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Case Study

A Pragmatic Approach to Study Vulnerability Using Livelihood Vulnerability Index: A Case Study from Cold Desert of Nubra Valley, Ladakh (Himalaya)

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Abstract: Livelihood Vulnerability Index (LVI) is being proposed to assess the degree of vulnerability and adaptability against the impacts of natural disasters in the Nubra valley. The index comprises households variables of all the three dimensions of vulnerability such as Exposure, Sensitivity, and Adaptive Capacity. Exposure is described by 'Natural disaster', 'Its impact', and 'Flood warning'. Sensitivity is defined by 'Water', 'Housing', 'Health' and 'Finance', and Adaptive Capacity by 'Socio-demographic profile', Livelihood strategies', 'Food', and 'Social networks'. The study is based on the primary data and information collected from 300 sample households in the three blocks such as Turtuk, Diskit, and Panamik in the Nubra valley (Union Territory of Ladakh), India. Data were aggregated using a composite index and disparity vulnerabilities were compared. The result reveals that Panamik block was higher exposed (0.402) to the impacts of natural disasters and higher sensitivity (0.333) of water, housing, health, and finance due to the less adaptive capacity 0.298) of socio-demographic profile, livelihood strategies, food, social network in respect to other blocks. The LVI of Turtuk 0.889, Diskit 0.836, and Panamik 0.904 or LVI-IPCC was 0.004, -0.017, and 0.035 for Tutuk, Diskit and Panamik blocks, respectively, and this suggests that overall vulnerability was higher to Panamik households, and least vulnerability to Diskit households. This pragmatic LVI approach may be used to monitor vulnerability under different stress situations. The result obtained by LVI may have implications for improving adaptation or coping strategies to the region.

***Keywords*:** livelihood vulnerability index, natural disaster, flood, Ladakh, adaptation, Nubra valley

JEL Codes: C83, Q23, Q24, Q25, Q54

1. Introduction

The Himalayan mountain communities are highly vulnerable to the adverse impacts of climate change such as floods, cloudbursts, droughts, and landslides (Tran et al., 2021), and natural disasters have frequently occurred because of poor adaptive capacity, high sensitivity of water, health due to socio-economic factors, and its harsh climate as compare to other regions (Baffoe & Matsuda, 2018). According to the report of the United Nation Office for Disaster

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Risk Reduction (UNDRR), 2020 "Human losses from disasters 2000-2019" that the total number of world natural disasters has increased from 3,656 to 6,681, due to which high intensity of extreme rainfall arisen in a short duration, led to flash floods and landslides which causing massive casualties and property losses, and affected population has also raised from 3.2 billion to 3.9 billion in 2000-2019 (Yang et al., 2021). Furthermore, according to the reports, from 2010 to 2019, the frequency of the occurrence of natural disasters caused by heavy rain led to caused cloudbursts events in the Himalayan Mountains was around 74-90% (Huang et al., 2020). The global economic loss was USD 46.20 billion, and the number of people affected was reached 179.603 million (Zhou et al., 2021). The adverse impacts of natural disasters caused by climate change have threatened the livelihoods of the mountain communities. Thus, the fragile ecosystem of rural mountain communities needs special attention in order to strengthen livelihood opportunities by improving their indigenous adaptation strategies, local coping methods and focusing on scientific research to comprehend the causes of livelihood vulnerability due to the impacts of climate change (Priya et al., 2016).

The livelihood vulnerability of the mountain communities are relatively high and the magnitude of vulnerability does differ from region to region and community to community (Paudel et al., 2020). The study of mountain residents' vulnerability is significant to understand the deep extent of vulnerability in different livelihood components. In fact, one of the extreme vulnerabilities caused by the adverse impacts of natural disasters because of which the rural mountain communities become poorer and more vulnerable (Pandey & Jha, 2012). Thus, the extensive ground effective research on rural vulnerability could be helpful to the developmental planner to cope with the exposure of natural disasters, and its impacts, and to improve the adaptive capacity of the rural mountain peoples' (Nath et al., 2019).

Nubra valley is a cold desert in the mountain regions of trans- the Himalayas which is a very fragile ecosystem and has high sensitivity to various factors such as water because glacier melt water is the only source of water in the Nubra valley and due to any climatic variability it has direct impacts to the supply of water (Chevuturi & Thayyen, 2018). In fact, the Khardong La glacier of Nubra valley was receded up to 19.5 km which is on the edge of extinction (Gupta et al., 2012). Furthermore, in August 2010, natural disasters happened in the Leh town in which more than 255 people had killed, and destroyed 1,749 houses in 52 villages, and affected an area around 1,420 hectares of land. Moreover, the effect of the flash flood caused serious damage to the roads, bridges, and hospitals in the surrounding villages of Leh town and Turtuk Nubra (Tashi & Sudan, 2021). As a result, people of the region faced various problems and it has directly threatened to their livelihoods and economy which makes them more vulnerable and sensititive to the impacts of climate change.

In the present study, the index developed by Hahn et al. (2009) was modified by adding new components such as housing and finance. This part was added as in local situation, both the components finance and housing are utmost roles to increase or decrease of their livelihoods option. In several studies, the index was modified according to the local needs of research which make it a more flexible and innovative approach to be applied. Thus, the aim of this study is to determine the vulnerability of high prone or less prone areas to natural disasters of exposure such as floods, cloudbursts, landslides, and the sensitivity of health, water, housing, and finance caused by natural disasters or socio-economic factors, and also to evaluate the impacts of climate events to local livelihood using the methodologies of livelihood vulnerability index and Livelihood Vulnerability Index of Intergovernmental Panel on Climate Change (LVI-IPCC). Accordingly, to evaluate the indices of Socio-demographic components, Food and Livelihood options to adapt to the impacts of natural disasters and how these adaptation strategies reduce the livelihood vulnerability in the three blocks of Nubra valley, Ladakh.

2. Literature review

According to LVI-IPCC, the vulnerability assessment of any region to climate change exposed to natural disasters is dependent on the nature, rate, and the degree of the impacts of climate change and variation to which the region is exposed, its sensitivity, and its adaptive capacity (IPCC, 2018). The exposure to climate change such as floods, cloudbursts, and landslides are higher in the communities of cold arid areas whereas, the exposure to climate change of cyclones is more in the coastal communities (Houng et al., 2019). Sensitivity is the magnitude to which a region is either adversely or positively, directly or indirectly affected by the impacts of climate change and variability (IPCC, 2014a).

The climate change is a global issue and its impacts on the environment, agriculture, and health is a serious concern

over the world (Endalew & Sen, 2020). Throughout the 21st century, the vulnerability of the mountain region has been rising especially due to the climate variability and high exposure of natural disasters (Nath et al., 2020). The natural disaster has negative potential effects on the poor, marginalized and rural livelihoods in a multi-dimensional ways (Khanal et al., 2018) and the Intergovernmental Panel on Climate Change (IPCC) reported that the impacts of climate change are more on agricultural activities of hilly or mountain areas (IPCC, 2014b). Thus, the mountain regions are highly vulnerable because of its fragile ecosystem, less adaptive capacity, and high sensitivity (Mehzabin & Mondal, 2021).

Himalayan mountain communities are the most vulnerable region of the natural disasters in the world due to its fragile environment and socio-economics backwardness (Parvin et al., 2016). The livelihoods of 84% population of this region are severely affected by floods, cloudbursts, and droughts, etc. This type of disturbance has been rising in the areas where people have the least amount of financial availability, social opportunity, and political power to effectively deal with the external disasters (Hoq et al., 2021). Moreover, the lack of health facilities, infrastructure accessibility, and livelihood opportunities leads uneven exposure to environmental threats (Alam et al., 2016). The rural communities always tend to traps in a vicious circle of vulnerability with the impacts of natural events, and as a result, they become poorer and more vulnerable as compared to other regions (Paudel et al., 2020).

The Greater Himalayan mountain region is covered by 17% of glaciers, and snow which provids water supply to most of the Asian countries and is receding more rapidly (Adu et al., 2018). The rate of receding has been drastically increasing in recent years due to global warming, and the glaciers located on the Tibetan Plateau are likely to shrink from 500,000 km^2 (the 1995 baseline) to 100,000 km^2 by 2035 (Panthi et al., 2016). As a result, caused several types of natural events have frequently occurred in recent years, thus, water vulnerability is a serious issue in the Himalayan region. Ladakh region is situated in the Trans-Himalaya, and they are highly sensitive to the impacts of climate-related events due to their agrarian economy. Where, agriculture is the most leading livelihoods and a foremost driver of socio-economic development (Simotwo et al., 2018). However, the impacts of climate change have severely damaged to the farming activity due to flood, and cloudbursts causing more vulnerable to the agriculture dependent livelihood.

The Livelihood Vulnerability Index (LVI) was used to measure the vulnerability of agricultural households to climate change and its impacts (Hoq et al., 2021). This index was developed by Hahn et al. (2009). There are two types of indices that are measured on the basis of different indicators. The Livelihood Vulnerability Index (LVI) is a composite index of all major components, while the LVI-IPCC vulnerability is to assess the major components of three contributing factors such as exposure, sensitivity, and adaptive capacity. The LVI framework comprise of different variables indicating the level of exposure, sensitivity, and adaptive capacity to climate-encouraged disasters such as cloudbursts, droughts, floods, landslides, etc. The LVI is a method to identify how vulnerability varies among different place even among the same regions and to understand the key factors contributing to vulnerability, highlights adaptive strategies to reduce the sensitivity, level of exposure and also to assess how efficient these adaptive strategies to reducing the vulnerable level of the concerned area (Madhuri et al., 2014). In the past decade, the LVI has become a significant of assessing farmers' vulnerability to climate change and disasters around the world (Baffoe & Matsuda, 2018).

In none of the above studies in Nubra valley, vulnerability assessment of natural disasters on local livelihood was studied. There was a study on perceived impacts on economic activities and adaptation strategies to climate change and its impacts (Tashi & Sudan, 2021). Clearly, there is a research gap in Nubra valley regarding the Livelihood vulnerability index to determine the diversity of vulnerability on local livelihood and it caused of exposure, sensitivity, and adaptive capacity using different indicators. Similar researches were conducted in different area such as at two districts in Mozambique (Hahn et al., 2009), for Flood-prone Haor Ecosystem of Bangladesh (Hoq et al., 2021), in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo region of Ghana (Adu et al., 2018), for char land communities of Bangladesh (Azam et al., 2019), for mixed agro-livestock smallholders in three ecological zones in the Gandaki River Basin of central Nepal (Panthi et al., 2016).

The susceptibility of agricultural households to climate change and its effects was assessed using the Livelihood Vulnerability Index (LVI) (Hoq et al., 2021). Hahn et al. (2009) created this index. There are two categories of indices that are calculated using various indicators. The LVI-IPCC vulnerability is used to evaluate the primary components of three contributing aspects, such as exposure, sensitivity, and adaptive capability. The Livelihood Vulnerability Index (LVI) is a composite index of all significant components. The LVI framework includes various factors that show the degree of exposure, sensitivity, and the ability for adaptation to disasters caused by climate change, such as cloudbursts, droughts, floods, and landslides, among others.

The LVI is a method to determine how vulnerability varies between locations, even within the same regions, and to comprehend the primary causes of vulnerability. It also highlights adaptable strategies to reduce sensitivity and level of exposure and evaluates how effective these strategies are at lowering the vulnerability of the concern area (Madhuri et al., 2014). The LVI has grown significantly during the past ten years as a tool for determining how vulnerable farmers are to catastrophes and climate change globally (Baffoe & Matsuda, 2018). for char land communities of Bangladesh (Azam et al., 2019), for mixed agro-livestock smallholders in three ecological zones in the Gandaki River Basin of central Nepal (Panthi et al., 2016).

The impact of natural disasters on local livelihoods was not examined in any of the aforementioned studies in the Nubra valley. A study was conducted on the perceived effects of climate change on economic activity and adaption measures (Tashi & Sudan, 2021). There is undoubtedly a study void in the Nubra valley regarding the Livelihood Vulnerability Index, which is used to assess the many livelihood vulnerabilities and how exposure, sensitivity, and adaptive capability contribute to them. Similar studies were carried out in several locations, including two districts in Mozambique (Hahn et al., 2009), Bangladesh's flood-prone Haor Ecosystem (Hoq et al., 2021), Ghana's Brong-Ahafo region (Adu et al., 2018), and for char land communities of Bangladesh (Azam et al., 2019), for mixed agro-livestock smallholders in three ecological zones in the Gandaki River Basin of central Nepal (Panthi et al., 2016).

3. Study area

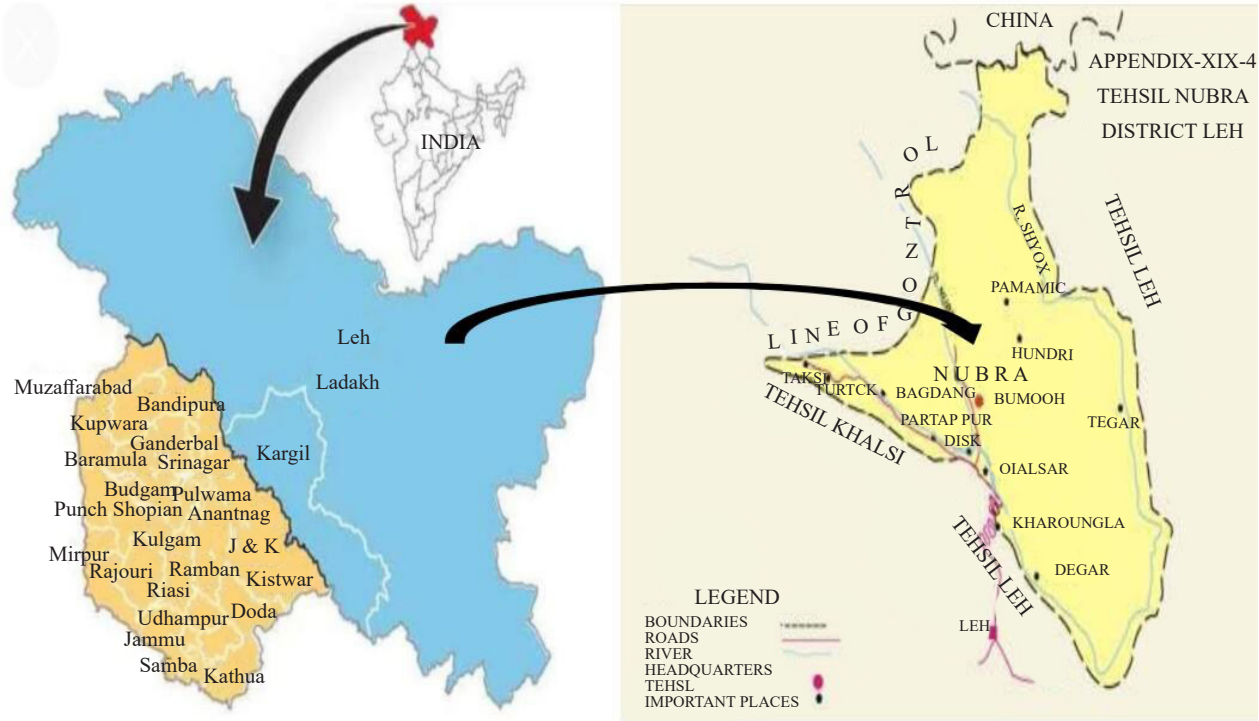


Figure 1. Map of the study area

The present household survey was undertaken in Nubra valley (Union territory of Ladakh) lies between the two well-known Himalayan mountain ranges i.e., the Karakoram (on the North), and the Ladakh (on the South). The Nubra valley is situated between 34° 15' 45' to 35° 31' 00' N and 76° 55' to 78° 05' E in the cold desert area of Karakoram mountain range of Himalaya, Union Territory of Ladakh, India (Figure 1). The climate of the regions is extremely harsh with scanty rainfall along with less moisture contained in air. The minimum temperature in winter drop to -30 °C, and the maximum temperature is around 25 °C in the summer. In Nubra valley, the source and supply of water from glaciers

is the only option for irrigation purposes, and portable water which is flowing through the two main rivers such as Nubra and Shayok, originates from the Siachen glacier and Remo glacier, respectively. The rural populations are primarily dependent on agricultural production for their livelihoods. However, Nubra valley is also known for a high prone area to the impacts of natural events. The natural disasters have frequently been happening in the last decades (Tashi & Sudan, 2021). The village households' survey was taken from three blocks such as Turtuk, Diskit, and Panamik of Nubra valley in a cold desert area of Trans-Himalaya.

4. Methods

4.1 *Sampling design*

There are 3 blocks and 28 villages in the Nubra valley. Out of the total villages, 11 households were selected from each village by using random sampling, with a total of 308 households were selected to assess the vulnerability of local livelihood using the methods of Livelihood vulnerability index and LVI-IPCC. Descriptive research was used to collect data from each household through the closed ended questions to investigate proper information about the ongoing livelihood options, natural disasters, and its impacts in the study area. The households' questionnaire was constructed on the basis of each indices indicator, and three major components of LVI-IPCC such as exposure, sensitivity, and adaptive capacity. Data were analyzed, calculated, and coded using SPSS software.

4.2 *Calculating the LVI: composite index approach*

The LVI contains nine major components such as Socio-demographic Profile, Livelihood Strategies, Social Networks, Food, Health, Water, Natural Disaster and its impact, Housing, and Finances. Each of the major components is comprised of various sub-components or indicators.

The LVI calculates a balanced weighted average method (Suryanto & Rahman, 2019), where each sub-component gives an equal contribution to the overall index even though each major component is consisted of a different number of sub-components. Because, we projected to develop an assessment method available to a different set of users in resource poor assessable, the prime need to use the LVI formula is to apply equal weights to all major components.

The data assessed in the calculation of sub-components have calculated at different scales and in order to make the normalization of maximum and minimum techniques. It is very important to normalize data before measuring the livelihood vulnerability index (Hahn et al., 2009), using the following formula.

$$\text{Index } S_b = \frac{S_b - S_{min}}{S_{max} - S_{min}} \tag{1}$$

Where S_b is the original sub-component of the block b and S_{min} and S_{max} are the minimum and maximum values for each sub-component determined using data from the three blocks of the Nubra valley. The percentage of households reporting in their community was set a minimum of 0 and a maximum of 100. After each was standardized, the sub-component was averaged using Equation 2 to calculate the value of each major component:

$$M_b = \frac{\sum_{i=1}^{n} \text{index}_{sb}{}^{i}}{n} \tag{2}$$

In the index, M_b is the single major component for the block b such as Socio Demographic Profile (SD), Livelihood Strategies (LS), Social Network (SN), Food (F), Health (H), Water (W), Natural Disaster (ND) and its impacts, Housing (H), and Finances (F), indexs_{bi} represents the sub-components, index by i, that shows each major component, and n is the number of sub-components in each major component (Table 1).

Once a value for each of the nine major components for a block was measured, then, it was averaged using Equation 3 or 4 to obtain the LVI at block level:

$$LVI_b = \frac{\sum_{i=1}^{9} W_{Mi} M_{bi}}{\sum_{i=1}^{9} W_{Mi}} \quad (3)$$

Which can also be expressed as:

$$LVI_b = \frac{W_{SDP}SDP_b + W_{LS}LS_b + W_{SN}SN_b + W_{Fo}F_b + W_H H_b + W_W W_b + W_{ND}ND_b + W_H H_b + W_{Fa}F_b}{W_{SDP} + W_{LS} + W_{SN} + W_{Fo} + W_H + W_W + W_{ND} + W_H + W_{Fa}} \quad (4)$$

Where LVI_b is the livelihood vulnerability index for the block b, and the weightage of the nine major components, W_{Mi}, determined by the number of sub-components that make up each major component, contribute equally to the overall LVI (Hahn et al., 2009; Sullivan, 2005). The scale of LVI in this study is from 0 (least vulnerable) to 1 (most vulnerable).

Table 1. Livelihood Vulnerability Index (LVI) of major components and sub-components of three blocks of Nubra valley

Major components	Sub-components	Explanation of sub-components	Survey question	Source of data	References
Socio demographic profile	Family dependency ratio	Ratio of the population under 15 and over 65 years of age to the population between 19-64 years of age	Household age distribution	Household survey	Revised from DHS (2006)
	Percent of households heads who just haven't studied upto primary level	Percentage of households heads who haven't studied upto primary level	Education qualification	Household survey	Revised from Panthi et al. (2016)
	Percent of female-headed households	Head of households If a male head is away from the home more than 6 months per year then female is considered as the head of the household	Is your household headed by a woman?	Household survey	Revised from DHS (2006)
Livelihood strategies	Percent of households depends solely on agriculture for their livelihood option	Percentage of households who are solely depends on agriculture for their livelihood	What is your family primary source of income?	Household survey	Revised from Cutter et al. (2008)
	Percent of households who has not changed crop pattern	Percentage of household reported who has not changed crop pattern	Are your family changing crops pattern?	Household survey	Revised from Panthi et al. (2016)
	Percent households who are not solely dependent on livestock as major livelihoods option	Percentage of households not solely dependents on livestocks is the primary source of livelihood	What is your family primary source of income?	Household survey	Revised from World Bank (1998)
	Percent of households who has not introduced new crop in last 10 years	Percentage of household reported who was not introduced new crop in last 10 years	Do your family Introduces new crop in last 10 years?	Household survey	Revised from Hahn et al. (2009)
Social network	Percent of households who aren't approached for assistance from their community leader in one year	Percentage of households reported that they have not approached for any assistance from their community leader in one year	Have you approached any assistance help from local leader in one year?	Household survey	Revised from Panthi et al. (2016)
Food	Percent of households depends solely on own farm for food	Percentage of households who are solely dependents on their own farm for food	Where does your family get most of its food?	Household survey	Revised from Hahn et al. (2009)

	Average crop diversity index	The inverse of (the number of crops grown by a household +1) Suppose, a households that cultivates carrot, kidney bean, broccoli and capsicum will have a Crop Diversity Index = 1/4 + 1 = 0.20	What type of crops that your family grows?	Household survey	Revised from Panthi et al. (2016)
	Percent of households who haven't saved crops	Percentage of households reported who haven't saved crops	Have your family saved crops for whole year?	Household survey	Revised from Cutter et al. (2008)
Health	Average time taken to reach health facility (minute)	Average time taken to reach nearby health facility	How much time do you take to reach hospital?	Household survey	Revised from Panthi et al. (2016)
	Percent of households whose family members with chronic sickness	Percentage of households reported at least one family member with chronic sickness	Is anybody in your family often getting sick?	Household survey	Revised from Cutter et al. (2008)
	Percent of children suffering from various climates related disease	Percentage of households reported at least one children of the family member who are suffering from climate related disease	Are your children infected from climate related diseases?	Household survey	Revised from Cutter et al. (2008)
Water	Percent of households with problem for access of drinking water	Percentage of households reported do not access the drinking water throughout the year	Do you have drinking water accessibility throughout the year?	Household survey	Revised from Panthi et al. (2016)
	Percent of households who do not get sufficient water for irrigation purpose	Percentage of households reported they do not access irrigation water over the year	Do you have irrigation water accessibility throughout the year?	Household survey	Revised from Cutter et al. (2008)
	Percent of households not using natural water source	Percentage of households reported not using lake, spring, and stream as the primary sources of water	What is your sources of water?	Household survey	Revised from Hahn et al. (2009)
Natural disasters, warning and impact	Average number of natural disasters such as cloudbursts, floods, drought events in the past 10 years	Total number of floods, cloudbursts, drought that were reported by households in the past 10 years	How many times has this area been affected by a floods/cloudbursts/ droughts in last 10 years?	Household survey	Revised from DHS (2006)
	Percent of household with an injured or death due to natural disaster in the past 10 year	Percentage of households reported that injured or death due to the natural disasters	Have your family impacted because of extreme event such as floods, droughts, cloudbursts, and landslide etc.	Household survey	Revised from Hahn et al. (2009)
	Percent of household whose property has damaged or losses due to natural disaster	Percentage of household reported losses of house or property due to natural event	Have your family ever losses of property or damaged because ofnatural event?	Household survey	Revised from Cutter et al. (2008)
	Percent of households who has not received flood warning	Percentage of households reported who has not received flood warning	Have you received any flood warning?	Household survey	Revised from Hahn et al. (2009)
Housing	Percent of households not having pacca houses	Percentage of households not having pacca house	What type of house you own?	Household survey	Revised from Panthi et al. (2016)
	Percent of households whose house has been damaged due to natural disasters (floods, cloudbursts, landslides and droughts)	Percentage of households reported damaged of house due to climate events such as floods, cloudbursts, landslides and droughts	Has your house ever got damaged due to climate events?	Household survey	Revised from Panthi et al. (2016)
Finance	Percent of households who have under debt	Percentage of households that reported under debt	Are you under any kind of debt?	Household survey	Revised from Cutter et al. (2008)
	Percent of households who don't have any kind of savings	Percentage of households who haven't saved money	Do you have any kind of savings?	Household survey	Revised from Cutter et al. (2008)

4.3 *Livelihood Vulnerability Index of Intergovernmental Panel on Climate Change (LVI-IPCC) framework approach*

The IPCC classified livelihood vulnerability on the basis of three major components of exposure, sensitivity, and adaptive capacity. The LVI-IPCC approaches used the primary data from households to calculate the sub-components. Major components of LVI-IPCC explaining the vulnerability are exposure such as (natural disasters, flood warnings, losses and injury experienced), adaptive capacity (socio-demographic profile, livelihoods strategies, social network, Food), and sensitivity (health, water, housing, finance) (Table 2). All three major components are combined in Equation 5 (Hahn et al., 2009).

$$CF_b = \frac{\sum_{i=1}^{n} W_{Mi} M_{bi}}{\sum_{i=1}^{n} W_{Mi}} \tag{5}$$

In the index, CF_b is an IPCC which well-defined contributing factors such as exposure, sensitivity, or adaptive capacity for block b, M_{bi} is the major component for block b, indexed by i, W_{Mi} is the weightage of each major component, and n is the number of each major components (Hahn et al., 2009). Once exposure, sensitivity and adaptive capacity were calculated, the three contributing factors were combined using the following formula:

$$LVI - IPCC_b = (eb - ab) * sb \tag{6}$$

Where LVI-$IPCC_b$ is the LVI for the block b presented using the IPCC vulnerability approach, e is the calculated exposure score for the block (equivalent to the natural disasters and its impact), a is the calculated adaptive capacity for the block (weightage average of the socio-demographic profile, livelihoods strategies, social network as major components), and s is the calculated sensitivity aggregate for the block (weightage average of health, water, food, housing, finance as major components) (Pandey & Jha, 2012). The LVI-IPCC is scaled from -1 (least vulnerable) to 1 (most vulnerable).

Table 2. Assessing IPCC-LVI using major components

IPCC contributing factors to vulnerability	Major components
Adaptive capacity	Socio-demographic profile Livelihood strategies Social network Food
Sensitivity	Water Housing Health Finance
Exposure	Natural disaster, warning and impact

5. Results

5.1 *Livelihood Vulnerability Index (LVI)*

The study analysis revealed the vulnerability of the first major component was Socio-demographic Profile which is comprised of three sub-components. Overall, Diskit showed greater vulnerability on the socio-demographic profile index (SDP_{Diskit} 0.37; $SDP_{Panamik}$ 0.36; SDP_{Turtuk} 0.34), Diskit respondents reported a higher proportion of dependent

persons and a lower proportion of young, and a smaller proportion of household heads that attended school and female-headed households than Turtuk and Panamik blocks respondents. The family dependency ratio was higher in Diskit (0.051), followed by Panamik (0.039), and lower in Turtuk (0.036) (Table 3). This implies that the population proportions under the age of 15 and over 65years that were dependent greater in Diskit and lower in Turtuk block. The family dependency ratio was compared with the education level of the heads of households. The results revealed that the block in which the head of the households was a higher education level indicated a lower level of family dependency ratio. Turtuk (0.17), where the majority of the head of households were educated, had the lower family dependency ratio (0.036) in comparison to Panamik and Diskit blocks. It means that the education facility was good in the Turtuk block as compare to other blocks (Table 3). This shows that family dependency ratio is inverse relationship to education level in the study area of Nubra valley. Hence, higher the education level of the households helps to lower the family dependency ratio. The female headed of households was higher in the Turtuk (0.18), Panamik (0.16), and less in Diskit (0.13). This happens due to the male household members lived away from the house for earning wage. If the male households member lived away from the home for more than six months per year. In this case, the female respondent was considered as the head of the household (Table 3).

Table 3. Indexed major components, sub-components for measuring livelihood vulnerability

Major components	Sub-components	Sub-components			Major components		
		TURTUK	DISKIT	PANAMIK	TURTUK	DISKIT	PANAMIK
Socio demographic profile	Family dependency ratio	0.036	0.051	0.039	0.34	0.37	0.36
	Percent of households heads who haven't studied up to primary level	0.83	0.92	0.86			
	Percent of female-headed households	0.18	0.13	0.16			
Livelihood strategies	Percent of households not solely depends on agriculture as a major livelihood option	0.21	0.13	0.27	0.50	0.43	0.65
	Percent of households who has not changed crop pattern	0.59	0.60	0.76			
	Percent of households who are not solely depends on livestock as major livelihoods option	0.68	0.39	0.81			
	Percent of households who has not introduced new crop	0.55	0.61	0.77			
Social network	Percent of households who aren't approached for assistance from their community leader in one year	0.57	0.71	0.74	0.57	0.61	0.74
Food	Percent of households who are not solely dependents on own farm for food	0.57	0.62	0.52	0.28	0.31	0.33
	Average crop diversity index	0.13	0.19	0.27			
	Percent of households who haven't saved crops	0.14	0.15	0.19			

Health	Average time taken to reach health facility (minute)	0.098	0.264	0.207	0.08	0.14	0.11
	Percent of households whose family members with chronic sickness	0.07	0.13	0.06			
	Percent of children suffering from various climates related disease	0.07	0.03	0.08			
Water	Percent of households with problem for access of drinking water	0.28	0.11	0.39	0.16	0.14	0.33
	Percent of households who do not get sufficient water for irrigation purpose	0.21	0.31	0.38			
	Percent of households who are not using natural water source	0.00	0.00	0.22			
Natural disasters, flood warning and impact	Average number of natural disasters such as floods, cloudbursts, drought events in the past 10 years	0.33	0.21	0.76	0.240	0.177	0.530
	Percent of household with an injury or death due to natural disaster in the past 10 year	0.01	0.0	0.05			
	Percent of household whose property has damaged or losses due to natural disaster	0.19	0.14	0.38			
	Percent of households who has not received flood warning	0.43	0.36	0.48			
Housing	Percent of households not having pacca houses	0.00	0.00	0.00	0.01	0.005	0.035
	Percent of households whose house has been damaged due to natural disasters (floods, cloudbursts, and landslides)	0.02	0.01	0.07			
Finances	Percent of households who have under debt	0.11	0.07	0.09	0.15	0.14	0.19
	Percent of households who don't have any kind of savings	0.19	0.21	0.29			
Overall LVI					0.257	0.248	0.372

Source: Field Survey

The second major component was livelihood strategies or option of the households which is diverse and these strategies included collecting natural resources, growing crops, family members migrating to other areas and raising animal. Panamik showed a greater vulnerability on the livelihood strategies ($LS_{Panamik}$ 0.65; LS_{Turtuk} 0.50; LS_{Diskit} 0.43), and a smaller livelihood vulnerability score was Diskit block (Table 3). A higher percentage of Panamik households indicated agriculture is not a primary source of livelihood (Panamik 0.27; Turtuk 0.21, and lowest in Diskit (0.13). But the two livelihood strategies indicators such as changing crops pattern, and to introduce new crops were higher in Turtuk (0.41), (0.45), and the lower in the Panamik (0.24), (0.23), respectively (Table 3). There are not many differences in the score of sub- indicators of livelihood options in Diskit and Turtuk blocks such as changing crops pattern and cultivating new crops and both the blocks were higher Livelihood options as compared to Panamik block. The cause

of major livelihood options in Turtuk and Diskit could be understood like their land is significantly fertile due to which they could able to cultivating different crops and introduced new crops comparatively Panamik.

The Social Network was the fourth major component which consisted of one sub-component. Panamik was more vulnerable (0.74) in terms of a social network than Diskit (0.61), and lower vulnerable in Turtuk (0.57). This reported that the majority of Panamik and Diskit households did not approach to take any kind of assistance from their local government authority, but 43 percent of Turtuk households preferred to take assistance from their local authority in the last one year (Table 3).

Overall, Panamik was more vulnerable (0.33) in terms of Food, followed by Diskit (0.31), and the less vulnerable block was Turtuk (0.28). The maximum and the minimum number of households that depended solely on their own farm for food was Panamik (0.48), and Turtuk (0.43), respectively. The average crop diversity index showed that Panamik was more vulnerable (0.27), followed by Diskit (0.19), and less vulnerable was Turtuk (0.13). Lower the values of the crop diversity index mean more variety of crops cultivation. Turtuk block is more favorable to cultivates different varieties of crops as compared to other blocks in the Nubra valley. In terms of crops saving, there are not such differences in the value of three blocks. But Turtuk was the highest crops saving blocks (86%), followed by 85% of Diskit, and the lowest in Panamik block (81%) (Table 3). This result could be associated with the Turtuk block in which a higher number of households were cultivating different kinds of crops and changing crop patterns helps to increase their livelihoods. Which indicates that higher number of households who are cultivating new crops and the variety of crops cultivation can leads to an increase the crop saving.

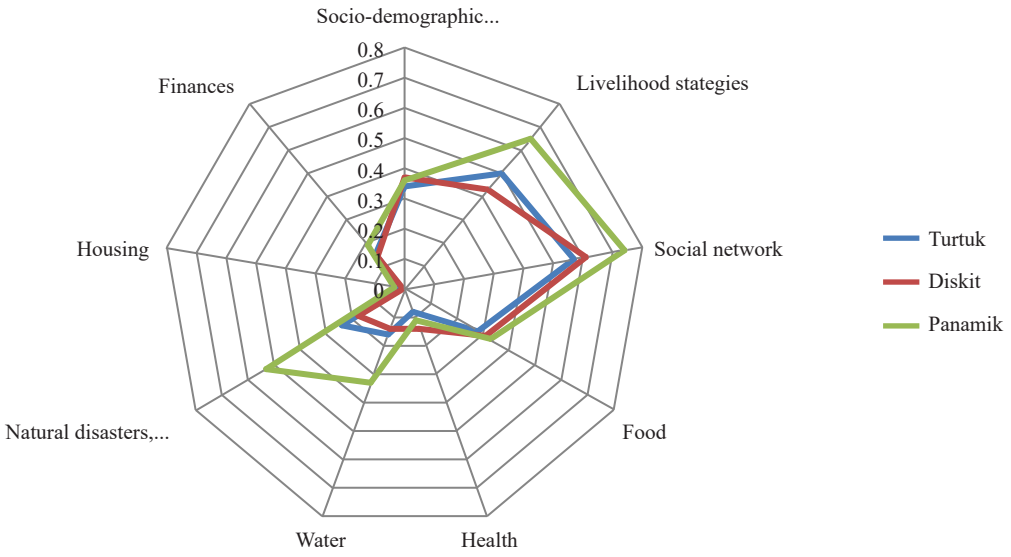
The Health was the fifth major component which comprised of three sub-components. Diskit households were reported traveling an average of 80.2 ± 0.264 min to reach the nearest health facility. While Panamik and Turtuk households reported an average of 63.2 ± 0.207 min and 30.5 ± 0.098 min, respectively. Diskit had greater vulnerability to get health facilities. In fact, chronic ill was reported to higher in Diskit (0.13), due to the lack of health facilities and chronic ill was smaller in Turtuk (0.7) and Panamik (0.6) blocks (Table 3). Panamik households had greater vulnerability (0.8) in terms climate-related disease like malaria etc., followed by Turtuk (0.7), due to the climatic factors and less vulnerability in Diskit block. When the sub-components were aggregated, then we get the overall Health vulnerability score in which Diskit (0.14) was higher than Panamik (0.11), and Turtuk (0.8) block, respectively.

Panamik had a higher water vulnerability score (0.33), than Turtuk (0.16), and Diskit (0.14). In Panamik, 22% of sampled households were getting water from a community hand pump. While all the sampled households of Turtuk (100%) and Diskit (100%) were using a natural water source. The problem of portable water was higher in Panamik (0.39), due to the lack of a natural source of water, followed by Turtuk (0.28), and the drinking water problem was lower in Diskit (0.11). The problem of access to irrigation water was also higher in Panamik block (0.38), and the problem of irrigation water was lower in Turtuk (0.21). Thus, Panamik block had higher water vulnerability as compared to other block in the Nubra valley.

The highest vulnerability to natural disasters, floods warning, and its impact were in Panamik (0.53), followed by Turtuk (0.24), and the lowest vulnerability of natural disasters in Diskit block (0.17). The average number of natural disasters such as floods, cloudbursts, and landslides had occurred in the past decade was maximum in the Panamik block (0.76), which is considered as the high prone block in terms of natural events, and the minimum average number of natural events had occurred in Diskit block (0.21) in the last 10 years. The higher number of death or injury due to natural disasters was higher in Panamik (0.05), followed by Turtuk (0.01). Whereas, none of the sampled households was reported to injury or death due to natural disasters in the Diskit block. But the losses of property such as lands, roads, bridges, houses, etc. were also highest in Panamik (0.48), followed by Turtuk (0.43), and lowest in Diskit block (0.36). The maximum number of households of Diskit (64%) was reported to get a warning about natural disasters. While the minimum number of Panamik (52%) households received a warning about natural disasters.

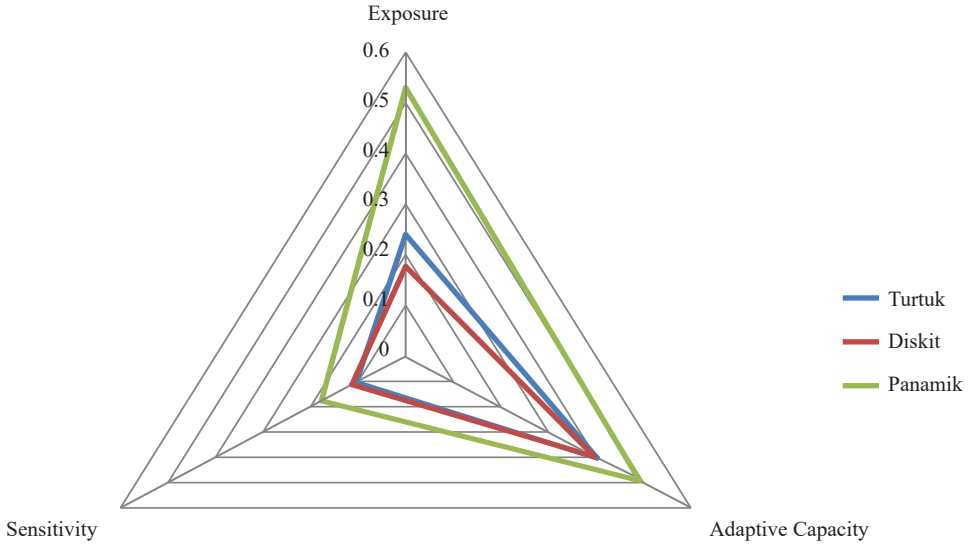
The Housing was the eighth major component which consisted of two indicators. All the households respondent (100%) of three blocks has own house in the Nubra valley (Table 3). But the higher number of the house has been damaged due to the natural events such as cloudbursts and floods in the Panamik (0.07), as compared to Turtuk (0.02), and Diskit blocks (0.01). The higher number of households of Turtuk (0.11) was under debt as compared to Panamik (0.9), and Diskit block (0.7). But the magnitude and size of the debt score among the three blocks were very low. This implies that the majority of the households of the three blocks has not preferred to borrow money from the financial institutions or other sources. This could be interpreted in two different ways like the result shows the majority of the households'

respondents of the three blocks were fully dependent on agriculture for their livelihoods. So, Nubra valley is considered as a self-sustain economy or on the other hand, they are risk averse in nature in inspite of high saving. Where the majority of households 81% of Turtuk, 79% of Diskit, and 71% of Panamik blocks have saved money, respectively. The overall, Livelihood vulnerability index by combined all the major components in which results show Panamik was the highest livelihood vulnerability (0.372), followed by Turtuk (0.257), and the lowest livelihood vulnerability (0.248) was Diskit block (Figure 2).



Source authors' own construction

Figure 2. Spider diagram of major components of the Livelihood Vulnerability Index (LVI) for Turtuk, Diskit, and Panamik Blocks, Nubra valley



Source: authors' own construction

Figure 3. Triangle diagram of the contributing factors of the Livelihood Vulnerability Index-IPCC (LVI-IPCC) for Turtuk, Diskit, and Panamik Blocks, Nubra valley

The LVI-IPCC results (LVI-IPCC: Turtuk -0.017, Diskit -0.025, Panamik 0.007) (Table 4), were similar to the results of overall LVI (Table 3). In Table 4, shows the highest LVI-IPCC was Panamik (0.007) in which various factors such as exposure, sensitivity, and adaptive capacity. The vulnerability triangle illustrates that Panamik was more exposed (0.530) and high sensitivity (0.177). Whereas, the lowest LVI-IPCC (-0.025) was Diskit block due to less exposed of natural disasters (0.177), and less sensitivity (0.108). Although, the adaptive capacity of Panamik was higher than other blocks, the degree of exposure and sensitivity score were very high (Figure 3). Hence, Panamik block was higher livelihood vulnerability in the Nubra valley.

Table 4. LVI-IPCC contributing factors calculation for Turtuk, Diskit and Panamik Blocks, Nubra valley

IPCC contributing factors to vulnerability	Turtuk	Diskit	Panamik
Exposure	0.240	0.177	0.530
Adaptive capacity	0.403	0.397	0.492
Sensitivity	0.104	0.113	0.177
LVI-IPCC	-0.017	-0.025	0.007

Source: Field Survey

6. Discussion

6.1 *Vulnerability assessment of the study area*

The livelihood vulnerability assessment is significant for the analysis about the different types of various components of the region such as Socio-demographic Profile, Livelihood Strategies, Social networks, Food, Water, Health, Natural Disasters, Housing and Health (Madhuri & Bhowmick, 2014).

The overall, score value of the Livelihood vulnerability index of the Intergovernmental Panel on Climate Change (LVI-IPCC) was showed that (Turtuk -0.017, Diskit -0.025, Panamik 0.007). According to LVI-IPCC, the most vulnerable block was Panamik (0.007) due to the high vulnerability of exposure (0.530) to natural disasters and its impact. This implies that Panamik block was a high prone area of natural disasters such as floods and cloudbursts. The indicators of major components of natural disasters, highest number of households of Panamik block (0.38) of natural resources such as land, water, and forest was damaged and lost due to the natural disasters in Nubra valley. Thus, Panamik block was higher exposure to natural disasters (0.530), and sensitivity indicators such as water, health, housing, and finance were also higher (0.177). Water is the utmost important indicator of sensitivity and water vulnerability was also higher in the Panamik block (Table 3). These combined values of vulnerability were high in the Panamik block (Table 4). Thus, overall values of both the Livelihood Vulnerability Index (LVI), and the Intergovernmental Panel on Climate Change Livelihood Vulnerability Index (LVI-IPCC), were highest in the Panamik block.

In the Turtuk block, adaptive capacity (0.403) was higher than Diskit (0.397), and sensitivity was lower (0.104) but due to the higher exposure to natural disasters (0.240) than Diskit block (0.177) (Table 4). The overall, LVI-IPCC of Turtuk was higher (-0.017) than Diskit (-0.025) but less than Panamik (0.007). The result shows that indicator of adaptive capacity, the Food was highly diverse in the Turtuk (0.49) than other blocks in the Nubra valley. Similarly, the vulnerability score of exposure of natural disasters was highest (0.240), after Panamik (0.402). But indicator value of natural disasters, the number of the person injured or dead due to the natural disasters such as floods and, cloudburst was high in Turtuk block (0.01) as compared to Diskit (0.0) in the Nubra valley.

The overall, LVI-IPCC score of Diskit (-0.025) was the least vulnerable as compared to other blocks because of their better adaptive capacity (0.397), and less exposure (0.177) in the Nubra valley. This implies that Diskit block has better access to basic amenities such as food, water, and livelihoods diverse options. Diskit block was the least vulnerable due to their higher adaptive capacity to recover their exposed and sensitivity indicators. Thus, the result shows that Diskit block was the less prone region to natural disasters in the Nubra valley comparatively to other blocks.

But the sensitivity indicators of health was highly vulnerable in the Diskit block due to the lack of health facility, and the average time taken to reach the nearby health Centre was also high (0.264) (Table 3). Hence, the overall vulnerability of both index LVI (0.248) and LVI-IPCC (-0.025) was lower in Diskit block.

7. Conclusion

The Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index-Intergovernmental Panel on Climate Change (LVI-IPCC) are associated with the methods for assessing the aggregate comparative vulnerability of rural mountain communities to climate change impacts. Each method represents a detailed illustration of various factors affecting rural household livelihood vulnerability. Both indexes' results were similar in which Panamik was the most vulnerable block in the Nubra valley. The household vulnerability varies because of the variability in the factors of LVI such as exposure, sensitivity and adaptive capacity. Panamik block was higher exposed to climate change impacts such as floods and cloudbursts, and high sensitivity of water vulnerability due to the lack of natural water source, and impacts of natural disasters. While Diskit was the least vulnerable block in the Nubra valley because of less exposed to natural disasters along with better livelihood options where the majority of the sampled household were solely depends on agriculture and livestock for their source of income. These could be helpful to reduce the vulnerability of exposure variables and enhance the adaptive capacity to cope with the vulnerability of climate change impacts in the Diskit block. LVI-IPCC specifically differentiates households' capacity to adapt or cope with the climate change impacts, exposure to climatic risks, and sensitivities to various risks related to natural events and its impact. This approach can be a useful tool for developmental planners to assess the livelihood vulnerability to the impacts of natural disasters in the local communities and regions in which they work and to improve adaptation strategies to uplift the extremely vulnerable regions.

Conflict of interest

The authors declare no conflict of interest.

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