sustainability

MDPI

Article

Indicator-Based Assessment of Resilience and Vulnerability in the Indian Himalayan Region: A Case Study on Socio-Economy under Different Scenarios

Soumya Dasgupta [1] and Ruchi Badola [2,*]

1 Project Scientist, DST-NMSHE, Wildlife Institute of India, Dehradun 248001, India; dgsoumya84@gmail.com
2 Department of Ecodevelopment Planning and Participatory Management, Wildlife Institute of India, Dehradun 248001, India
* Correspondence: ruchi@wii.gov.in

Received: 1 May 2020; Accepted: 10 July 2020; Published: 26 August 2020

Abstract: The Indian Himalayan region is vulnerable to climate change because of its geospatial fragility. The present study gives a framework for the analysis of household and village-level resilience and vulnerability in the Bhagirathi Basin of Indian Western Himalayan region under different climate change scenarios. Villages were selected depending on different biophysical criteria to have a good representation of the study area. Household-level survey using the household economy approach was done in 646 households of 30 villages to collect information on indicators of natural, physical, financial and human capital assets and scores were generated for each category. A cumulative resilience score was obtained for each household and village. Future climate projections on mean annual temperature were also accessed under Representative Concentration Pathway (RCP) 4.5 to estimate the change in mean temperature of the studied villages and probable change in agricultural production. The result shows that most of the villages of Tehri Garhwal are clustered in vulnerable classes in comparison to Uttarkashi villages and vulnerability scores of 11 and 8 villages changed under climate shock and future agricultural production change scenarios, respectively. The study has manifold implications on further research and policy implementation under socioeconomic vulnerability in the Himalayan region.

Keywords: climate change; Himalaya; household indicators; capital assets; vulnerability

---

1. Introduction

Humans and the environment have been closely associated with each other since antiquity. In this symbiotic relationship, humans have tried to adjust themselves with the environment initially, but subsequently molded the environment according to their needs. This has resulted in imbalances in the environment and the various ecological systems therein, thereby inviting several manmade environmental insecurities. The continued global rise in greenhouse gas emissions projected in most countries in the twentieth century ensures the unavoidable circumstances of climate change [1,2]. Climate change can, and is, accentuating the occurrence of extreme climate events throughout the globe [3,4]. It has mixed effects on the local changes in cropping pattern, availability of multiple ecosystems services like water supplies, vegetation and forest, biodiversity and system health, modifications in the economy, social and political system [5]. Global climate change presents a challenge to the future livelihood and existence of human beings, especially for those who are currently living in underdeveloped areas [6]. Climate change hazards also will increase unprecedentedly to increase the vulnerability of all the people depending on marginalized resources as livelihood and health of most of the human society is influenced by the climatic factors [6,7]. Southeast Asia and South Asia which harbors a large number of poor people depending on marginalized resources has experienced consistent and frequent extreme weather events and climatic variations in the past decades [8]. India has also witnessed flooding and high intensity rainfall during the last two decades [4,9,10] and an increase in extreme precipitation has also been predicted for the future [11]. Indian Himalayan Region (IHR) is extremely vulnerable due to its fragile ecosystem and seismic sensitivity [12]. The rugged terrain, lack of infrastructural development, arduous biophysical environment increases the concerns about the rising threats to the population belonging to the marginalized areas of IHR. The gap of knowledge on how these stresses will affect the villages and household-level economy and how intense the effect will be, create a critical situation, where at present, policy level intervention cannot be implemented efficiently.

By definition "vulnerability is a multilayered and multidimensional social space defined by the determinate political, economic and institutional capabilities of people in a specific place at a specific time" [13]. On the contrary, resilience was depicted as the capacity of a socioecological system to absorb external stress imposed upon it by reorganizing and evolving into more desirable units to improve the sustainability of the system and preparing it better for future impact [14,15]. It can be measured by assessing the different assets or capitals available for the system to cope with the hazards of climate change. However, not all the people depending on marginalized resources can be accounted as vulnerable. It depends on the exposure risk to shocks or crisis and lack of adaptive capacities to cope with the unprecedented stress or limited recovery from the crisis and shock [16,17]. There are concerns about the ever-increasing threats to the current livelihood and daily consumption patterns of households and individuals earning their livelihood from the stressful sectors. Critical gaps exist with regard to the methodological and evidence-based downscaled assessment of the impacts at the village and household-level vulnerability [18]. These constraints limit the understanding of the channels through which the climate related hazards will affect the vulnerable households and thus reduces the ability to design and implement effective policy measures for adaptation [19]. Vulnerability to poverty and food security resulting from extreme climate events depend on a range of factors that expose the resilience or adaptive capacity of households to cope with the short- and long-term effects of climate shock. These factors reflect the household's higher susceptibility or sensitivity to the stress event in the absence of adequate human, physical, financial and social assets, inability to access different societal and government aided services and absence of protection measures and insurance against greater exposure and uncertainty to stress [20]. The vulnerability or resilience of an individual or a household is determined by the stress response of the available resources and most significantly the ability of the households or individuals to avail the resources [13,17,21–25].

As per Smit and Wandel (2006) [26], among the four groups of focused studies on climate change research, the third group of studies deals with the relative adaptive capacity, i.e., country or region or community specific resilience or vulnerability, and involves comparative evaluation or ratings-based on the indicators/ variables selected by the researchers [27–30]. These studies provide an evaluation of the relative vulnerability as per UNFCC article 4.4 [26]. The present study comes under these focused studies to evaluate the relative vulnerability of selected villages of Bhagirathi basin of Indian Western Himalaya.

Vulnerability to climate change on the basis of socioeconomic condition and livelihood was assessed by several authors throughout the world using different indices. Following the pioneering work by Adger (1999) [22], several analytical techniques and indices were developed, such as the social vulnerability analysis [4,31–37], climate vulnerability index [38,39], livelihood vulnerability index [40–42], economic vulnerability index [43], multidimensional livelihood vulnerability index (MLVI) [44], livelihood effectiveness index [45], hazard and place model (HoP) and disaster resilience and place model (DROP) [37,46] and climate vulnerability and adaptive capacity analysis [7,30,47,48]. There are mainly two major approaches taken to analyze climate vulnerability. The deductive approach and the inductive approach [49]. The deductive approach relies on the preselected smaller number of variables [36], although its certainty to more subjectivity while choosing an indicator is inevitably high. Whereas on the other hand inductive methods requires a large set of indicators, and thus the subjectivity and accuracy became less [50–53]. Climate change vulnerability analysis majorly has two component the innate resilience of the society or household and the shock or stress imparted from climate change [6,29,54]. The major objective of the study is to establish an indicator-based approach to assess the adaptive capacity and vulnerability of selected households and villages that can be replicated in a larger spatial scale for identifying climate sensitive areas for effective adaptation and mitigation planning for better sustainability. In this study, an attempt was made to assess the village and household-level vulnerability in the Bhagirathi basin of the Indian Himalayan region (IHR). Indicators for vulnerability assessment were selected on the basis of sustainable livelihood framework and IPCC (Intergovernmental Panel for Climate Change) 2014 guideline from both climate shock and adaptive capacity components. Both Secondary information from census data of India and primary household and village-level survey data on selected indicators were used to assess the adaptive capacity and vulnerability of villages in the IHR.

2. Study Area

The study was carried out in the Bhagirathi Basin of Uttarakhand, (Uttarkashi and Tehri Garhwal District) India (Figure 1). Uttarakhand is a state of the Northern part of India with an area of 53,483 km^2. The terrain of the state is mountainous with dry soils and the climate and ecology vary greatly with elevation and slope. Bhagirathi River Basin (catchments) represents different biogeographic provinces (1B and 2B) [55] and physical as well as anthropogenic gradients and it has seven different subbasins, i.e., Bhagirathi I, II, III and IV, Asiganga, Balganga and Bhilangana covering approximately 10,000 km^2 area and different land cover and land use patterns including human habitation, agricultural land, large and small water reservoirs, rivers, streams and wetlands, subtropical and temperate forests, alpine rangelands, glacial moraines, permafrost areas and trans-Himalayan cold deserts. The study area encompasses a wide range of elevation zones starting from 500 m at subtropical forests to 5000 m at trans-Himalayan cold deserts and accordingly represents a mosaic of several microclimatic regimes. Uttarkashi and Tehri-Garhwal both the districts are situated in the Garhwal region of the state of Uttarakhand. Both the districts are traversed by tributaries of mighty river Ganga and the economy of the region is largely depending on agriculture. Uttarkashi district has both the sources of river Ganga and Yamuna. The district headquarter Uttarkashi city lies in the main route of Gangotri and Yamunotri and attracts millions of Hindu Pilgrims every year. The district has a population density of 41 km^{-2} and decadal growth rate from 2001 to 2011 was 11.75% ("district census 2011", http://www.census2011.co.in/district.php). Tehri Garhwal, having administrative headquarter is at New Tehri, is one of the most highlighted districts of Uttarakhand because of the Tehri dam.

The villages of the Bhagirathi basin differ both in biophysical and socioecological characteristics and so does the livelihood of the people. In the high-altitude areas, horticulture and pastoralism prevail, whereas in low altitude areas, agriculture. The economy of the villages near the district headquarters (Uttarkashi and New Tehri, India) and the villages far away also differ accordingly and so does the livelihood patterns of the villagers. Within and between village variances are also quite high since from historical times different groups of people like Gorkhas, Gujjars, Pundir, Rajputs, etc. have invaded the Garhwal region and later became residents. Thus, along with Garhwali culture other cultural inheritance also preserved in the study area.

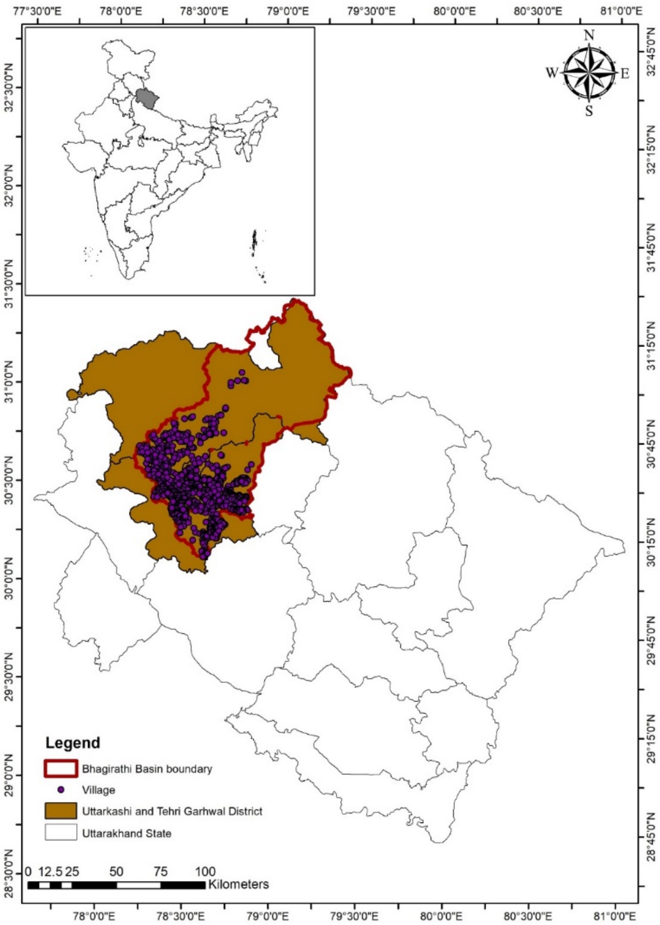

Figure 1. Study area within Uttarkashi and Tehri Garhwal District of Uttarakhand and location of the villages.

3. Methodology

Village-level information was collected from the Census India data set available in the census India website (http://www.censusindia.gov.in/) based on countrywide census carried out in 2011. Information on the number of households, total population, presence of medical facility, educational institute, market, road connectivity, nearest town and other important facilities of 1096 villages within the study area were collected. Locations of 824 villages out of 1096 were validated using Google Earth Pro in the study area, as the rest of the villages were not found in the Google Earth Pro database. To examine the access to resources and how it varies to different villages remoteness index was calculated for each village on the basis of weighted score of the availability of basic facilities using Equation (1). The information on presence, absence and distance from the motorable road, hospital, health center, primary and secondary school, market, police station, post office, bank, nearest town and tourist spot were used for calculating the value of remoteness index.

$$\text{Remoteness Index (RI)} = \sum_{i=0}^{n} \beta^i A^i \quad (1)$$

where β is the weighted score of the basic amenities of the village and

A is the score (presence absence or coded) of basic amenities of the village.

A two-step algorithm was used to cluster the villages on the basis of the total geographical area of the village, population, the altitude of the village and remoteness index of the villages. Three clusters were formed on the basis of the 4 criteria given for analysis (Figure 2). Cluster 1 comprises of 49 villages having high altitude, large geographic area, remote and less population. Cluster 2 comprises 11 villages having low altitude, easily accessible, moderate geographic area and high population. Cluster 3 again comprises of 49 villages having moderate elevation, small sized, moderately remote, sparsely populated. Climate change will increase the exposure of different villages to environmental hazards and will affect the agricultural sector more where irrigation facilities are limited. Conflict with wild animals and exposure to disasters will also increase due to climate shock. The villages having high dependency on agriculture, more prone to natural disasters and high wildlife conflict are more exposed to climate shock compare to the villages that lack those exposures. The village and household vulnerability also will be shaped by these factors. To include the factors associated with exposure to climatic stress in vulnerability analysis 102 villages from different clusters were selected for the primary data collection on the agricultural dependencies of the village, disaster proneness of the village and wildlife interaction. On the basis of this information another clustering was done using a two-step algorithm. A total of 10 sub-clusters were formed, 5 from each Cluster 1 and 3, (Table S2 of supplementary). Due to the smaller number of villages in Cluster 2 (11 villages) it remained as a single cluster. Thirty villages were selected representing all the clusters for detail household-level survey using household economy approach (Table 1). The household economy approach (HEA) is developed by Save the Children, UK and designed to get information based on livelihood and access the resources of a household for multilevel analysis [56].

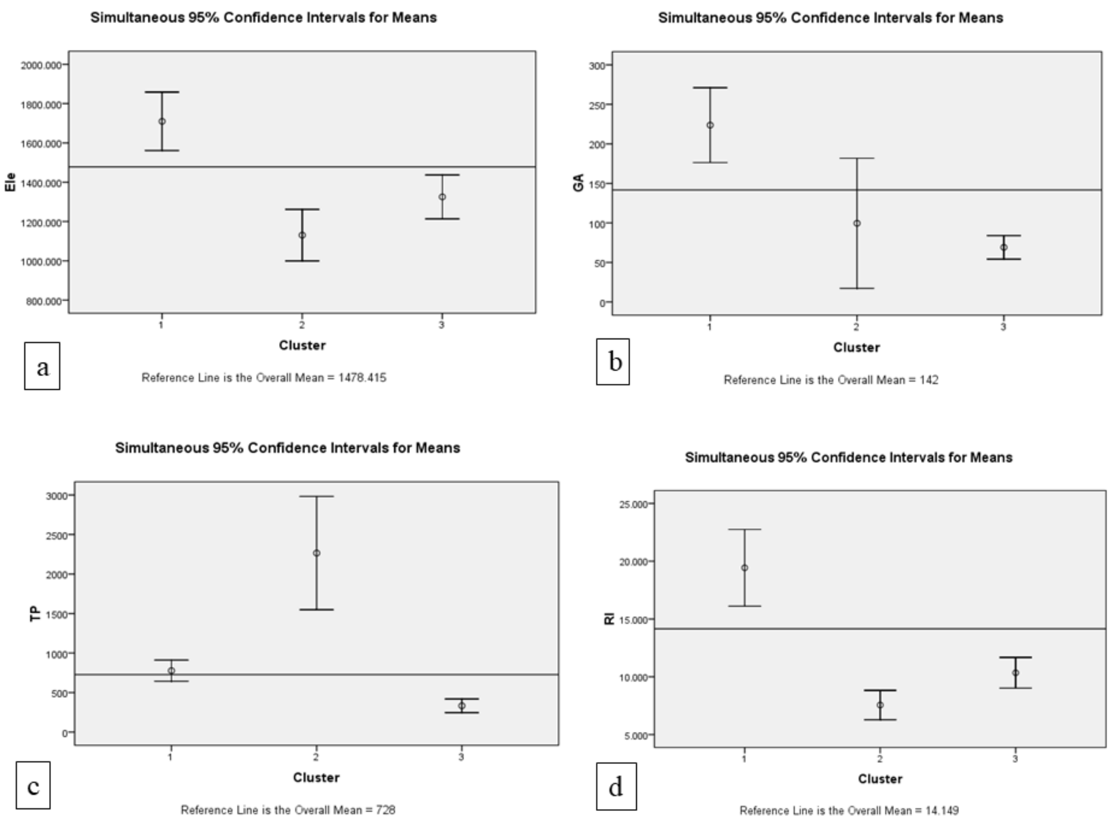

Figure 2. Clusters formed depending on the values of elevation (**a**) geographic area (**b**) Total population (**c**) and Remoteness index (**d**).

Table 1. Villages selected for survey, households surveyed within a village and percentage of male and female respondents within the village.

District	Village	Household Surveyed	Male Respondents (%)	Female Respondents (%)
Uttarkashi	Baijkot	14	35.71	64.29
Uttarkashi	Barshali/Nakori	13	84.62	15.38
Uttarkashi	Barsu	19	36.84	63.16
Uttarkashi	Bayana	18	50.00	50.00
Uttarkashi	Bhatwari	23	69.57	30.43
Tehri Garhwal	Chamiyala	21	42.86	57.14
Uttarkashi	Dharali	22	86.36	13.64
Tehri Garhwal	Dharwal	21	36.36	63.64
Uttarkashi	Gajoli	28	64.29	35.71
Uttarkashi	Garat	13	69.23	30.77
Tehri Garhwal	Girgaon	22	22.73	77.27
Tehri Garhwal	Gujetha	15	53.33	46.67
Uttarkashi	Hadiyari	17	64.71	35.29
Uttarkashi	Hitanu	19	31.58	68.42
Uttarkashi	Indergaao	9	77.78	22.22
Tehri Garhwal	Khand	26	76.92	23.08
Tehri Garhwal	Koti	28	46.43	53.57
Uttarkashi	Kumrada	43	44.19	55.81
Tehri Garhwal	Kyal Baghi	6	100.00	0.00
Uttarkashi	Ladari	48	51.06	48.94
Tehri Garhwal	Musan	10	40.00	60.00
Tehri Garhwal	Pabela	11	45.45	54.55
Tehri Garhwal	Pakh	35	54.29	45.71
Tehri Garhwal	Pata (TG)	25	36.00	64.00
Uttarkashi	Pata (U)	20	65.00	35.00
Tehri Garhwal	Pipola	21	33.33	66.67
Uttarkashi	Purali	15	46.67	53.33
Tehri Garhwal	Ramgarh	21	38.10	61.90
Tehri Garhwal	Sitakot	18	72.22	27.78
Tehri Garhwal	Srikot	45	55.56	44.44

The number of households to be surveyed within a village is selected using standard queries. If the villages have less than 50 households, 50 percent of the households were surveyed, as the number increases to 100, 250, 500 and more than 500, 30 percent, 20 percent, 10 percent, and 5 percent of the households were surveyed, respectively. Within a village, households were selected through a stratified random selection process, accounting for the differences in the social and economic conditions of the households, gender and age structure of the respondents. household-level questionnaire surveys were conducted in 646 households of 30 villages (15 each from Uttarkashi and Tehri Garhwal district, India) using semi structured questionnaire. Information on the household economy, dependency level to agriculture, forest and other natural resources for daily needs and perceptions on climate hazards were recorded from each and every household. Information on different preidentified indicators following the deductive method [49] were collected. Indicators were classified under the four major capital viz. physical, human, financial and natural resources as part of the adaptive capacity of the households as most of the indicators of social capital like access to basic amenities already been estimated while calculating the remoteness index. The list of subcomponents and selected indicators under each capital are given in Table 2. Some of the variables where the variance was very high and which were having non numeric responses, ranked information was used. In case of the education and occupation of the respondents, the information was non numeric, so responses were ranked as per the lowest to highest education and occupation classes. Similarly, in the case of agricultural area and agricultural production, the variance in the responses was very high so the data were ranked to different production classes from low to high. Individual scores of the indicators were transformed using minimum–maximum rescaling transformation using the equation used in Hahn et al. (2009) [42] (Equation (2)). Transformed scores were added to get the aggregate score for each subcomponent of four major capitals. The aggregate score of the components depicted the innate adaptive capacity or resilience of the households for climate change vulnerability. The average resilience of each village was calculated, and village-level indicator values were added to calculate the village-level innate resilience score. Cluster analysis was done using R software including the values of different capitals along with the resilience scores, as the variability of the resilience score within the villages was very small (ranges from 8.105 to 13.386). Villages and households were classified into different classes from highly resilient to highly vulnerable. The ratio of between and the total sum of squares was compared for deciding how many clusters can better classify the villages and households in different classes. The agricultural dependency of the villagers, instances of wildlife conflict, exposure to disaster in past and its effect on the villages were taken as indicators to assess the level of intensity of the climate change shock on the villages. Agricultural dependency of the villages was categorized as high, medium and low/nil and scored as 3, 2 and 1, respectively. Exposure to natural disasters and wildlife conflict was also categorized and scored similarly. The sum of the scores was transformed using Equation (2) [42] and the normalized value as a risk score was deducted from the innate resilience score of the respective villages to get the vulnerability score of the villages.

Agriculture and forest are the two major areas to get affected by the effect of climate change in the near future. An estimated 4.9% reduction on the agriculture production for change in 1° centigrade of temperature was projected by IPCC [57]. As natural and financial capital of the household and village largely dependent on the agriculture and forest resource of the villages, changes in the production and availability of these resources will definitely affect the vulnerability of the villages. Change in agricultural production in the future climate scenario was estimated for the villages to assess how changes in agricultural production will change the vulnerability score of the villages. For projections of future climate, Australian Community Climate and Earth System Simulator (ACCESS-01) jointly developed by the Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO), with help from the Australian universities [58] was used. The "middle of the road" Representative concentration pathway 4.5 for GHG (Green House Gas) scenario is used. For analysis, the change in average annual temperature of current and the year 2050 time series climate change scenario (https://worldclim.org/cmip5_30s) is assessed. The future mean annual temperature (Bioclimatic variable 1) for all the villages was extracted using extract values to points of spatial analyst tool in ArcGIS 10.2. The present mean annual temperature and expected mean annual temperature of the villages were compared and the difference in mean annual temperature was multiplied by 4.9 (as 4.9% decrease of agricultural crop production is expected for per degree centigrade temperature increase) to get the percentage change in the future agricultural production. The percentage score for all the villages was transformed using Equation (2), and the transformed score was deducted from the vulnerability score to get the future vulnerability score of the villages due to loss of agricultural production because of the climate change effect. Excel, SPSS and R software are used for the analysis of the data.

$$\mathrm{Index}_{\mathrm{sd}} = (\mathrm{S_d} - \mathrm{S}_{min})/(\mathrm{S_{max}} - \mathrm{S_{min}}) \quad (2)$$

Table 2. List of village and household-level indicators and data sources used to calculate the vulnerability score.

		Village Level	**Data Source**	**Data Used for Analysis**
No.	Capital	Indicator		
1	Physical	Altitude	Google Earth	Ranked
2	Physical	Disaster risk	Village survey	Ranked
3	Physical	Agricultural dependency	Village survey	Ranked
4	Physical	Remoteness	Village survey	Ranked
5	Physical	Wildlife interaction	Village survey	Ranked
6	Physical	Water accessibility	Village survey	Ranked
7	Physical	Total geographic area	Census 2011	Ranked
		Household-level		
1	Human	Education	Household-level survey	Ranked
2	Financial	Occupation	Household-level survey	Ranked
3	Human	Total members earn	Household-level survey	Number
4	Human	Number of dependent persons	Household-level survey	Number
5	Natural	Agricultural area	Household-level survey	Ranked
6	Financial	Variety of pulses	Household-level survey	Number
7	Financial	Production of pulses	Household-level survey	Ranked
8	Financial	Variety of cereals	Household-level survey	Number
9	Financial	Production of cereals	Household-level survey	Ranked
10	Financial	Variety of fruits and vegetables	Household-level survey	Number
11	Financial	Production of fruits and vegetables	Household-level survey	Ranked
12	Financial	House status (Kaccha/concrete) Wall material and roof material	Household-level survey	Ranked
13	Physical	Electricity	Household-level survey	Presence/absence
14	Physical	Running water	Household-level survey	Presence/absence
15	Physical	LPG connection	Household-level survey	Presence/absence
16	Physical	Fuel wood	Household-level survey	Presence/absence
17	Physical	Kerosene	Household-level survey	Presence/absence
18	Natural	Fodder variety	Household-level survey	Number
19	Natural	Fodder extraction	Household-level survey	Ranked
20	Natural	Fuelwood extraction	Household-level survey	Number
21	Human	Total family member	Household-level survey	number

4. Results

4.1. Demography

Among the 646 respondents, 306 were females and 340 were male. As in the villages of the Indian Himalayan region household and agricultural work are driven mostly by women, it was tried that ratio of male and female respondents be the same. The difference between the number of male and female respondents was not significantly different statistically ($p < 0.5$ at 95% confidence level). The percentage of male and female respondents in each village surveyed is given in Table 1. Similarly, the age and occupation of the respondent are also important as the perception and experience of the respondent are important while getting household information. An attempt was made to get equal respondents from all the age classes. Respondents were grouped in six different age classes from less than 20 to more than 60 years of age and in between 4 classes were of equal age width of 10 years (Figure S1 in supplementary material). There was no significant difference in the number of respondents in between the age classes except the less than 20 years age class ($p < 0.5$ at 95% confidence level) (Table 3). Agriculture is the major occupation (35.34%) followed by Government service, private service and casual labor, 6.67%, 6.18% and 6.02%, respectively (Figure 3).

Table 3. Matrix of pairwise comparison of difference values of age-classes.

Age Group	21 to 30	31 to 40	41 to 50	51 to 60	Above 60
21 to 30					
31 to 40	10 (NS)				
41 to 50	19.5 (NS)	9.5 (NS)			
51 to 60	18.5 (NS)	8.5 (NS)	1 (NS)		
Above 60	12 (NS)	2 (NS)	7.5 (NS)	6.5 (NS)	0.00

Critical Value for the difference 34.379. NS = nonsignificant difference, X = significant difference.

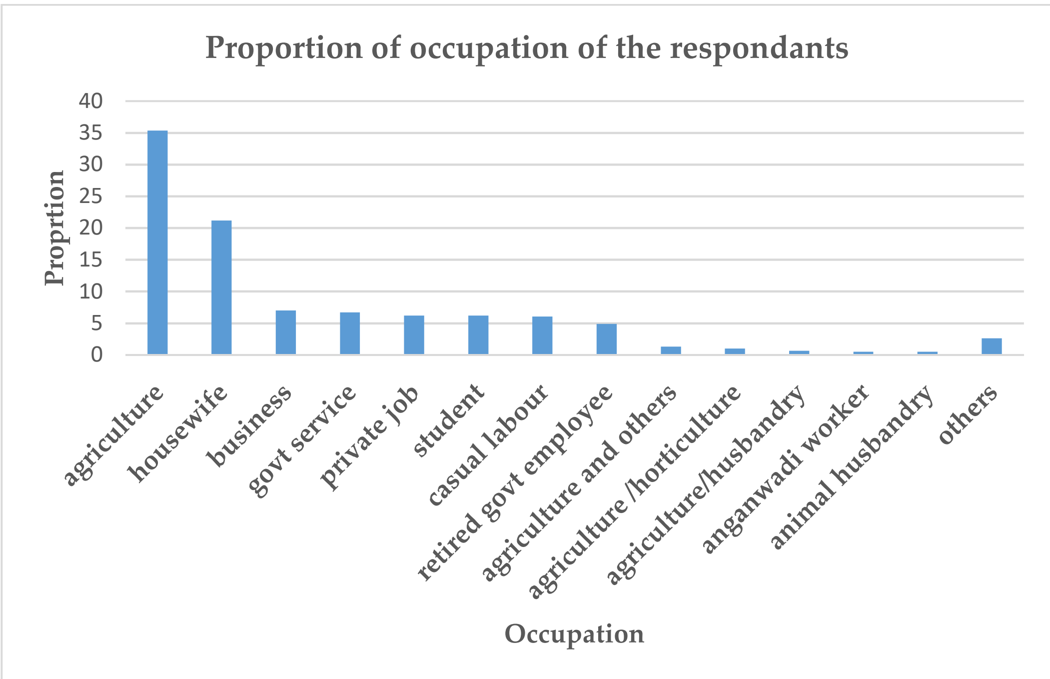

Figure 3. Occupation of the 646 respondents in the surveyed villages of Bhagirathi Basin.

4.2. Household-level Resilience

Resilience scores for household-level resilience ranged from 5.03 to 16.54 depicting high vulnerability to high resilience, respectively. Five different clusters were formed as the ratio of between and the total sum of square values were reaching the asymptote near the cluster size of 5 (Figure S2 of supplementary material). Along with the resilience score, values of different capitals were also used for clustering as range of resilience scores do not varied much between the households. Mean values of resilience scores and different capitals for each cluster were given in Figure 4.

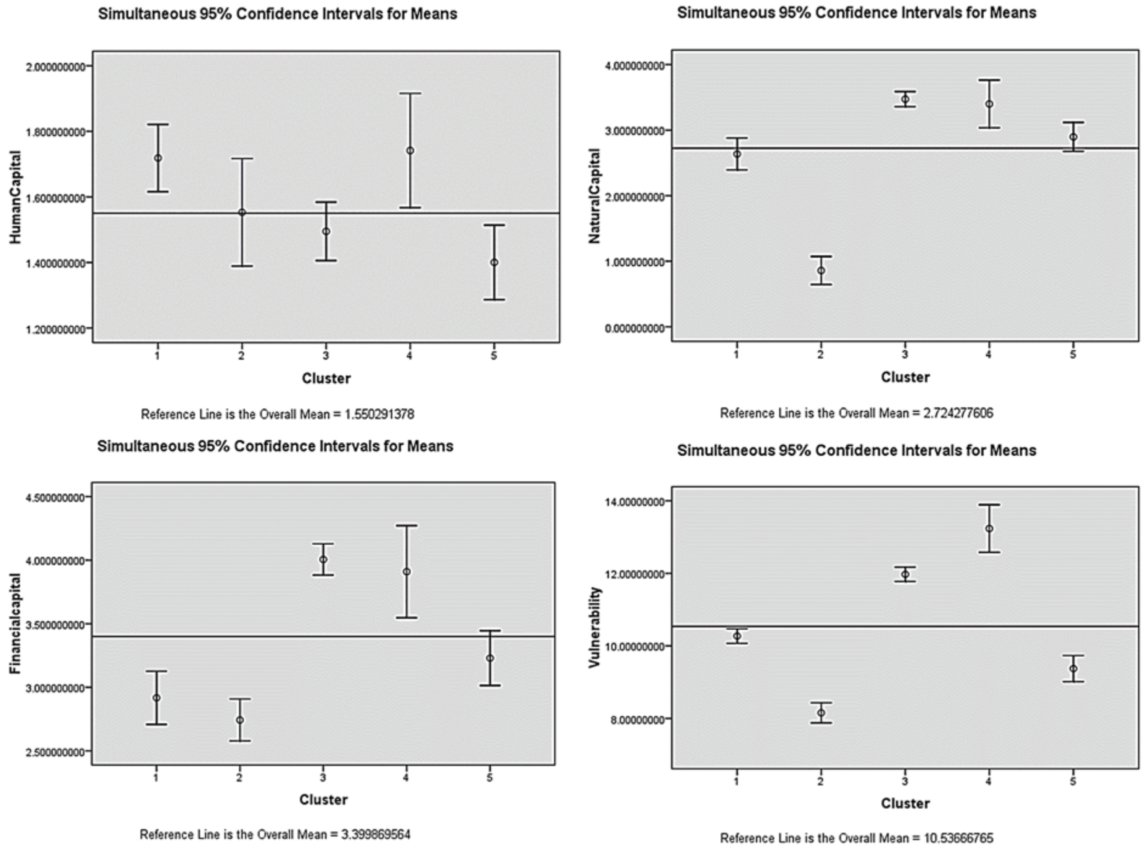

Figure 4. Value ranges of different parameters for clustering villages in different vulnerable and resilience classes. (**a**) Human capital; (**b**) natural capital; (**c**) financial capital; (**d**) vulnerability.

Household resilience status depicts the highest number of households were of resilient classes (31.57%) followed by vulnerable (22.29%), moderate vulnerable (18.575%) and highly vulnerable classes (17.49%). Only 10% of households fall in highly resilient classes (details are in Table S1 in Supplementary materials). Barsu (68%), Purali and Pata (60%) villages have most households of highly resilient classes. Indragaon, Sitakot and Baijkot villages have most of the resilient households (77.78%, 72.22% and 64.29%, respectively). Pabela, Dharali and Chamiyala villages have most of the moderately vulnerable households (54.45%, 45.45% and 42.86%, respectively). Pata village of Tehri Garhwal have the highest percentage of Vulnerable households (88%) followed by Kumrada and Koti (55.81% and 47.06%, respectively). Girgaon Barsali and Ladari have the highest number of highly vulnerable households (68.18%, 61.54% and 59.57%, respectively).

4.3. Village-level Vulnerability

Average household-level resilience score was calculated for each village and added to the normalized value of the village-level indicators viz: altitude, remoteness index, total geographic area, population, to get the village-level resilience score. Village resilience score along with the average of natural, physical, human and financial capital was used for clustering the villages in different vulnerability levels. Five different clusters were formed, and the range of each variable used for clustering in each cluster was given in Table 4 (supplementary materials Figure S3). Village-level resilience score is higher in Uttarkashi District (11.298 ± 1.35) than Tehri Garhwal District (9.965 ± 0.824) and the difference is statistically significant. The villages as per their vulnerable class are plotted in the altitudinal gradient of the Bhagirathi Basin in Figure 5a.

Table 4. Vulnerability class with lower and upper limit of resilience score.

Vulnerability Class	Mean	Std Dev	Lower Limit	Upper Limit
Highly resilient	14.378	1.089409	13.28859	15.46741
Resilient	13.6745	0.51129	13.16321	14.18579
Moderate	12.589	0.645	11.944	13.234
Vulnerable	11.664	0.455	11.209	12.119
Highly vulnerable	10.962	0.757	10.205	11.719

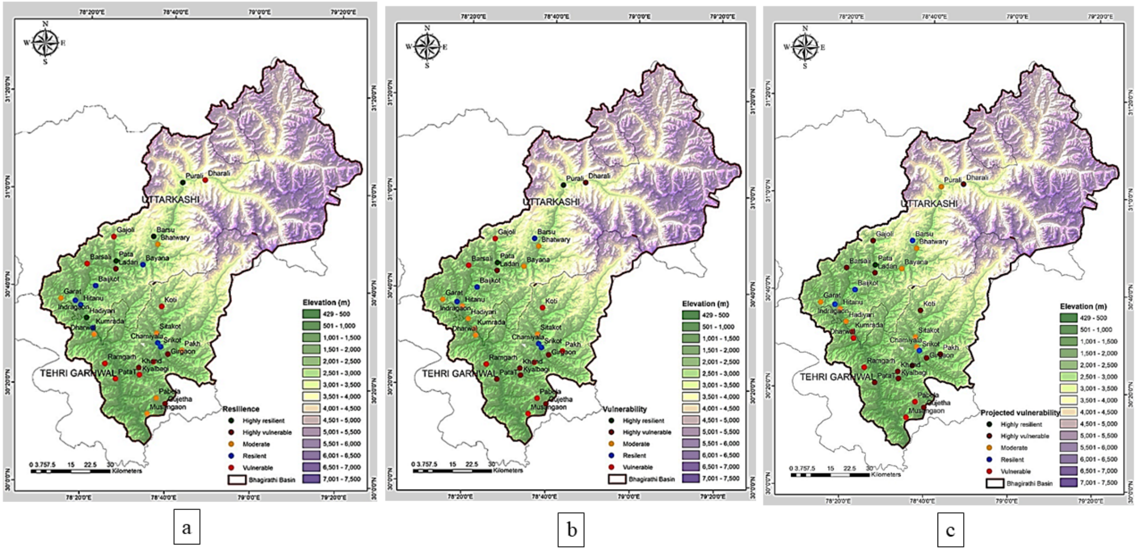

Figure 5. Thirty villages as per their (**a**) resilience class (**b**) vulnerability and (**c**) future predicted vulnerability in the elevation gradient in Uttarkashi and Tehri Garhwal district of Uttarakhand in the Bhagirathi Basin.

Among the five clusters, Cluster 1 represents seven villages (Baijkot, Bayana, Hitanu, Chamiyala, Kumrada, Indergaon, Srikot) with moderate resilience having higher financial and natural capital. Cluster 2 comprises of four villages (Pata, Barsu, Hadiyari, Purali,) with high resilience having higher natural physical and financial capital. Cluster 3 comprises of seven villages (Bhatwary, Garat, Pakh, Sitakot, Dharwal, Pabela, Musangaon) having moderate vulnerability because of high human capital, but lower scores for other capitals. Cluster 4 comprises of eight vulnerable villages (Dharali, Gajoli, Barsali, Koti, Kyal baghi, Pata (T), Ramgarh, Pipola) due to their very low physical and human capital and cluster 5 comprises of four highly vulnerable villages (Ladari, Khand, Girgaon, Gujetha,) due to their low financial and natural capital.

The vulnerability score deduced was then compared with the innate resilience score to group villages in different vulnerable categories on the basis of cluster averages of resilience score and the cumulative score of human, financial, physical and natural capital. Vulnerability status of 11 villages had changed after deducting the risk score (Figure 6). Barsu and Hadiyari village which were highly resilient in innate resilience shifted to resilient and moderate vulnerable group, respectively after deducting the climate risk score. Bayana, Hitanu and Kumrada shifted from resilience to moderate vulnerable group. Dharali, Kyal Bagi and Pata village of Uttarkashi shifted from vulnerable to highly vulnerable group. Same way Pakh, Pabela and Musangaon villages shifted from moderate vulnerable-to-vulnerable group (Figure 5b).

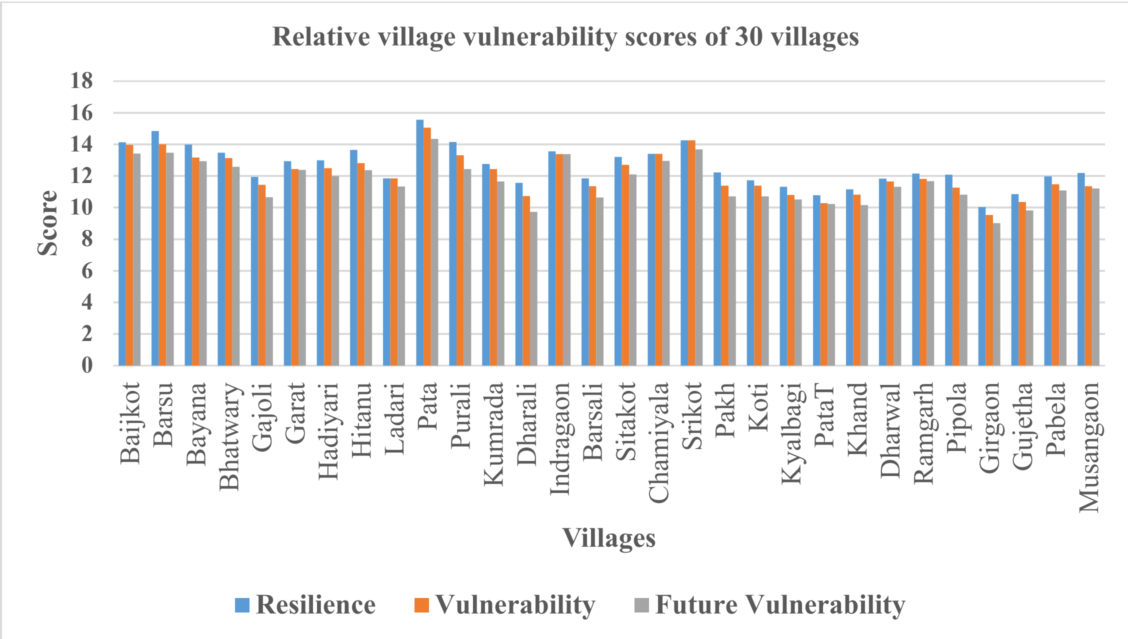

Figure 6. Village-level vulnerability score of Uttarkashi and Tehri Garhwal Villages.

Future agricultural production loss will also affect the vulnerability of the villages and the result shows 9 of the 30 villages shifted from present vulnerability class to higher vulnerability classes. Gajoli, Pakh, Barsali, Koti and Pipola were shifted from vulnerable to highly vulnerable class (Figure 5c). Dharwal and Kumrada shifted from moderate vulnerable-to-vulnerable class and Purali and Chamiyala village shifted from highly resilient and resilient to moderate class. The villages under different resilience and vulnerability class in the different scenario were given in Table 5.

Table 5. Villages under different vulnerable class in different scenario and reason.

Village	Resilience	Present Vulnerability	Reason	Future Vulnerability	Reason
Baijkot	resilient	resilient	Less stress for climate related effects	resilient	High natural and financial capital and low dependency on climate sensitive resources
Barsu	highly resilient	resilient	high stress for climate related effects	resilient	High physical and financial capital for adaptation to climate stress
Bayana	resilient	moderate	high stress for climate related effects	moderate	High financial capital and less dependency on climate sensitive resources
Bhatwary	moderate	moderate	Moderate to less stress for climate related effects	moderate	High physical capital and support due to block and circle headquarter
Gajoli	vulnerable	vulnerable	Moderate to less stress for climate related effects	highly vulnerable	high dependency on agriculture and low financial capital
Garat	moderate	moderate	Moderate to less stress for climate related effects	moderate	High human capital and less dependency on climate sensitive resources
Hadiyari	highly resilient	moderate	High dependency on natural capital and low financial capital to cope up with	moderate	Less dependency on climate sensitive resources
Hitanu	resilient	moderate	high stress for climate related effects	moderate	Less dependency on agriculture
Ladari	highly vulnerable	highly vulnerable	Less stress for climate related effects	highly vulnerable	Less dependency on agriculture
Pata	highly resilient	highly resilient	Moderate to less stress for climate related effects	highly resilient	High physical and financial capital to cope up with the stress
Purali	highly resilient	highly resilient	high stress for climate related effects	moderate	High dependency on climate sensitive resources and natural capital

Table 5. *Cont.*

Village	Resilience	Present Vulnerability	Reason	Future Vulnerability	Reason
Kumrada	resilient	moderate	Low physical capital and medium effect of climate stress	vulnerable	Low physical capital and medium effect of climate stress
Dharali	vulnerable	highly vulnerable	Low financial capital and high stress for climate related effects	highly vulnerable	High dependency on climate sensitive resources and less financial capital to cope up with stress
Indragaon	resilient	resilient	Less stress for climate related effects	resilient	Less stress for climate related effects
Barsali	vulnerable	vulnerable	Moderate to less stress for climate related effects	highly vulnerable	Low human capital and dependency on climate sensitive resources
Sitakot	moderate	moderate	Moderate to less stress for climate related effects	moderate	Moderate to less stress for climate related effects
Chamiyala	resilient	resilient	moderate stress for climate related effects	moderate	Low natural capital and high agricultural dependency
Srikot	resilient	resilient	Less stress for climate related effects	resilient	Less stress for climate related effects
Pakh	moderate	vulnerable	high stress for climate related effects	highly vulnerable	High dependency on climate sensitive resources
Koti	vulnerable	vulnerable	Moderate to less stress for climate related effects	highly vulnerable	Low financial capital and high dependency on climate sensitive resources
Kyalbagi	vulnerable	highly vulnerable	Low financial capital and moderate stress of climate change	highly vulnerable	Low financial capital and moderate stress of climate change
PataT	vulnerable	highly vulnerable	high stress for climate related effects	highly vulnerable	high stress for climate related effects
Khand	highly vulnerable	highly vulnerable	Moderate to less stress for climate related effects	highly vulnerable	Moderate to less stress for climate related effects
Dharwal	moderate	moderate	Less stress for climate related effects	vulnerable	High dependency on climate sensitive resources

Table 5. *Cont.*

Village	Resilience	Present Vulnerability	Reason	Future Vulnerability	Reason
Ramgarh	vulnerable	vulnerable	Moderate to less stress for climate related effects	vulnerable	Moderate to less stress for climate related effects
Pipola	vulnerable	vulnerable	high stress for climate related effects	highly vulnerable	Low human capital and high dependency on climate sensitive resources
Musangaon	moderate	vulnerable	high stress for climate related effects	vulnerable	high stress for climate related effects
Girgaon	highly vulnerable	highly vulnerable	Moderate to less stress for climate related effects	highly vulnerable	Moderate to less stress for climate related effects
Gujetha	highly vulnerable	highly vulnerable	Moderate to less stress for climate related effects	highly vulnerable	Moderate to less stress for climate related effects
Pabela	moderate	vulnerable	high stress for climate related effects	vulnerable	high stress for climate related effects
Musangaon	moderate	vulnerable	high stress for climate related effects	vulnerable	high stress for climate related effects

5. Discussion

South Asia is home of about 600 million poor people of a total of about 1.5 billion people residing in and the number exceeds half of the world's total poor and marginalized people and their dependency on climate sensitive sectors like agriculture, forestry and other natural resources are high for the fulfillment of day-to-day needs [59]. As an extremely vulnerable region to climatic hazards 750 million people of South Asia were affected between 1990 and 2006 and experiences 230,000 deaths and damages that cost about $45 billion [60]. Countries in the Hindukush Himalayan region, includes India, Bangladesh, Nepal, Bhutan and Pakistan are facing increased frequency and magnitude of extreme weather events and more extreme weather events are likely due to climate change in future, and this will worsen the situation of South Asia over the next decades [61,62]. Extreme temperature reduces yields of agricultural crops and exposes the land for weed and pest proliferation whereas changes in the precipitation pattern increases the chance of crop failure and ultimately causes production decline in the long run and will ultimately threatens food security [63]. The overall impact of climate change on the agricultural sector is likely to be negative, although for some crops there will be gain in production to some specific regions to some extent [57]. As the global climate change shows its effect over the last two decades, sectors like biodiversity, human health, water and energy, agriculture and food security will get intense stress and will cause immense poverty and vulnerability in South Asia [59,62].

The Himalayan ecosystem is the lifeline of the people of South Asia, mostly the people living in the flood plains of the major rivers and their tributaries. The impact of climate change is predicted to change the flow of river water mostly during the dry summer season and expected to have large scale impact on irrigation, hydropower and other ecosystem services [62,64]. In the present study, the innate resilience of the households and villages of Indian Western Himalaya was assessed on the basis of the assets and capitals of the particular households. The difference in the resilience score and differences in assets to form different clusters are mainly based on natural, financial, physical and human capital. Although vulnerability or resilience of the villages depends on multiple components, identified as indicators and all the indicators act differently and additively for portraying vulnerability. All the indicators taken in the natural capital and most of the indicators of financial capital were directly dependent on nature and thus under the effect of climate related responses of different environmental parameters. On an average 64.66% of the financial capital value of the households are dependent on the climate variables. Production of all agricultural products are likely to be affected with change in temperature in future climate scenario. Hence, change in the availability of these parameters had changed the indicator values and had shifted the household and villages to the next vulnerable or resilient classes (Table 5). The villages which were highly dependent on agriculture and natural resources were prone to climate change impact and the vulnerability scores of the villages were also found low and grouped in vulnerable and highly vulnerable classes. It is evident from the result, that the villages of Tehri Garhwal are much more vulnerable. Human capital is found to be less in households and villages surveyed in Tehri Garhwal district. Due to the inception of Tehri Dam and the new township, most of the villages in the periphery of the dam lost the bulk of their agricultural area. Although compensatory schemes were given, but the one-time financial assistance for that inevitable loss of the land to the agriculture dependent community was not sufficient for generating enough livelihood options for the residents. The youth of those villages were compelled to leave for the nearest township for better livelihood resulting in the decrease of human capital for the households and the villages. Villages near the town and on the road connectivity to the several pilgrimage areas get some financial assistance from small scale businesses, but others deprived of the facility are under the shock of the developmental prejudice. The shock generated from the climate related hazards cannot be bearable by the households and the villages having less capital or assets and minimum livelihood options. Thus, the status of resilient household and villages changes as per their coping potentials. In the Indian Himalayan region, under the fragile landscape and the arduous geophysical condition livelihood option of the inhabitants are very much restricted and mostly dependent on the natural resources available to them. The change in the availability of natural resources and bioclimatic factors are thus crucial for their future livelihood strategies. The chances of getting other sources of income being there is negligible so far. The trend of outmigration for a better livelihood facility was also documented.

Strategies envisioned for future climate change adaptation should be developed with the full understanding of the complexities involved that causes the vulnerability at the present time [6]. The place and time specific configuration of three analytical components, the human ecology, expanded entitlement and political economy define the dimensions of the vulnerability. The dimension of vulnerability that determines the risk exposure, coping capacity and recovery potential is defined by the three components [6,19]. Vulnerability analysis helps to identify the vulnerable and resilient group of households or villages. It also allows the clear identification of whether there are other important factors that threaten the livelihood and resilience of the inhabitants except climate change. The analysis can assist in the designing of the safety nets or interventions that will help in the method of reducing the risk or improve the risk management capacity (resilience). As Vulnerability analysis is done using multiple indicators it is able to accommodate the multiple dimensions in terms of asset base, the flow of income, farming productivity, access to social and government support, resources and services at the households, etc. Thus, the profiling of vulnerable groups can be built and factors can be identified for improving the reliability of safety nets [7]. The present study gives a replicable analytical framework to use different indicators for analysis of innate resilience and vulnerability of villages in the Indian Himalayan Region. The process of evaluation of vulnerability and resilience can be followed for assessing the same at a landscape level and will be helpful for future administrative and policy level interventions. Hence, the result of the present study has manifold implications on the policy level to decide where the assistance is needed, how much is needed, and for how long as per the framework of household economy approach.

6. Conclusions

Before vulnerability can be addressed, it is vital to identify who is vulnerable and to what extent. Vulnerability assessment allows investigation of the complex relationship of socioeconomic and demographic factors that are being impacted by different climate stressors. The Indian Himalayan region is socioeconomically vulnerable to climate change. Imbalance in wealth distribution, remote rural population and dependency on agriculture for the economic stabilization enhance the chances of vulnerability. The index-based approach used in the present study is useful to assess both the impacts and the societal capabilities to adapt to climate change effects. The present study has explored the analytical utility of using index-based assessment of adaptive capacity and thus provides an assessment tool that can be used on a local scale and assess household and village-level adaptive capacity. The methodology can also be adopted to compare and contrast adaptive capacity and vulnerability in larger spatial scale and different socioeconomic settings. The study identifies both the villages and the factors responsible for the resilience and vulnerability that can be used and integrated into microplanning and macro-policy development for better resource allocation to the vulnerable community as part of the climate change mitigation and adaptation planning.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/17/6938/s1, Figure S1: Age-class distribution in the respondents, Figure S2: Ratio of between and Total sum of squares of cluster numbers, Figure S3: Range of each variables used for village clustering, in each cluster (a) village resilience score; (b) Human capital; (c) Natural Capital; (d) Financial capital; (e) Physical capital, Table S1: Households in different clusters, Table S2: Villages of Uttarkashi and Tehri Garhwal districts under different cluster and sub-clusters.

Author Contributions: S.D.: Conceptualization, methodology, investigation, formal analysis, writing—original draft preparation; R.B.: conceptualization, supervision, methodology, visualization, writing—reviewing and editing, project administration. All authors have read and agreed to the published version of the manuscript.

Funding: Department of Science and Technology, Govt of India, Grant Number-DST/SPLICE/CCP/NMSHE/TF-2/WII/2014 [G].

Acknowledgments: The study is a part of National Mission for Sustaining the Himalayan Environment (NMSHE) Project under Wildlife Institute of India. Authors want to acknowledge the Director, Wildlife Institute of India, G.S. Rawat, Dean (Wildlife studies) Wildlife Institute of India, S. Sathyakumar Nodal Scientist, National Mission for sustaining Himalayan Environment (NMSHE) project, Wildlife Institute of India for their help and support throughout the study. The work was carried out under the financial support of Department of Science and Technology (DST), Govt. of India, Grant Number-DST/SPLICE/CCP/NMSHE/TF-2 / WII/2014 [G]. Authors want to thank TIME LEARN Project of Department of Science and Technology, Govt of India, for partial funding support. Authors want to thank Papori Khatonier, Ashish Kumar, Monideepa Mitra and Tamali Mondal for helping in data collection and data entry. Tapajit Bhattacharya and Pariva Dobriyal were thanked for their suggestion for improving the manuscript.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

References

1. Bolin, B. The Kyoto negotiations on climate change: A scientific perspective. *Science* **1998**, *279*, 330–331. [CrossRef]
2. Wigley, T.M.L.; Richels, R.; Edmonds, J.A. Economic and environmental choices in the stabilization of atmospheric CO2 concentrations. *Nature* **1996**, *379*, 240–243. [CrossRef]
3. Fussel, H.M.; Klein, J.T.R. Climate change vulnerability assessments: An evolution of conceptual thinking. *Clim. Chang.* **2006**, *75*, 301–329. [CrossRef]
4. Rajesh, S.; Jain, S.; Sharma, P.; Bhahuguna, R. Assessment of inherent vulnerability of rural communities to environmental hazards in Kimsar region of Uttarakhand, India. *Environ. Dev.* **2014**, *12*, 16–36. [CrossRef]
5. Summary for Policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability. WGII, Fifth Assessment Report (AR5). 2014. Available online: http://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf (accessed on 28 April 2014).
6. Bohle, H.G.; Downing, E.T.; Watts, M.J. Climate change and social vulnerability Toward a sociology and geography of food insecurity. Global Environmental change-human and policy dimensions. *Glob. Environ. Chang.* **1994**, *4*, 37–48. [CrossRef]
7. Adger, W.N. Social aspects of adaptive capacity. In *Climate Change, Adaptive Capacity and Development*; Smith, J.B., Klein, R.J.T., Huq, S., Eds.; Imperial College Press: London, UK, 2003.
8. Dev, S.M. Climate Change, Rural Livelihoods and Agriculture (Focus on Food Security) in Asia-Pacific Region. Indira Gandhi Institute of Development Research: Mumbai, India, 2011. Available online: http://www.igidr.ac.in/pdf/publication/WP-2011-014.pdf (accessed on 22 May 2013).
9. Magrath, J.; Bray, I.; Scriven, K. *Climate Alarm, Disasters Increase as Climate Change Bites. From Weather Alert to Climate Alarm*; Oxfam Briefing Paper; Oxfam International: Oxford, UK, 2007.
10. Goswami, B.N.; Venugopal, V.; Sengupta, D.; Madhusoodanan, M.S.; Xavier, P.K. Increasing trend of extreme rain events over India in a warming environment. *Science* **2006**, *314*, 1442–1445. [CrossRef]
11. Kumar, A. Demystifying a Himalayan tragedy: Study of 2013 Uttarakhand disaster. *J. Indian Res.* **2013**, *1*, 106–116.
12. Sharma, M.; Mishra, S.K.; Tyagi, S. The Impact of Torrential Rainfall in Kedarnath, Uttarakhand, India during June, 2013. *Int. Res. J. Environ. Sci.* **2013**, *2*, 34–37.
13. Watts, M.; Bohle, H.G. The space of vulnerability. The causal structure of hunger and famine. *Prog. Hum. Geogr.* **1993**, *17*, 43–67. [CrossRef]
14. Nelson, D.R.; Adger, W.N.; Brown, K. Adaptation to Environmental Change: Contributions of a Resilience Framework (PDF). *Annu. Rev. Env. Resour.* **2007**, *32*, 395–419. [CrossRef]
15. Folke, C. Resilience: The emergence of a perspective for social-ecological systems analyses. *Glob. Environ. Chang.* **2006**, *16*, 253–267. [CrossRef]
16. Lundberg, M.; Wuermli, A. *Children and Youth in Crisis: Protecting and Promoting Human Development in Times of Economic Shocks*; World Bank: Washington, DC, USA, 2012. [CrossRef]
17. Sen, A.K. *Development as Freedom*; Oxford University Press: Oxford, UK, 1999.
18. FAO. *Climate Change and Food Security: A Framework Document*; Food and Agriculture Organisation of United Nations: Rome, Italy, 2008.
19. Karfakis, P.; Velazco, J.; Moreno, E.; Covarrubias, K. *Impact of Increasing Prices of Agricultural Commodities on Poverty*; ESA Working Paper Series, No. 2011b; FAO: Rome, Italy, 2011; pp. 11–14. [CrossRef]

20. Skoufias, E.; Quisumbing, A.R. Consumption Insurance and Vulnerability to Poverty: A Synthesis of the Evidence from Bangladesh, Ethiopia, Mali, Mexico and Russia. *Eur. J. Dev. Res.* **2005**, *17*, 24–58. [CrossRef]
21. Sen, A.K. *Poverty and Famines: An Essay on Entitlement and Deprivation*; Clarendon: Oxford, UK, 1981.
22. Adger, W.N. Social vulnerability to climate change and extremes in coastal Vietnam. *World Dev.* **1999**, *27*, 249–269. [CrossRef]
23. Hewitt, K. *Regions of Risk: A Geographical Introduction to Disasters*; Longman: Harlow, UK, 1997.
24. Hewitt, K. *Interpretations of Calamity from the Viewpoint of Human Ecology*; Allen and Unwin: Boston, MA, USA, 1983.
25. Ribot, J.C.; Magalhães, A.R.; Panagides, S.S. *Climate Variability, Climate Change and Social Vulnerability in the Semi-Arid Tropics*; Cambridge University Press: Cambridge, UK, 1996.
26. Smit, B.; Wandel, J. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 282–292. [CrossRef]
27. Van der Veen, A.; Logtmeijer, C. Economic hotspots: Visualizing vulnerability to flooding. *Nat. Hazards* **2005**, *36*, 65–80. [CrossRef]
28. Brooks, N.; Adger, W.N.; Kelly, P.M. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environ. Chang.* **2005**, *15*, 151–163. [CrossRef]
29. Adger, W.N.; Brooks, N.; Bentham, G.; Agnew, M.; Eriksen, S. *New Indicators of Vulnerability and Adaptive Capacity*; Technical Report 7, Tyndall Centre for Climate Change Research; University of East Anglia: Norwich, UK, 2004.
30. Kelly, P.M.; Adger, W.N. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Clim. Chang.* **2000**, *47*, 325–352. [CrossRef]
31. Armaş, I.; Gavriş, A. Census-based social vulnerability assessment for Bucharest. *Procedia Environ. Sci.* **2016**, *32*, 138–146. [CrossRef]
32. Dunning, C.M.; Durden, S.E. Social Vulnerability Analysis: A Comparison of Tools; Institute for Water Resources, 2013. Available online: http://www.iwr.usace.army.mil/docs/iwrreports/2011-R-07.pdf (accessed on 17 July 2020).
33. Tapsell, S.; McCarthy, S.; Faulkner, H.; Alexander, M. *Social Vulnerability to Natural Hazards*; State of the art report from CapHaz-Net's WP4: London, UK, 2010.
34. Schmidtlein, M.C.; Deutsch, R.C.; Piegorsch, W.W.; Cutter, S.L. A sensitivity analysis of the social vulnerability index. *Risk Anal.* **2008**, *28*, 1099–1114. [CrossRef]
35. Rygel, L.; O'sullivan, D.; Yarnal, B. A method for constructing a social vulnerability index: An application to hurricane storm surges in a developed country. *Mitig. Adapt. Strateg. Glob. Chang.* **2006**, *11*, 741–764. [CrossRef]
36. Vincent, K. Creating an index of social vulnerability to climate change for Africa. *Tyndall Cent. Clim. Chang. Res. Work. Pap.* **2004**, *56*, 41.
37. Cutter, S.; Boruff, B.J.; Shirley, W.L. Social vulnerability to environmental hazards. *Soc. Sci. Quart.* **2003**, *84*, 242–261. [CrossRef]
38. Pandey, R.; Jha, S. Climate vulnerability index-measure of climate change vulnerability to communities: A case of rural Lower Himalaya, India. In *Mitigation and Adaptation Strategies for Global Change*; Springer: Berlin/Heidelberg, Germany, 2012; Volume 17, pp. 487–506.
39. Smit, B.; Pilifosova, O. Adaptation to climate change in the context of sustainable development and equity. In *Climate Change Impacts, Adaptation and Vulnerability*; IPCC Working Group II, McCarthy, J.J., Canziani, O., Leary, N.A., Dokken, D.J., White, K.S., Eds.; Cambridge University Press: Cambridge, UK, 2001; pp. 877–912.
40. Legese, S.A.; Olutayo, O.A.; Sulaiman, H.; Rao, P. Assessing climate change impacts in the Lake Tana Sub-Basin, Ethiopia using livelihood vulnerability approach. *J. Earth Sci. Clim. Chang.* **2016**, *7*, 368. [CrossRef]
41. Can, N.D.; Tu, V.H.; Hoanh, C.T. Application of livelihood vulnerability index to assess risks from flood vulnerability and climate variability-A case study in the Mekong Delta of Vietnam. *J. Environ. Sci. Eng.* **2013**, *A2*, 476.
42. Hahn, B.M.; Riederer, A.M.; Foster, S.O. The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Glob. Environ. Chang.* **2009**, *19*, 74–88. [CrossRef]
43. Cariolle, J. *The Economic Vulnerability Index*; FERDI Working Paper: Clermont-Ferrand, France, 2011.

44. Gerlitz, J.Y.; Macchi, M.; Brooks, N.; Pandey, R.; Banerjee, S.; Jha, S.K. The Multidimensional Livelihood Vulnerability Index–An instrument to measure livelihood vulnerability to change in the Hindu Kush Himalayas. *Clim. Dev.* **2017**, *9*, 124–140. [CrossRef]
45. Urothody, A.A.; Larsen, H.O. Measuring climate change vulnerability: A comparison of two indexes. *Banko Janakari* **2010**, *20*, 9–16. [CrossRef]
46. Cutter, S.L.; Finch, C. Temporal and spatial changes in social vulnerability to natural hazards. *Proc. Natl. Acad. Sci. USA* **2008**, *7*, 2301–2306. [CrossRef]
47. Reed, M.S.; Podesta, G.; Fazey, I.; Geeson, N.; Hessel, R.; Hubacek, K.; Ritsema, C. Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. *Ecol. Econ.* **2013**, *94*, 66–77. [CrossRef]
48. Car, E.R. Between structure and agency: Livelihoods and adaptation in Ghana's Central Region. *Glob. Environ. Chang. Hum. Policy Dimens.* **2008**, *18*, 689–699. [CrossRef]
49. Ge, Y.; Dou, W.; Liu, N. Planning Resilient and Sustainable Cities: Identifying and Targeting Social Vulnerability to Climate Change. *Sustainability* **2017**, *9*, 1394. [CrossRef]
50. Nguyen, T.T.X.; Bonetti, J.; Rogers, K.; Woodroffe, C.D. Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices. *Ocean Coast. Manag.* **2016**, *123*, 18–43. [CrossRef]
51. Singh, S.R.; Eghdami, M.R.; Singh, S. The Concept of Social Vulnerability: A Review from Disasters Perspectives. *Int. J. Interdiscip. Multidiscip. Stud. (IJIMS)* **2014**, *1*, 71–82.
52. Yoon, D.K. Assessment of social vulnerability to natural disasters: A comparative study. *Nat. Hazards* **2012**, *63*, 823–843. [CrossRef]
53. Vincent, K. Uncertainty in adaptive capacity and the importance of scale. *Glob. Environ. Chang.* **2007**, *17*, 12–24. [CrossRef]
54. Niles, M.T.; Salerno, J.D. A cross country analysis of climate shocks and smallholder food insecurity. *PLoS ONE* **2018**, *13*, e0192928. [CrossRef] [PubMed]
55. Rodgers, W.A.; Panwar, H.S.; Mathur, V.B. *Wildlife Protected Area Network in India: A Review*; Wildlife Institute of India: Dehradun, India, 2000; p. 44.
56. Lawrence, M.; Holzmann, P.; O'Donnell, M.; Adams, L.; Holt, J.; Hammond, L.; Duffield, A. The Practitioners' Guide to the Household Economy Approach. In *Save the Children*; Boudreau, T., Ed.; Save the Children: London, UK, 2008.
57. Challinor, A.J.; Watson, J.; Lobell, D.B.; Howden, S.M.; Smith, D.R.; Chhetri, N. A meta-analysis of crop yield under climate change and adaptation. *Nat. Clim. Chang.* **2014**, *4*, 287. [CrossRef]
58. Bi, D.; Dix, M.; Marsland, S.J.; O'Farrell, S.; Rashid, H.; Uotila, P.; Hirst, A.; Kowalczyk, E.; Golebebiewski, M.; Sullivan, A.; et al. The ACCESS coupled model: Description, control climate and evaluation. *Aust. Meteorol. Ocean. J.* **2013**, *63*, 41–64. [CrossRef]
59. Ahmed, M.; Suphachalasai, S. *Assessing the Costs of Climate Change and Adaptation in South Asia*; Asian Development Bank: Mandaluyong City, Philippines, 2014.
60. World Bank. 2009. Available online: http://go.worldbank.org/OJ4FWPUB10 (accessed on 20 December 2017).
61. Xu, J.; Badola, R.; Chettri, N.; Chaudhary, R.P.; Zomer, R.; Pokhrel, B.; Hussain, S.A.; Pradhan, S.; Pradhan, R. Sustaining Biodiversity and Ecosystem Services in the Hindu Kush Himalaya. In *The Hindu Kush Himalaya Assessment*; Wester, P., Mishra, A., Mukherji, A., Shrestha, A., Eds.; Springer: Cham, Switzerland, 2019.
62. ADB. *Building Climate Resilience in the Agriculture Sector in Asia and the Pacific*; ADB/International Food Policy Research Institute: Manila, Philippines, 2009.
63. Nelson, G.C.; Rosegrant, M.W.; Koo, J.; Robertson, R.; Sulser, T.; Zhu, T.; Ringler, C.; Msangi, S.; Palazzo, A.; Batka, M.; et al. *Climate Change: Impact on Agriculture and Costs of Adaptation*; Food policy reports 21; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2009.
64. Singh, P.; Bengtsson, L. Hydrological sensitivity of a large Himalayan basin to climate change. *Hydrol. Process* **2004**, *18*, 2363–2385. [CrossRef]