the climate-related vulnerability of the rural communities at the village level. The questions for the study are identification of the most vulnerable villages and perception of the villagers on nature of climate change, its impacts and current coping mechanisms. The results of this analysis are intended to provide to the Government, voluntary sector and international donors a basis for improved developmental planning and policy, whereby the results are used to devise strategies that support in managing vulnerability and to raise awareness on rural livelihood issues to a broader audience.

METHODOLOGY

The Intergovernmental Panel on Climate Change IPCC (2007) defines Climate-related vulnerability as a function of climate change exposure, sensitivity, and adaptive capacity. Exposure is defined by the magnitude, character and rate of climate change in a given geographical area. Sensitivity to climate change is the degree to which a community is adversely or beneficially affected by climate-related stimuli. The adaptive capacity of a community is its ability to adjust to climate change, to moderate or cope with the impacts. In some cases high levels of exposure are observed but they might get negated by high adaptive capacity thus resulting in lower vulnerability values. Developing countries owing to their comparatively lower adaptive capacity are considered to be inherently more vulnerable to climate change. Indicators for exposure, sensitivity, and adaptive capacity were derived from disaggregated attribute datasets. We used this conceptual framework to undertake a preliminary assessment of the current vulnerability of all the villages of Sikkim. This study is preliminary in the sense that a rapid approach was used, and is dependent on available data from public sources.

There are a total of 163 Gram Panchayats (or villages) in the State, having an average population of 3000 and an extent of 10 km^2. The current study builds largely on secondary information in the form of reliable government sourced datasets and primary information collected from village consultations. A total of ten indicators available in a disaggregated manner at the village level were used to measure vulnerability. Ground truthing in the form of participatory approaches is also integrated. The whole study was completed in six months from April to October 2010 incurring a field expenditure of less than Rs 5 lakh.

1.1 Data sources

Table 2 shows the ten indicators used and their source, grouped into sectors and into exposure, sensitivity and adaptive capacity components.

Table 2: Indicators used and their source, grouped into sectors and into exposure, sensitivity and adaptive capacity components

Component	Sector	Proxy indicators	Sources
Exposure	Temperature	Annual mean temperature	worldclim.org
	Rainfall	Mean annual rainfall	NBSSLUP 2000
Sensitivity	Water resources	% Rainfed farming	Census 2001
	Livelihoods	% farming population	Census 2001
		Elevation	SRTM DEM
	Human health	Family size	DESME 2005
Adaptive capacity	Economic capacity	Poverty rate	DESME 2005
	Human capacity	% of class ten pass population	DESME 2005
	Environmental capacity	Population density	DESME 2005
	Physical connectivity	Rural connectivity	Census 2001

Exposure indicators

Long term, reliable meteorological data is available only for Gangtok station and was sourced from the Indian Meteorological Department, Gangtok office. Hence, the disaggregated annual mean temperature data was obtained from the website www.worldclim.org. However the annual mean rainfall pattern indicated here was not found to be accurate and consequently this was sourced from the rainfall distribution map of the State (NBSSLUP 2010).

Sensitivity indicators

Sensitivity component includes three sectors: water resources, livelihoods and human health. For each of this sector, 1-2 indicators were selected to represent aspects of the sector that was quantitatively analyzed. The percentage of rainfed farming was used as a proxy indicator of the water resources availability. To represent the sensitivity of the livelihoods sector, two indicators were selected namely elevation and percentage of population mainly dependent on farming. Elevation was chosen since the crops in the subtropical belt (less than 1000m) have been impacted the most by pests, disease and weed. Elevation was obtained from the Shuttle Radar Topographic Mission (SRTM) produced by NASA originally. The SRTM 90m DEM file (srtm_54_07.zip) was downloaded from the CGIAR-CSI GeoPortal (Jarvis et al. 2001). This file in Geotiff format was processed in Erdas Imagine software (version 8.5) to subset the study area from this image and exported to grid format. The percentage of population mainly dependent on farming was obtained from the Census of India (2001).

Adaptive capacity indicators

The socio-economic conditions that bear on adaptive capacity component include economic capacity, human capacity, environmental capacity and physical connectivity. While poverty rate was used as a measure of economic capacity, the percentage of population passed class ten was used to represent human capacity. Population density was used as a proxy indicator of environmental capacity and the type of rural connectivity (paved road, mud road, and footpath) was used to represent physical connectivity of the village. These socio-economic data at village level was sourced from the Census of India (2001) and State Socio-economic Household Census (DESME 2006).

Limitations

There are several limitations of this preliminary framework wherein the choice and representativeness of the indicators may not be adequate. Also many of the indicators like poverty, literacy, road access etc are not strictly independent. While there will always be a certain degree of arbitrariness in any set of indicators, however what has to be ensured is that the dataset must be as meaningful as possible. Further research is needed to strengthen the exposure index by incorporating high intensity rainfall events, landslides etc and also by using the weather data from recently installed automatic weather stations. The sample size of the villages where PRA was conducted needs to be further enlarged, especially by including a few villages of North district to make the sample representative. Predictions of future vulnerability through climate change prediction models can also be attempted.

Ground truthing

Participatory Rural Appraisal (PRA) was conducted with support from German Technical Cooperation (GIZ) in five villages covering all the eco-regions in three of the four districts. Four tools namely resource based seasonal dependency matrix, seasonal activity calendar, weather event chart and hazard ranking using spider web were used. These PRAs took place in July-Aug 2010 and were attended by a group size of around 35, with representation of all the stakeholders.

Data analysis

We construct an index of climate change vulnerability at the village level using the following steps. There are three components namely exposure, adaptive capacity and sensitivity which are used to calculate the vulnerability. Then to make the indicators of a component comparable, we normalize them using the formula:

$$I_{n} = (I - I_{min}) / (I_{max} - I_{min})$$

where I_n is the standardized value of the indictor and I is the unstandardized value. I_{max} is the maximum value of the indicator and I_{min} is the minimum value of the indicator. Then we used the simple average of the standardized indicators to calculate the value of each of the components. Since we did not have knowledge of the degree of importance of each hazard in assessing the vulnerability, we assumed equal weights for all.

$$C = \text{Average}\ (I_n)$$

Following this the climate-related vulnerability (V) is calculated as:

$$V = (\text{Exposure} - \text{Adaptive capacity}) \times \text{Sensitivity}$$

This value is standardized again to obtain the vulnerability index (VI) so that the scale used is 0-1, indicating the lowest vulnerability level (0) to the highest vulnerability level (1). To identify the vulnerable areas, we ranked the regions according to the index and divided the list into four equal parts or quintiles. Those villages falling were further classified as least vulnerable, mildly vulnerable, moderately vulnerable and highly vulnerable.

Data integration

The developmental units in the state comprise of 163 Gram Panchayat Units (GPU), 24 developmental blocks and 4 districts namely North, East, South and West. The village is defined as the GPU, and its administrative boundaries were marked on the Survey of India 1:25000 scale topographical sheets. These boundaries for all the GPUs were then digitized and the village maps prepared. The census data was integrated on a Geographic

Information System (GIS) platform. ArcGIS software (version 9) was used for integration of the various layers on a GIS platform.

RESULTS

Both temperature and rainfall showed large variations over short distances. While the annual mean temperature varied from 5^0C to 22.5^0C the annual mean rainfall varied from 1200 mm to 3200 mm (Fig 1). Exposure index was found to spatially vary from 0.05 to 0.91 with the mean being 0.53 ± 0.16. The south central part of the state which has the lowest altitude and is also drought prone as it falls in the rain-shadow of the Darjeeling Himalaya was found to have the highest exposure (Fig 1). The observations of the local community regarding the pattern of climate change and the associated impacts (Table 3) are corroborated by the scientific studies (Table 1).

Table 3: Community observations on climate change and associated impacts

Climate events	Community observations on climate-change	Associated impacts
Snow fall	Reduced snow fall since last four years in the temperate belt villages, less frost as well	Warm dry winter and less frost
Rainfall	Rainfall months have decreased but the intensity has increased. The spread of rainfall had declined from nine months in a year to five to seven months, with the sub-tropical zone being adversely impacted. There is heavy downpour during monsoons compared to constant low intensity rainfall in the past. The winter rainfall has decreased significantly over the last five years specially in lower belt	Frequent landslides, unreliable connectivity, floods, longer dry period in winter
Hail Storm	Hailstorms have become unpredictable and also size of hail has increased	Severe damage to tender maize, potato and orange crop
Cold Temperature	Winters have become warmer and duration has reduced from six months to three to four months with the sub-tropical zone being adversely impacted	Increased population of insects and vector borne disease
High Temperature	The high temperature has increased from five months to six to eight months with the sub-tropical zone being adversely impacted. Autumn heat is being experienced now.	Villagers have started using refrigerators and fans. Increase in outbreaks of pest, diseases and weeds resulting in decrease in yield of crops like ginger, fruits and tomatoes. Farmers in middle belt have started growing these crops.
Dry season	Hardly any rainfall for continuous six months from October to March	Frequent and ascending forest fires, drying of spring water sources, decline in production of winter crops and vegetables

Figure 1: Map of exposure component along with the indicators of mean annual rainfall and annual mean temperature of the rural communities of Sikkim, India

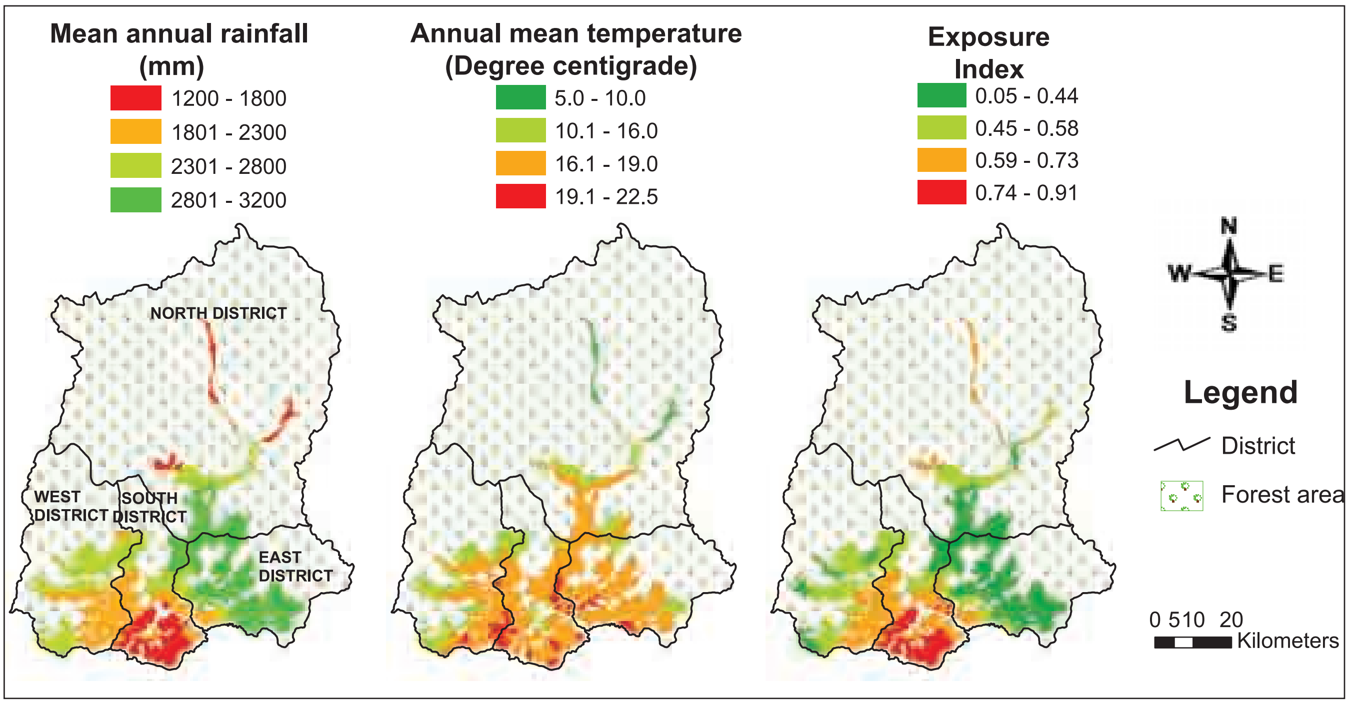
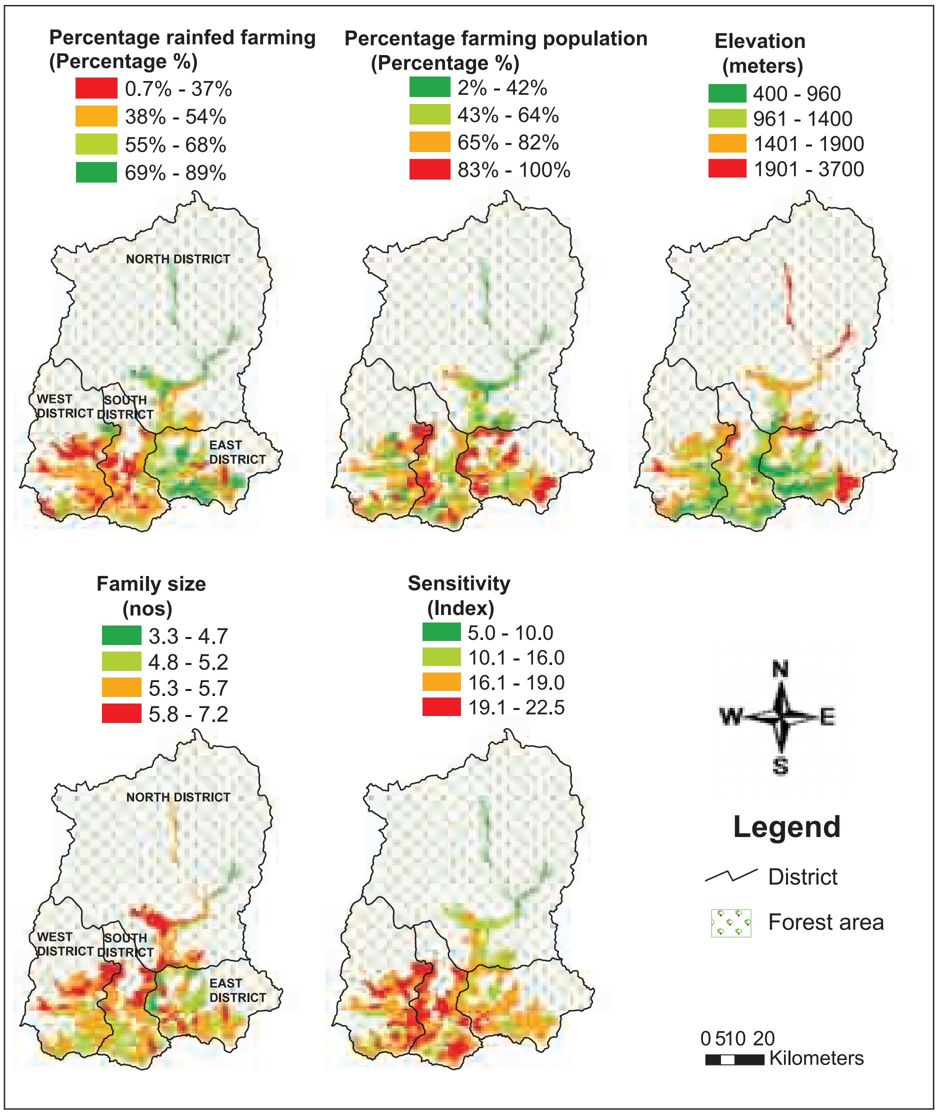
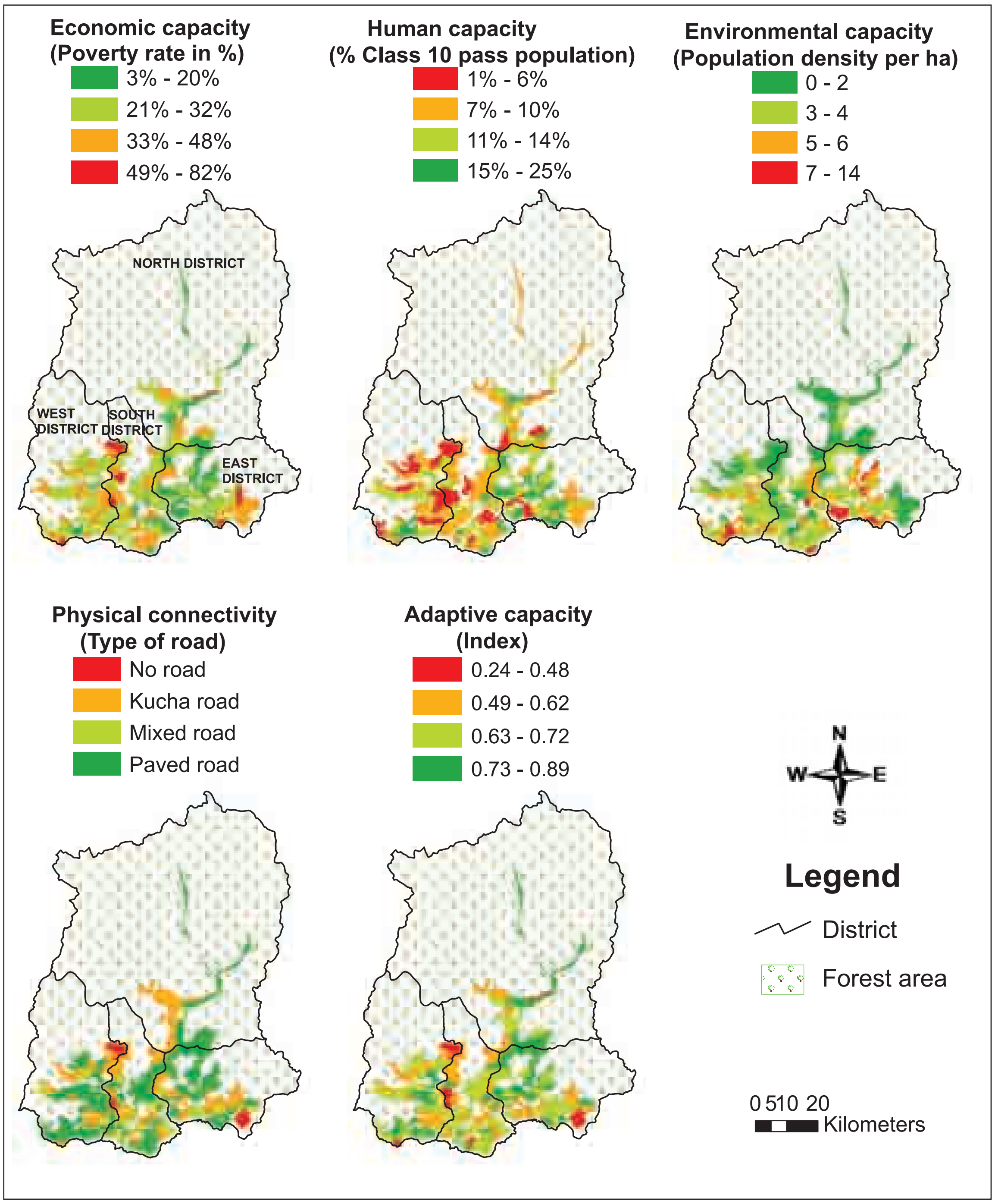


Figure 2: Map of the sensitivity component of the rural communities of Sikkim along with the participating sector values, India



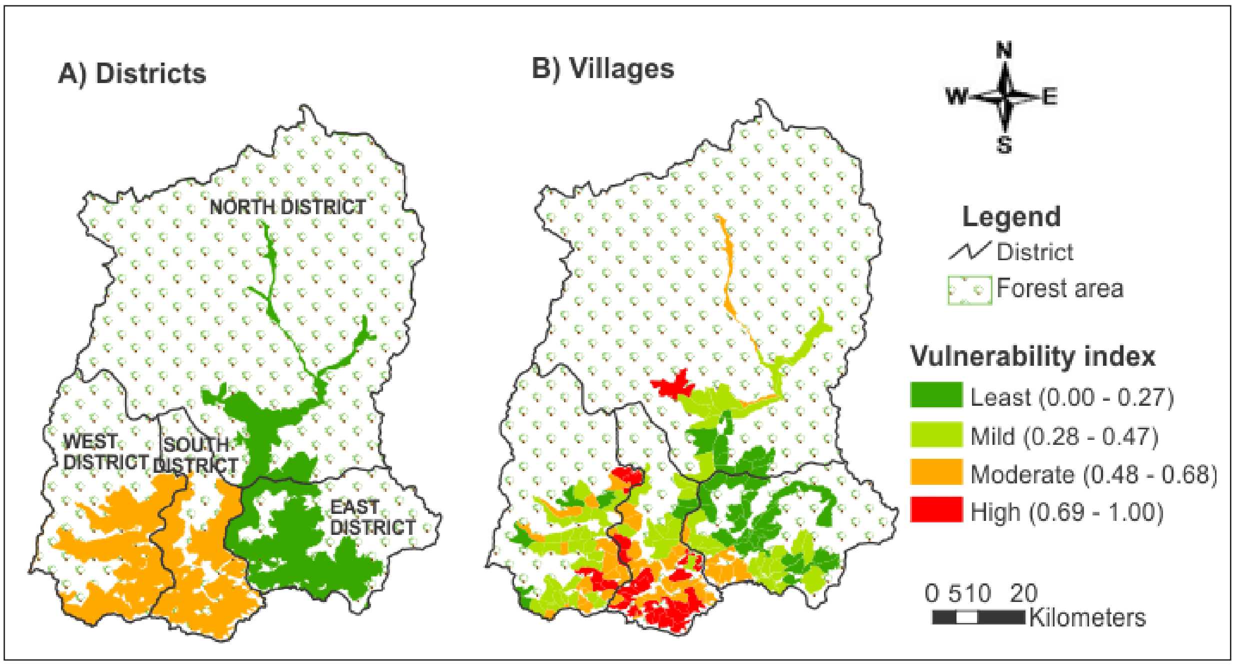
The sensitivity indicator varied from 0.23 to 0.72 with the mean being 0.59±0.08 (Fig 2). In the subtropical zone (less than 1000m) the production of important cash crops like ginger, orange and fruits has declined due to prolonged droughts and outbreak of pests, disease and weeds. Plants such as maize, broom grass and turmeric were found to be the most resilient. This zone was earlier a very productive area with multiple cropping, now due to less winter rain only single cropping during the monsoons is possible. Storage and preservation of seeds is also becoming increasingly difficult due to pest, disease and dry winter. Communities in the middle and upper hills were found to be less vulnerable, and warmer winters provided new opportunities for vegetables such as tomato, chilly, carrot, cucumber, passion fruit, beetroot etc coupled with higher production and early ripening as well. Adaptive capacity varied from 0.24 to 0.89 with the mean being 0.66±0.1 (Fig 3). Remote villages with lack of physical connectivity also showed high illiteracy and poverty resulting in weak adaptive capacity. Villages adjacent to urban centers with good connectivity and diverse opportunities displayed high adaptive capacity.

Figure 3: Map of the adaptive capacity of the rural communities of Sikkim and the participating sector values, India



The climate-related vulnerability index of the 163 Gram Panchayats had a mean of 0.43±0.22. We identified the most vulnerable areas, which are concentrated in the subtropical zone of the South and West districts (Fig 4). These areas include the Blocks of Melli, Jorethang, Sikkip, Namchi, Namthang, Soreng and Kaluk. In general these results do not provide any surprises to the commonly held perceptions since these villages face the highest exposure to climate change which coupled with high sensitivity and low adaptive capacity results in high vulnerability. South district was found to be the most vulnerable followed by West. East and North districts were found to be relatively resilient to climate related change. However areas like Karzi-Mangnam and Sakyong-Pentong village which were not highly exposed were found to be highly vulnerable due to the high sensitivity and low adaptive capacity.

Figure 4: Map of climate related vulnerability of rural communities of Sikkim, India



The rural communities have already started coping with the impacts of climate change using indigenous methods. The national flagship programme, Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) has become an important source of climate-proof cash income in the rural areas. Rural folk have started supplementing farming livelihoods with non-farm activities like MGNREGA, tourism, trade, non-farm labour and in extreme cases even migration. Ginger seed is now being protected from dry winter by storing it underground. Seeds of pulses, beans and soyabean are preserved by mixing with kerosene, ash, camphor etc. The seed bank has also been enlarged to account for replanting when young crops get damaged by hail. Fruit trees are protected from increased incidences of insect borers by applying kerosene, petrol and diesel in the holes. Springs are drying up especially during the dry winter months, and the local communities are coping by improving the water storage infrastructure, storing water overnight in tanks and containers and also pumping water from downstream. Crop residue is being stored for use as winter fodder for livestock.

DISCUSSIONS

Recent impacts of climate change indicate a warmer and dry winter which has resulted in a decline in the production of the winter crops in the lower belt. Due to increased runoff and dry winters, springs have started drying up and their lean season discharge is reducing drastically. Annual mean rainfall showed high variation due to the geography, with the rain shadow areas in the subtropical zone receiving only half the rainfall compared to East District. Fig 5 shows the exposure indicators for the five most and least vulnerable villages. As can be seen most of the vulnerable villages other than Karzi-Mangnam lie in the drought prone, subtropical zone of South and West district.

Also Karzi-Mangnam village was found to be most sensitive due to large family size (of seven) and the total dependence (100%) on farming (Fig 6). Comparatively, Rawatey-Rumtek village was found to be the least sensitive owing to the smaller family size (of five), coupled with diversified livelihood opportunities and better irrigation facilities. Consequently, the percentage of rainfed farming and population dependent on farming

Figure 5: Exposure indicators of annual mean temperature and annual mean rainfall of the five least and most vulnerable villages of Sikkim, India

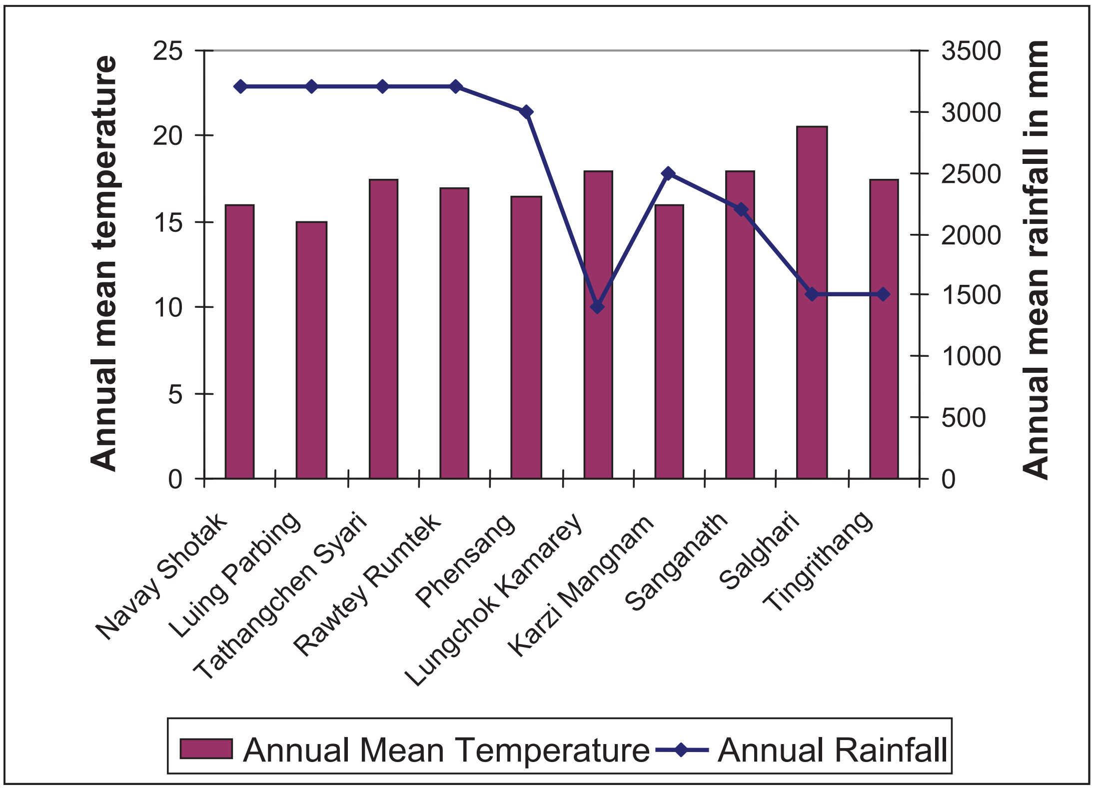
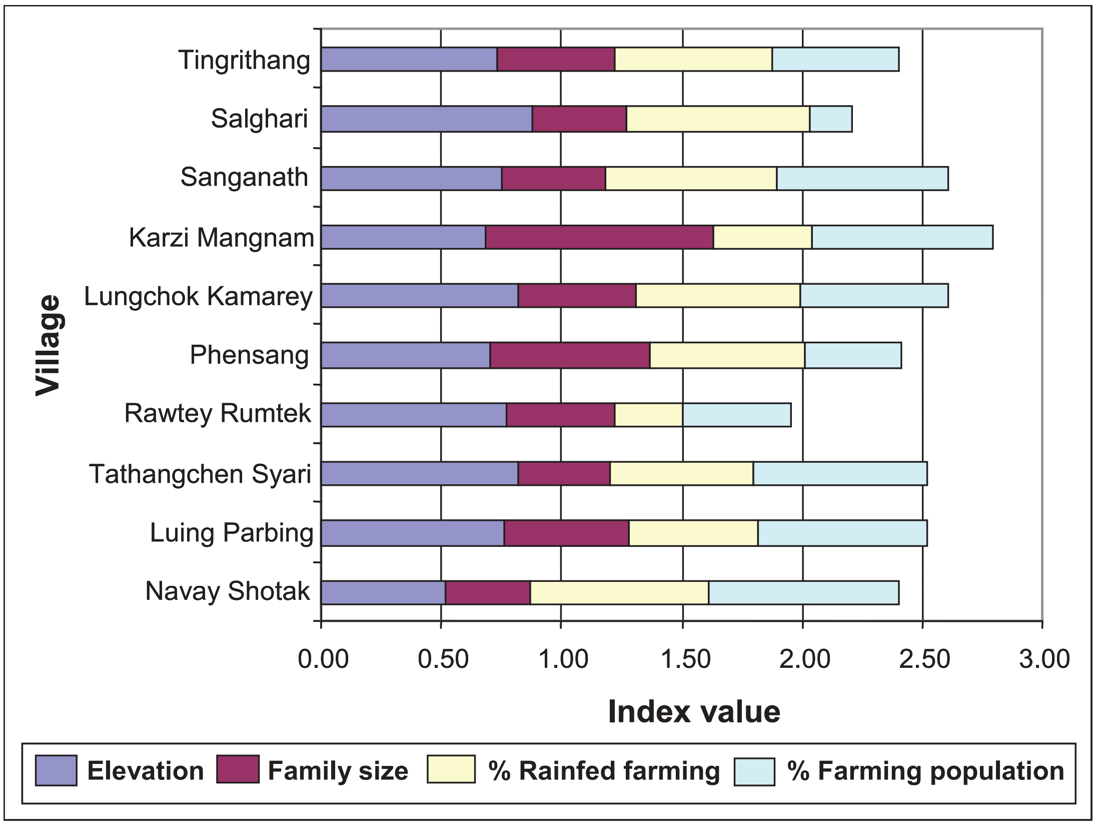


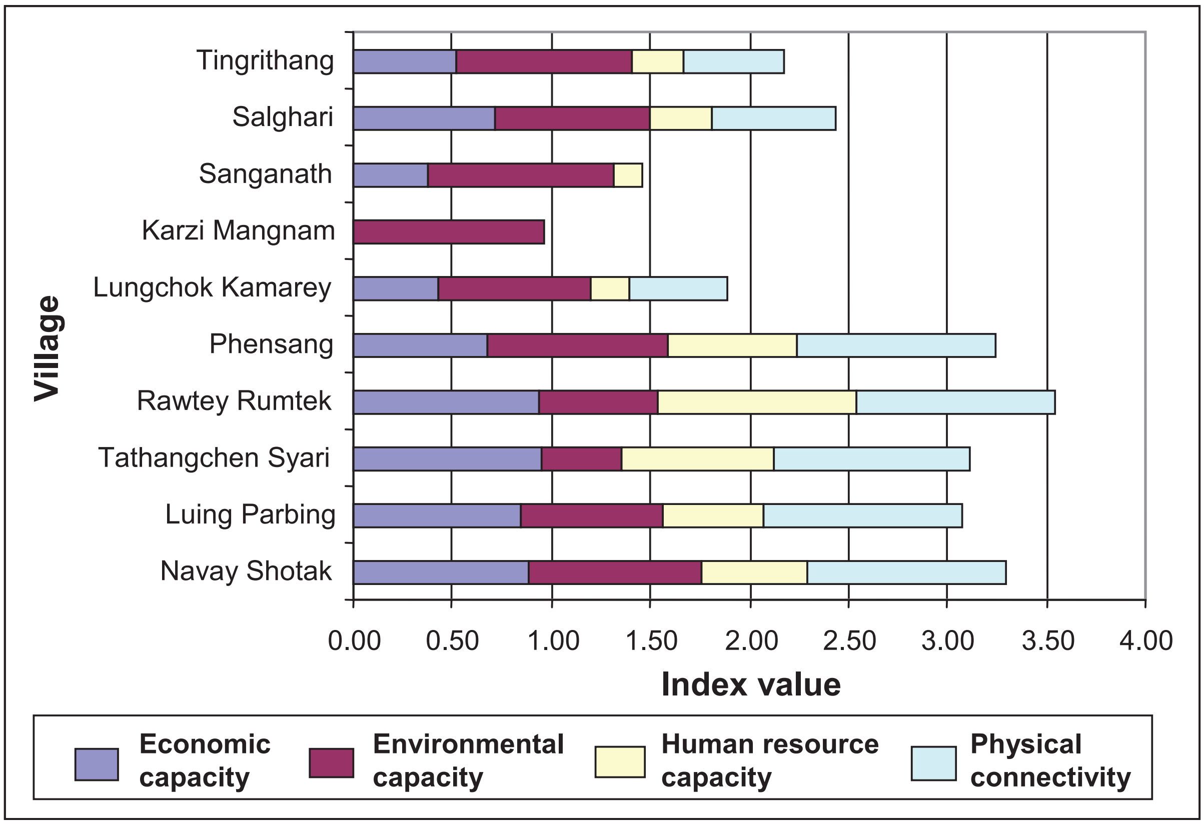
Figure 6: Sensitivities of the five least and most vulnerable villages of Sikkim and the participating sector values, India



(61%) was much less here. In terms of a comparison of the adaptive capacity it was found that Karzi-Mangnam village had favourable environmental capacity which was offset by a high poverty rate (82%), low education levels (1% have passed class ten) and poor road connectivity resulting in the weakest adaptive capacity (Fig 7). On the other extreme, Rawatey-Rumtek village had a low poverty rate (8%), high education level (25% have passed class ten) and is well connected resulting in a high adaptive capacity.

In spite of having moderate exposure, due to high sensitivity and low adaptive capacity, Karzi-Mangnam village showed high vulnerability. Also Lungchok-Kamarey village had the highest vulnerability owing to a high exposure, high sensitivity and a low adaptive capacity. Similarly Navay-Shotak village had the least vulnerability owing to the low exposure, low sensitivity and high adaptive capacity (Fig 8). The vulnerability

Figure 7: Adaptive capacity of the five least and most vulnerable villages of Sikkim and the participating sector values, India



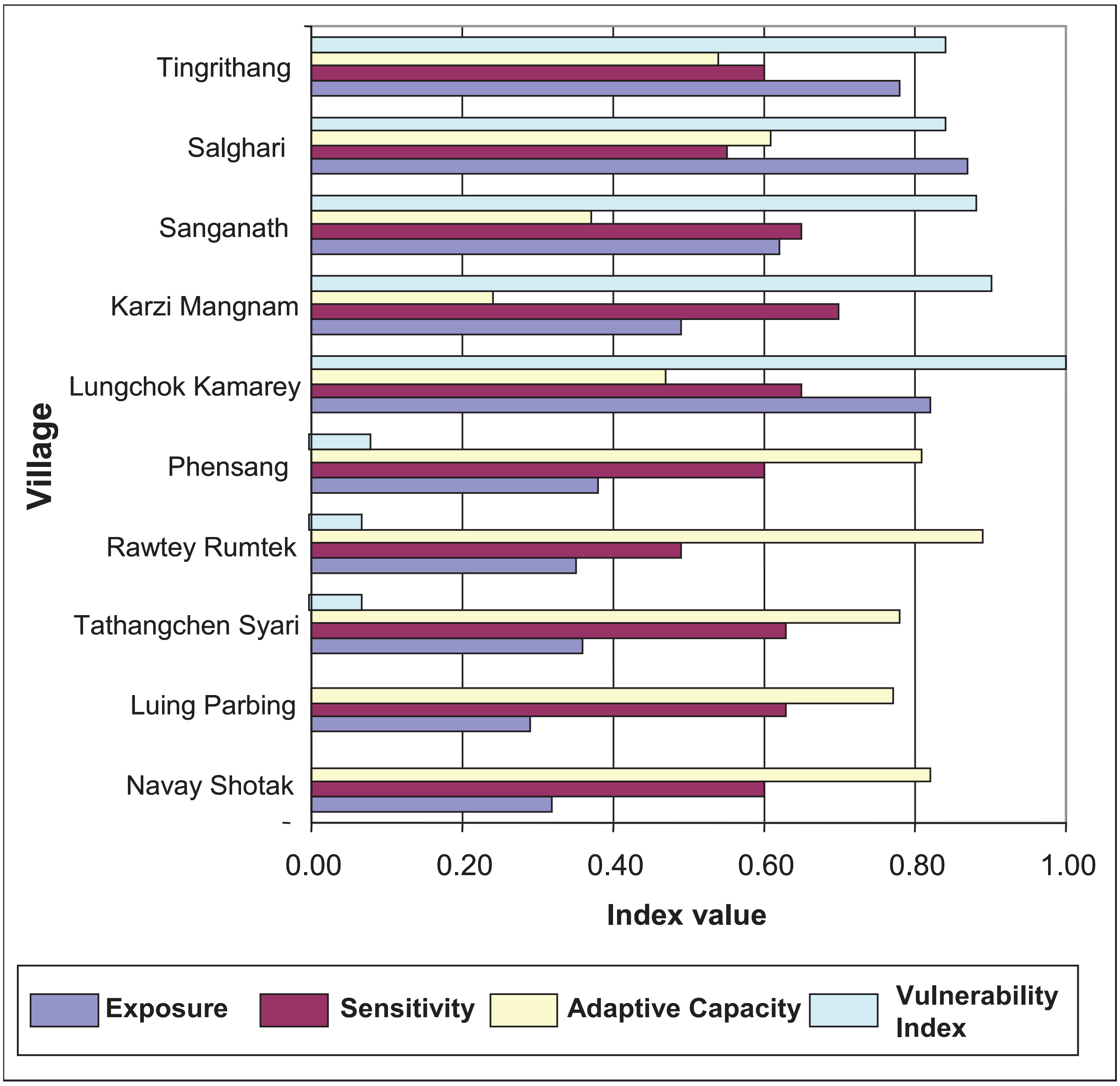
was stark since the communities that practiced the most climate sensitive livelihoods, had least adaptive capacity and also faced high exposure. Communities practicing sensitive livelihoods of rainfed farming were found to have the least adaptive capacity (poverty, education, infrastructure etc) and also faced high exposure of climate-related change (drought, pests).

To counter the climate change impacts, diverse development interventions are needed. For example while in Karzi-Mangnam interventions are needed in the sectors of education, health (family planning), incomes and roads, in others like Sanganath the priority sectors are education and roads. Significant variation in vulnerability was found within a district. Vulnerable villages like Sakyong-Pentong and Lachen (in North district) and Central-Pendam, West-Pendam and Singbel (in East district) were found to occur in less vulnerable districts. Also less vulnerable villages like Okhrey-Ribdi and Yuksam (in West district) and Lingmo-Kolthang, and Paiyong (in South district) were found to occur in the vulnerable districts. This high intra-district variation in vulnerability calls for high resolution vulnerability assessment studies to ensure that errors of inclusion and exclusion are minimized and climate change adaptation funds are efficiently targeted especially in mountain areas.

CONCLUSIONS

To conclude, with impacts of climate change becoming increasingly visible locally, identification of areas vulnerable to climate change risks is emerging as an urgent policy need. This assessment responds to this requirement by identifying the most vulnerable villages using a rapid, cost effective and high resolution methodology. Maps were also prepared to show the climate change related vulnerability of rural communities in the state. While it is difficult to reduce the exposure which is an external driver, the sensitivity and adaptive

Figure 8: An overview of the range of vulnerability indicators for the five least and most vulnerable villages of Sikkim, India



capacity which are local drivers, can be addressed with local interventions. A high variation was found in the sensitivity and adaptive capacity due to the diverse developmental profile of the villages. Hence to counter this, the climate change adaptation strategy needs to be fine scale and multi-sectoral, to encompass the diverse sectors of education, health, environment, roads, irrigation, agriculture, water, poverty alleviation, skill development, non-farm employment etc. It is expected that the outputs of this analysis will be used by policy makers and donor agencies for better designing and targeting of the climate change adaptation policy and programs.

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Households totally dependent on farming as the only source of income, are more vulnerable to the impact of climate change

Poor households who are fully dependent on farming livelihoods need to be made resilient to climate change impacts