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Assessing Local Vulnerability to Climate Change by Using Livelihood Vulnerability Index: A Case Study of Dipang Watershed in Central Himalaya Region of Nepal

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Abstract

The current study uses the livelihood vulnerability index (LVI) and the Intergovernmental Panel on Climate Change livelihood vulnerability index (IPCC-LVI) approaches to assess household's livelihood vulnerability in the Dipang watershed located in the Central Himalayan region of Nepal. Primary data was collected through various participatory rural appraisal (PRA) tools such as direct observation, key informant interviews (KIIs), focus group discussions (FGDs) and household surveys. Similarly, data on climatic variables were collected from the nearby meteorological station over 30 years (1987-2018). The mean annual average temperature increased by 0.036°C while the average rainfall decreased by 2.30 mm. Respondents perceived a similar trend of rising temperatures, decreasing rainfall intensity, dryness in the atmosphere, and dwindling water sources. The overall LVI score (0.416) indicated that the households are vulnerable to climate change. Food (0.642) and natural disasters and climate variability (0.566) were the most vulnerable among all contributing factors. Similarly, the overall LVI-IPCC score (0.104) indicated that the households were moderately vulnerable due to high exposure (0.566), sensitivity (0.448), and low adaptive capacity (0.334). The study findings suggest an urgent need to reduce high exposure to climate risks, improved livelihood strategies, and boost agricultural productivity and health in the watershed area.

Keywords

Vulnerability assessment; Climatic variables; Exposure; Sensitivity; Adaptive capacity

Introduction

Climate change is widely regarded as the most devastating threat to human well-being in recent history. The global average temperature has risen by 0.7°C over the last century and is expected to rise by another 1.1-6.4°C by the end of the twenty-first century (IPCC, 2013). Similarly, global average precipitation has increased by 2% over the same time and is expected to increase (IPCC, 2013). Climate change and its variability endangers various geophysical, biological, and socio-economic systems, impacting negatively the biodiversity (Chand *et al*., 2018; Sintayehu, 2018; Soni and Ansari, 2017), food security (Fanzo *et al*., 2017; FAO, 2018), water resources (Chhetri *et al*., 2018; Versini *et al*., 2016), economics (Hallegatte *et al*., 2018), health (Butler, 2018) and social equality (Denton *et al*., 2014).

Climate change is expected to have serious ecological, economic, and social consequences in South Asia, particularly in areas where livelihoods rely on the use of natural resources (Mishra *et al*., 2019). The Hindu Kush Himalayan region is extremely vulnerable to climate change due to its diverse geological and climatic conditions (Gertlitz *et al*., 2017; Gupta *et al*., 2019; Wester *et al*., 2019). Among them, Nepal is the fourth most vulnerable country in the world to climate change (Eckstein *et al*., 2018). Nepal is vulnerable to many natural disasters such as illnesses, floods, and landslides, with an average of 900 natural disasters claiming lives and endangering livelihoods each year (MoHA, 2009). As a result, over 1.9 million people are projected to be extremely vulnerable, with another 10 million facing the increased risks (MoEnv, 2010). Nepal, a developing country, is especially vulnerable to the consequences of climate change due to its exposure and sensitivity to climate extremes and its low adaptation capability (Kates, 2000).

Vulnerability assessment has proven to be a useful tool in assessing vulnerable systems to develop appropriate climate change policies (Schroth *et al*., 2016). Vulnerability assessment refers to a wide range of methods for systematically integrating and investigating the interactions between humans and their physical and social environments (Hahn *et al*., 2009). Vulnerability assessment is widely used in various research applications that include ecology, environmental health, sustainability, poverty alleviation, livelihood, development, and hazard and impact assessment for climate change (Füssel, 2007). The Livelihood Vulnerability Index (LVI) is useful for understanding climate change vulnerability. It provides a framework for analyzing the key components of livelihoods and the contextual factors that influence them (Adu *et al*., 2017). The LVI uses various indicators to assess exposure to natural disasters, climate variability, and household social and economic characteristics that influence their adaptive capacity and current health, food, and water resource characteristics that influence their sensitivity to climate change impacts. It has also been useful in factoring in biophysical and socio-economic components for better adaptation and mitigation measures and decision making (Panda and Amaratunga, 2016).

There is new and stronger evidence of climate change impacts on unique and vulnerable systems such as mountain communities and ecosystems, with increasing levels of negative impacts as temperature rise (Zemp *et al*., 2009). Dipang watershed is a part of the lake cluster of Phewa Lake, a designated Ramsar site. The watershed not only provides freshwater for agriculture and domestic use, but it also provides varieties of ecosystem services (Tognetti *et al*., 2017). These watershed services include provisioning services (irrigating water supply, fish supply, timber, fuel wood, food, medicine, and handicraft), regulatory services (climate regulation, disease regulation, and water purification) and cultural services (aesthetic and scenic beauty, recreational and tourism, educational resource service and festivals) (MoFE, 2018). However, the watershed is facing difficulties as a result of climatic and anthropogenic activities. Residents of the watershed rely on watershed services to support their livelihoods. Climate change is likely to influence these people's livelihoods. Moreover, limited studies exist regarding climate change vulnerability assessment at the watershed level in Nepal. Against this backdrop, the current study attempts to analyze the climatic variable trends and assess the livelihood vulnerability of the households using the LVI and LVI-IPCC approaches in the watershed. The study will provide government organizations and local policymakers with

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practical tools to understand demographics, social and other related factors contributing to framing better adaptation strategies.

Materials and methods

Study area

The study was conducted in the Dipang watershed of Kaski district situated in Central Himalayan region of Nepal. The watershed lies at latitude 28° 10′ 55.77″ N and longitude 84° 04′ 15.19″ E (Figure 1). The watershed includes Dipang Lake, one of the lake clusters in the Pokhara Valley, a designated Ramsar site. The lake cluster is home to 263 plant species (203 terrestrial and 60 aquatic plant species), 168 bird species, 28 fish species, 11 frog species, 28 reptile species, and 36 animal species (Tamrakar, 2008). The main draw for tourists is the spiny babbler *(Turdoides nepalensis*), wren babbler (*Pnoepyga immaculate*), comb duck (*Sarkidiornis melanotos*), Baer's pochard (*Aythya baeri*), and ferruginous duck (*Aythya nyroca*). The lake also contains common otter (*Lutra lutra*), which is listed as Appendix I (CITES)[1] and nearly extinct (IUCN)[2] (Tamrakar, 2008). Dipang lake is the fourth largest lake in the cluster, covering a total catchment area of 2.39 km^2 and a water body area of 0.14 km^2 (MoFE, 2018). Dipang watershed is the representation of the middle mountain forest ecosystem inhabited by 182 households. It is covered mostly by swampland and water bodies. The Khatre and Kusunde rivers are its major watersheds, with the Kahur, Kaure and Deurali rivers as other tributary streams (MoFE, 2018). The watershed is rich in biological diversity and is a great spot for recreational activities outside Pokhara city. The watershed's main draws are white lotus and swans. It is also the habitat of a rare aromatic local rice variety i.e., Samunderphinj. The watershed is under threat due to the expansion of invasive species such as water hyacinth (*Eichhornia crassipes*), gajar ghans (*Parthenium hysterophorus*), morning glory (*Ipomoea purpurea*) and ban mara (*Lantana camara*) (MoFE, 2018).

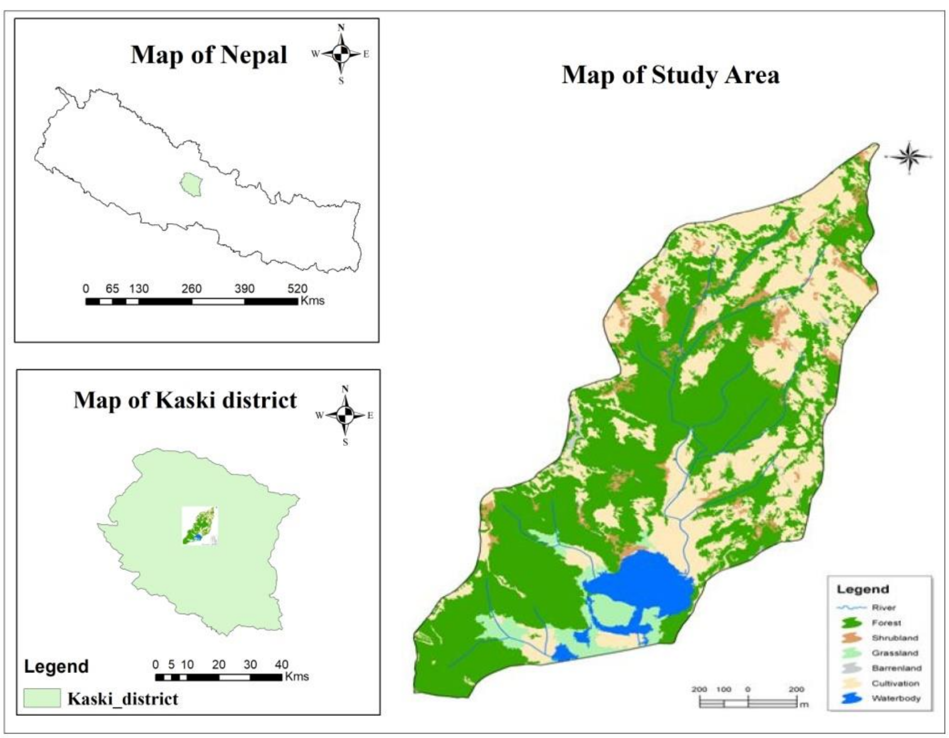

Figure 1: Map showing the study area (Dipang watershed)

[1] The Convention on International Trade in Endangered Species of Wild Fauna and Flora
[2] International Union for Conservation of Nature

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Data collection

The study employed both primary and secondary data. Primary data was collected during 2018-19 to identify the livelihood vulnerability related to climate change at the watershed level. Several PRA tools were used for this purpose, such as direct observation, KIIs (Key Informant Interviews), FGDs (Focus Group Discussions) and household surveys. A total of 10 key informants representing the local community in terms of their social status, economic well-being, knowledge and ecological regions were interviewed. FGDs were conducted in the study area to gather information related to the social-economic dimensions of the watershed. Similarly, household data were collected using a pre-tested, semi-structured questionnaire. A total of 10 households were initially surveyed to test the questionnaire. With the help of the supervisor and climate change experts, the questionnaire was then finalized based on pre-test surveys. The finalized questionnaire consisted of 2 sections, namely: socio-economic profile and livelihood vulnerability. The socio-economic profile included the respondent's basic social and economic profile, whereas the livelihood vulnerability section included seven livelihood components and their sub-components (Table 1). Due to the homogeneity of the population under investigation, a simple random sampling approach was used to gather household data. As the total number of households is relatively low, 30% of them were surveyed. Furthermore, secondary data, i.e., data related to climatic variables for a period of 30 years (1989-2018), were collected from the nearby Meteorological Station of Pokhara, Kaski district to study climatic variations of the watershed.

Table 1: List of major components and sub-components of LVI used in the study

S.No.	*Major Components*	*Sub-components*
1.	Natural disasters and climate variability	Average number of flood, drought and landslides etc. events in the past 10 years
		Percentage of households that did not receive a warning about recent natural disasters
		Percentage of households with an injury or death as a result of natural disasters
		Mean standard deviation of the monthly average of average maximum daily temperature (1989-2018)
		Mean standard deviation of the monthly average of average minimum daily temperature (1989-2018)
		Mean standard deviation of average monthly precipitation (1989-2018)
2.	Social Networks	Percentage household had to receive help through social networks
		Percentage household borrowed money through social networks
		Percentage of households that have not gone to their local government for assistance for the past 12 months
3.	Livelihood strategies	Percentage of households with family members working in a different community
		Percentage of households dependent solely on agriculture as an income source
		Average Agricultural Livelihood Diversification Index
4.	Sociodemographic profile	Dependency ratio
		Percentage of female-headed households
		Percentage of households where the head of household has not attended school
		Percentage of households with orphans

S.No.	*Major Components*	*Sub-components*
5.	Water	Percentage of households reported having water availability problem
		Percentage of households that utilize a natural water source
6.	Food	Percentage of households dependent solely on the family farm for food
		Percentage of household struggle to find food support for whole year
		Average Crop Diversity Index
		Percentage of households that do not save crops
		Percentage of households that do not save seeds
7.	Health	Average time to the health facility
		Percentage of households with a family member with chronic illness
		Percentage of household with members missed school/work in past two weeks

Climatic variability trend analysis

To find a linear trend in the data, simple linear regression was used. Equation 1 depicts the linear trend between time-series data (y) and time (t).

$Y = a+bt$ ……………………………………………1

where, y= temperature or rainfall, t= time (year), 'a' and 'b' are constants estimated by the principle of least squares.

Vulnerability analysis

LVI approach

The livelihood vulnerability index developed by Hahn *et al.* (2009) was adopted to assess the risk derived from climate variability. This approach consists of seven major components, i.e., natural disaster and climate variability, social networks, livelihood strategies, socio-demographic profile, water, food and health. Each major component has several sub-components, and each sub-component contributes equally to the overall index. The sub-components were developed based on a review of the relevant literature and consultation with experts, as shown in Table 1. A balanced weighted approach was followed for the LVI calculation (Sullivan, 2002; Pandey and Jha, 2012). To standardize each sub-component, equation 2 was used:

$\text{Index}_{\text{Sb}} = \frac{S_C - S_{min}}{S_{max} - S_{min}}$……………………………………2

where, Sb = original sub-component or indicator value for the watershed

S_{max} and S_{min} = the maximum and minimum sub-component values determined using all the sub-component values from the communities.

After standardization, the value of each major component was calculated using equation 3.

$\text{M}_\text{b} = \frac{\sum_{i=1}^{0} -Index_{Sb^i}}{n}$……………………………………………3

where, M_b = one of the seven major components for the watershed

$\text{Index}_{\text{Sb}^i}$ = the sub-component value of indicator belonging to major component for the watershed.

n = the number of sub-components in each major component

The watershed level LVI was calculated as the weighted average of the seven major components as in equation 4, i.e.,

$$\mathrm{LVI_b} = \frac{\sum_{i=1}^{7} -W_{Mi}M_{bi}}{\sum_{i=1}^{7} -W_{Mi}} \qquad \ldots\ldots 4$$

where, $\mathrm{LVI_b}$ = the Livelihood Vulnerability Index for the watershed.
W_{Mi} = the weight of major component i, decided by the number of sub-components in the major component.
M_{bi} = the value of the ith major component in the watershed

The LVI was scaled from 0 (least vulnerable) to 1 (most vulnerable). The index below 0.5 was interpreted as not vulnerable, while above 0.5 was interpreted as vulnerable (Hahn *et al*., 2009).

LVI-IPCC approach

LVI-IPCC approach incorporates the IPCC vulnerability definition. The IPCC definition characterizes vulnerability (to climate change) as a function of a system's exposure and sensitivity to climatic stimuli and its capacity to adapt to their (adverse) effects, which corresponds to outcome (or endpoint) vulnerability. In this approach, seven major components were classified into three categories, i.e., exposure, sensitivity and adaptive capacity. The exposure index contained natural disasters and climate variability, the sensitivity index contained food, water and health, and the adaptive capacity index contained socio-demographic profile, livelihood strategies and social networks. Each of these three categories of IPCC factors was calculated based on the equation:

$$\mathrm{CF_b} = \frac{\sum_{i=0}^{n} \mathrm{WMiMbi}}{\sum_{i=1}^{n} \mathrm{WMi}} \qquad \ldots\ldots 5$$

Where, $\mathrm{CF_b}$ is an IPCC-defined contributing factor (exposure, sensitivity, adaptive capacity) for watershed b, Mbiis the major component for Watershed indexed by i, WMi is the weight of each major component, and n is the number of major components in each contributing factor.

Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$\mathrm{LVI - IPCC_b} = (e_b - a_b) * S_b \qquad \ldots\ldots 6$$

where, $\mathrm{LVI–IPCC_b}$ is the LVI for watershed 'b' expressed using the IPCC vulnerability framework, 'e' is the calculated exposure score, 'a' is the calculated adaptive capacity score and 's' is the calculated sensitivity score for the watershed. The LVI – IPCC was scaled from -1 (least vulnerable) to +1 (most vulnerable) as follows:

Table 1: Categories for LVI-IPCC Scale

S.N.	*Vulnerability class*	*LVI*
1	Very high	0.61-1
2	High	0.21-0.60
3	Moderate	0.20-(-0.19)
4	Less	(-0.20)-(-.60)
5	Very less	(-0.61)-(-1)

Source: IPCC (2001)

Results and Discussion

Socio-demographic characteristics of the respondents

Most of the respondents were males (84.21%), and a few were females (15.79%). The respondents belonged to three categories of castes, namely upper caste Brahmin/Chettri (45.61%), scheduled castes (35.09%) and scheduled tribes (19.30%). Most of the respondents were older than 50 years (56.14%), while only 12.28% of the respondents were less than 30 years. Agriculture (85.96%) was the major occupation of the respondents, followed by services (7.02%) and business (3.51%). In terms of educational attainment, the majority of respondents (50.88%) had completed 10th grade, followed by illiterates (30.33%), intermediate level (7.02%), and graduates and above (1.75%). Only 3.51% of all households had enough food from agriculture for the whole year, while the majority had adequate food for 3-6 months (49.12%), followed by 9-12 months (28.07%), and 6-9 months (19.03%). Table 3 shows the respondent's socio-demographic characteristics.

Table 3: Socio-demographic characteristics of the respondents

S.N.	*Characteristics of the respondents*		*Frequency*	*Percentage (%)*
1	Gender	Male	48	84.21
		Female	9	15.79
2	Caste	Schedule caste	20	35.09
		Scheduled Tribe	11	19.30
		Brahmin/Chettri	26	45.61
3	Major Occupation	Agriculture	49	85.96
		Services	4	7.02
		Business	2	3.52
		Others	2	3.51
4	Age	<30 years	7	12.28
		31-50 years	18	31.58
		>50 years	32	56.14
5	Education	Illiterate	19	33.33
		Up to 10th grade	29	50.88
		Intermediate level	4	7.02
		Graduation and more	1	1.75
6	Food sufficiency from agriculture	3-6 month	28	49.12
		6-9 month	11	19.30
		9-12 month	16	28.07
		> 12 month	2	3.51

Climatic data trend

Temperature

The analysis revealed that the mean annual maximum temperature, minimum temperature and average temperature have increased by 0.04, 0.03 and 0.04ºC per year, respectively (Figure 2). The mean annual maximum temperature was recorded highest in 2009 and the mean annual minimum temperature in 2006. The trend of the maximum temperature of the watershed is less than that of the overall Gandaki province (0.078ºC per year) and Nepal (0.054ºC per year) (Upadhayaya and Baral, 2020). The result of the trend analysis is similar to the findings of Karki *et al*. (2020) who recorded the mean annual temperature, minimum temperature and average temperature and accounted an increase in temperature by 0.04, 0.02 and 0.03ºC per year, respectively. This might be due to the topo-climatic environment of the watershed, which is in between the Terai[3] and Himalayan regions of the country.

[3] Lands lying at the foot of a watershed/Himalayas

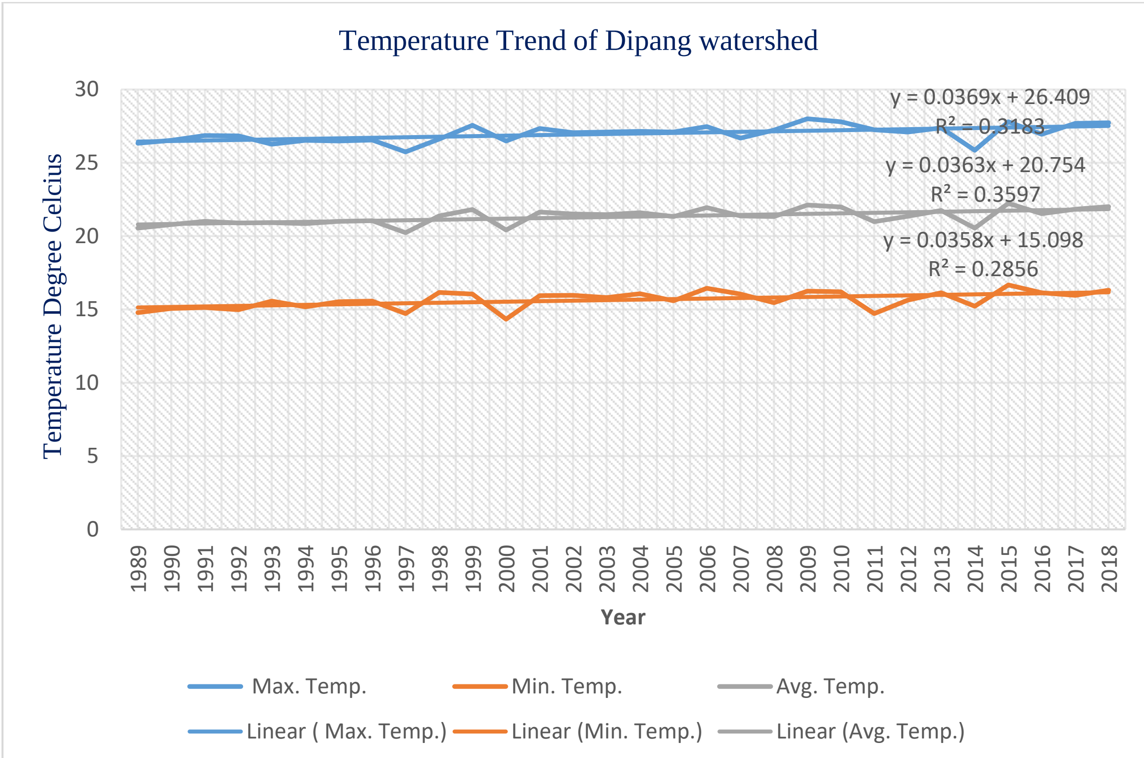

Figure 2: Temperature trend of the Dipang watershed

Precipitation

The average annual rainfall from 1989 to 2018 was estimated to be 3,907.85 mm. The average annual rainfall was found maximum in 1998 (4,879) and minimum in 2009 (2,716.8 mm). The average annual rainfall was found to be decreasing at the rate of 2.30 mm per year. The data showed large inter-annual rainfall variability, as shown in Figure 3. The decreasing rainfall trend in the country is quite evident in many studies (DHM, 2017). The decreasing rainfall trend can adversely impact agricultural productivity and food security (Lamichhane *et al*., 2020), eventually impacting the well-being of agriculture dependent communities.

Perception on changes in climatic variables and its perceived impacts

There has been a shift in climatic circumstances, according to the majority of the respondents. Based on their observations and personal experiences, the individuals perceived that the climate patterns had altered. 82.4% of respondents perceived an increase in temperature; none stated it was cooler than before, while 7% indicated there had been no change in the temperature, and 10.6 percent had no idea about the temperature rise/fall. Similarly, 66.7% of respondents reported a decrease in rainfall, 17% reported an increase in rainfall, and the rest reported that rainfall had remained constant. Figure 4 depicts the impression of a shift in climatic variables.

61.4% of the respondents perceived that dryness in weather has increased, while 26.32% responded that dryness has decreased and 5.26% responded that there has been no change in dryness over the 30 years (1989-2018). Similarly, 78.9 % of the respondents expressed their views that the intensity of rainfall has decreased, 14% perceived it has increased, and 7.1% had no idea about the intensity of rainfall. Regarding water sources, 42.10%, 35%, and 17.5% of the respondents perceived a decrease, an increase, and no change, respectively. Figure 5 depicts respondent's perception of changes in climate trends.

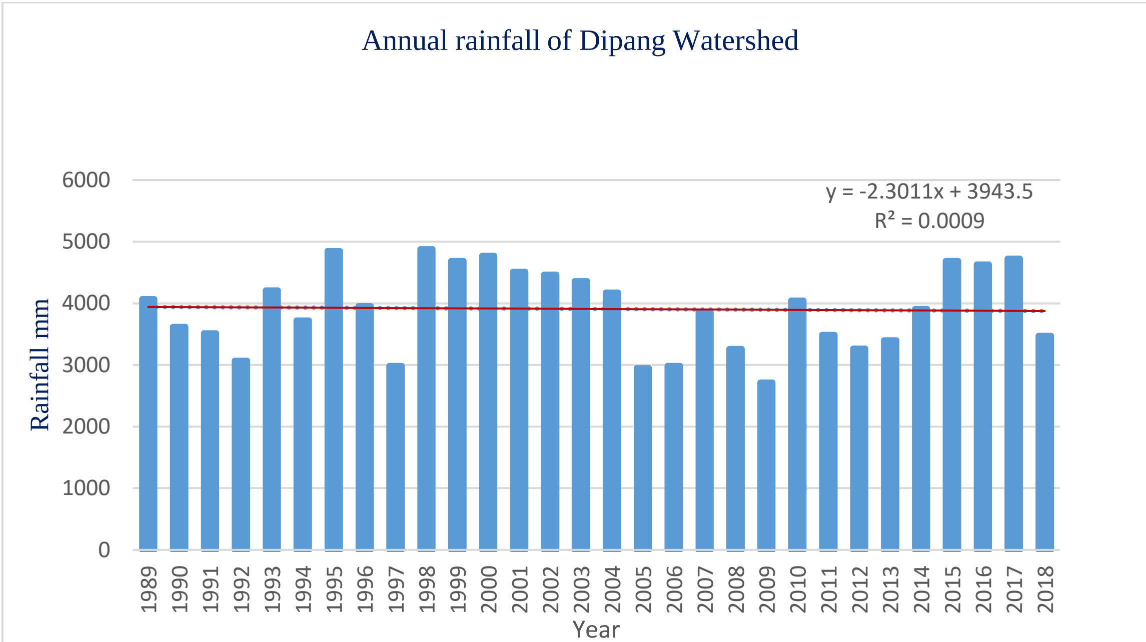

Figure 3: Rainfall trend of the Dipang watershed

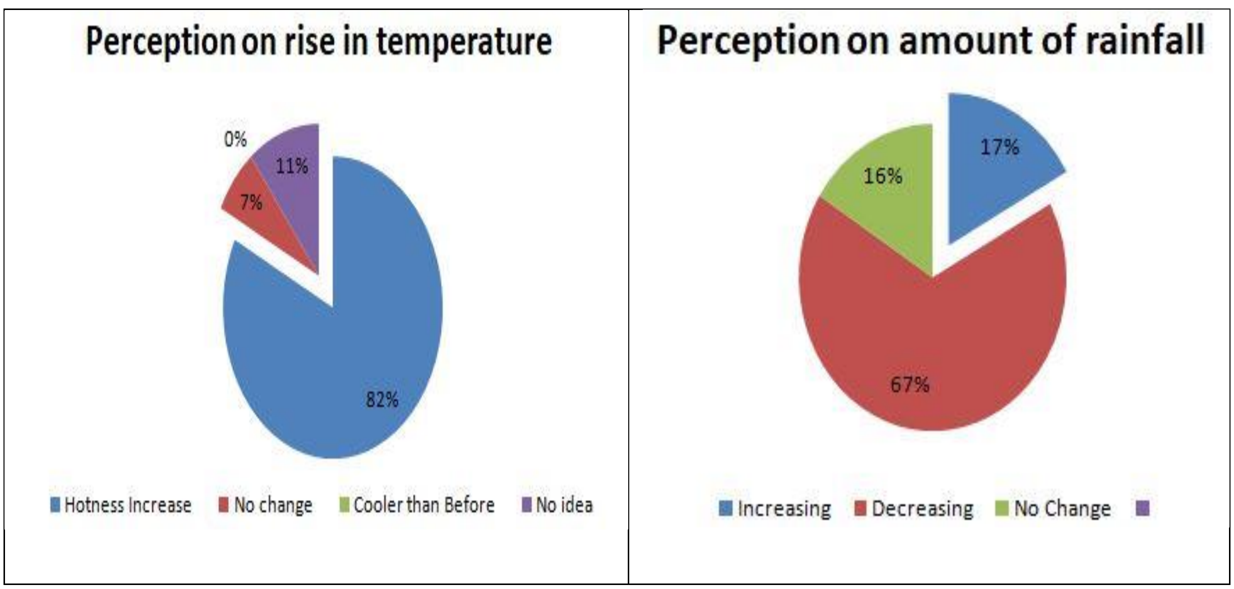

Figure 4: Perception on change in climatic variables

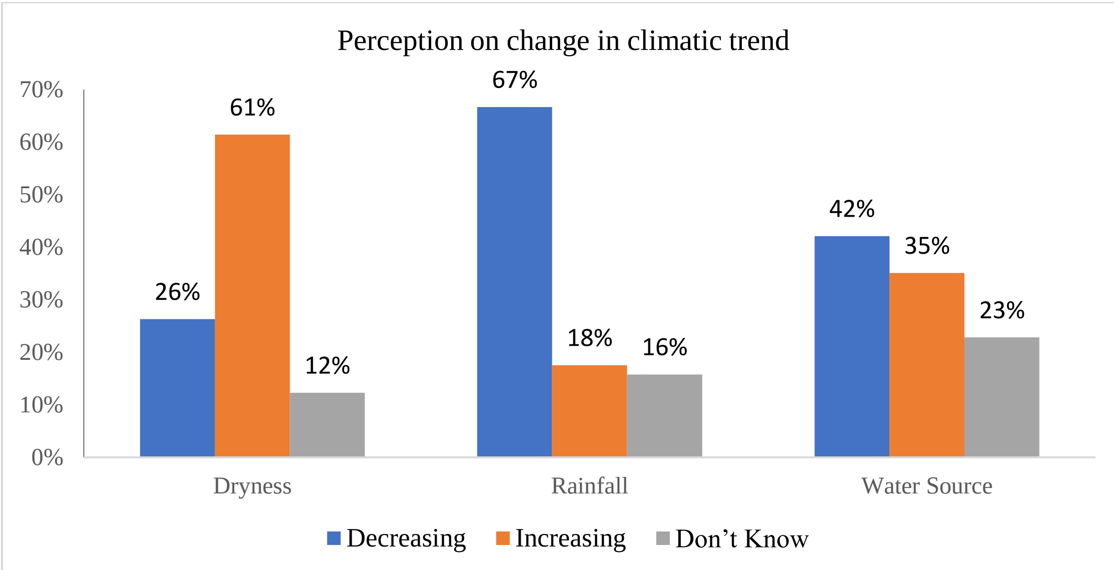

Figure 5: People perception of change in climatic trend

Livelihood vulnerability index analysis

The values of the main components and sub-components contributing to LVI of the watershed are presented in table 3, along with its composite values. A higher index value score signifies higher vulnerability and vice-versa. The overall result showed low household livelihood vulnerability (0.416) in the study area. Out of the seven major components undertaken for the study, households were highly vulnerable to food (0.642) and natural disasters and climate variability (0.566) components. All other components, i.e., water (0.241), socio-demographic profile (0.276), livelihood strategies (0.306), social networking (0.420) and health (0.460), showed low household vulnerability.

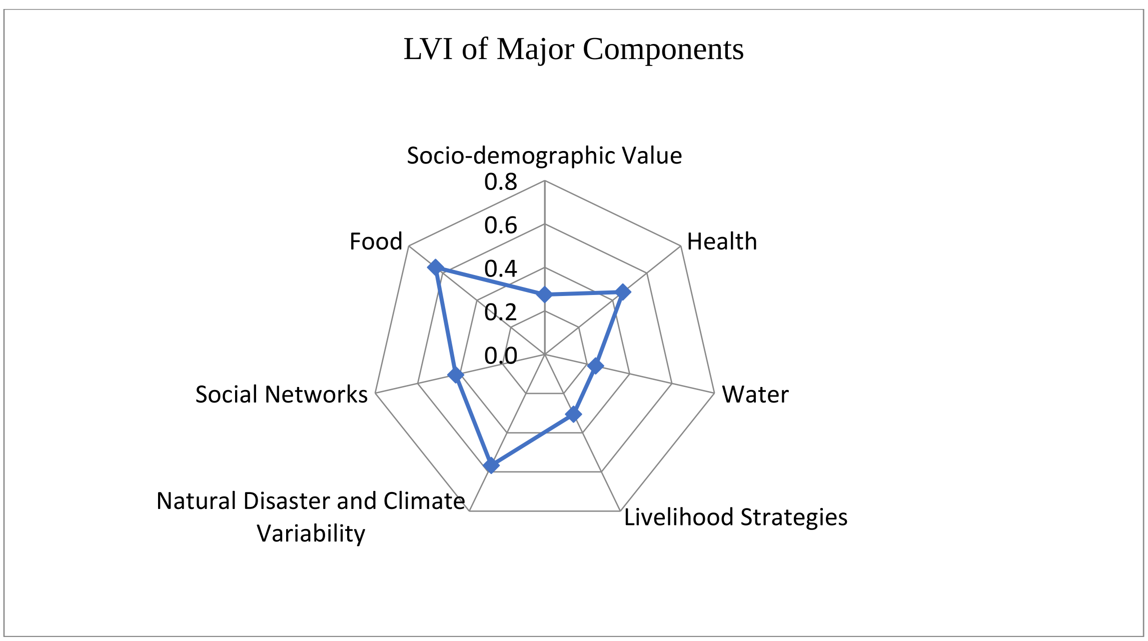

Figure 6: LVI scores of the major components

Table 3: Values of main components and sub-components contributing to LVI

Major component	*Subcomponents*	*Units*	*Actual value*	*Standardized value*
Sociodemographic	Dependency ratio	Ratio	0.27	0.09
	% of female-headed households	%	15.79	0.16
	Avg. age of female-headed households	1/years	0.02	0.40
	% household heads did not complete school	%	33.33	0.33
	The average age of household head	1/years	0.02	0.40
Livelihood Strategies	% of households with a family member working in a different community	%	36.20	0.36
	% of households solely dependent on agriculture as an income source	%	44.45	0.44
	Average livelihood diversification index	1/(no. of livelihoods+1)	0.20	0.11
Social Networks	% household had to receive help through social networks	%	66.67	0.67
	% household borrowed money through social network	%	36.84	0.37
	% household that has not gone to their local government for assistance	%	22.40	0.22
Health	Average time to the health facility	min	77.40	0.59
	% households who reported diseases	%	33.33	0.33
	% households where a family member missed school/work in the past 2 weeks due to illness	%	8.50	0.09
	% households that did not treat water	%	82.45	0.83
Food	% of households dependent solely on the family farm for food	%	42.00	0.42
	% of households struggle to find food in a year	%	78.94	0.79
	Average crop diversity Index	1/(no.of crops+1)	0.25	0.25
	% of households that do not save crops	%	96.49	0.96
	%of households that do not save seeds	%	78.94	0.79
Water	% of households reported having water availability problem	%	32.50	0.33
	% of households that utilize a lake water source	%	15.60	0.16
Natural disasters and climate variability	The average number of flood, drought and landslides, pest and diseases events in the past 20 years	count	2.00	1.00
	% of households that did not receive a warning about recent natural disasters	%	100.00	1.00
	% of households with an injury or death as a result of natural disasters	%	1.70	0.02
	Mean Standard deviation of average monthly Temperature (1989 - 2018)	degree C	0.585	0.10
	Mean Standard deviation of average monthly precipitation (1989 - 2018)	mm	53.89	0.12

	% of households reporting the change in temperature in the last 20 years	%	87	0.87
	% of households reporting the change in precipitation in the last 20 years: 85 percent	%	85	0.85

The food component (0.642) contributed to the highest household vulnerability. Food produced from agriculture has only been sufficient for a few months of sustenance, and only a few households have been able to store food and seeds from agricultural operations. Natural disasters and climate variability consisted of high household livelihood vulnerability (0.566). A similar study conducted in the Moma and Mabote districts of Mozambique (Hahn *et al*., 2009) reflected the lower index values of natural disasters and climate variability compared to this study. The higher values are the results of the perception of change in climatic parameters, incidences of frequent natural disasters such as floods, droughts and landslides and lack of early warning system.

The lowest value for LVI was found for the water component, as most households have access to water round the year. The availability of water from the lake has not been affected by climate change, which indicates the increase in the water area in the lake during the last decade (MoFE, 2018). The lower values of the socio-demographic profile of the study area were consistent with the findings of the study carried out in Lete and Kunjo village of Mustang, Nepal (Urthody and Larsen, 2010), Melamchi River Valley, Sindhupalchowk, Nepal (Sujakhu *et al*., 2019) and Ghana (Baffoe and Matsuda, 2017). As people have job opportunities in other communities and nearby city, and are diversifying income sources, the study found alternate livelihood strategies have been adopted in the area because the livelihood strategies index is low, which is similar to the findings obtained in Moma and Mabote districts of Mozambique (Hahn *et al*., 2009). The social networks component value (0.420) is similar to the study conducted by Urothody and Larsen (2010), which can be attributed to different cooperatives and sub-village development committees and better linkage with the local government. The value of the health index of the study (0.46) is the same as the health index of Nariva wetland (0.46), but higher than Caroni wetland (0.36) (Shah *et al*., 2013). No water is treated for drinking purposes in the study area. This situation can outrage water-borne diseases in the upcoming years as the lake water has been adequately unnoticed for management by government agencies. The results revealed that the vulnerability indices of the major components ranged from 0.241 (water) to 0.642 (food). The graphical presentation of livelihood vulnerability indices is shown in figure 6.

LVI-IPCC

The LVI-IPCC was computed by grouping the seven major components into three categories: exposure, sensitivity, and adaptive capacity. Exposure was made up of only one major component score, while sensitivity and adaptive capacity comprised the aggregated scores of three major components each. According to the LVI-IPCC vulnerability scale, the overall household LVI was moderately vulnerable (0.104). This was similar to the findings from Langtang Valley, Nepal (Nepal *et al*., 2019) and Lower Niumi and Kombo South district, Gambia (Amuzu, 2018), where households were moderately vulnerable with the values of 0.098, 0.023 and 0.02, respectively. The average values of factors contributing to the IPCC-LVI were 0.334, 0.448 and 0.566 for adaptive capacity, sensitivity and exposure, respectively. This indicates that the study area is more exposed to climate change and has a lower adaptive capacity. The graphical representation of the different contributing components to LVI-IPCC is given in figure 7.

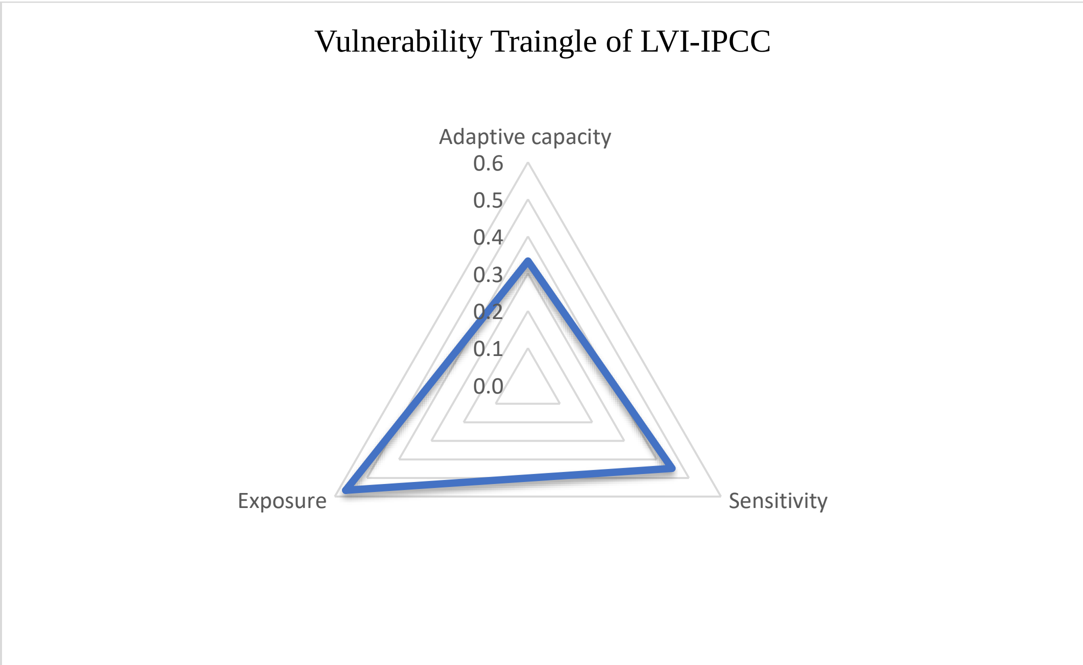

Figure 7: Values of different components contributing to LVI-IPCC

Conclusion and Policy Implication

This study examined the current understanding of climate change impacts on local people's livelihoods in the Dipang watershed by analyzing trends in climatic variables and employing a livelihood vulnerability index. The watershed has witnessed a rise in average annual temperature and decreased rainfall over the 30 years (1989-2018).The LVI (0.416) and LVI-IPCC (0.104) scores indicated that the watershed is low and moderately vulnerable to climate change, respectively. Among all the major components of LVI, food and natural disasters and climate variability contributed significantly to the watershed's vulnerability. The water (0.241) and socio-demographic profile (0.276) were two major components that contributed the lowest for LVI. According to the LVI-IPCC contributing factors, the watershed has high exposure (0.566) and sensitivity (0.448), but low adaptive capacity (0.334).

Climate variability is expected to increase over time, implying an urgent need to reduce the watershed's high exposure to climate risks, improve livelihood strategies, and boost agricultural productivity and health. Agriculture being the main occupation of the people, policy and decision makers should design and implement strategies that reflect the needs of farmers by providing climate resilient seeds, bio-fertilizers, adoption of new farming technologies, integration of diversified agricultural systems and suitable market for agro-based products to make a living. Furthermore, government organizations and policymakers should also, focus on diversifying local people's income sources beyond agriculture. These findings will be critical in developing appropriate adaptation strategies, thereby safeguarding the livelihoods of the watershed's vulnerable population.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5	Author 6
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes	Yes
Collected the data	Yes	No	No	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes	Yes
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes
Supervision	Yes	Yes	Yes	Yes	Yes	No
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