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Vulnerability of Tribal Communities to Climate Variability in Lahaul and Spiti, Himachal Pradesh, India

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ABSTRACT
India is home to many physiographic divisions, climatic regions, diverse cultures, and ethnicities. The greater Himalayan and trans-Himalayan regions are home to many tribal communities. However, climatic variability brings new challenges to the tribal households in mountainous regions, particularly in India's greater Himalayan and trans-Himalayan regions. This study aims to create a Tribal Household Livelihood Vulnerability Index (THLVI) that takes into account factors such as exposure, sensitivity, and adaptive capacity. The research focuses on three subdivisions in the Lahaul and Spiti district, namely: Lahaul, Udaipur and Spiti, which are part of the western Himalayas cold deserts. The data for the THLVI was collected from 300 randomly selected households in 62 villages through a survey of indigenous people. The results of the study reveal that the vulnerability of tribal households varies across different socio-economic and ecological conditions due to differences in adaptability, sensitivity, and exposure to climate change. In the Lahaul and Udaipur subdivisions, the vulnerabilities of social networks, water, and health were found to be 0.390, 0.262, 0.545, and 0.525, 0.514, 0.512, respectively. The THLVI based on IPCC values ranges from -1 (least vulnerable) to +1 (most vulnerable). For further research, the THLVI index can be used as a tool to assess the livelihood vulnerability of tribal communities living in Himalayan regions, furthermore the sustainable livelihood policies can be formulated in order to strengthen the livelihood security.

Keywords: Vulnerability; Climate Change; Tribal livelihood; Adaptation; Himachal Himalayas

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1. INTRODUCTION

The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) was released, which concluded that the Himalayas were a highly vulnerable mountain in the world (IPCC, 2014). The western Himalayas are more vulnerable to climate change when compared to the eastern Himalayas (ICIMOD, 2011). Its effects disproportionately impact the young, poor, elderly, sick and marginalized populations.

The mountain inhabitants live under constant threat and risk posed by climate change, which is becoming more severe every passing year. This risk is attributed to specific socio-economic features and mountain characteristics like marginality, limited accessibility, remoteness, fragility and dependency on primary resources. Although mountainous regions are abundant in several kinds of resources, it is a fact that mountain inhabitants are among the most vulnerable and poorest in the world. The over-exploitation of natural resources by the government and other agencies as well as its remoteness, make these mountain tribal communities vulnerable. (Pandey et al., 2017). The risk and vulnerability to the inhabitant communities multiplied with socio-ecological changes in the region, and have escalated over time. This resulted in frequent occurrences of extreme events like, scorching heat, landslides, cloudbursts, and flash floods. Furthermore, there has been a resultant upsurge in temperature and erratic precipitation throughout the mountain region in the past few decades.

The communities that rely heavily on natural resources are greatly impacted by the effects of climate change, which led to severe and lasting consequences on their livelihood and well-being (Kofinas and Chapin III, 2009). Therefore, it is projected that the vulnerability of rural tribal households are perceptibly heightened due to climate change. It further triggered irreversible risks to the human ecosystem, leading to an increased number of people in penury and causing more serious damage to the ecology of the area (Li et al., 2014; Lioubimtseva, 2015). In order to develop strategies for adaptation, knowledge of climate-related hazards that could occur in the mountainous region with existing populations and the assets available is important. It could even provide the rationale needed for proper implementation of such strategies. (Oppenheimer et al., 2014; Zhang et al., 2014). There are various methods used to estimate climate change to minimize vulnerability (Pandey et al., 2016; UNDP, 2014; Vignieri, 2015), which has been emphasized in studies on the vulnerability and resilience of socio-economic systems in different geographical regions (Kates et al., 2001).

This vulnerability was defined by various authors in several ways (Füssel, 2006). For this study, the definition of vulnerability given by IPCC (2007) was adopted, i.e., "Vulnerability is a degree that their system has not able to cope up with severe impacts of climate change" (IPCC, 2007). Three components are effectively conceptualized in this definition: adaptive capacity, sensitivity, and exposure (Adger, 2006). However, it cannot be reduced to a single quantifiable measure (Alwang et al., 2001).

In this research, the Tribal Household Livelihood Vulnerability Index (THLVI) was modified and applied to rural household's calculations, by using important characteristics such as topographical location, household income, educational status, livelihood, diversification, and extent of agricultural and as well as non-agricultural land in an environmentally vulnerable area of Lahaul and Spiti.. The THLVI has three overarching dimensions; exposure, sensitivity, and adaptive capacity, and it is made of eight major components and forty-six sub-components. The outcomes of THLVI are indicative of vulnerability that tribal communities could face. The proposed tribal index based on a bottom-up approach could explain the differences that primarily exist in tribal household livelihood susceptibilities. The findings of this research paper could be important for policy making and directing government efforts towards the necessary action for poverty eradication, combating climate change, and sustainable development in the Lahaul and Spiti district of the trans-Himalayan region. Several academic studies were conducted to better comprehend the relationship between climate change and mountain susceptibility (ICIMOD, 2011).

This study could contribute knowledge through creating an index that assessed the vulnerability posed by climatic variability upon the tribal communities in Himachal Himalaya. The broader objectives of this study were to understand and map determinants of the vulnerability of tribal communities; to assess the vulnerability; and discuss the sustainable adaptation practices and measures in Lahaul and Spiti. This study did not pose a hypothesis but rather sought answers to certain questions to achieve the objectives.

1.1. Climate change vulnerability assessment

To study climate change and scientifically assess its impact, a variety of methods and approaches have been developed. The evaluation of indicators of climate-induced vulnerability examines crucial connections that exist between people and their physical and social environments to develop a better understanding of the climate, its variability and impact. Other

geographical data analysis on poverty, health status, and globalisation are used to target food aid, including the World Food Program's Vulnerability Analysis (World Food Programme, 2007; Chen et al., 2006; O'Brien et al., 2004; and Holt, 2007). In this study an attempt was made to quantify visible multi-dimensional matters appropriately using the relevant indicators and sub-indicators. These are frequently put together to create a composite index, which enables the integration of many variables. For example, the Human Development Index uses factors such as life expectancy, health, education, and living standards as indicators to offer a comprehensive portrait of national well-being (UNDP, 2007). The Water Poverty Index uses parameters like water provision and water utilization for assessing the deviation from a predetermined standard. This is done by using a 'gap method' by Sullivan (2002, p. 1204). The Human Development Index is an example of a composite indices used to determine the weighted averages for individual metrics. For choosing the weighting methods, Vincent (2004, 2007) and Sullivan et al. (2002) recommended consulting with experts and holding stakeholder discussions.

To address this issue, approaches were developed and contributed (Polsky et al., 2007). It is crucial to remember that a variety of fields heavily rely on the IPCC's assessed vulnerability. The IPCC definition is dependent on the exposure, sensitivity, and capacity for adaptation (IPCC, 2001). Exposure to climate-related occurrences, such as a flood or increase in snowfall is necessary to gauge size and duration. Sensitivity measures how much exposure alters the system. Additionally, "adaptive capacity" is the ability to bounce back after exposure (Ebi et al., 2006).

Fussel and Klein (2006) systematically defined first and second-generation vulnerability assessments for the sake of convenience. First-generation vulnerability valuations were based on the assessment of climatic impact relative to baseline or threshold conditions, whereas second-generation assessments were the ones that incorporated adaptive capacity measures. There are a multitude of interpretations on second-generation studies and how to apply the parameters of exposure, sensitivity, and adaptive capacity to quantify as well as reduce the risk of vulnerability (O'Brienet al., 2004; Vincent, 2004; Thornton et al., 2006; Polsky et al., 2007).

Several recent studies in South and Southeast Asia used the Socio-economic Vulnerability Index to quantify vulnerability posed by climatic variability-induced incidents/extreme events (Sam et al., 2017), the Livelihood Vulnerability Index (Alam et al., 2017; Bhattacharjee & Behera, 2018), the socio-ecological vulnerability index (Pandey & Bardsley, 2015) as well as the modified Livelihood Vulnerability Index (Madhuri et al., 2014). Many of the studies focused on vulnerability related to extreme natural hazards (Devi et al., 2016; Alam et al., 2017; Sam et al., 2017; Bhattacharjee & Behera, 2018). Robust social networks and a supportive institutional framework were highlighted as the major techniques for decreasing vulnerability (Sam et al., 2017) as well as economic diversification, including migration (Bhattacharjee & Behera, 2018) in the Himalayas and South Asia.

1.2. The Tribal Household Livelihood Vulnerability Index

Aryal et al. (2014), noted that the vulnerability to climate change varied from one place to another depending on the community's location, socio-cultural setup, and economic practices. Indigenous communities that relied on natural resources for their livelihood were more prone to climate change-induced vulnerabilities. Indigenous communities that relied on climate change had a negative impact on those who depended on natural resources for their livelihood. When determining a household's development requirements, the sustainable livelihoods approach considers all natural, social, physical, financial, and human capital assets (Chambers and Conway, 1992). This approach is effective in helping households cope with shocks such as natural disasters. However, climate change adds an additional layer of complexity to the issue of household livelihood security. While the sustainable livelihoods approach considers some aspects of climate change vulnerability, such as sensitivity and exposure and thereforea new approach is needed to more fully evaluate the risks to livelihoods posed by climate change and account for micro level household adaptation strategies.

To assess the impact of climate change-induced vulnerability on populations in the district of Lahaul and Spiti, Himachal Pradesh, this study used the Tribal Household Livelihood Vulnerability Index (THLVI). The Tribal Household Livelihood Vulnerability Index combines existing indicators with new indicators to comprehensively measure households' exposure to natural hazards and climate variability, the socio-economic characteristics that affect adaptive capacity in terms of food, water, migration, and health resources, and sensitivity to the impact of climate change. The THLVI combines components of previous methods as well as other components to measure a household's exposure to natural hazards and climate variability.

It uses socio-economic characteristics that affect adaptive capacity in terms of food, water, migration, and health resources, and sensitivity to the impact of climate change. The THLVI can be used as a composite index made up of eight components, or it can be aggregated into three contributing factors of exposure, sensitivity, and adaptation capability that the Intergovernmental Panel on Climate Change (IPCC) identified as vulnerability index(Table 1).

An advantage of this approach is that it uses primary as well as secondary data to construct the index. This helps to avoid gaps in the data and reduces a reliance on climate models that may not provide accurate projections relevant to community development scheduling (Sullivan, 2006; Patz et al., 2005).

The THLVI is made to be adaptable so that development organizations, policymakers, and public health professionals can use it to examine the demographic, socioeconomic, water, and health elements that affect climate vulnerability at meso and micro level that is community level. Sectoral vulnerability ratings can be separated to identify possible areas for intervention, and it can be honed and concentrated to meet the requirements of different geographic regions.

2. METHODS

2.1. Study Area

Lahaul and Spiti is a district located in the state of Himachal Pradesh. Physiographically, it is considered a cold desert situated in the western part of the Indian Himalaya.. It is the biggest district in Himachal Pradesh, covering an area of 13,835 square kilometers. It is situated between the latitudes of 31°44′ 57″ N to 32° 59′ 57″ N and the longitudes of 76° 29′ 46″ E to 78° 41′ 34″ E (Fig.1), and surrounded by snow-capped mountains. Lahaul and Spiti is the least populated district as compared to other districts of the state as well as India. It shares an international boundary with Tibet (China). Due to its isolation, it is difficult to obtain a clear and coherent history of the Lahaul and Spiti district.

The area has long been home to people who endured and withstood the harshness of nature and the difficult living conditions in these isolated, mountainous regions. Located near the border with Tibet and bordering the districts of Ladakh, Chamba, Kangra, Kullu, and Kinnaur, the Lahaul and Spiti valleys have some differences in their physical and cultural characteristics. The Spiti valley is wider but more rugged and barren, while the Lahaul valley is narrower but has green patches of forests. The altitude in the Spiti valley ranges from around 10,000 feet at the entrance to about 16,000 feet near Kunzum La, while the elevation in the Lahaul valley ranges from about 6,500 feet at Arat nallah to about 14,000 feet near the source of Chandra Bhaga River.

High Rocky Mountains covered in snow and glaciers rise to 6,600 meters above mean sea level in both valleys. The Chandra and Bhaga River valleys up to the confluence near Tandi, as well as the major Chandra Bhaga valley as far as Thirot Nallah, are all part of the Lahaul region. The valleys of the main Spiti River and its tributary, the Pin River, make up the Spiti region. The population of Lahaul and Spiti was 33,244 in 2001 but in 2011 it declined to 31,564 which made a negative population growth rate of -5.1%.

2.2. Calculating the THLVI: A Composite Index

The Tribal Household Livelihood Vulnerability Index (THLVI) is divided into eight components: socio-demographic profile, livelihood approaches, social system, health, food, migration, water, climate variability and natural disasters (Table 1). Each component is made up of several sub-components, which were identified through a review of literature on each major component.

To calculate the THLVI, a balanced weighted average is used (Sullivan et al., 2002). In this approach, each sub-component makes an equal contribution to the overall index, regardless of the number of sub-components in the major components. To ensure that all sub-components are compared, they are converted into an index which is used to calculate the life expectancy index derived from that employed in the Human Development Index. This index is calculated as the ratio of the difference between the existent life expectancy and a pre-selected minimum life expectancy, and the range between the pre-selected maximum and pre-selected minimum life expectancy (UNDP, 2007). To standardize the sub-components for comparision they are transformed into an index using the formula:

$$Index\ ri = (Sr - Smn) / (Smx - Smn) \quad (1)$$

Where *Sr* is the raw sub-component for region r, *Smn* is the minimum value for the sub-component calculated using data from all three regions, and *Smx* is the maximum value for the sub-component. For example, if the sub-component average time to travel to the primary water source location ranges from 1

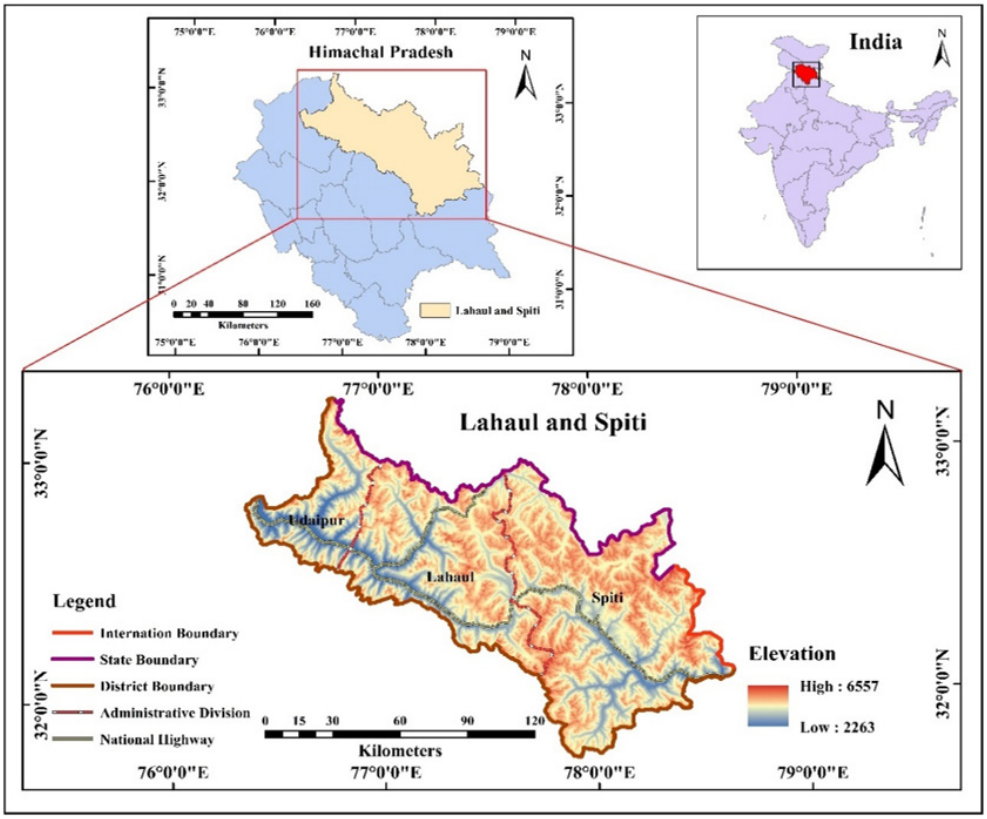

Figure 1: Location map of Lahaul and Spiti district.

to 80 minutes in each region, the minimum and maximum values of 1 and 80 and say 40 minutes to collect water, then 40 is the raw value of sub-component.

Some sub-components were computed by taking the inverse of their original values, examples include the mean index for agricultural livelihood diversity, as a rise in the crude indicator was assumed to decrease vulnerability. For example, a household that engaged in both farming and animal husbandry could be considered less vulnerable than a household that only farms. The maximum and minimum values were also transformed using this logic, and the standardized index was calculated using Equation 1.

To compute the value of each major component, the sub-components were averaged using Equation 2 after they had been standardized:

$$Mr = \sum_{i=1}^{n} indexri \frac{1}{n} \quad (2)$$

Where Mr is the value of the main component, indexri comprised of sub-components indexed by "i", and "n" represents the total number of sub-components within the major component. The main components are Food (F), Water (W), Migration (M), Socio-Demographic Profile (SDP), Livelihood Approaches (LA), Social System (SS), Health (H), and Climate Variability and Natural Disasters (CVND).

To obtain the sub-district level THLVI, the values for each of the eight main components for each region were averaged using Equation 3:

$$THLVIr = \frac{\sum_{i=1}^{n} WmiMri}{\sum_{i=1}^{n} Wmi} \quad (3)$$

Where THLVIb is the Tribal Household Livelihood Vulnerability Index for Region r, Wmi is the weight of each main component based on the number of sub-components it contained, and Mri is the value of each main component. The weights are included to ensure that all sub-components contributed equally to the total THLVI score (Sullivan et al., 2002). The THLVI was scaled from 0 (least vulnerable) to 1 (most vulnerable).

2.3. Calculating the THLVI-IPCC: IPCC framework approach

The THLVI-IPCC is an alternative technique for calculating the THLVI that incorporates the IPCC's definition of vulnerability. It

Table 1: Major components and their sub-components of Tribal Household Livelihood Vulnerability Index (THLVI) .

Major Components	Sub-components	Explanation of Sub components	Survey Question	Source
Socio-demographic profile (AC)	Dependency ratio	The proportion of the population under 15 and over 65 years old to the population 19 to 64 years old.	Could you kindly make a list of everyone that eats and sleeps in this residence, including their ages and genders? Please add any visitors who ate and slept in your home for the last three days.	Hahn et al., (2009). Measure DHS: Model Questionnaire with Commentary
	Female-headed Households	The percentage of families with a female as the principal adult. If a male head of family is absent for more than six months each year, the female is considered the household's leader.	Are you the family's head of household?	Hahn et. al. (2009)
	Households in which the head of the household has not completed all the metrics.	The percentage of families where the head of the family did not finish the tenth grade.	Would you ever go to school?	Hahn et. al. (2009)
	Percentage of orphaned households	The percentage of families with at least one orphan living with them. Children under the age of 18 who lost one or both parents are known as orphans.	Are there any children under the age of 18 from other families who live with you because one or both of their parents have passed away?	Hahn et. al. (2009)
	Household with a combined family.	In each house, there is just one family	Are you a member of a joint family?	Derived from Hahn et. al. (2009)
	Household having nuclear family	More than one family live in a house	Do you live in nuclear family?	Derived from Hahn et. al. (2009)
Livelihood Options (AC)	Percent of families with a family member who works in a separate community	Percentage of families with at least one family member who works as their major source of income outside of the community.	How many members of your family commute to work in a different community?	Taken with from the World Bank (1997). Questionnaire: Uttar Pradesh and Bihar living conditions survey.
	Percentage of families whose primary source of income is agriculture	Only agriculture is reported as a source of income by a certain percentage of families.	Do you or a member of your family keep pets? Do you or someone else in your family go to the forest, rivers, etc. to collect something to sell?	Taken from World Bank (1997).
	Percent of irrigated land	Percent of households having fully irrigated land.	Have your agricultural land all irrigated or not?	Derived from Zhang Qin (2018).
	The average measure of agricultural livelihood diversification	The inverse number of agricultural livelihood activities +1 recorded by a household	Do you or anybody else in your family keep animals? Do you or someone else in your family go out into the wilderness, the forest, rivers, etc. to collect items to sell?	Taken from DHS (2006)
	Percent of un-irrigated land	Percent of households having non-irrigated land.	Have your agricultural land all irrigated or not?	Derived from Zhang Qin (2018).
	As a source of income, Percent of households relied on sources other than agriculture.	The percentage of families that report having a source of income other than agriculture.	Do you have income from other than agriculture?	Derived from World Bank (1997).
	Percent of households reliant on both agriculture and other sources	Percentage of families that say they earn money from both agriculture and non-agricultural sources.	Do you have from both source agriculture as well as other than agriculture?	Derived from World Bank (1997).
	Per family average land availability (Bigha)	Average landholdings of households.	How many bighas land in your home?	Derived from Zhang Qin (2018).
	Average number of livestock	Average number of livestock in your households.	How many animals are in your home?	Derived from Hahn et. al. (2009).

Table 1: Continue.

Major Components	Sub-components	Explanation of Sub components	Survey Question	Source
Health (S)	Average travel time to a medical institution (minutes)	Time it takes for a household to go to the nearest health institution on average.	What is the average time it takes you to travel to a medical facility?	Hahn et. al. (2009).
	Percent of the total of homes with a family member suffering from a chronic disease	Respondent specified the proportion of households that have at least one family member with a chronic disease	Is there anyone in your family who suffers from a chronic illness?	Hahn et. al. (2009).
	Percent of families depended on traditional medicines	Percent of families that solely depend on traditional medicines of that region.	When you are ill, then do you go to traditional doctors?	Derived from Pandey et. al. (2018).
	Percent of families depended on English medicine	Percent of families that solely depend on English medicines of that region.	When you are ill, then do you go to English doctors?	Derived from Pandey et. al. (2018).
	Percent of families depended on both type of medicines	Percent of families that solely depend on both English and traditional medicines of that region.	When you are ill, then do you go to both English and traditional doctors from time to time?	Derived from Pandey et. al. (2018).
	Percent of households having toilet within premises	Percent of households having toilet within or outside premises.	Do you go toilet outside?	Developed by authors for this study.
	Per-capita availability of beds in hospital (per 1000)	Availability of beds in local hospital.	How many beds in your nearest hospital?	WHO (2017)
	Per-capita availability of doctors in hospital (per 1000)	Availability of doctors in your local hospital.	How many doctors in your nearest hospital?	WHO (2017)
Migration (AC)	Average quantity of migrants in families	A typical number of persons from households leave their territory and go to another location in search of a better living.	How many people from your family leave home for employment or education, etc.	Derived from (Maharjan et al., 2020)
	Percent of migrants due to employment	Percent of households that migrate due to employment.	How many people are migrating due to employment?	Derived from (Maharjan et al., 2020)
	Percent of families getting remittances	Percent of household getting remittances from their migrated people.	How many migrated persons send remittances to their families?	Derived from (Maharjan et al., 2020)
Water (S)	Percentage of homes that get their water from a natural source	The percentage of homes have a natural water supply.	What source do you use to get your water?	Taken from DHS (2006)
	Time to reach to water source on average (minutes)	The average amount of time it takes for a household to get to their principal water supply.	How much time takes you to get to your water source?	Taken from DHS (2006)
	Percentage of households without a reliable water supply	Percent of households reporting that water is not accessible from their major water source daily	Is this water available daily?	Taken from World bank (1997)
	The inverse of the average amount of water held each home.	(The average number of litres of water stored by each home + 1) is the inverse of (the average number of litres of water stored by each family + 1).	What kind of containers do you use to keep water? How many are there? How many litres do they contain?	Derived from Hahn et. al. (2009).
Social Systems (AC)	Percent of people who neither received or nor aided others	Percent of households, who helped relatives in the form of income.	Does your family get money from sibling's home and vice versa?	Derived from Hahn et. al. (2009).
	Percent of household visiting their relatives to attend social functions (last 12 months)	Percent of households, how many households go to each other family home.	Does your family go to siblings' home and vice versa?	Derived from Hahn et. al. (2009).
	For last 12 months, what percentage of households went to their local government for help	The percentage of families that said they had not sought their local government for help in the previous 12 months.	I Have you or a member of your family sought help from your community leader in the last 12 months?	Taken from WHO (2003).
Food (S)	Percent of families whose only source of food is a family farm	Percentage of households who receive most of their food from their own farms.	Where does the majority of your family's food come from?	Hahn et. al. (2009).
	The average number of months a household worked for food	The average number of months that families struggle to feed their families.	Is there enough food for your family throughout the year, or are there periods during the year when there is not enough? How many months of the year does your family struggle to eat enough?	Taken from World Bank (1997).

Table 1: Continue.

Major Components	Sub-components	Explanation of Sub components	Survey Question	Source
Food (S)	Crop diversity index on average	The inverse of (a household's number of crops multiplied by 1).	What kinds of crops does your family raise?	Taken from World Bank (1997)
	Crops that are not saved by a certain percentage of households	Percentage of households who do not store crops.	Do you and your family store part of the crops you harvest to consume later?	Derived from Hahn et. al. (2009).
	Households that do not store seeds as a percentage	Percentage of homes without seeds from one year to the next.	Do you and your family preserve seed for the next year?	Derived from Hahn et. al. (2009).
	Percent of households eating just vegetables	Percentage of households that taking only veg in food habit.	Are you vegetarian?	Developed by authors for this study.
	Percentage of households that eat both vegetables and non-vegetables	Percentage of households that taking both veg and non-veg in food habit.	What is your food habit?	Developed by authors for this study.
Climate variability and natural disasters (E)	Injuries or deaths among household members because of recent natural catastrophes	Percentage of households reporting animal harm or death because of the disaster.	Was any animal killed or wounded because of the disaster?	Hahn et. al. (2009).
	Percent of households that did not get a warning about impending natural disasters or calamities	In the previous six years, the percentage of homes that did not get a warning of the most severe landslide, cloudburst, flood, and snowstorm.	Did you receive advance notice of the landslide, cloudburst, flood, or snowfall?	Hahn et. al. (2009).
	Animals in families that have been injured or killed because of recent natural catastrophes	Percentage of households reporting animal harm or death because of the disaster.	Was any animal killed or wounded because of the disaster?	Derived from Hahn et. al. (2009).
	Monthly average of average snowfall mean standard deviation (years 2009 to 2020)	For each region, the standard deviation of the average daily month snowfall from 2009 to 2020 was averaged.	Data from the regional centre from 2009 to 2020; weather station data from the provinces	Indian Meteorological Department.
	Average monthly standard deviation of average sunshine (years 2009 to 2020)	For each region, the standard deviation of the average daily month sunlight from 2009 to 2020 was averaged.	Data from the regional from 2009 to 2020; weather station data from the provinces	Indian Meteorological Department.
	Monthly average rainfall mean standard deviation (years 2009 to 2020)	For each region, the standard deviation of the average daily month precipitation from 2009 to 2020was averaged.	Data from the regional centre from 2009 to 2020; weather station data from the provinces	Indian Meteorological Department.

AC- Adaptive Capacity; S- Sensitivity; E- Exposure

consists of eight major components: exposure, climate variability, demographic profile, livelihood strategies, social networks, adaptive capacity, sensitivity, and present level of health and security of food and water. These components are used to determine the vulnerability of tribal communities. The frequency of recent natural catastrophes serves as a proxy for exposure, whereas the average standard deviation of temperatures and precipitation over the same time serves as a proxy for climatic variability. The demographic profile, livelihood strategies, and social networks of a district are used to determine adaptive capacity, while sensitivity is measured by the assessment of food, water and health. The THLVI-IPCC is calculated using subcomponents of these major components, as well as equations 1-3. The major components of the THLVI-IPCC are combined using a categorization scheme, rather than being merged into the THLVI in a single step.

$$CFr = \frac{\sum_{i=1}^{n} WmiMri}{\sum_{i=1}^{n} Wmi} \quad (4)$$

The IPCC defines three contributing factors for a region: exposure, sensitivity, and adaptive capacity. These factors are represented as CFr for region r. The major components of region d are represented by Mri, with the weight of each component being represented by Wmi. The number of major components in each contributing factor is represented by n. The three contributive factors are calculated by using the following equation:

$$\text{THLVI} - \text{IPCCr} = e_r - a_r \times S_r \quad (5)$$

The THLVI for region r, expressed using the IPCC vulnerability framework, is represented by THLVI–IPCCr. The calculated exposure score for region r is represented by e, which is equivalent to the Climate Variability or Natural Disaster major component. The calculated adaptive capacity score for region r is represented by a, which is the average of the four main components: sociodemographic, livelihood, migration, and

social network variables. The sensitivity estimates score for region r is represented by S, which is the weighted average of the Health, Food, and Water major components. The THLVI–IPCC is scaled from -1 (least vulnerable) to +1 (most vulnerable).

2.4. Household Survey

Primary data was collected through fieldwork. The Random sampling method was used for data collection and proportionately villages were selected from three regions Lahaul, Udaipur and Spiti respectively. Thus, a total of 300 households (131 from Lahaul, 95 from Udaipur, and 74 from Spiti) were surveyed in these three regions and from that out of 62 villages surveyed 31 villages from Lahaul, 19 villages from Udaipur and 12 villages from Spiti were done. The households surveyed were chosen based on various factors, including the size of the village, the type of settlement (e.g., socio-ethnic), the primary means of livelihood, and the level of accessibility and transportation. To ensure the reliability of the collected data, a local guide was recruited as a language interpreter during the survey. The senior-most member of each selected household was interviewed, with each interview lasting at least 30 minutes. The indicators of various components and sub-components used in this research were selected from a variety of sources, including peer-reviewed literature, input from farmers, and the experiences of professionals working in the area and residents. These indicators encompassed both biophysical and socio-ecological-economic parameters that reflected the current social and environmental conditions in the region.

3. RESULTS

The purposive random sampling was adopted for the data collection as the preference was given to the households headed by an elderly person, especially women. Results of the calculated sub-components values in Table 2, THLVI (Table 3) and THLVI-IPCC (Table 4) are discussed below.

3.1. THLVI: Lahaul, Spiti and Udaipur

Table 2 shows the values for each sub-component of the THLVI of each three regions, as well as the minimum and maximum values for all three regions. The major components and the overall THLVI for all three regions are in Table 3.

The dependency ratio values were higher in Lahaul (0.094) as compared to Spiti (0.086) and Udaipur (0.088). However, overall, Spiti had a higher vulnerability in the Socio-Demographic Profile index than Lahaul and Udaipur (SDP Lahaul 0.354; SDP Udaipur 0.271; SDP Spiti 0.412). Female respondents frequently identified their spouse as the head of the house. Then, the female respondent was considered the head of the family. The average percentage of female heads of household in Lahaul was 59.4%, 18.0% in Udaipur, and 34.6% in Spiti. Over 9% of households in Spiti reported raising an orphan, with 2% reporting raising more than one.

In Lahaul, the proportions were 5.97% and 2.08% in Udaipur. Spiti also had a higher vulnerability in the Livelihood options component (0.388) compared to Lahaul (0.367) and Udaipur (0.35). Additionally, Lahaul households on average reported employing more people than Spiti and Udaipur households and compromisingly the livelihood diversification indices have Lahaul 0.367, Udaipur 0.35, and Spiti 0.388 (Table 3).

Lahaul had a higher vulnerability in the Livelihood Strategies as compared to Spiti and Udaipur. More households in Udaipur and Spiti reported having family members who worked outside the community. When the three sub-components were combined, Lahaul had a higher total Livelihood Strategies vulnerability score than Udaipur and Spiti.

The Social Networks indicators varied between regions. Overall, households in Spiti had a higher vulnerability on the Social Networks component (0.564) compared to Lahaul (0.390) and Udaipur (0.525) (Fig. 2).

Lahaul households were reported to be more vulnerable to chronic diseases than households in Spiti and Udaipur (chronic disease: Lahaul 0.403, Spiti 0.382, Udaipur 0.270). The total score for the sub-components of the health vulnerability for Lahaul (0.578) was higher than that for Udaipur (0.526) and Spiti (0.512).

The percentage of Spiti households (78.24%) reported that they are mostly dependent on their crops for food requirements compared to Lahaul households (88.02%), and Udaipur households. Additionally, Lahaul households reported growing 1.4 time of crops on average, while Spiti households reported growing 3.2 times of crops on average.

As far as natural disaster sub components under exposure is concerned, all three regions had similar numbers of vulnerability based the average rainfalls, snowfalls, and extreme temperature events that occurred in the last 11 years. However, when data on the percentage of households that did not receive a warning and

Table 2: Tribal Household Livelihood Vulnerability Index (THLVI) of Lahaul, Udaipur and Spiti region have minimum and maximum values of sub-components values.

Major component	Sub-component	Units	Lahaul	Udaipur	Spiti	Maximum value	Minimum value	Indexed value calculated by Eq. 2		
Socio-demographic profile	Dependency ratio	Ratio	0.47	0.44	0.43	5.0	0	0.094	0.088	0.086
	Female-headed Households	Percent	10.45	6.25	17.65	100	0	0.104	0.062	0.176
	Households in which the head of the household has not completed all the metrics.	Percent	67.16	54.17	70.33	100	0	0.671	0.541	0.703
	Percentage of orphaned households	Percent	32.83	45.83	29.66	100	0	0.328	0.458	0.297
	Household with a combined family.	Percent	32.83	45.83	37.60	100	0	0.328	0.458	0.376
	Household having nuclear family	Percent	5.97	2.08	9.33	100	0	0.597	0.020	0.933
Livelihood Approaches	Percent of families with a family member who works in a separate community	Percent	13.43	8.33	12.67	100	0	0.134	0.083	0.127
	Percentage of families whose primary source of income is agriculture	Percent	65.67	58.33	63.94	100	0	0.657	0.583	0.639
	Percent of irrigated land	Percent	89.55	93.75	87.45	100	0	0.895	0.937	0.874
	The average measure of agricultural livelihood diversification	1/livelihoods	0.25	0.20	0.33	1	0	0.25	0.20	0.33
	Percent of un-irrigated land	Percent	10.25	6.25	12.55	100	0	0.104	0.062	0.125
	Source of income, Percent of households relied on sources other than agriculture.	Percent	11.94	16.67	10.04	100	0	0.119	0.167	0.1
	Percent of households reliant on agriculture and other sources	Percent	32.83	43.75	30.76	100	0	0.328	0.437	0.308
	Per family average land availability (Bigha)	Bigha	19.92	13.60	18.76	50	0	0.398	0.272	0.375
	Average number of livestock	Count	8.34	7.58	12.35	20	0	0.417	0.379	0.617
Social Systems	Percent of people who neither received or nor aided others	Percent	22.38	33.00	35.17	100	0	0.119	0.542	0.352
	Percent of household visiting their relatives to attend social functions (last 12 months)	Percent	83.58	83.33	83.66	100	0	0.216	0.2	0.837
	In the last 12 months, what percentage of households went to their local government for help	Percent	88.05	45.83	50.38	100	0	0.836	0.833	0.504
Migration	Average quantity of migrants in families	Count	2.55	4.77	3.25	10	0	0.255	0.477	0.325
	Percent of migrants due to employment	Percent	68.32	61.76	50.75	100	0	0.683	0.618	0.507
	Percent of families getting remittances	Percent	52.63	55.55	70.38	100	0	0.526	0.555	0.704
Health	Average travel time to a medical institution (minutes)	Minutes	52.98	48.33	50.03	60	0	0.883	0.805	0.834
	Percent of the total of homes with a family member suffering from a chronic disease	Percent	40.29	27.08	38.21	100	0	0.403	0.270	0.382
	Percent of families depended on traditional medicines	Percent	16.41	2.08	45	100	0	0.164	0.020	0.45
	Percent of families depended on English medicine	Percent	17.91	70.83	20.0	100	0	0.179	0.708	0.2
	Percent of families depended on both type of medicines	Percent	65.57	27.08	35.0	100	0	0.656	0.270	0.35
	Percent of households having toilet within premises	Percent	98.5	100	100	100	0	0.985	1	1
	Per-capita availability of beds in hospital (per 1000)	Ratio	3.7	3.3	2.6	5	1	0.675	0.575	0.4
	Per-capita availability of doctors in hospital (per 1000)	Ratio	0.68	0.56	0.48	1	0	0.68	0.56	0.48

the percentage of households that experienced disaster-related injuries or deaths over the last six years was considered, Udaipur was found to be more vulnerable than Lahaul and Spiti.

Table 2: Continue.

Major component	Sub-component	Units	Lahaul	Udaipur	Spiti	Maximum value	Minimum value	Indexed value calculated by Eq. 2		
								Lahaul	Udaipur	Spiti
Food	Percent of families whose only source of food is a family farm	Percent	100	97.91	80.33	100	0	1	0.979	0.803
	The average number of months a household goes without food	Months	7.72	7.43	7.23	12	0	0.643	0.619	0.602
	Crop diversity index on average	1/ crops	0.24	0.20	0.33	1	0.1	0.155	0.111	0.255
	Crops that are not saved by a certain percentage of households	Percent	88.24	100	78.24	100	0	0.882	1	0.782
	Households that do not store seeds as a percentage	Percent	17.65	60.42	23.52	100	0	0.176	0.604	0.235
	Percent of households eating just vegetables	Percent	0	0	0	100	0	0	0	0
	Percentage of households that eat both vegetables and non-vegetables	Percent	100	100	100	100	0	1	1	1
Water	Percentage of homes that get their water from a natural source	Percent	60.0	70.0	55.0	100	0	0.6	0.7	0.55
	Time to get to a water source on average (minutes)	Minutes	12.31	65	60	80	5	0.154	0.812	0.75
	Percentage of households without a reliable water supply	Percent	25.37	50.0	40.0	100	0	0.254	0.5	0.4
	The inverse of the average amount of water held each home.	1/Litres	0.039	0.044	0.056	1	0	0.039	0.044	0.056
Climate variability and Natural disasters	Injuries or deaths among household members because of recent natural catastrophes	Percent	22.05	14.58	30.76	11	0	0.220	0.146	0.308
	Percent of households that did not get a warning about impending natural disasters or calamities	Percent	45.59	60.42	52.65	100	0	0.456	0.604	0.526
	Animals in families that have been injured or killed because of recent natural catastrophes	Percent	26.47	12.5	17.03	100	0	0.265	0.125	0.170
	Mean standard deviation of average annual snowfall (2009 to 2020)	Centimetres	16.7	16.7	16.7	50	10	0.58	0.58	0.58
	Mean standard deviation of average monthly sunshine/temperature (2009 to 2020)	Hours	6.71	6.71	6.71	10	0	0.671	0.671	0.671
	Mean standard deviation of average monthly rainfall (2009 to 2020)	Millimetres	8.97	8.97	8.97	40	10	0.885	0.885	0.885

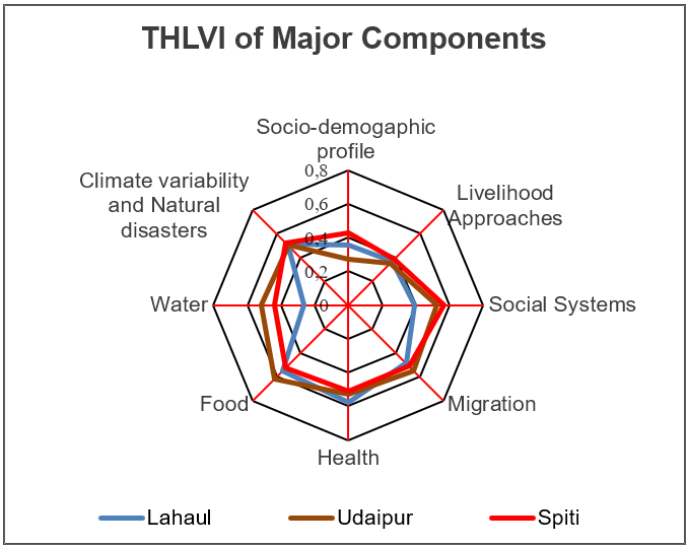

Figure 2: Spider diagram of THLVI's major components of the Lahaul, Udaipur and Spiti.

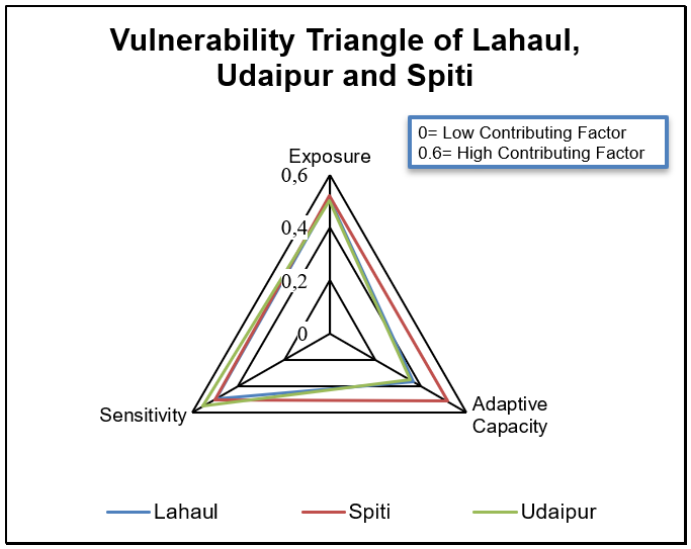

Figure 3: Triangle diagram of THLVI-IPCC for Lahaul, Udaipur and Spiti.

The proportion of missing replies in the questionnaire varied respondents to respondents and can be seen as limitations of questionnaire survey. However, when calculating the climate variability and natural disaster values, Spiti households were found to be more susceptible than Lahaul and Udaipur households. Overall, Spiti showed higher THLVI (0.477) than Lahaul (0.449) and Udaipur (0.469) respectively (Table 3).

3.2. THLVI-IPCC assessment: Lahaul, Udaipur and Spiti

The data depicted in Figure 3 suggests that the comparatively low estimated adaptive capacity in Udaipur households was due to demographic imbalances and a high percentage of families who raised orphans. Adaptation observations such as livelihood diversification, planned migration, food, and water were the main reasons behind Udaipur's low THLVI-IPCC result.

THLVI-IPCC calculations vulnerability is less in Udaipur region (0.003) and more in Lahaul (0.073) and Spiti (0.083) (Table 4). Spiti families could be more exposed to the effects of climate change than Lahaul and Udaipur households, according to the aggregate THLVI-IPCC ratings (Fig. 3).However, it is uncertain whether these approaches are sufficient to compensate for climatic changes within the range of possible climate variations. Additionally, Figure 3 shows that although Lahaul family's demographic pressures and low rates of school attendance are not reported in the same manner, similar response techniques were prevalent in Udaipur.

4. DISCUSSION

It was well-established in scholarly literature that agriculture is the primary source of livelihood for Himalayan villages (Macchi et al., 2014; Gerlitz et al., 2016). Many scholars documented the increasing and disparate vulnerability faced by agricultural communities over time (Pandey and Jha, 2011; Tiwari and Joshi, 2012; Panthi et al, 2015). As Shukla et al. (2018) noted, "The Himalayan region's agricultural populations are disproportionately vulnerable because of difficulties in sustaining their livelihoods brought on by a variety of internal and external variables."

The landscape changes dramatically as soon as one passes across the Rohtang Pass from Manali. Green conifer-lined slopes give way to harsh, brown alpine peaks. The selected components were aggregated under 46 different sub-components for three major components of Lahaul, Spiti and Udaipur. THLVI was calculated at the village level using various major and sub-components. In the major components, exposure was very high in Spiti. At the village level, the more vulnerable to exposure were Marango Rangarik (0.789), Chicham Khas (0.585) and Pinjoor (0.559); then Lahaul and within its villages, Jobrang (0.856), Kowaring and Sissu (0.689) and then Udaipur and within its village's exposure are Madgram (0.559), Jahalman and Manrung (0.522) respectively. Climate change directly affected the livelihood of people in the Lahaul and Spiti district.

The second major component 'Sensitivity' comprises Health, Food, and Water. Sensitivity is directly proportional to vulnerability. If we are more sensitive, then the possibility of exposure is also high and vice versa. There is only one season for cropping, which runs from April to October, when the mean minimum and maximum temperatures range from approximately 12°C to 24°C. Although they can range from as low as 5°C to 30°C. During the winter months, temperatures drop well below freezing (-20°C to -10°C). Rainfall also varies between regions, with an average annual rainfall of 250 mm ranging from as low as 90 mm to as high as 1200 mm. Most of the rainfall is received as snowfall in the winter from November to early March. The rainfall in Spiti is generally scarcer than in Lahaul, and Udaipur.

Unlike other tribesmen in the nation, the tribal farmers of Spiti were discovered to be highly inventive and fast learners. The crops in this region underwent a higher degree of revolution compared to other districts in the state. The cultivators are dominated by marginal and small farmers. The sensitivity is very high due to the high demand for food and water melting at a speedy rate. This causes Lahaul and Spiti to become mainly a six-month natural cage due to heavy snowfall. In Lahaul's villages Lepchang (0.614), Stingiri (0.600) and Jobrang (0.599) have attained the lowest sensitivity in between three regions. In Udaipur's villages Kurched (0.594), Madgram (0.569) and Jholing (0.566) attained very high sensitivity in these three regions. Spiti's villages sensitivity is lower than Lahaul because of 365 days of connectivity. In villages, Marango Rangarik (0.701) had the highest and Tabo (0.338) the lowest sensitivity.

The adaptive capacity of a community regulates its susceptibility to hazards or disasters by adjusting exposure and sensitivity or responsiveness levels. Adaptive capacity includes socio-demographic profile, social system, migration and Livelihood strategies. Households of Spiti were more vulnerable to dangerous relief and the cold Himalayan winds have a negative effect on Spiti. The high number of children who were orphaned and the single-parent households in Udaipur limited its ability to

implement various adaptation strategies. On the other hand, Spiti had both high vulnerability and high adaptive capacity. Udaipur could be more vulnerable to the outcomes of climate change than Lahaul and Spiti when considering the existing state of health as well as the security of food and water. In comparison to Lahaul and Udaipur, Spiti showed a stronger potential for adaptation based on demography, livelihoods, and social networks.The values for the adaptive capacity dimensions are related to the descriptions of each surveyed village of three regions and have various irregularities of adaptive capacity in these regions. The Spiti households are moving towards nuclearization. This factor plays a significant role in the vulnerability of Spiti. Udaipur is the least vulnerable because it has more choices for livelihood. The adaptive capacity of Lahaul (0.366) and Udaipur (0.353) are almost the same. In the villages of Lahaul, Jobrang (0.599) had the highest and Darcho Sumda (0.220) the lowest adaptive capacity. The villages of Udaipur; Manrung (0.516) had the highest and Hinsa (0.297) attained the lowest. However, the adaptive capacity was far better in the Spiti region than in the two other desert regions. In the villages of Spiti, Tabo (0.590) attained the highest and Marango Rangarik (0.206) the lowest. Sheep, churi and goats were the most prominent livestock owned by households in this region. Among cattle, Churi (a cross breed between cow and yak) was the most common dairy animal, preferred by every household. Farmers keep yaks for ploughing, and the average milk yield of Churi is 1.5 to 2 killograms per day. To meet the main fodder needs, farmers utilized dry grass, straw, and leftover pea crops in the winter, while relying on indigenous legume varieties and wild willow branches during the summer months. The households of Lahaul, Udaipur, and Spiti reported high numbers of people migrating to Shimla, Manali, Chandigarh and Delhi for work, employment, education, marriages, etc.

Most households face a shortage of fodder during April-May. The emerging farm-based micro-enterprises have the potential to improve the socio-economic status and livelihood options in the district. Lahaul and Spiti authorities provide full subsidized food to more than 95% of households at the interval of 6 months.

5. CONCLUSION

This study calculated the THLVI and THLVI-IPCC as modified alternate methods for assessing the vulnerability of tribal communities of mountainous regions as an impact of climate variability. The approach provided a picture of the factors of tribal household livelihood vulnerability in a mountainous region. The overall vulnerability of this district is high. Natural factors have severely impacted tribal communities. Sensitive factors can be improved by the better adaptive capacity approaches. The exposure, capacity for adaptation, and sensitivity of district may change when adaptation techniques are implemented or are anticipated to be implemented in the future. This study's replication in the same place over time could give information on how these factors evolve. Further studies on this topic should focus on the refinement of the Migration and Health sub-components of THLVI to evaluate the challenges more accurately. In general, the THLVI could offer development planners a valuable instrument to assess the livelihood vulnerability impact of climate change on communities and it could be useful in developing resilience strategies for vulnerable social groups. Ultimately, it aims to help achieve the targets of Sustainable Development Goals (SDGs).

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