

Vulnerability of agricultural households to climate change in hill state of north Western Himalaya

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सार – इस अध्ययन में, भारत के उत्तर-पश्चिमी राज्य हिमाचल प्रदेश में प्रत्येक परिवारों के जलवायु परिवर्तन के प्रति संवेदनशीलता की जांच की गई है। प्रिंसिपल कंपोनेंट एनालिसिस (पीसीए) का इस्तेमाल कृषक परिवार के लिए संवेदनशीलता सूचकांक विकसित करने के लिए किया गया। इस अध्ययन क्षेत्र में औसत घरेलू संवेदनशीलता सूचकांक 0.27 था। कुल्लू जिले के कृषक परिवार सबसे अधिक असुरक्षित (5.94) थे जबकि हमीरपुर जिले के लोग इनसे कम असुरक्षित (-3.37) थे। इस अध्ययन में संवेदनशीलता के क्षेत्रीय स्रोतों की पहचान सफलतापूर्वक की गई और अनुकूलन योजना के लिए जिलों को प्राथमिकता दी गई है। इस अध्ययन से प्राप्त हुए परिणामों से इन क्षेत्रों के विशिष्ट और लक्षित जलवायु अनुकूलन नीतियाँ बनाने में नीति निर्माताओं को सहयोग मिलता है जो परिसंपत्ति निर्माण को बढ़ावा देते हैं ताकि जलवायु परिवर्तन के प्रति असुरक्षा को कम किया जा सके और दीर्घकालिक स्थिति स्थापक निर्माण हो सके।

ABSTRACT. In the present study, vulnerability level of individual farming households to climate change is examined in Himachal Pradesh, North-western state of India. Principal Component Analysis (PCA) was used to develop vulnerability index for individual household. Mean household vulnerability index in the study area was 0.27. The farming households from Kullu district were the most vulnerable (5.94) while those from Hamirpur district were least vulnerable (-3.37). The study successfully identified the regional sources of vulnerability and prioritises the districts for adaptation planning. Implication of the study results lays with the policy makers in formulating region specific and targeted climate adaptation policies that foster asset building so as to reduce vulnerability and build long-term resilience to climate change.

Key words – Adaptive capacity, Climate change, Exposure, Sensitivity, Vulnerability index.

1. Introduction

India is a large emerging economy closely tied to its natural resource base and to climate sensitive sectors such as agriculture, water, forestry etc. Nearly 70% of the working population of the country dependent on agricultural activities for their livelihood (Krishna Kumar *et al.*, 2004). With large population dependant on agriculture, this sector is particularly vulnerable to climate change as the amount of rainfall and its distribution has become highly uncertain (Guhathakurta and Rajeevan, 2007). Climate change is expected to impact the agricultural sector in multiple ways through yield losses, increased insect-pest population, by affecting water availability and through perturbations in ecosystems. NATCOM (2008) reports that over 60% of the crop area under the rainfed agriculture in the country is highly

vulnerable to climate variability and change. One way to cope with the challenges put forth by climate change is to build resilience for adaptation in the agriculture sector (ICAR-NICRA, 2011).

In the context of climate change, IPCC (2007) defines vulnerability as “the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes” and specifically highlights three components of vulnerability: exposure, sensitivity and adaptive capacity. Agricultural vulnerability to climate change can be described in terms of exposure to and the sensitivity of crop yields to the elevated temperatures and the inability of the farmers to adapt to the effects of this exposure and sensitivity (Smit and Wandel, 2006). Vulnerability varies widely across

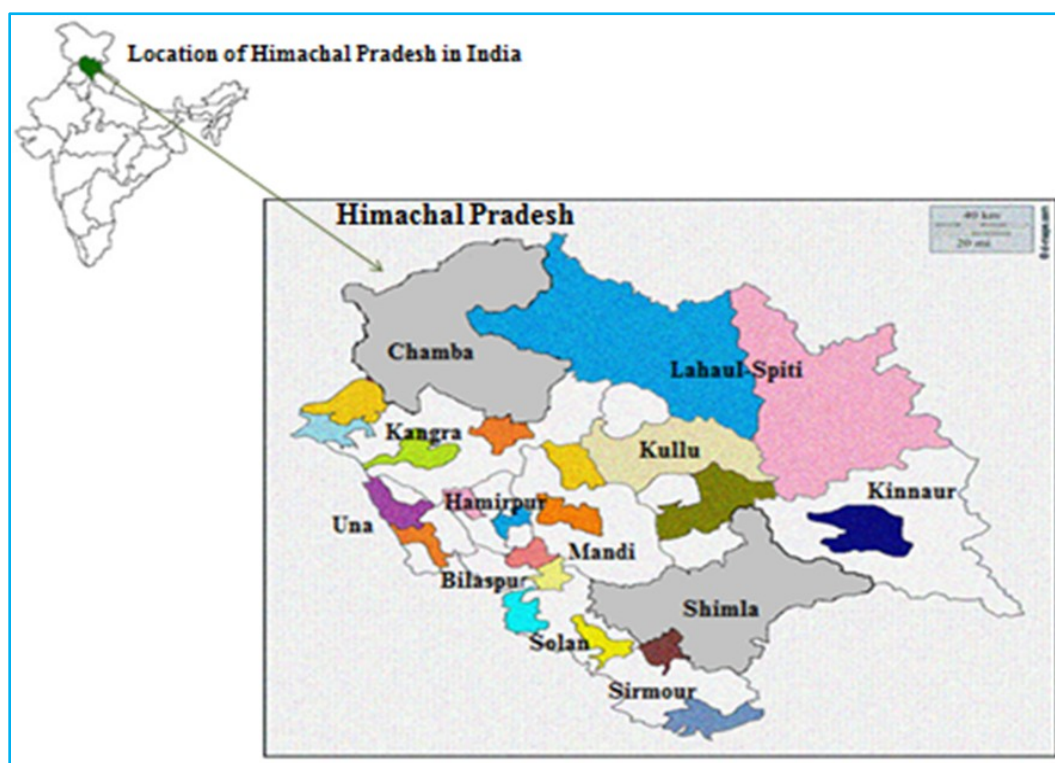


Fig. 1. District map of Himachal Pradesh in India. [Source: Himachal Pradesh Official website (www.himachal.nic.in)]; Coloured patches represents blocks in which survey was done (Map not to scale)

regions, sectors, communities and households and the capacity to adapt to climate change is unequal across and within societies.

Himachal Pradesh is predominately an agricultural state in India and as a part of Himalayan mountain ecosystem, it is projected to be extremely sensitive under future climate (Chaturvedi *et al.*, 2011). Observed impacts of climate change in the state include movement of apple growing areas to higher altitudes, loss of certain tree species, drying of traditional water sources, changes in bird types and population, reduction in crop yield and increased vulnerability of winter cropping due to changes in rainfall patterns and planting dates (ADB, 2010). Communities, who are deriving services from agriculture, have always been adjusting their livelihood against the vagaries of climate. With the change in climatic conditions, these communities have been placed at greater risk of vulnerability as the weather and extreme events have become more frequent and unpredictable. High levels of socio-economic vulnerability of communities living away in remote mountainous areas have been reported by Opiyo *et al.* (2014). However, enough studies specific to different areas of Himachal Pradesh have not been made though there have been some efforts to examine farmers'

choices of adaptation strategies to climate change and the respective determinants. Therefore, there is a need for more studies at household and/or community level which are very essential to know household characteristics and thus help in identifying current vulnerability levels and in designing appropriate policies and strategies.

2. Materials and method

2.1. Study area and sample selection

The study was carried out in the state of Himachal Pradesh, India. It is located between latitude $30^{\circ} 22'$ to $33^{\circ} 12' N$ and longitude $75^{\circ} 45'$ to $79^{\circ} 4' E$. The total geographical area of the state is $55,673 \text{ km}^2$ and the altitude varies from 248 m to 6735 m above mean sea level. Stratified random sampling was followed for selection of households in villages. Ten districts of the state were covered in the study. From each district at least 20 percent development blocks were chosen to further select the villages and households in the respective blocks for survey (Fig. 1). From each block two gram panchayats were taken and in each gram panchayat two villages were selected, thus a total of 66 households were selected for the detailed study.

TABLE 1
Description of vulnerability indicators

Component	Sub-component	Indicator	Unit	Hypothetic relation
Exposure	Historical change in climate variables	RCA annual maximum temperature	CV	+
		RCA annual minimum temperature	CV	+
		RCA annual ppt	CV	+
	Climate events (People perception)	Change in temp., rainfall, droughts, vegetation, hailstorms and snow intensity over the years	Ordinal	+
Sensitivity	Dependence on n/r	% rainfed area	%	+
		Water availability (perennial/seasonal)	Ordinal value	+
	Damage to livestock	Loss of livestock	Ordinal value	+
	Income structure	Income from n/r	%	+
		Income from non n/r	%	-
	Market access	Marketing channel	Ordinal value	+
	Soil loss	Soil erosion trend	Ordinal value	+
Adaptive capacity	Physical asset	% irrigated land	% of total land	+
		Distance to AH hospital	Distance in Km	-
		Age	Number	+
	Human assets	Education	No. of years of schooling	+
		Household size	Number	+
		No. of employed persons in family	Number	+
		Farming experience	No. of years	+
		Ownership of labour	Ordinal value	+
		Livestock	Number	+
	Natural assets	Ownership of bullock	Ordinal value	+
		Source of irrigation water (Surface/ Ground)	Ordinal value	+
		Monthly H.I.	INR	+
	Financial assets	Monthly cost incurred on F.O	INR	+
		Access to credit	Ordinal value	+
	Social assets	SWC activity	Ordinal value	+
		Extension service	Ordinal value	+
		Training on NRM	Ordinal value	+
		Watershed knowledge	Ordinal value	+

RCA - Rate of change of average; CV - Coefficient of variation; Max. Temp. - Maximum temperature; Min. Temp. - Minimum temperature; ppt- Precipitation; n/r - Natural Resources; temp. - Temperature; AH - Animal husbandry; H.I - Household income ; SWC - Soil and water conservation; F.O - Farm operations; NRM - Natural Resource Management; INR - Indian rupees

2.2. Data collection

The process of data collection involved discussion with villagers and representative of gram panchayats during 2016-17. The household was selected as the main

unit of analysis because major decisions about adaptation to climate change and livelihood processes are taken at the household level (Thomas *et al.*, 2007). Data was collected on the basis of selection of suitable indicators and the indicator selection was done based on literature review

TABLE 2
Descriptive statistics of household characteristics in study area (quantitative variables)

Variables	District										
	Bilaspur	Hamirpur	Kangra	Kinnaur	Kullu	Lahaulspiti	Mandi	Sirmour	Solan	Una	Average
Age of head of household	54.71 (11.80)*	58.63 (13.66)	54.08 (8.14)	52.75 (8.92)	41.00 (10.75)	50.57 (8.60)	53.83 (7.17)	55.50 (11.39)	48.20 (16.44)	57.29 (11.97)	53.21 (11.09)
Education of head of household	7.57 (3.99)	9.38 (4.31)	7.46 (5.36)	9.25 (6.99)	10.00 (6.12)	10.00 (6.16)	9.17 (2.04)	8.50 (1.91)	9.60 (4.16)	8.14 (3.48)	8.73 (4.53)
Household size	6.86 (3.02)	7.13 (2.17)	6.46 (2.93)	8.25 (4.35)	6.60 (3.21)	8.43 (3.78)	9.17 (3.06)	7.25 (3.40)	12.80 (12.74)	7.00 (3.70)	7.74 (4.60)
Number of persons employed per household	0.57 (0.53)	1.13 (0.99)	1.00 (1.00)	1.50 (1.29)	1.00 (1.00)	2.00 (1.83)	0.83 (0.98)	1.00 (1.41)	1.20 (0.84)	0.14 (0.38)	1.02 (1.10)
Cultivated land	0.39 (0.37)	0.37 (0.87)	1.52 (0.91)	1.16 (1.45)	0.72 (0.97)	0.77 (0.65)	0.14 (0.34)	0.85 (0.41)	1.00 (1.22)	1.61 (1.55)	0.90 (1.01)
Number of livestock owned	3.86 (2.04)	4.63 (4.57)	1.38 (0.77)	9.25 (9.43)	1.60 (1.52)	7.86 (6.91)	1.00 (0.63)	1.75 (1.50)	6.60 (4.10)	2.71 (1.11)	3.74 (4.43)
Monthly household income ('000 INR)	32.74 (6.98)	32.92 (19.22)	31.73 (14.88)	80.21 (61.37)	24.17 (22.13)	19.06 (14.14)	24.17 (14.24)	52.08 (51.09)	24.17 (17.53)	21.19 (12.67)	31.86 (26.29)
Monthly cost incurred on farm operations ('000 INR)	3.09 (3.69)	3.92 (8.52)	3.16 (2238.41)	5.00 (5.31)	3.50 (5.12)	1.78 (1.09)	2.47 (4.28)	2.32 (2.23)	6.72 (4.53)	13.28 (12.31)	4.47 (6.39)

*Figures in parenthesis are standard deviation; INR : Indian National Rupee

and discussions with the stakeholders that provide insight into the nature and causes of vulnerability. In this way, a total of twenty nine indicators were selected and grouped into exposure, sensitivity and adaptive capacity as presented in Table 1. In addition to the primary data collection, indicators from secondary data sources were also taken. The secondary sources of data collection include data for weather parameters viz., maximum temperature, minimum temperature and average rainfall from India Meteorological Department, Meteorological Centre, Shimla.

2.3. Vulnerability analysis

The first stage of analyses was the descriptive analysis of the household characteristics for both quantitative and qualitative variables that describe the vulnerability components of the districts to climate change. In second stage of analysis, Principal Component Analysis (PCA) was performed to obtain the weights for indicators of exposure, sensitivity and adaptive capacity separately (Filmer and Pritchett, 2001). The magnitude of the weights shows the contribution of indicator towards the respective index and the sign of the indicator denotes the relationship with other indicators used to construct the respective index. Vulnerability Index of districts was formulated mathematically using three components of vulnerability viz., Exposure, Sensitivity and Adaptive

capacity. Assessment of these three components was done on the basis of selected indicators. In order to ensure that all the indicators are comparable, standardisation was carried out following Vincent (2004) equation 1:

$$A_i = \frac{a_{ji} - \bar{x}_i}{S_i} \quad (1)$$

where, A_i is standardised value of i^{th} indicator, a_{ji} is the value of i^{th} indicator of the j^{th} component, ' $\bar{x}_i$ ' is the mean value of i^{th} indicator and ' S_i ' is the standard deviation of the indicator. After standardisation of data, the weights which were generated for each indicator using PCA were multiplied with the standardised value obtained from equation (1). The respective index value for exposure, sensitivity and adaptive capacity were then worked out following Madu (2012) equation 2:

$$I_j = \sum_{i=1}^k A W_i \quad (2)$$

where, ' I_j ' is the index value of j^{th} component, W_i is the weight of the i^{th} indicator obtained from PCA and A is the standardised value of indicator. Finally, the vulnerability index was calculated by subtracting the adaptive capacity index from the sum of exposure and sensitivity index. Districts were then ranked according to their vulnerability index value.

TABLE 3
Descriptive statistics of household characteristics in study area (qualitative variables)

Variables	District										Average
	Bilaspur	Hamirpur	Kangra	Kinnaur	Kullu	Lahaulspiti	Mandi	Sirmour	Solan	Una	
Perception of change in temperature	6 (0.38)*	8 (0.00)	13 (0.00)	4 (0.00)	4 (0.48)	7 (0.00)	6 (0.00)	4 (0.00)	4 (0.45)	7 (0.00)	63 (0.21)
Perception of change in rainfall	7 (0.00)	8 (0.00)	13 (0.00)	4 (0.00)	5 (0.00)	6 (0.38)	6 (0.00)	3 (0.5)	5 (0.00)	7 (0.00)	64 (0.17)
Perception of change in snow intensity	2 (0.48)	4 (0.53)	10 (0.44)	4 (0.00)	4 (0.48)	7 (0.00)	3 (0.55)	3 (0.5)	3 (0.55)	2 (0.49)	42 (0.48)
Gender of household head	7 (0.00)	5 (0.52)	12 (0.28)	4 (0.00)	3 (0.55)	7 (0.00)	5 (0.41)	3 (0.5)	5 (0.00)	5 (0.48)	56 (0.36)
Households with access to credit	7 (0.00)	8 (0.00)	13 (0.00)	4 (0.00)	4 (0.45)	7 (0.00)	6 (0.00)	4 (0.00)	5 (0.00)	7 (0.00)	65 (0.12)
Households with soil and water conservation measures	2 (0.48)	3 (0.52)	7 (0.52)	1 (0.5)	1 (0.45)	4 (0.53)	4 (0.52)	2 (0.58)	1 (0.45)	2 (0.49)	27 (0.49)
Households with extension services	3 (0.53)	2 (0.46)	5 (0.51)	3 (0.5)	1 (0.45)	5 (0.48)	2 (0.52)	2 (0.58)	0 (0.00)	3 (0.53)	26 (0.49)

*Figures in parenthesis are standard deviation

3. Results and discussion

3.1. Quantitative variables

Eight quantitative variables were assessed for ten districts of Himachal Pradesh (Table 2). The results of descriptive statistics revealed that average age of the household head in the study area was around 53 years whereas average numbers of years of schooling of household head were around nine. Age and Education are the important factors to be considered while undertaking vulnerability studies as these represent the experience in farming and the level of knowledge respectively. The older farmer is more acquainted with past and present changing climatic conditions and he is more inclined towards following traditional methods familiar to him rather than adopting modern farming techniques (Acquah, 2011). The educated farmers have a greater ability to understand and respond to anticipated changes and have greater access to information and opportunities which might encourage adaptation to climate change (Quayum and Ali, 2012). Average household size was around 8 and on an average only one person was employed in the household which was not quite impressive as less employment in the family reduces the household capacity to sustain themselves in response to climate vagaries. Deressa *et al.* (2009) presented similar type of results based on this assumption. The average total cultivated

land per household in the study area was 0.9 hectares which was good enough for agricultural households. However, higher cultivated land can develop both negative as well as positive relation with respect to climate vulnerability. The logic behind the double relation can be explained as large cultivated land with proper planning can fetch more income to the farmers which helps them to cope up with the environmental changes while contrary to this, large cultivated land requires more investment in the form of seeds, fertilizers, pesticides, irrigation etc. which in turn stresses the farm budget and makes household more sensitive and less likely to adapt (Uddin *et al.*, 2014). Average monthly household income and monthly cost incurred on farm operations was INR 31857.32 and INR 4466.04 respectively. Monthly household income plays a dominant role in adoption of adaptation strategies to climate change effects as the farmers with higher income are more interested to adapt by using irrigation, changing planting practices, taking soil and water conservation activities and altering the amount of land farmed (Kim *et al.*, 2012).

3.2. Qualitative variables

The results of descriptive statistics of the household for seven qualitative variables are presented in Table 3. Results revealed that most of the farmers have perceived changes in the average temperature (95.94%) and

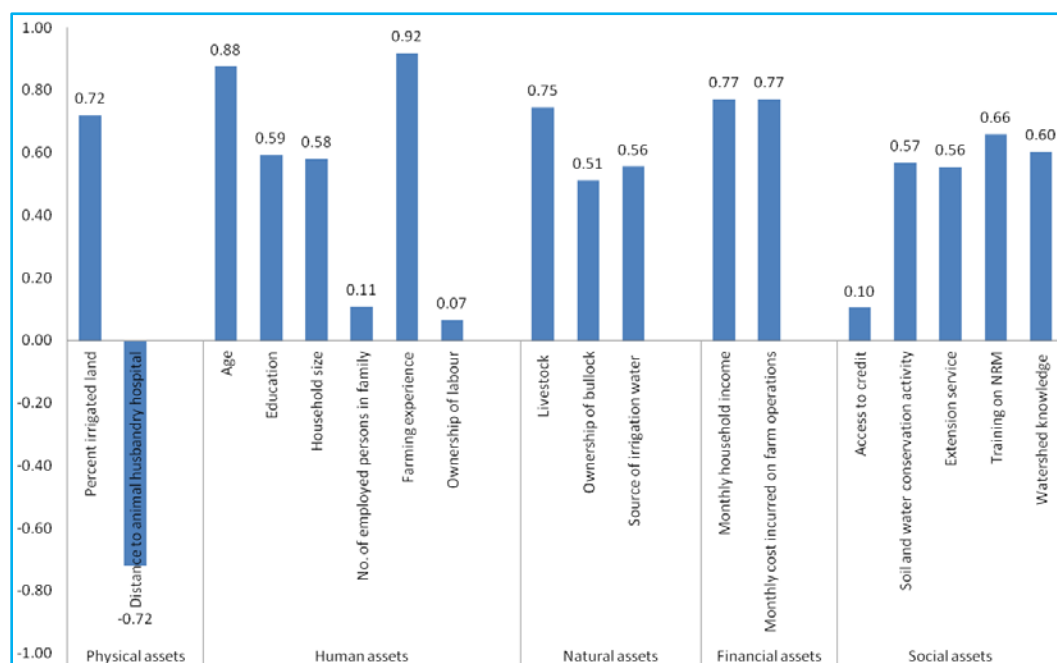


Fig. 2. Weights obtained by adaptive capacity indicators

rainfall (96.97%), while 63.64% of the farmers in the study area perceived that there is change in snowfall intensity. Similar type of observation for temperature and rainfall change has been made by Rana *et al.* (2013) in his study. It can be expected from the results that the farmers who perceive changes in climatic conditions are more likely to take adaptation measures to acclimatize to it. It was also clear from the results that most of the respondents as household head were males (84.85%) and almost every household (98.49%) has access to credit. It is assumed that access to credit may affect vulnerability by influencing adaptation to climate change (Fosu-Mensah *et al.*, 2012).

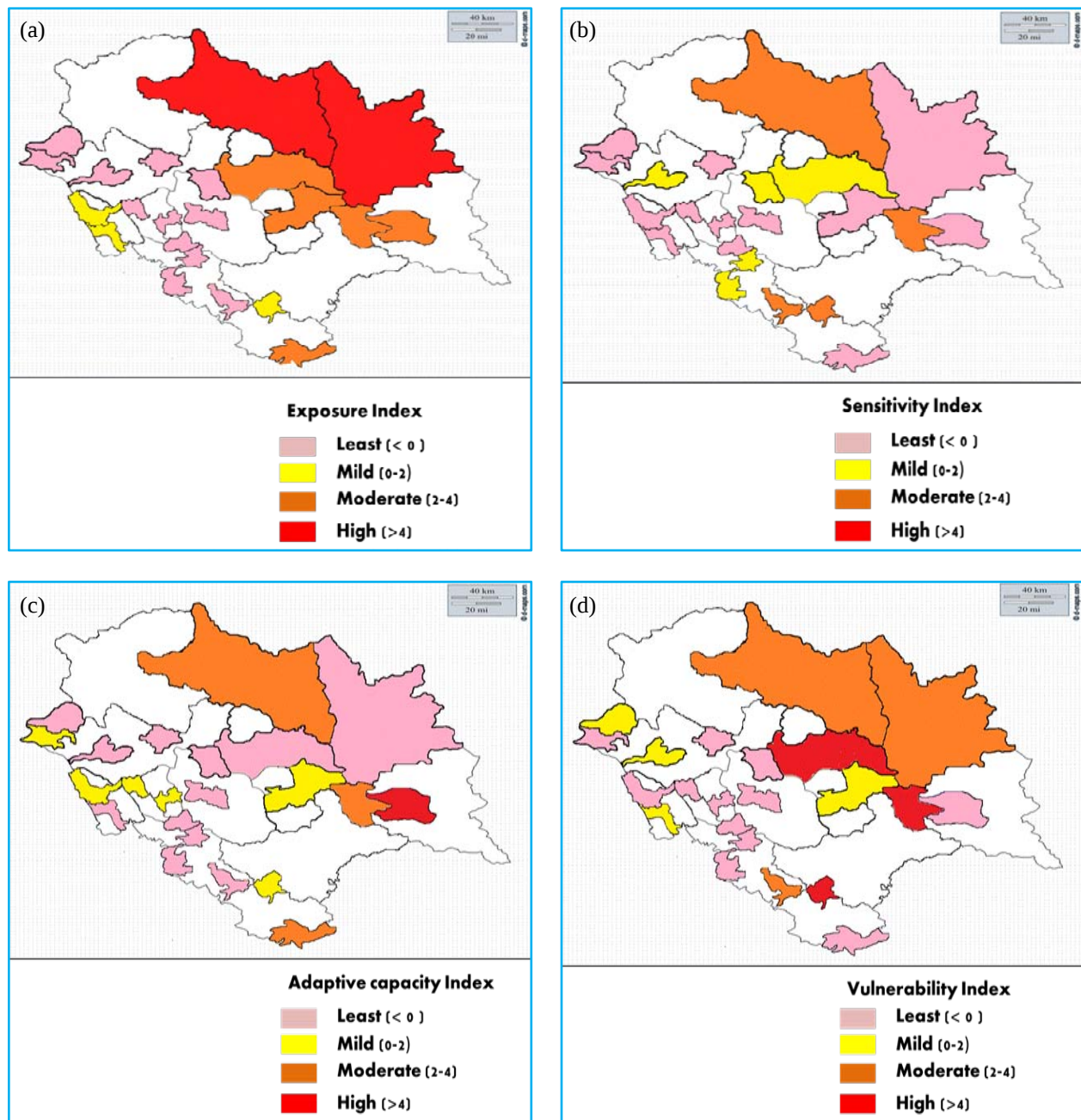
3.3. PCA for weights

PCA analysis was done for three groups of indicators of vulnerability viz., exposure, sensitivity and adaptive capacity. Among exposure indicators, trend in weather parameters (temperature and rainfall) received the higher weightage (0.93, 0.83 and 0.8 for max. Temperature, minimum temperature and rainfall, respectively), as compared to the composite environmental hazards (0.383). All the weights are positive as hypothesized, thus affecting exposure positively. The results confirms the findings of Tsue *et al.* (2014) who observed that temperature and rainfall variability contributed towards higher exposure of households to environmental changes.

The weights for sensitivity indicators was least for soil erosion (0.03), loss of livestock (0.26), marketing

channel (0.28), rainfed area (0.36), water availability (0.47) and highest for income from natural resources (0.94). All the indicators have a positive relationship with sensitivity index except the share of non-natural resource-based income which is having a negative relationship (-0.94). The absolute values for the weights indicate that share of natural resources based income (0.94) and share of non-natural resources based income (-0.94) contributed more to the sensitivity index than the other indicators in the region. Higher share of natural resource-based income (composed of agriculture, livestock *etc.*) increase the sensitivity of the household as these sources are more dependent on climate; while higher share of non-natural resource based remunerative income sources (composed of salaried jobs, non-farm skilled jobs) reduces the sensitivity. The results are in consonance with the findings of Luni *et al.* (2012) who reported that share of natural and non-natural resources-based income contributes more towards the sensitivity index.

Examination of the absolute weights for adaptive capacity (Fig. 2), reveals that among the physical assets, percentage of irrigated land and distance to animal husbandry hospital both are having equal weights (0.72) in the region. However, the distance to animal husbandry hospital has been found to influence the adaptive capacity negatively. Therefore, there is a need for strengthening mobile veterinary services including frozen semen services this would increase the adaptive capacity of the farmers. Among human assets, farming experience of the household head got the highest weight (0.92) whereas



Figs. 3(a-d). Maps showing (a) degree of exposure (b) degree of sensitivity (c) degree of adaptive capacity and (d) degree of vulnerability of selected blocks in Himachal Pradesh

ownership of labour had the least weightage (0.06). All the indicators for human assets are having a positive influence on the adaptive capacity. Antwi-Agyeiet *et al.* (2012) also reported that livestock offers readily available cash in times of crop failure due to erratic rainfall patterns and hence reduces vulnerability. Among financial assets, monthly income and total cost incurred on farm operations are having equal influence as indicated by their weight of 0.77 each.

Second-step PCA indicated that financial assets (0.81) contributes maximum towards adaptive capacity of the community followed by physical (0.60) and human assets (0.54). This trend may be explained on the basis that financial assets can be converted to other forms of asset when needed whereas, physical assets are important because they enhance extraction and utilisation of natural assets (Zhang *et al.*, 2007). Human assets are important as they create employment opportunities for income

TABLE 4
Exposure, Sensitivity, Adaptive capacity and Vulnerability Indices

District	Exposure Index	Sensitivity Index	Adaptive capacity Index	Vulnerability Index	Rank
Bilaspur	-2.19	-0.52	-0.92	-1.789	8
Hamirpur	-2.06	-1.02	0.29	-3.37	10
Kangra	-0.51	-0.68	-0.52	-0.66	6
Kinnaur	2.87	-0.34	3.68	-1.15	7
Kullu	2.29	1.04	-2.60	5.94	1
LahaulSpiti	4.51	1.04	2.09	3.45	2
Mandi	-2.53	-0.12	-0.85	-1.795	9
Sirmour	1.82	1.12	1.84	1.09	3
Solan	-2.23	1.36	-1.31	0.43	5
Una	0.47	-0.13	-0.24	0.59	4
Mean	0.36	0.17	0.15	0.27	

generation. Hegrenes *et al.* (2000) reported in their study that human and financial assets improve the capacity to adapt to changes. Furthermore, local institutions and social networks have also been found equally crucial as demonstrated by the importance of social assets (0.20). In the present study, natural assets received the least weightage (0.11), which may be explained on the fact that these have been influenced greatly by environmental changes and related disasters compared to other asset types.

3.4. Vulnerability index

Different degrees of exposure, sensitivity, capacity to adapt and vulnerability among the selected blocks are shown in Figs. 3(a-d). Exposure index for blocks varied from -2.58 to 4.56 [Fig. 3(a)], with 54.5 per cent of the blocks under the category of least exposed followed by moderately exposed (22.7%), mildly exposed (13.6%) and highly exposed (9.09%). Blocks of Lahaul Spiti had highest values for exposure. Sensitivity index ranged from -1.94 to 3.90 [Fig. 3(b)], 59.09 per cent of blocks being least sensitive, mildly sensitive (22.72%), moderately sensitive (18.18%) and there was practically no highly sensitive block. One block each in Lahaul Spiti, Shimla, Solan and Sirmour districts were moderately sensitive. Adaptive capacity varied from -4.57 to 4.04 [Fig. 3(c)]. High adaptive capacity was of block selected in Kinnaur district. In case of degree of vulnerability [Fig. 3(d)], 54.5 per cent blocks were found least vulnerable followed by mildly vulnerable (18.18%), moderately vulnerable

(13.6%) and highly vulnerable (13.6%). The vulnerability was high in blocks of Kullu, Sirmour and Shimla districts.

The results of assessment of exposure, sensitivity, adaptive capacity and Vulnerability Index values and ranking of districts as per their vulnerability are presented in Table 4. A higher value for the vulnerability index represents higher vulnerability; however negative value of vulnerability index does not mean that the districts are not vulnerable at all; it just means that these districts are comparatively less vulnerable. Accordingly, the most vulnerable districts in descending order of vulnerability are Kullu, Lahaul-Spiti, Sirmour, Una, Solan, Kangra, Kinnaur, Bilaspur, Mandi and Hamirpur. Overall results revealed that vulnerability varied widely across districts within the state and vulnerable districts were characterised by households with comparatively higher exposure to changes in climatic conditions and limited options for adaptation to these changes. These results are in line with the findings of Paavola (2008), who have also reported that vulnerable communities were characterised by households with limited options in terms of livelihood diversification.

4. Conclusions

Vulnerability to climate change was determined at the district level by developing vulnerability index using exposure, sensitivity and adaptive capacity indicators representing household characteristics. The analysis shows that vulnerable districts tend to have households

that are characterised by low levels of human, natural, financial, physical and social assets. The study successfully identified the current sources of vulnerability and prioritizes major districts in Himachal Pradesh for adaptation planning. The results revealed that Kullu was the most vulnerable district due to its limited capacity to adapt which could be enhanced by strengthening financial assets through diversifying sources of income so as to reduce vulnerability and build long-term resilience to climate change. It can be recommended that vulnerable households should be given more support from the government in terms of trainings, information and knowledge sharing and also be encouraged to divert to alternative avenues, to build assets that would help them adapt better in response to climate vagaries.

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The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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