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Vulnerability Assessment of Rural Communities to Environmental Changes in Mid-Hills of Himachal Pradesh in India

[1]Ndungu Charles Kimani, [1]Bhardwaj S.K., [2] Sharma D.P., [3]Sharma R., [4]Gupta R.K., [5]Sharma B.

[1]Department of Environmental Science
[2]Department of Silviculture and Agroforestry
[3]Department of Social Sciences
[4]Department of Basic Sciences
[1,2,3,4]Dr. Y S Parmar University of Horticulture and Forestry, Nauni (Solan) India
[5]Himalayan Forest Research Institute, Panthaghati, Shimla (Himachal Pradesh)

Corresponding author: charlesndungu70@gmail.com

Abstract:

Field survey was conducted during 2014 to study the vulnerability of rural communities to environmental changes in mid-hills of Himachal Pradesh in India. Integrated vulnerability analysis approach was employed based on indices constructed from carefully selected indicators for exposure, sensitivity and adaptive capacity. The household was selected as the main unit of analysis because major decisions about adaptation to environment-induced stresses and livelihood processes are taken at that level. The indicators were weighted using Principal Component Analysis (PCA). Those which got the highest weights included historical changes in climate (1.00), share of non natural resources based income (0.98) and physical assets (0.74) among the indicators of exposure, sensitivity and adaptive capacity, respectively. Inter-block analysis of the vulnerability index indicated that households located away from district headquarters have higher levels of biophysical and socio-economic vulnerabilities compared to those near the district headquarters, due to higher reliance on natural resources which are now being impacted by ongoing environmental changes. Policy measures and development efforts should therefore aim towards addressing the high biophysical and socio-economic vulnerabilities of the rural communities of the mountain of Himachal Pradesh and more emphasis should be laid on the enhancement of their adaptive capacity.

Keywords: Adaptive capacity, biophysical vulnerability, climate change, natural resources, socio-economic vulnerability

1.0 Introduction:

Resource use intensification coupled with mountain specificities and concomitant environmental changes have led to pronounced vulnerability of rural communities inhabiting the mountainous areas of North West Himalayas. Inaccessibility, marginality, fragility and other constraints in topography have been associated with the difficulty of increasing mountain agricultural productivity through intensification and other plains-centric strategies (Jodha, 2000). Over the years and due to mountain specificities, urbanization and other developmental activities have been concentrated in valleys and other gentle sloped areas, leaving steeply sloped and remote areas largely unaffected by anthropogenic activities. However, increasing population pressure and concomitant need to enhance livelihood opportunities for people residing in far flung areas in the mid hills region of Himachal Pradesh has in the recent years led to mushrooming of development activities to the fragile and environmentally sensitive areas. Such developmental activities have caused environmental and natural resources degradation in the area. The changing climate and weather vagaries have also contributed towards the degradation of natural resources and consequently impacted socio-economic conditions of rural people in the region.

Vulnerability has been defined by the United National Development Programme (UNDP) as a human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard. (UNDP, 2004). Faulty agricultural practices in severely constrained mountain areas have degraded the natural resources, resulting in the vulnerability of Himalayan mountain people (ICIMOD, 2014). The changing climate situation in rain fed agriculture system has further aggravated the problem and consequently affected the growth of the region. Moreover, population pressure and deceasing per capita land holding has forced the mountain people to use marginal lands for agriculture and other developmental activities, resulting in degradation of natural resources and ultimately affecting the socio-economic conditions (Jenny and Egal, 2002) In hilly areas factors such as education, access to credit and information technology, wealth status and transportation facilities have also been reported to affect socio-economic vulnerability(Adger and Kelly, 1999; Fussel, 2007). On the other hand biophysical vulnerability in hilly areas has been attributed to relatively more undulating and steeply sloping farmlands, steep and rugged terrain impeding road construction and making transport difficult and costly, low soil fertility due to land degradation by soil erosion, diminishing water resources and increasing trends of environmental hazards like drought, floods, landslides, forest fires and hailing events (Liverman, 1990; Hewitt, 1995).

Specific sources of vulnerabilities for communities inhabiting mid-hills of Himachal Pradesh include scattered and very limited land holding (0.013 ha/capita), environmental constraints (climate, soils, slope, natural hazards), food insecurity, lack of access to markets, education, health care, dependence on one single economic factor, poor communication facilities, inappropriate governmental or industrial interventions; and globalization. Many of these elements of vulnerability are not well documented and there are few studies that quantify the vulnerability of mountain people to these different elements (Huddleston *et al.,* 2003).

Therefore, the present study focused on household-level vulnerability assessment to environmental changes in mid hills of North Western Himalayan region of Himachal Pradesh in India. It identifies some of the determining factors for vulnerability based on certain household social, economic and environmental (biophysical) characteristics. The findings of this study can be useful for targeting interventions, priority setting and resource allocations at community level for enhancing adaptive capacity of mountain people.

2.0 Materials and Methods:

2.1 Profile of the Study Area:

The study area consisted of mid-hills (800-1600 m above mean sea level) regions falling in two districts namely Kullu and Solan of Himachal Pradesh in North Western Himalayas. The region has mild temperate climate with annual average precipitation amounting to 1150 mm. The soils vary from sandy loam to loam in texture. The area has a steep and rugged terrain which amplifies biophysical and socioeconomic vulnerability of the communities. Overall, the Mid Hill region occupies about 33% of the geographical area and 53% of the cultivated area of Himachal Pradesh State.

2.3 Research Design and Data Collection:

In order to collect primary data on various indicators of vulnerability, a total of 275 farm households were considered at the selected sites of mid-hills in Solan and Kullu districts (Figure 1) during the year 2014. The two districts were stratified on the basis of development considering distance from the district headquarters. Consequently, two administrative blocks were purposefully selected from each district, one near the district headquarters and the other away from it i.e. in remote areas. Kullu and Solan blocks from Kullu and Solan districts, respectively formed study sites near the district headquarters while Naggar and Kandaghat blocks from Kullu and Solan districts, respectively formed study sites away the headquarters. Households falling within an altitudinal range of 800 to 1600 m above mean sea level (amsl) were randomly selected from study area to constitute the sample and data relating to exposure, sensitivity and adaptive capacity collected from the household heads using a pretested questionnaire. The household was selected as the main unit of analysis because major decisions about adaptation to environment-induced stresses and livelihood processes are taken at that level. Data were coded and analyzed by using SPSS 16.

2.4 Selection of Vulnerability Indicators:

The process of construction of vulnerability index progressed from selection of indicators, assignments of weights to them and finally their aggregation to form an index. Review of literature supplemented with participant observation and focus group discussions was used to select the indicators for exposure, sensitivity and adaptive capacity.

2.4.1 Exposure:

To capture the direct impact (stimulus) of environmental change on households, two parameters were considered, namely the historical changes in climate variables and trend of occurrence of extreme hazardous events. Coefficient of variation (%age) of average annual maximum temperature, average annual minimum temperature and average annual precipitation for the time period 1984- 2011 (Solan district) and 1991- 2005 (Kullu distict) represented the historical climate changes. Computation of the coefficient of variation for these parameters was done at district level and extrapolated to house hold level. The trend of occurrence of extreme hazardous events such as floods, landslides, droughts, snow events and hailstorms was obtained from the household survey. It was hypothesized that increasing trend of occurrence of these extreme events and rate of change of climate variables will increase the exposure of the households to the impacts of environmental change.

2.4.2 Sensitivity:

Sensitivity was indicated by impacts of development projects and extreme events on land and water resources and household income structure. Higher share of natural resource based income (composed of agriculture, livestock and forest products) 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, and remittances from abroad) reduce the sensitivity. These three income sources are categorized as remunerative sources because the return from these sources is comparatively higher than other sources of income.

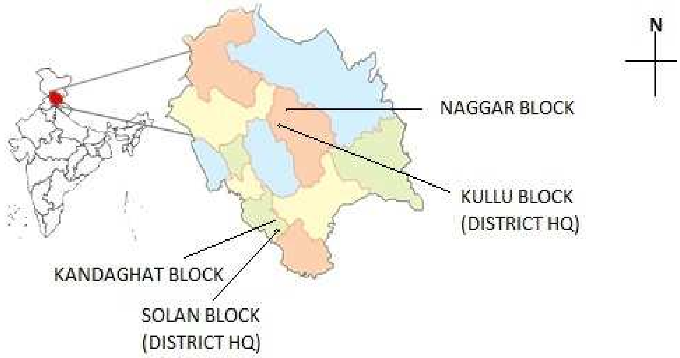

Figure 1: Map of the study area showing selected administrative blocks in mid-hills of Himachal Pradesh

2.4.3 Adaptive Capacity:

Adaptive capacity of a household was taken to be an emergent property of the five types of livelihood assets viz. physical, human, natural, financial, and social (Ellis, 2000; DFID, 1999). These indicators help in addressing shocks from environmental and climate change through minimization, pooling and redistribution of risks or as buffer against extreme environmental events.

2.5 Construction of Vulnerability Index:

The study followed integrated assessment approach in assessing household level community vulnerability to environmental and climate change, in which vulnerability was operationalized as a function of exposure, sensitivity and adaptive capacity following the IPCC definition (Füssel, 2007). The integrated approach combines both biophysical and socio-economic vulnerabilities to arrive at final vulnerability index. In this approach biophysical vulnerability is a function of exposure and sensitivity while adaptive capacity is analogous to socio-economic vulnerability and the overall community/ household vulnerability is conceptualised as a net effect of the two types of vulnerabilities. The framework was first proposed by Madu (2012) and later adopted by Tesso *et al*. (2012) in Ethiopia and Opiyo *et al.* (2014) in Kenya.

To begin with, the indicators were normalized to bring them within a comparable range using the following formula;

$$a^*_{ji} = {(a_{ji} - x_i)}/{s_i} \tag{1}$$

where a^*_{ji} is the normalised score of the jth variable in the ith household, a_{ji} is the indicator score being normalised and x_i is the mean and s_i standard deviation of the indicator score.

The next step involved assignment of weights to the indicators using principal component analysis (PCA) in SPSS. The weights assigned for each indicator varied between -1 and +1, sign of the indicators denoting the direction of relationship with other indicators used to construct the respective index. The magnitude of the weights describes the contribution of each indicator to the value of the index. PCA was run separately for the indicators of exposure, sensitivity and adaptive capacity. Stepwise PCA was run for the indicators of exposure and adaptive capacity, and overall indices calculated using the weights (loadings) obtained from second step PCA.

The normalized variables were then multiplied with the assigned weights to construct the indices for exposure, sensitivity, and adaptive capacity, each separately. The overall equation looked as follows;

$$I_j = \sum_{i=1}^{k} b_i \left[\frac{a_{ji} - x_i}{s_i}\right] \qquad (2)$$

where, 'I' is the respective index value, 'b' is the loadings from first component from PCA (PCA1) taken as weights for respective indicators, 'a' is the indicator value, 'x' is the mean indicator value, and 's' is the standard deviation of the indicators.

Finally, vulnerability index for each household was calculated as: V = E + S – AC, where, V is the vulnerability index, E the exposure index, S is the sensitivity index and AC is the adaptive capacity index for respective household. The study assumed a linear relationship between the three components of vulnerability.

The overall vulnerability index facilitates inter-household comparison within the study administrative blocks and inter-administrative block comparison as well. Higher value of the vulnerability index indicates higher vulnerability. However negative value of the index does not imply that the household is not vulnerable at all. This index gives a comparative ranking of the sampled households and/or selected sites. Tests of analysis of variance (ANOVA) were conducted to compare the means among the four study sites and four vulnerability quartiles.

3.0 Results and Discussion:

3.1 Exposure Indicators:

The weights obtained from PCA analysis for the indicators of natural disasters (Table 1) ranged from 0.90 (drought) to -0.04 (snow events). The weights for drought, floods, landslides and hail events were positive indicating a positive relationship with the overall environmental hazard composite score and consequently the exposure index. The weight for snow events was negative indicating thereby a negative relationship with overall environmental hazards composite score and consequently the exposure index. This implies that in mid-hills of Himachal Pradesh droughts, floods, landslides and hailing events have increased the exposure of mountain people whereas occurrence of snow events proved to have reduced the exposure probably due to its better infiltration in the soil thereby recharging ground water and reducing runoff. Similar findings by Vedwan and Rhodes (2001) while working in Himachal Pradesh, indicated that increase of floods lead to destruction of property and subsequent exposure of the people to hazards. Moreover, occurrence of snow events is accompanied by low temperatures which realise the chilling requirements of temperate crops such as apples. Conversely, plummeting snow events could affect production of temperate crops as also reported by Vedwan (2006) in other studies. Drought was weighted highest followed by landslides, floods, hail and snow events. In Himachal Pradesh, 80% of agriculture is rainfed and therefore, increase in drought events may enhance exposure of the people to vulnerability and hence management of drought need to be considered on priority for the upliftment of mountain people. Similar studies by Vishwa *et al.* (2013), Vedwan (2006) and Vedwan and Rhoades (2001) showed that incidents of meteorological, hydrometeorological and agricultural droughts lead to massive crop failures thereby increasing the exposure of the farmers.

Examination of mean values for the environmental hazards across the study sites revealed that study sites away from the district headquarters (Naggar and Kandaghat blocks) comparatively recorded significantly higher mean values than study sites near the district headquarters (Kullu and Solan blocks) for all the hazards except the snow events whose mean values were not significantly different across the study sites. This may probably be due to the fact that Kandaghat and Naggar areas being inaccessible, marginal and fragile with steep slopes and swallow soils with poor water retention capacity are prone to drought and surface runoff. Similar studies by Hallegatte and Przyluski (2010) indicated that people inhabiting far flung remote areas and with low income perceive and experience high incidence of environmental hazards. On the other hand Kullu and Solan district headquarters are located relatively on less steep slopes characterised by low incidents of environmental hazards. Major commercial and administrative centres at these locations also attract huge investments from governments and private investors and these enhance the development of adaptive structures and facilities in these areas. Therefore, people living in these areas perceive less apparent risks and threats from the physical environment.

The data in Table 2 indicated that weights for indicators of exposure ranged from 1.0 (historical changes in climate) to 0.14 (natural disasters composite score). All the weights were positive as hypothesized, thus affecting exposure positively. The absolute values of the weights indicate that temperature and rainfall trends contribute more to the exposure index compared to the composite environmental hazards. Both minimum and maximum temperature coefficients show a slow increasing trend for all the study sites, with Solan and Kandaghat blocks registering significantly higher mean values in maximum temperature than Kullu and Naggar blocks. The situation was reversed for minimum temperature whereby Kullu and Solan registered significantly higher mean values than Solan and Kandaghat. Precipitation also exhibited an increasing trend, the rate for Solan and Kandaghat being significantly higher compared to the other two blocks. The increase in biophysical vulnerability due to climate change of people inhabiting hilly areas has also been noticed by Negi *et al*. (2012) and Vishwa *et al.* (2013) while working in Himachal Pradesh. The trend for environmental hazards over the last ten years is highest for Kandaghat, followed by Solan, Naggar, and Kullu regions.

3.2 Sensitivity Indicators:

The weights for indicators of sensitivity are presented in Table 3 and ranged from 0.98 (share of natural based income) to 0.10 (number of livestock killed by extreme events). All the indicators had a positive relationship with sensitivity index except trend in availability of water resources and share of non natural resource based income which had a negative relationship. The absolute values for the weights indicate that share of natural resources based income and share of non natural resources based income contribute more to the sensitivity index than the other indicators. However, the share of non natural resources based income decrease the overall household sensitivity as shown by negative sign of the weight, while higher share of natural resource based income makes the household more sensitive to environmental change.

Table 1: Weights and mean values of natural disaster indicators in mid-hills of Solan and Kullu districts of Himachal Pradesh

Indicators	Weight	Aggregate (n=275)	Kullu (n=81)	Naggar (n=63)	Solan (n=72)	Kandaghat (n=59)	P-Value
Frequency of floods	0.68	2.56 (0.52)	2.43 (0.57)	2.68 (0.47)	2.53 (0.503)	2.63 (0.49)	0.02**
Frequency of drought	0.90	2.55 (0.53)	2.36 (0.60)	2.68 (0.47)	2.53 (0.50)	2.69 (0.46)	0.00***
Frequency of landslides	0.88	2.51 (0.54)	2.33 (0.59)	2.63 (0.49)	2.49 (0.53)	2.66 (0.48)	0.00***
Frequency of hail events	0.79	2.54 (0.54)	2.42 (0.50)	2.59 (0.64)	2.53 (0.50)	2.68 (0.51)	0.04**
Frequency of Snow events	-0.04	1.06 (0.26)	1.07 (0.26)	1.05 (2.15)	1.08 (0.31)	1.03 (0.18)	0.66

Note: Figures in parenthesis indicate standard deviation
***, **indicates significant at 1% and 5% level of significance, respectively

Table 2: Weights and mean values of exposure indicators in mid-hills of Solan and Kullu districts of Himachal Pradesh

Indicators	Weight	Aggregate (n=275)	Kullu (n=81)	Naggar (n=63)	Solan (n=72)	Kandaghat (n=59)	P-Value
Trend in Maximum Temperature	1.00	4.55 (0.50)	4.07 (0.00)	4.07 (0.00)	5.08 (0.00)	5.08 (0.00)	0.00***
Trend in Minimum Temperature	1.00	9.14 (1.97)	11.02 (0.00)	11.02 (0.00)	7.08 (0.00)	7.08 (0.00)	0.00***
Trend in Rainfall	1.00	4.48 (0.01)	4.46 (0.00)	4.46 (0.00)	4.51 (0.00)	4.51 (0.00)	0.00***
Environmental disaster composite score	0.14	8.20 (1.43)	7.69 (1.51)	8.56 (1.26)	8.13 (1.39)	8.62 (1.34)	0.00***

Note: Figures in parenthesis indicate standard deviation
***indicates significant at 1% level of significance

Higher share of natural resource based income (composed of agriculture, livestock, forest, honey and handicrafts) 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, and remittances from abroad) reduce the sensitivity. These three income sources are categorized as remunerative sources because the return from these sources is comparatively higher than other sources of income. Similar studies conducted by Collier *et al.* (2008) indicated that off farm income is stable, reliable and less climate sensitive. Further, Davis *et al*. (2007) has reported contribution of off farm income towards reducing sensitivity of the rural people. The negative sign of the weight of trend in water resources shows movement in the opposite direction compared to the other indicators. Decreasing trend in water resources will have positive effect to sensitivity index while increasing trend will have a negative effect. Number of livestock killed and physical property destroyed by extreme events contributed least to the sensitivity index as shown by their respective weights.

Table 3: Weights and mean values of sensitivity indicators in mid-hills of Himachal Pradesh

Indicators	Weight	Total (n=275)	Kullu (n=81)	Naggar (n=63)	Solan (n=72)	Kandaghat (n=59)	P-Value
Physical Property destroyed by extreme events	0.16	0.66 (0.47)	0.63 (0.47)	0.71 (0.46)	0.58 (0.50)	0.75 (0.44)	0.174
Number of livestock killed by extreme events in the last 10 years	0.10	0.13 (0.34)	0.10 (0.30)	0.14 (0.35)	0.08 (0.28)	0.22 (0.42)	0.94*
Trend in availability of water resources	-0.31	1.25 (0.44)	1.37 (0.49)	1.17 (0.38)	1.32 (0.50)	1.08 (0.28)	0.00***
Percentage of land destroyed by extreme events in the last ten years	0.21	9.75 (13.03)	4.46 (10.52)	13.33 (14.50)	7.36 (10.24)	16.10 (14.30)	0.00***
Share of natural resources based income	0.98	58.24 (34.33)	38.98 (29.10)	81.68 (24.57)	46.23 (33.10)	74.28 (29.29)	0.00***
Share of non natural resource based income	-0.98	41.77 (34.33)	61.02 (29.10)	18.32 (24.57)	53.77 (33.10)	25.72 (29.29)	0.00***

Note: Figures in parenthesis indicate standard deviation
***, *indicates significant at 1% and 10% level of significance, respectively

As expected areas located away from the district headquarters registered significantly lower mean values compared to those which fall near them for all the indicators except physical property destruction by extreme events which was found to be non significant. Increasing trends of number of livestock killed by extreme events, decreasing trends in water resources, higher percentage of land destroyed by extreme events and high dependence on natural based incomes all underlie higher sensitivity to impacts of environmental change in Kandaghat and Naggar blocks compared to Kullu and Solan blocks.

3.3 Adaptive Capacity Indicators:

The mean average values of the indicators for adaptive capacity revealed that Kullu block had comparatively higher asset possession, with figures ranging from 65.04 (irrigated land), 79.94 (share of more productive land) and 9.58 (monthly savings) among others while Kandaghat had the least asset possession, except ownership of number of bullocks (1.24) (Table 4). Examination of the weights for the five groups of indicators for adaptive capacity revealed that among the physical assets distance to the market had the highest influence (-0.93) followed by distance to the nearest motorable road (-0.91), percentage of irrigated land (0.69) and the type of the house (0.74) (Figure 2). Distances to the nearest natural produce market and the nearest motorable road influenced the adaptive capacity negatively as indicated by the negative sign of their weights. Among the human assets, education level of the household head got the highest weight (0.82) followed by number of people with salaried employment (0.63) and number of people with vocational skills (0.06). All had a positive influence on the adaptive capacity. Under natural assets category both percentages of productive (0.97) and unproductive land (-0.97) had the highest impact on adaptive capacity while the number of bullocks owned had the least (0.45). Percentage of unproductive land influenced the adaptive capacity negatively as indicated by the negative sign of the weight. For financial assets, both monthly income and savings had equal influence (0.99) and the same picture is replicated under social assets category whereby the number of CBOs that the household had membership had equal weight with the household access to credit (0.76).

Second-step PCA shows that physical assets are the most important determinants of overall adaptive capacity followed by human and social assets. Physical assets are very important because they enhance extraction and utilisation of natural assets. For example, without proper roads and transport services inputs such as fertiliser and planting materials may not be easily available for farming and this may result in a decrease in agricultural yield, and it is even more difficult and expensive to transport produce to the market. Moreover, a higher percentage of irrigated land will lessen dependence on rain fed agriculture which is becoming more unpredictable with the advent of environmental climate change. The index values for adaptive capacity and its components indicated that Kullu block fared the best in three of the asset categories (physical, financial and natural) and second best in social and human assets, thereby scoring the highest in overall adaptive capacity (Figure 3). The mean values of individual indicators in Table 4 indicated that Kullu's households ranked first in terms of possession of the best house type, are the nearest to the road and market for natural produce, have comparatively higher percentage of irrigated land, highest number of people with vocational training, highest monthly income, highest savings and highest share of productive land. Kandaghat stands the last in terms of all the asset categories (except number of bullocks owned) and thus had the least adaptive capacity. Solan ranked the second and Naggar third in terms of adaptive capacity index. The higher adaptive captive capacity of the households near the district headquarters can be explained by easy access to infrastructure and services e.g. better roads linkages, access to credit and market facilities. The present trend of the study may also be ascribed to higher income and access to technology of the households which might have increased the adaptive capacity (Kim *et al*., 2012; Burton *et al.* 2000). Moreover, wealthier farmers are more interested to adapt by changing planting practices, using irrigation and altering the amount of land farmed (Uddin *et al.,* 2014).

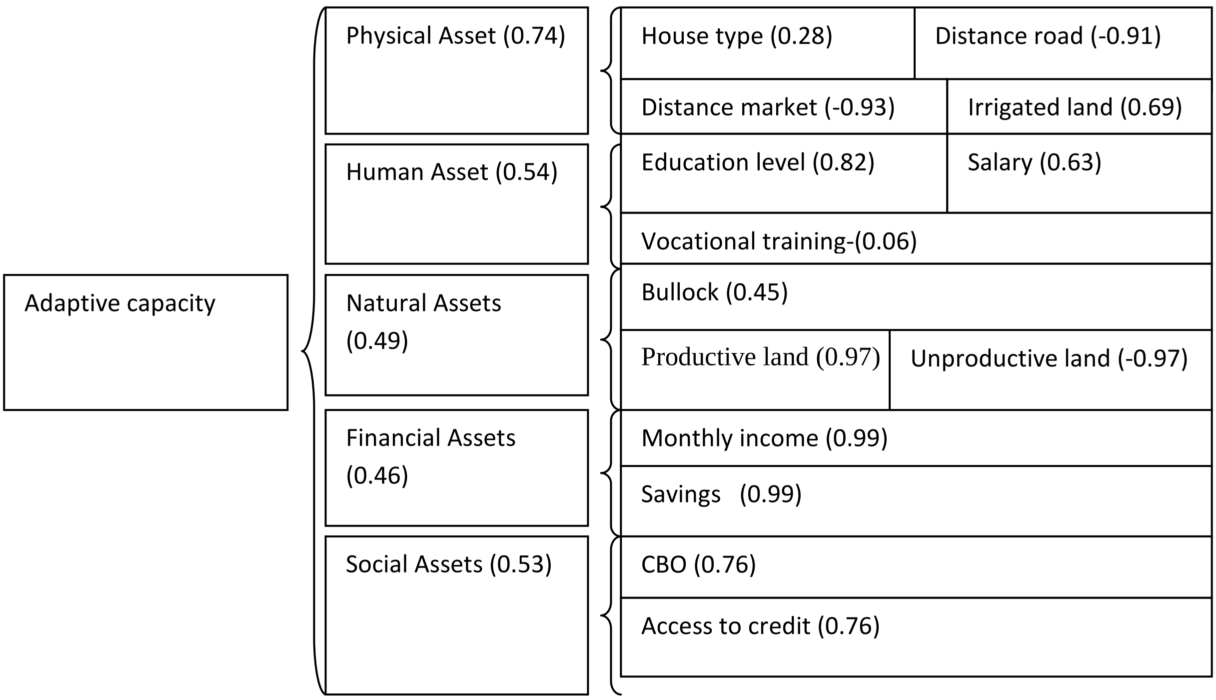

Figure 2: Structure of aggregate adaptive capacity index, composite sub-indices, and component indicators
Note: Figures in parenthesis are the loadings obtained from first principal component taken as weights for the respective indicators

Table 4: Mean values of indicators of adaptive capacity in mid-hills of Himachal Pradesh

Indicators	Total (n=275)	Kullu (n=81)	Naggar (n=63)	Solan (n=72)	Kandaghat (n=59)	P- Value
Type of house	3.89 (0.32)	3.93 (0.26)	3.89 (0.31)	3.90 (0.30)	3.81 (0.39)	0.21*
Walking distance to the nearest motorable road	17.63 (12.61)	8.15 (4.90)	28.00 (11.21)	10.29 (5.63)	28.54 (10.73)	0.00***
Walking distance to the nearest agricultural produce market	58.82 (43.20)	21.01 (10.23)	101.16 (28.40)	29.76 (10.00)	100.98 (29.81)	0.00***
Irrigated land	54.10 (35.13)	65.04 (29.68)	43.12 (35.98)	60.80 (30.01)	42.65 (40.51)	0.00***
Education qualification of the household head	12.31 (4.65)	11.89 (5.05)	13.00(4.44)	12.06 (4.29)	12.44 (4.65)	0.51
Number of persons in the household having salaried employment	1.01 (0.82)	1.10 (0.72)	0.83 (0.77)	1.33 (0.92)	0.71 (0.74)	0.00***
Number of persons in the household with vocational training	0.30 (0.81)	0.41 (1.20)	0.19 (0.47)	0.39 (0.68)	0.17 (0.46)	0.17
Have bullock	0.63 (0.88)	0.17 (0.5)2	1.05 (0.97)	0.28 (0.61)	1.24 (0.88)	0.00***
Share of more productive land	73.28 (18.33)	79.94 (17.65)	65.57 (14.58)	76.81 (19.28)	68.09 (17.49)	0.00***
Share of less productive land	27.11 (17.86)	21.24 (16.78)	34.07 (14.35)	24.09 (19.43)	31.43 (17.43)	0.00***
Gross monthly household income	33.41 (20.18)	38.20 (21.83)	30.56 (18.82)	36.32 (19.48)	26.34 (17.94)	0.00***
Monthly household savings	8.35 (5.24)	9.58 (5.60)	7.60 (4.76)	9.11 (4.97)	6.54 (5.03)	0.00***
Membership to CBOs	0.81 (1.02)	0.91 (1.10)	0.60 (0.79)	1.01 (1.20)	0.66 (0.82)	0.06
Access to credit from credit & savings societies	0.67 (0.47)	0.73 (0.45)	0.59 (0.50)	0.78 (0.42)	0.56 (0.50)	0.02*

Note: Figures in parenthesis indicate standard deviation, ***, *indicates significant at 1% and 10% level of significance, respectively

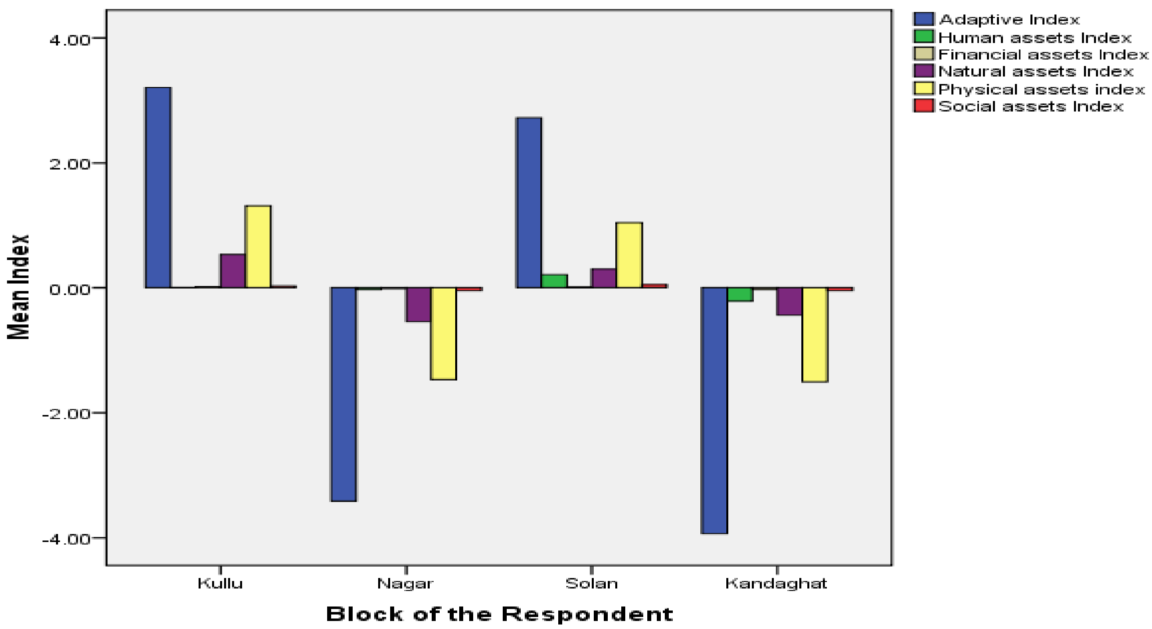

Figure 3: Index scores for adaptive capacity and it's components in mid-hills of Himachal Pradesh

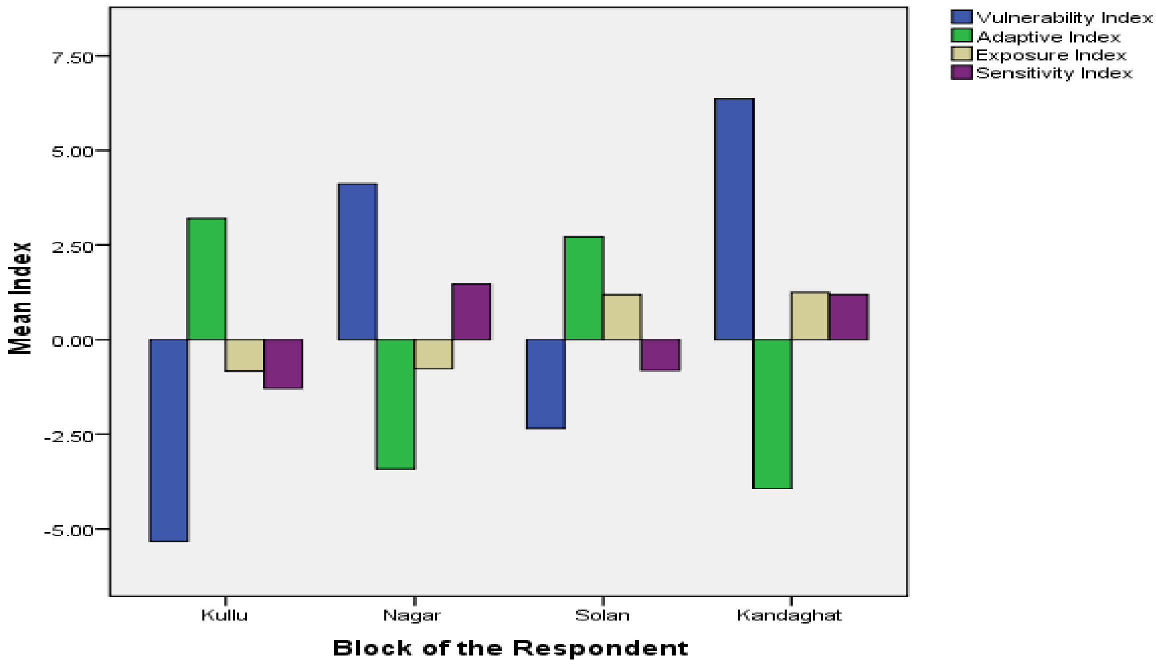

Figure 4: Index scores for vulnerability and it's components for the study sites in mid-hills of Himachal Pradesh

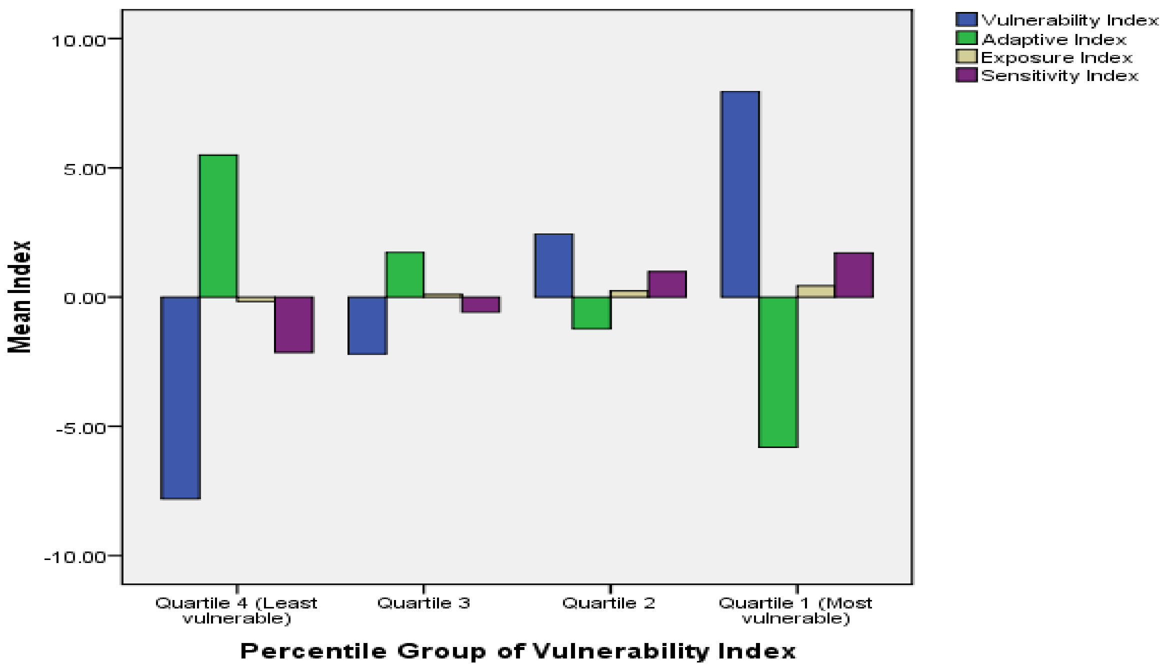

Figure 5: Index scores for vulnerability and it's components by vulnerability quartiles

3.5 Vulnerability Index:

The order of vulnerability index was Kandaghat > Naggar > Solan > Kullu (Figure 4). The results indicated that among the selected sites, Kandaghat block of Solan district has highest vulnerability index to environmental changes whereas Kullu was the least vulnerable. The highest exposure coupled with lowest adaptive capacity in Kandaghat block made it the most vulnerable. Naggar on the other hand, despite having a lower value of exposure index ranks the second most vulnerable study site owing to its highest sensitivity index and lower adaptive capacity index. The lowest sensitivity index and highest adaptive capacity index makes Kullu to emerge as the least vulnerable study site. Solan was second best both in sensitivity and adaptive capacity indices and it was in the second position overall in vulnerability index. Further examination of the results revealed that study sites near the district head quarters (Kullu and Solan) were less vulnerable compared to the study sites located away from the district head quarters (Kandaghat and Naggar). This is because households located away from the district head quarters experience more social economic and biophysical vulnerability. High social economic vulnerability is caused by households operating on less diversified livelihoods, low off farm engagement, low access to credit and markets, small landholding, low holding of perennial crops and small or no area under irrigation among others. Similar studies by Ellis and Freeman (2004) found that households which diversify their livelihood activities in the form of nonfarm business activities such as trade, transport, shop keeping and brick making among others are better off economically and hence less vulnerable. Moreover, high levels of social economic vulnerability due to poor livelihood options of communities living away in remote mountainous areas have also been reported in Ethiopia, Kenya and India, respectively by Tesso *et al.* (2012), Opiyo*, et al*. (2014) and O'Brien (2004).

On the other hand biophysical vulnerability is exacerbated by relatively more undulating and steeply sloping farmlands, steep and rugged terrain impeding road construction and making transport difficult and costly, low soil fertility due to land degradation by soil erosion, diminishing water resources and increasing trends of environmental hazards like drought, floods, landslides, forest fires and hailing events. All these factors lead to deterioration of agroecosystmes thereby compromising their ability to provide ecosystem services leading to farmers' vulnerability as also reported by Callo-Concha and Ewert (2014) in other studies. Moreover, households in these far flung mountainous areas depend more on natural resources as source of their livelihoods which are becoming more susceptible to environmental climate change and consequently exacerbating vulnerability. Similar results of pronounced biophysical vulnerability of communities inhabiting remote areas characterised by low developments were found by Deressa *et al.* (2008) and IPCC (2014). Inter-household analysis of vulnerability revealed that indices for exposure and sensitivity were highest for the first quartile (most vulnerable) and least for the last quartile (least vulnerable) as expected (Figure 5). Similarly, adaptive capacity followed the expected order, with the value being lowest for the first quartile and consecutively higher for the subsequent quartiles. This shows that irrespective of the locations, households with lower adaptive capacity are faced with higher exposure and higher sensitivity to climate change and extreme events. Poorer households are thus vulnerable anywhere irrespective of their locations.

4.0 Conclusion and Policy Implications:

The study revealed that mountain people of mid-hills of Himachal Pradesh face social economic and biophysical vulnerabilities which are mediated by environmental change and amplified by the mountain specificities. Exposure of a locality to impacts of environmental change which constitute long term changes in climate variables and occurrences of environmental hazards is the most important component determining the overall vulnerability of the people of mid-hills. Out of the three components of vulnerability, adaptive capacity is the component having direct policy implications. Improving the adaptive capacity also has indirect implications on improving the sensitivity of the community. Therefore adaptive capacity of the mountain people need to be enhanced by creating facilities such as irrigation, infrastructure for community development and options for non farm income.

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References:

1) Adger, W.N. and Kelly, P.M. (1999): Social Vulnerability and the Architecture of Entitlements. *Mitigation and Adaptation Strategies for Global Change*, 4: 253-266.
2) Burton, I. H., Saleemal, L. B. and Schipper, E. L. (2002): From Impacts Assessment to Adaptation Priorities. *The Shaping of Adaptation Policy,* 2: 145- 159.
3) Callo-Concha, D. and Ewert, F. (2014): Using the Concept of Resilience, Vulnerability and Adaptability for the Assessment and Analysis of Agricultural systems. *Change Adaptation Socio Ecol. Syst*., 1: 1-11.
4) Collier, P., Conway, G. and Dewey, J. (2008): Climate Change and Africa. *Oxford Rev Econ Pol,* 24(2): 337- 350.
5) Davis, B, Winters, P. and Lee, K. (2007): Rural Income Generating Activities: A Cross Country Comparison. ESA Working Paper 68. FAO, Rome.
6) Deressa, T., Hassan, R.M. and Ringler, C. (2008): Measuring Ethiopian Farmers' Vulnerability to Climate Change Across

Regional States. IFPRI Discussion Paper No. 806.
7) DFID (1999): Sustainable Livelihoods Guidance Sheets. London, UK: Department for International Development
8) Ellis, F. (2000): Rural Livelihoods and Diversity in Developing Countries. Oxford University Press, New York. 45-46.
9) Ellis, F. and Freeman, H.A. (2004): Rural Livelihoods and Poverty Reduction Strategies in Four African Countries. *Journal of Development Studies*, 40: 104- 120.
10) Füssel, H. (2007): Vulnerability: A Generally Applicable Conceptual Framework for Climate Change Research. *Global Environmental Change* 17:155–167.
11) Hewitt, K. (1995): Excluded Perspectives in the Social Construction of Disaster. *International Journal of Mass Emergencies and Disasters*, 13: 317-319.
12) Hallegatte, S., and V. Przyluski (2010): The Economics of Natural Disasters: Concepts and Methods. Policy Research Working Paper 5507, World Bank, Washington.
13) Huddleston, B., Ataman, E and Ostiani, L. (2003): Towards a GIS-based Analysis of Mountain Environments and Populations. Environment and Natural Resources Working Paper, No. 10. Food and Agriculture Organisation of the United Nations, Rome.
14) International Centre for Integrated Mountain Development (ICIMOD) (2014): Issues in Mountain Development, Kathmandu, Nepal
15) Intergovernmental Panel on Climate Change (2014): Climate change: Impacts, Adaptation, and Vulnerability. Working Group II contribution to the IPCC 5th Assessment Report.
16) Jenny, A. and Egal, F. **(**2002): Household Food Security and Nutrition in Mountain Areas: An often Forgotten Story. FAO, Rome.
17) Jodha, N.S. (2000): Globalization and Fragile Mountain Environments: Policy Challenges and Choices. *Mountain Research and Development,* 20 (4):296-299
18) Kim, C.; Jung, H.; Lee, S.; Park, S. and Takei, A. (2012): An analysis on Determinants of Farmers' Adaptation to Climate Change in Korea. *J. Rural Dev.* 35: 53–72.
19) Liverman, D. (1990): Vulnerability to Global Environmental Change. In: Kasperson, R.E., *et al.*, *Understanding Global Environmental Change*, 27-44, Center for Technology, Environment, and Development, Clark University, Worcester
20) Madu, I.A. (2012): Partial Vulnerability of Rural Households to Climate Change in Nigeria: Implication for Internal Security. Working paper number 2; May 2012. University of Texas, USA: The Robert S. Strauss Center for International Security and Law.
21) Negi, G.C., Samal, P.K., Kuniyal, J.C., Kothyari, B.P., Sharma, R.K. and Dhyani, P.P. (2012): Impact of climate change on the western Himalayan Mountain Ecosystems: An Overview. *Tropical Ecology,* 53 (3): 345- 356
22) O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L. and West J. (2004): Mapping Vulnerability to Multiple Stressors: Climate Change and Globalisation in India. *Global Environmental Change***,** 14:303-313
23) Opiyo, E.O, Wasonga, O.V. and Nyangito, M.M. (2014): Measuring Household Vulnerability to Climate-Induced Stresses in Pastoral Rangelands of Kenya: Implications for Resilience Programming. *Pastoralism,* 4:10-25
24) Tesso, G., Emana, B. and Ketema, M. (2012): Analysis of Vulnerability and Resilience to Climate Change Induced Shocks in North Shewa, Ethiopia. *Agricultural Sciences,* 3: 871–888.
25) Turner II, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A. (2003): A framework for Vulnerability Analysis in Sustainability Science. Proceedings of the National Academy of Sciences of the United States of America 100, 8074–8079.
26) Uddin, M. N., Wolfgang, B. and Jason, S. E. (2014): Factors Affecting Farmers' Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh. *Climate,* 2: 223- 24.
27) United Nations Development Programme (UNDP) (2004): Reducing Disaster Risk: A Challenge for Development. A Global Report, New York: UNDP, Bureau for Crisis Prevention and Recovery (BRCP).
28) Vedwan, N. (2006): Culture, Climate and the Environment: Local Knowledge and Perception of Climate Change among Apple Growers in North-Western India. *Journal of Ecological Anthropology*, 10: 20-36.
29) Vedwan, N. and Rhoades, E. (2001): Climate Change in the Western Himalayas of India: A Study of Local Perception and Response. *Climate Research*, 19: 109–117.
30) Vishwa, B., Chandel, S. and Karanjot, K. (2013): Drought in Himachal Pradesh, India: A Historical-Geographical Perspective, 1901-2009. *Transactions,* 35: 260-273.