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Understanding households' livelihood vulnerability to climate change in the Lamjung district of Nepal

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Abstract
Based on spatial variation and time, climate change has various levels of impacts on different communities and sometime with the state of development as well. The rural mountainous households that depend on natural resources for subsistence livelihoods and agriculture are particularly vulnerable with changing climate. Livelihood vulnerability assessment at local level is imperative to formulate appropriate adaptation policy and programs to address their livelihood challenges. This paper explored two vulnerability assessment indices, livelihood vulnerability index and IPCC vulnerability index by surveying 150 households from three village development committees (VDCs) in Lamjung district, Nepal. Data related to climate variables, natural disasters, water and food security, health, socio-demographics, livelihood strategies, and social network were collected and combined into indices. Both indices differed based on well-being status, gender of the household head and location across the households of three VDCs. The analysis was based on indices constructed from selected indicators measuring exposure, sensitivity, and adaptive capacity. Results indicated that very poor and poor households, and female-headed households were more vulnerable than medium, well-off and male-headed households. The availability of livelihood diversified strategies, education, establishment of early warning system to climate extreme will help to reduce vulnerability to climate change in the study areas. The findings help in designing priority areas of intervention for adaptation plan to reduce vulnerability and enhance the resilience of the mountainous households to climate change.

Keywords Mountainous region · Vulnerability · Exposure · Sensitivity · Adaptive capacity

1 Introduction

Based on spatial variation and time, climate change has various levels of impacts on different communities (Bellard et al. 2012; Lejeusne et al. 2009; Mearns and Norton 2009; Wagener et al. 2010). The rural mountainous communities that depend on natural resources

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for subsistence livelihoods and agriculture are mostly affected by climate change (Poudel and Shaw 2015). International and national organizations have focused on two major policy responses to address climate change. They focus on reducing the emission of greenhouse gases to slow down the rate of change and increasing the coping capacity of countries, sectors, and communities with the adverse impacts of climate change through adaptation (Ford and Smit 2004). The identification of adaptation needs to start with vulnerability assessment, which is the state of susceptibility to harm from exposure to environmental change (Adger 2006). This vulnerability is influenced by socioeconomic profile, resource use, and other factors. Therefore, not all the communities are equally vulnerable (Fussel 2007).

Several studies have identified several vulnerable groups in low- and middle-income countries (Ayers and Huq 2009). They include households dependent on natural resources for their livelihoods and geographically remote areas (Kohler et al. 2010; Mirza 2011; Terry 2009). In addition, poor households and women are highly vulnerable to climate change (Gentle et al. 2014; Wang et al. 2013). The Ministry of Environment (MoE) (2010) reported that Nepal has witnessed erratic rainfall, unpredictable onset of monsoon seasons, and increasing temperatures. The average annual temperature is increasing by 0.06 °C/year with a higher rate of warming at higher altitude (Ebi et al. 2007; Mishra et al. 2014). Precipitation is becoming more unpredictable and more erratic with prolonged droughts. Similarly, monsoon and pre-monsoon precipitation have become heavier than historical records (Duncan et al. 2013; Poudel and Shaw 2016; Shrestha et al. 2000). These have all led to an increasing vulnerability to droughts, flash floods, landslides, and Glacial Lakes Outburst Floods (GLOFs). However, household vulnerability varies according to time and location (Fang et al. 2016) and thus, substantial frameworks and index systems for measuring household vulnerability in different countries or regions have been introduced, focusing on Ghana (Antwi-Agyei et al. 2013), India (Pandey and Bardsley 2015), Mozambique (Hahn et al. 2009), Nepal (Lamichhane 2010), Vietnam (Can et al. 2013), and other developing countries. However, these studies have not addressed rural mountainous households in Nepal who are threatened by climate change. Since Nepal is ranked as the fourth most vulnerable country based on its extremely vulnerable situation (Maplecroft 2010), climate change will also likely to have a significant impact on the livelihoods of households in the mountainous region. This will eventually increase the vulnerability of households living in the hilly and mountainous parts of Nepal, and a detailed study is urgently needed.

The intergovernmental panel on climate change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes" (IPCC 2001). Most of the analyses are based on the IPCC's definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity, and this is considered as a powerful analytical tool for assessment (Aryal et al. 2014; Ebi et al. 2007; Hahn et al. 2009; O'Brien et al. 2004; Piya et al. 2016; Vincent and Cull 2010). The causes of vulnerability can be different at different social, geographical, and temporal scales, but vulnerability is always experienced locally (Ribot 2009).

Based on the convenience of data collection, some of the previous researches primarily used statistical data to analyze large-scale household vulnerability like household vulnerability at the national level (Adger et al. 2005; Ericksen et al. 2009; Peng et al. 2018). However, this research can overlook the local-level variability (at the household or community level) and shows particularly poor regions seem less vulnerable than they actually are (Antwi-Agyei et al. 2013; Eakin and Bojo 2008; Liu and Li 2016; Morse and Fraser 2005). With the emergence of micro-studies of household vulnerability have gradually transitioned from the macro-perspective to a micro-perspective (e.g., households) (Antwi-Agyei et al. 2013; Can et al. 2013; Etwire 2013; Hahn et al. 2009; Pandey et al. 2016). When measuring household vulnerability, most scholars have considered only household-level indicators; some have noted that households' ability to cope with climate change may be affected by community-level factors (e.g., service facilities, infrastructure construction) (Abdulai et al. 2011; Ahumada et al. 2015; Shah et al. 2013). But in actual empirical research, studies considering household livelihood vulnerability based on well-being status, gender, and location in the same territory are scarce (Antwi-Agyei et al. 2013).

While indexes provide a useful means of comparing and evaluating different units of analysis (e.g., households, geographic regions), they must also be able to incorporate local, context-specific variables (Eakin and Bojo 2008). Without such flexibility, assessments can suffer from a lack of specific, local indicators that may be used to differentiate between vulnerability assessments based on the best quality information obtainable and the limited resources and expertise available (Shah and Rivera 2007). At the household level, an index assessing livelihood vulnerability should provide an explicit indication of the capabilities, assets, and activities required for a sustainable means of living for the respective household (Chambers and Conway 1991). A livelihood is considered sustainable when it can cope with and recover from shocks and maintain or enhance its capabilities and assets, while not undermining the natural resource base. Livelihood vulnerability assessments can provide decision-making information both for adaptation and planning levels.

Hahn et al. (2009) developed a livelihood vulnerability index (LVI) aimed at using household-level data to inform strategic community-level planning. Having incorporated climate exposures and household adaptive practices into their approach, they tested the LVI in two communities in Mozambique, where it proved insightful in capturing differentials in community-level climate vulnerability. The ability of the LVI to draw out subtle yet critical differences in specific vulnerabilities (e.g., related to water, food, etc.) is valuable in formulating policies that can meet the needs of resource-dependent communities in the low- and middle-income countries. Although used in the southern African context of Mozambique, its structured approach provides a realistic framework for the low- and middle-income countries context in general. Drawing upon Hahn et al. (2009), this study explores the analytical utility of using the LVI to understand livelihood and climatic vulnerability in the mountainous households in Nepal.

Few suitable adaptation policies and programs have already been formulated and implemented in some developing countries (Mertz et al. 2009). Nevertheless, only limited knowledge is available on livelihood vulnerability in Nepal at the regional, national (MoE 2010), and household levels (Ghimire et al. 2010). Therefore, the understanding of household vulnerability to climate change is imperative in the context of Nepal, especially to explore how climate change is impacting different well-being groups (Gentle et al. 2014) in the community and different communities in the same territory. Thus, this study aims to analyze the vulnerabilities at the local level in-depth by integrating quantitative data with qualitative information obtained from a field survey. The objective of this research was to identify the most vulnerable households based on location, well-being status, and gender of the household head. To achieve this objective, this research has the following research questions:

1. What are the key contributing factors of vulnerability to climate change for the mountainous households?

2. Who are the most vulnerable households on the basis of location, well-being status, and gender of the household head?

The research set hypothesis as follows:

1. Is there relationship between location of the households and exposure, sensitivity, and adaptive capacity?
2. Is there relationship between well-being status of the households and exposure, sensitivity, and adaptive capacity?
3. Is there relationship between gender of the household head and exposure, sensitivity, and adaptive capacity?

To prove the hypothesis, the analysis was done by analyzing micro-level climate change vulnerability at the household level developing and comparing two types of indices based on different indicators. The livelihood vulnerability index (LVI) is a composite index of all major indicators, while the IPCC vulnerability approach frames the major indicators into three contributing factors to vulnerability: exposure, sensitivity, and adaptive capacity (Aryal et al. 2014; Gentle et al. 2014; Hahn et al. 2009; Panthi et al. 2015; Piya et al. 2016). This makes it easy to identify hazard-induced risks, vulnerability, and the most vulnerable population in the Lamjung district of Nepal. The overall research framework is presented in Fig. 1.

2 Climate change vulnerability

The intergovernmental panel on climate change has developed a holistic approach to climate change vulnerability that combines various methods related to ecological, biophysical, and social vulnerability (Panthi et al. 2015; Piya et al. 2016). In the Fifth Assessment Report (AR5), the IPCC defines vulnerability as "the propensity or predisposition to be adversely affected." Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC 2014). Vulnerability is a function of the character, magnitude, and exposure to climate variation, as well as sensitivity and adaptive capacity (IPCC 2001). This definition considers that exposure is the magnitude and duration of the climate-related exposure due to climate-induced disasters and variability such as landslides, droughts, floods, and variability in average annual temperature and precipitation. Sensitivity is defined as the degree to which a system or its major components are affected by exposure, such as sensitivity to water, food, and health. Adaptive capacity is defined as the system's ability to withstand or recover from exposure, which is mainly based on the social network, livelihood strategies, and socio-demographic profile. The state of exposure is mainly based on geographical locations rather than individual and social characteristics (Adger 1999; Gentle et al. 2014). The adaptive capacity of individuals and society varies according to social dimensions and inequities, such as gender and socioeconomic status (Ribot 2009).

More specifically, vulnerability is a positive function of the system's exposure and sensitivity, as well as a negative function of the system's adaptive capacity (Aryal et al. 2014; Ford and Smit 2004). These dimensions are dynamic and specific to the system (Macchi 2011; Smit and Pilifosova 2003). Adaptive capacity is an important element in most conceptual frameworks of vulnerability and risk. It refers to the positive features of people's

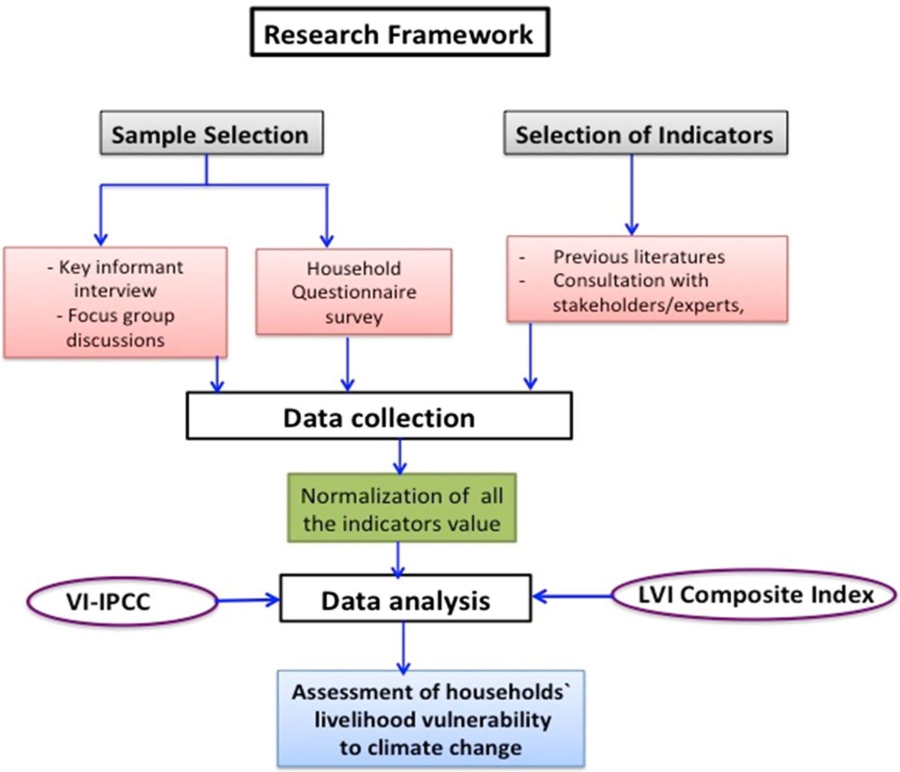

Fig. 1 Overall research framework

characteristics that may reduce the risk posed by certain hazards. The livelihood vulnerability index (LVI) was developed to quantify the vulnerability of different livelihood assets (Hahn et al. 2009). The LVI has been applied in micro-level vulnerability analyses (Hahn et al. 2009; Urothody and Larsen 2010), and it is supported by participatory rural appraisal (PRA) (Chambers and Conway 1991) and other participatory tools for assessing livelihoods vulnerabilities, and risks related to disaster and climate change (Dazé et al. 2009; Gaillard et al. 2013; Pasteur 2011). Accordingly, some studies have used an integrated approach for vulnerability assessments by combining biophysical vulnerability (exposure and sensitivity) with social vulnerability (adaptive capacity) (Gbetibouo and Hassan 2005; Nelson et al. 2010; Piya et al. 2016). This study takes an integrated approach and uses a combination of biophysical and socioeconomic indicators to formulate the IPCC vulnerability index.

3 Materials and methods

Both quantitative and qualitative methods were used based on pragmatism using an interpretivist perspective for this research (Gentle et al. 2014; Johnson et al. 2007). This perspective links quantitative data collection methods with social science-based qualitative methods that often deal with individual actions and their relationship with society.

3.1 Data collection

Data were collected through a mixed method involving quantitative and qualitative approaches. Total 150 households (50 households from each village development committee-VDC) were selected for in-depth interview using stratified random sampling process and represented all well-being groups. The field survey was conducted in May 2015 and January 2016. Key informant interviews (KIIs) ($n=20$ key informants), focus group discussion (FGDs) ($n=9$ events), and participant observations were used to obtain both quantitative and qualitative data. The three VDCs, Kunchha, Khudi, and Ilampokhari were selected based on the availability and the proximity of the observed climatic datasets. The secondary data were collected from different organizations. Temperature and precipitation observations from 1980 to 2013 from stations in these VDCs were obtained from the Department of Hydrology and Meteorology (DHM). Climate-related hazard data were collected from the District Development Committee (DDC) of Lamjung and the International Disaster Database (EM-DAT).

3.2 Selection of indicators

This paper used the LVI composite index framework and exposure, sensitivity, adaptive capacity analytical framework referring the studies of Antwi-Agyei et al. (2013), Can et al. (2013), Etwire (2013), Gerlitz et al. (2017), Guo et al. (2014), Hahn et al. (2009), Liu and Li (2016), Pandey et al. (2014) and Xu et al. (2015) in setting these indicators as dimensions. Participatory rural appraisal (PRA) was applied to select the relevant indicators. Interactive discussion was conducted in multidisciplinary team of subject specialist, local leaders, representative of farmers, women's group, and local government to choose indicators for the vulnerability analysis. The most common criteria used were landholding size, quantity and quality of land, house quality, food sufficiency, income sources, educational status of family, and involvement in saving and credit cooperatives/social organizations. To fully characterize the vulnerable environment faced by the households, this paper selects climate-related disasters floods, landslides, and droughts when measuring the exposure dimension. Similarly, food availability/accessibility, water resource, and health indicators are used for sensitivity dimensions. Households' income sources, involvement in social groups/cooperative, and education are under the adaptive capacity dimensions.

Households were categorized into four well-being groups of well-off, medium, poor, and very poor (Table 1). To categorize households, participatory well-being ranking was applied in the research sites based on the relative well-being status of households in the community using local criteria (Mosse 1994). Different researchers have tested the empirical validity of this method as a means of socioeconomic stratification of households in Nepal and abroad (Gentle et al. 2014; Gentle and Maraseni 2012; Richards et al. 2003; Sharma 2010).

3.3 Data analysis

The sustainable livelihood approach and livelihood vulnerability index (LVI) (Hahn et al. 2009) were modified based on the local environment after consultation with local stakeholders, climate vulnerability experts, researchers, and governmental officials. Several previous researchers followed similar approaches (Gentle et al. 2014; Ghimire et al. 2010; Panthi et al. 2015; Piya et al. 2016). Descriptive and quantitative data collected from

Table 1 Local criteria of well-being developed and applied in this research

Local criteria of well-being	Characters of different well-being groups			
	Well-off	Medium	Poor	Very poor
Food production and sufficiency	Food production enough or more than the year, sale of surplus production	Food production enough around for 9-month period	Food production enough for around 6-month period	Food production enough for 3 months or less
Quality and size of agricultural land	Large size of irrigated and non-irrigated land	Limited irrigated and some non-irrigated land	Limited irrigated land and non-irrigated land	Mostly landless or small parcel of non-irrigated land
Education	Most of the family members are educated, children go to private or urban cities for education	Family members are partially educated, children admitted to local private schools or public schools	Few members in the family are educated, children go to public schools	Family members are rarely educated, either children go to public schools or dropped out from schools
Sources of income	Additional source of income (job, pension, remittance or business) in addition to agriculture	Additional source of income (job, pension, remittance or business) in addition to agriculture	Mostly depend on agriculture and some remittances and other jobs	Mostly depend on agriculture and sale labor in the market
Involvement in saving and credit cooperatives/social organizations	Mostly involved in saving and credit cooperatives and other social organizations	Mostly involved in saving and credit cooperatives and other social organizations	Few involved in saving and credit cooperatives and other social organizations	Rarely involved in saving and credit cooperatives and other social organizations
Quality of houses	Pucca/semi-pucca house	Pucca/semi-pucca house	Semi-pucca house	Kutcha house[a]

[a]Kutcha house means the house made of mud, wood, straw, and low-quality materials in the villages

the household survey were framed by the data needs of the LVI, and the data were analyzed using the Statistical Package for the Social Sciences (SPSS). Analysis of variance (ANOVA) and the Chi-squared test were performed to test the significance of mean values between groups.

3.4 Concept of livelihood vulnerability index (LVI)

The LVI was used to understand the contribution of demographic, social, and physical factors to climate change vulnerability. It was originally designed as a practical tool to provide the required vulnerability information to development organizations, policy makers, and planners. It is a flexible approach where development planners can focus their analysis to match the needs of each geographical location and well-being group (Panthi et al. 2015). From the overall composite index, sectorial vulnerability indices can be segregated to identify potential areas for intervention for adaptation planning (Hahn et al. 2009). Furthermore, vulnerability indicators developed to estimate livelihood vulnerability in two districts of Mozambique (Hahn et al. 2009) were modified to fit the context of Nepal and applied according to well-being status, gender of the household head, and location of the respondents. Descriptive information generated from the survey based on 19 sub-components was grouped into eight major components: climate variability, natural disasters, heath, food, water, socio-demographic profile, livelihood strategies, and social networks (Table 2). The data were collected from household survey, KIIs, and Focus Group discussions for each component. For example, for Natural Disaster component, we collect the data of the disaster indicators, i.e., floods, landslides, and droughts for the last 30 years from EM-DAT then calculated the average number of disaster per year. For the justification of the number of disasters, we did focus group discussion with different groups. Indicators and variables were chosen in consultation with experts, the extensive literature review and came from statistical data sets combined by simple addition with equal weights (Aryal et al. 2014; Gentle et al. 2014; Hahn et al. 2009; Panthi et al. 2015; Piya et al. 2016).

3.5 Livelihood vulnerability index calculation

3.5.1 Calculating the LVI: composite index approach

All eight major components of the LVI comprise several indicators or sub-components, and their functional relationship is presented in Table 2. The sub-components within the major components of vulnerability were customized to the local context by consultation with several field-level experts and stakeholders and based on the previous literature. Many authors have used a similar approach in various contexts because this assessment tool is accessible to a diverse set of users in resource-poor settings (Aryal et al. 2014; Etwire 2013; Panthi et al. 2015; Shah et al. 2013). The LVI applies equal weights to all major components. We used the equal weights method since we do not have enough information to compute the weight of individual component (Hahn et al. 2009; Panthi et al. 2015; Sullivan 2002). Additionally, the equal weight is a simple method. It makes the analysis easier straightforward to interpret and therefore more transparent and accessible to policy advisor. Each of the sub-components was measure on a different scale, so it was first necessary to normalize them for comparability. The equation for normalization is given in Eq. 1.

Table 2 Major components and sub-components, information sources, and their functional relationship

Major components	Sub-components	Data source	Assumed functional relationship
Climate variability	Mean standard deviation of monthly average of average maximum daily temperature (1980–2013)	Department of Hydrology and Meteorology	Higher variability implies higher exposure
	Mean standard deviation of monthly average of average minimum temperature (1980–2013)	Department of Hydrology and Meteorology	Higher variability implies higher exposure
	Mean standard deviation of monthly average of precipitation (1980–2013)	Department of Hydrology and Meteorology	Higher variability implies higher exposure
Natural disasters	Average numbers of floods in the past 30 years	District development committee/Survey data	More reflects higher exposure
	Average numbers of landslides in the past 30 years	District development committee/FGDs	More reflects higher exposure
	Average numbers of droughts in the past 30 years	District development committee/FGDs	More reflects higher exposure
	Percent of households that did not receive a warning about recent natural disasters	District development committee/FGDs	More reflects higher exposure
Health	Percent of households with emergence of insects health problems/diseases	Household survey	Higher percentage implies higher sensitivity
Food	Average food insufficiency months of households (0–12)	Household survey	More months implies more sensitivity
	Percent of households with food availability decreased	Household survey	Higher percentage implies higher sensitivity
	Percent of households with food accessibility decreased	Household survey	Higher percentage implies higher sensitivity
	Percent of households with food utilization deteriorated	Household survey	Higher percentage implies higher sensitivity
Water	Percent of households with decreased water resources	Household survey	Higher percentage implies higher sensitivity

Table 2 (continued)

Major components	Sub-components	Data source	Assumed functional relationship
Socio-demographic status	Percent of female-headed households	Household survey	Women typically have less adaptive capacity (Gentle et al. 2014; Mainlay and Tan 2012; Panthi et al. 2015) Most households in Nepal are male-headed; female headed means males are outside home or single parent, which definitely suggests less adaptive capacity
	Percent of household with school not attended household head	Household survey	Education makes people more aware and able to adjust to change in environmental condition
Livelihood strategies	Percent of landless households (less than 0.1 ha)	Household survey	Having more land increase adaptive capacity
	Percent of households without other sources of income	Household survey	Income diversification increases adaptive capacity
	Percent of households with no irrigation facility to grow primary crops	Household survey	Irrigation facility implies sustainable yield that increase adaptive capacity in an extreme weather
Social network	Percent of households not involve in saving and credit cooperatives/social groups	Household survey	Involvement in social groups makes people more aware about current affairs, and they can receive support from the community with high priority, which increases adaptive capacity

$$\text{Index}\,S_{\mathrm{V}} = \frac{S_{\mathrm{V}} - S_{\min}}{S_{\max} - S_{\min}}. \tag{1}$$

where S_V means original sub-components for the VDCs, and S_{max} and S_{min} are the maximum and minimum values that reflect high and low vulnerability for each sub-component. S_{max} and S_{min} are determined using data from all three surveyed VDCs. For example, the sub-component measuring the percentage of households with decreased food availability ranged from 0 to 100. These minimum and maximum values were used to transform this indicator into a normalized value between 0 and 1 so that it would be possible to integrate it into the food component of the LVI. Similarly, the sub-component measuring the average numbers of months where households faced food insufficiency ranged from 0 and 12. The minimum value was set as 0, and the maximum was 12.

An index for each major component of vulnerability was created by averaging the normalized sub-components most related to it:

$$M_{\mathrm{V}} = \frac{\sum_{i=1}^{n} \mathrm{index}S_{\mathrm{V}i}}{n} \tag{2}$$

where M_V is one of the eight major components for the VDC, S_{Vi} represents the sub-components indexed by i that make up the major component, and n is the number of sub-components in each major component. Once values for each of the eight major vulnerability components for VDC are calculated, they are averaged using Eq. (3) to obtain the VDC-level LVI:

$$\mathrm{LVI}_{\mathrm{V}} = \frac{\sum_{i=1}^{8} W_{\mathrm{m}i} M_{\mathrm{V}i}}{\sum_{i=1}^{8} W_{\mathrm{m}i}} \tag{3}$$

This equation can be expressed in an expanded form as:

$$\mathrm{LVI}_{\mathrm{V}} = \frac{W_{\mathrm{CV}}\mathrm{CV}_{\mathrm{V}} + W_{\mathrm{ND}}\mathrm{ND}_{\mathrm{V}} + W_{\mathrm{H}}H_{\mathrm{V}} + W_{\mathrm{F}}F_{\mathrm{V}} + W_{\mathrm{w}}W_{\mathrm{V}} + W_{\mathrm{SDP}}\mathrm{SDP}_{\mathrm{V}} + W_{\mathrm{LS}}\mathrm{LS}_{\mathrm{V}} + W_{\mathrm{SN}}\mathrm{SN}_{\mathrm{V}}}{W_{\mathrm{CV}} + W_{\mathrm{ND}} + W_{\mathrm{H}} + W_{\mathrm{F}} + W_{\mathrm{W}} + W_{\mathrm{SDP}} + W_{\mathrm{LS}} + W_{\mathrm{SN}}}. \tag{4}$$

where CV is climate variability, ND is natural disasters, H is health, F is food, W is water, SDP is social demographic profile, LS is livelihood strategies, and SN is social network.

LVI_V is the livelihood vulnerability index for VDC_V, and it equals the weighted average of the eight major components. The weights W_{mi} of each major component are determined by the number of sub-components that make up the component and are included to ensure that all sub-components contribute equally to the overall LVI (Hahn et al. 2009; Panthi et al. 2015; Sullivan 2002). The overall LVI was scaled from 0 (least vulnerable) to 0.8 (most vulnerable). For illustrative purposes, a detailed example of calculating the LVI is given in Online Resources 1 and 2. A similar method was applied to calculate the LVI of different well-being groups and gender of the households' head.

3.5.2 Calculating the VI-IPCC: IPCC framework approach

Another method is applied for calculating the LVI based on the IPCC vulnerability definition, which focuses on exposure, sensitivity, and adaptive capacity. All the components/sub-components that are used for the composite index are also applied for VI-IPCC. Table 2 shows the organization of the eight major components in the VI-IPCC framework.

Exposure is measured by the climate variability and natural disasters. Climate variability is calculated by the mean standard deviation of the monthly average of average maximum and minimum daily temperature and precipitation. The numbers of natural disasters that occurred in the past 30 years was considered. In addition, the value of the precipitation sub-component was derived from averaging the mean standard deviation of the monthly average precipitation of the three stations for the well-being status and gender of the household head. Similarly, sensitivity was measured by assessing the current state of a VDC's food security, water resources, health, diseases, and emergence of insects. Adaptive capacity is quantified by the demographic profile of households and VDCs (e.g., male-headed households), types of livelihood strategies (% of households with other sources of income), and strength of social network (involvement in saving and credit cooperatives). Because these indicators are suitable in the local context of Nepal where involvement in the social organization, migration of male member are increasing. Involvement in the social groups could help communities through livelihood support and preparedness against risk during climatic extremes. The remittance received from the migrated member fulfills the economic requirements of the family during and after the disasters.

When calculating the index, it is necessary to calculate the value of the adaptive capacity from the inverse of the sub-components that make up this factor. This is because the adaptive capacity contributes to vulnerability in a different way than the exposure and sensitivity, high values of exposure, and sensitivity contribute positively to vulnerability. In contrast, high values for adaptive capacity contribute negatively to vulnerability (it reduces vulnerability).

The same components outlined in Table 2 and Eqs. (1), (2), and (3) were used to calculate the VI-IPCC. The index value is different from the LVI in how the major components are combined. Instead of merging the major components into the LVI in aggregate, they are first combined according to the categorization into exposure, sensitivity, and adaptive capacity:

$$\mathrm{CF}_{\mathrm{V}} = \frac{\sum_{i=1}^{n} W_{\mathrm{m}i} M_{\mathrm{V}i}}{\sum_{i=1}^{n} W_{\mathrm{m}i}} \tag{5}$$

where CF_{V} is one of the contributing factors to VI-IPCC (exposure, sensitivity, or adaptive capacity) for $\mathrm{VDC}_{\mathrm{V}}$, $W_{\mathrm{m}i}$ is the weight of one of the major contributing factors, and $M_{\mathrm{V}i}$ is the major component for the $\mathrm{VDC}_{\mathrm{V}}$ indexed by i. Equal weight was given to all the components because we did not have detailed information to justify assigning different weights (Aryal et al. 2014; Hahn et al. 2009; Panthi et al. 2015). After calculating the contributing factors, the vulnerability is calculated using the following formula:

$$\text{Vulnerability} = \text{Exposure} + \text{Sensitivity} - \text{Adaptive Capacity} \tag{6}$$

The vulnerability index ranges from − 1 (least vulnerable) to 1 (most vulnerable).

4 Study area

Lamjung district is the study area of this research, and it is located in the western mountainous region of Nepal. Its elevation varies from 596 to 7893 m above sea level (masl) and covers the area of 1692 km^2 with population of 167,724 (CBS 2012). More than two-third of the population of Lamjung depends on agriculture for their livelihood (Gentle et al.

2014). Occasional frosts, hailstorms during the spring and autumn, and floods/landslides caused mostly by heavy monsoon season are the key natural calamities in the study area. Those have direct impact on the livelihood of the natural resources depended mountainous households. Most importantly, Lamjung district is one of the most vulnerable districts (due to climate change) among the 75 districts in Nepal (Poudel and Shaw 2016). This study was conducted in three VDCs namely Kunchha, Khudi, and Ilampokhari of Lamjung district (Fig. 2) to explore the livelihood vulnerability to climate change. These VDCs were chosen based on the availability of hydrological and meteorological data. These VDCs are the good representative of the mountainous region of Nepal. Previous study has showed that most of the households in this region had noticed and experienced the variation of weather pattern such as increased temperature, intense rainfall, frequency of natural disasters, increasing numbers of existing insects. (Poudel and Shaw 2016). The identification of priority areas of intervention for adaptation plan and implementation is crucial for this region. Therefore, it is imperative to start with understanding of vulnerability to design the effective adaptation strategies.

5 Results and analysis

5.1 Livelihood vulnerability index (LVI)

The results of understanding the livelihood vulnerability are presented in two different ways. First, the results derived from the assessment of individual major components and sub-components' contributions to each major component are presented together with the overall LVI (Fig. 3, Online Resources 1 and 2). Second, the estimated values for the

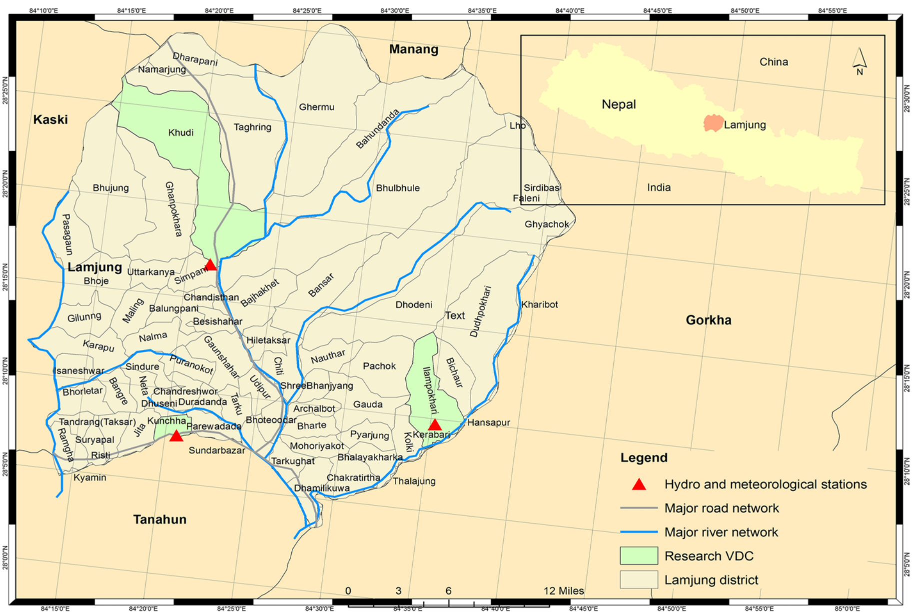

Fig. 2 Map of study area

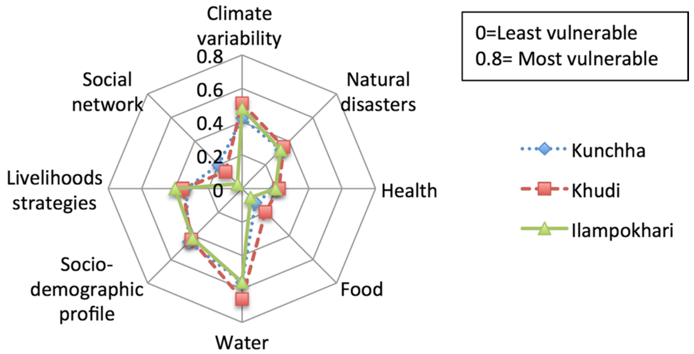

Fig. 3 Vulnerability spider web diagram for the major components of the livelihood vulnerability index (LVI) for the Kunchha, Khudi, and Ilampokhari VDCs

different dimensions (exposure, sensitivity, and adaptive capacity) of the climate vulnerability index are presented (Figs. 4, 5, 6, and Online Resource 3). Climate change vulnerability was tested to examine the vulnerable communities according to location of the households (Kunchha, Khudi, and Ilampokhari), their well-being status, and gender of the household head. Exposure was measured in terms of climate variability and natural disasters; sensitivity was measured in terms of impacts on health, food, and water; and the adaptive capacity was measured in terms of socio-demographic profile, livelihood strategies, and social network of the households.

The overall LVI was higher for Khudi VDC (0.351) as compared to the Kunchha VDC (0.310), and Ilampokhari VDC (0.309), indicating that households of Khudi are more vulnerable. The results for major components are presented in a spider web diagram in Fig. 3. Khudi households were rated more vulnerable in terms of climate variability, natural disasters, health, food, and water. Kunchha was more vulnerable in regard to socio-demographic profile and social network. The livelihood strategies

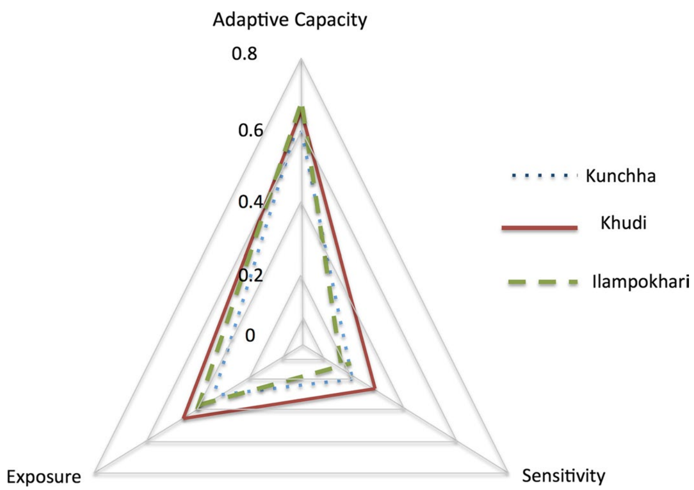

Fig. 4 Vulnerability triangle diagrams of the contributing factors of the livelihood index-IPCC (VI-IPCC) for Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

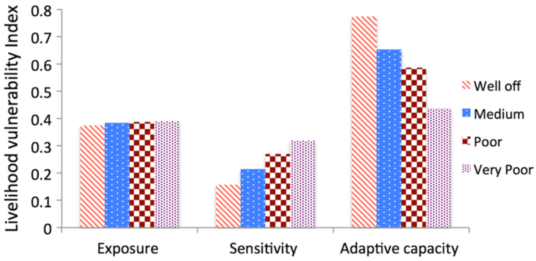

Fig. 5 Livelihood vulnerability according to well-being status of the households in Lamjung LVI value of 0 indicates the lowest, while 0.8 indicates the highest

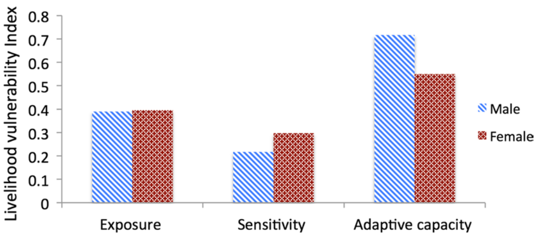

Fig. 6 Livelihood vulnerability according to gender of the household head LVI value of 0 indicates the lowest, while 0.8 indicates the highest

component had the highest value in Ilampokhari. The Khudi VDC is more exposed to extreme climate conditions, and the mean standard deviation of the monthly average of precipitation is higher than in Ilampokhari and Kunchha. However, the mean standard deviations of the monthly average minimum and maximum temperatures are the same for all study sites. Temperature data were available from only one station in the study areas.

The huge deviation in precipitation is also reflected in natural disasters, particularly landslides, and droughts in the Khudi VDC. Therefore, natural disaster vulnerability is also higher in comparison with Ilampokhari and Kunchha. In Khudi, 56% of the households reported that the availability of water resources decreased in winter over the 20-year period. Water vulnerability of the mountainous households is a particular problem when there is a high dependency of agriculture on rainwater and when the existing infrastructure is poor (Pandey et al. 2014). Due to the higher average number of food-insufficient months (6.09 months) and higher percentage of households (24%) with decreased food availability, food vulnerability of the Khudi VDC (0.1968) was also higher than in Kunchha (0.1162) and Ilampokhari (0.0737). The reason behind decreased food availability was the production loss by floods in the study area. In addition, the small size of land holdings (10% HH had less than 0.1 ha) and higher percentage of households (60%) with no irrigation facilities were other contributing factors for the higher LVI of Khudi.

The Kunchha VDC (0.45) was more vulnerable in regard to the socio-demographic profile and social network in comparison with Khudi (0.43) and Ilampokhari (0.42) (as indicated by the LVI value). Most of the sub-components were highest in this VDC, including the average numbers of floods, and the percentage of households with decreased food accessibility (4%) and deteriorated food consumption patterns (6%). The percentage of female-headed households (58%) was also highest in this VDC, which reflects that the majority of the population is from ethnic groups (42%, CBS

2012) where most of the male counterparts go abroad for employment (Gurungs, Magars, Tamangs, marginalized groups, etc.).

Compared with Khudi and Kunchha, the LVI of households was lower in the Ilampokhari VDC, indicating that they were less vulnerable to climate change. The most promising result was that none of the components had the highest index value except for livelihood strategies. Even at the sub-component level, only two sub-components had the highest value for this VDC: households with heads who did not attend school (58%), and households without other sources of income (60%). All other sub-components were relatively good in this VDC. A similar result was shown by a report prepared by the district development committee of Lamjung, which showed that Ilampokhari VDC is less vulnerable in comparison with Khudi and Kunchha (DCEP 2014).

5.2 Vulnerability index-IPCC approach

The VI-IPCC score indicates vulnerability on a scale of −1 to +1. The results are similar in that households of Khudi (0.042) are the most vulnerable, followed by Kunchha (−0.077) and Ilampokhari (−0.085). The indexed values are calculated for each dimension of exposure, sensitivity, and adaptive capacity (Online Resources 2 and 3). The results show that Khudi is more exposed (0.421) to climate variability and natural disasters than Ilampokhari (0.392) and Kunchha (0.368). Similarly, accounting for current health status and the availability of food and water, Khudi (0.277) was also more sensitive to climate change impact than Kunchha (0.204) and Ilampokhari (0.175). Kunchha (0.650), Khudi (0.656), and Ilampokhari (0.653) all had similar adaptive capacity, although there was a difference in exposure and sensitivity. In the VI-IPCC approach, the adaptive capacity is higher than the exposure and sensitivity to climate change in all three VDCs (Fig. 4). However, the Khudi VDC had the highest value in two major factors of vulnerability (exposure and sensitivity).

Khudi had the highest index value in the sub-component of the mean standard deviation of monthly average precipitation compared to the two other VDCs. This indicated that Khudi experienced more extreme climate events that lead to a high exposure value. Similarly, sensitivity in Khudi was attributed to all components of food, health, and water. There were a large number of households that had been affected by decreased water and food availability, and a higher number of food-insufficient months from their own production. In addition, a large number of families reported increasing numbers of insects or diseases in the research area.

Regardless of the similar adaptive capacity, the Khudi VDC is considered more vulnerable than the Kunchha and Ilampokhari VDCs due to higher exposure and higher sensitivity. However, no significant relationship was observed from the ANOVA between the vulnerability of the three VDCs and exposure ($P > 0.05$), sensitivity ($P > 0.05$), and adaptive capacity ($P > 0.05$) as major factors of vulnerability (online resource 4). The analysis shows that there was a uniform pattern or trend between vulnerability factors and components within the three VDCs. Although the three VDCs varied according to altitude, livelihood opportunities, distance from district headquarters, and ethnicity of the households, the differences were neither significant nor decisive factors in defining the level of vulnerabilities.

5.2.1 Livelihood vulnerability according to well-being status of the households

Livelihood vulnerability was analyzed according to well-being status of the households. The results reveal that the vulnerability factors (exposure, sensitivity, and adaptive capacity) varied according to the well-being status of the households (Fig. 5). Very poor and poor households are more exposed to natural disasters, as they reported more events of natural disasters such as landslides and droughts. In the remote areas of Nepal, mostly poor households are concentrated on slopes and steep hills for their livelihood due to the lack of access to the lowland areas. Sensitivity is also higher for very poor and poor households, followed by medium and well-off households. The differences in the food component are mainly higher due to (1) higher average food-insufficient months of very poor and poor households, (2) higher percentage of decreased in food availability or accessibility, and (3) higher percentage of deterioration in food consumption patterns.

The adaptive capacity of the households is significantly different (P value $0.0001 < 0.05$) according to well-being status. The differences are mainly due to (1) a higher percentage of household heads who did not attend school among very poor and poor households, (2) higher percentage of households that did not have alternative sources of income besides agriculture among very poor and poor households, and (3) small landholding size and rarely irrigated land among very poor and poor households in comparison with well-off and medium households. Survey data revealed that 50% of all respondents had irrigation facilities to grow their primary crops, including 81% of well-off, 40% of medium, 42% of poor, and 23% of very poor households. Chi-square analysis (Chi-square value = 22.922, $DF = 3$) showed that irrigation facilities to produce primary crops had a significant association with well-being status ($P < 0.05$) of the respondents. However, there was no statistically significant difference between well-being status, exposure ($P > 0.05$), and sensitivity ($P > 0.05$).

5.2.2 Livelihood vulnerability according to gender of household head

LVI analysis showed that climate change vulnerability varied according to the gender of the household head. The survey data show that the percentages of male- and female-headed households are 62% ($n = 93$) and 38% ($n = 57$), respectively. The analysis of vulnerability according to household head was relevant in the context of rural mountainous areas of Nepal, as the number of female-headed household was increasing because of migration of male members to other places and countries for better opportunities. The population census carried out in Nepal in 2011 revealed that the female-headed households have increased between 2001 and 2011 from 14.87% to 25.73% (CBS 2012). The percentage of female-headed household was higher (38%) than the national average (25.73%) at the research site.

According to the well-being status, well-off households had the highest percentage (41%) of female-headed households, followed by poor (39%), very poor (38%), and medium households (35%). The analysis shows that female-headed households had slightly higher exposure (0.395) and sensitivity (0.296), as well as lower adaptive capacity (0.549) in comparison with male-headed households (Fig. 6). Similar results were derived by previous researchers (Gentle et al. 2014; Mainlay and Tan 2012; Panthi et al. 2015). The exposure was slightly higher among female-headed households, as higher numbers of natural disasters such as landslides and floods are reported by female-headed households. Females are traditionally bound to household works, but in recent years, they have been facing increased burdens of household work along with agricultural activities due to the absence of their male counterparts.

The difference in sensitivity was due to higher differences in health, food, and water components between male-headed households and female-headed households. The differences were (1) a higher percentage (66.66%) of female-headed households reported the emergence of insects or diseases, as well as (2) a higher percentage (3.5%) of decreased food accessibility, and (3) a higher percentage (64.91%) of decreased water resources. Similarly, female-headed households had a higher percentage of landlessness (89.47%) and lower percentage (22.81%) of involvement in saving and credit cooperatives. Therefore, the adaptive capacity is also lower in comparison with male-headed households.

The adaptive capacity (P value $0.018 < 0.05$) of the households is significantly different according to the gender of the household head. Because male-headed households had less sensitivity value (0.217) and had more adaptive capacity (0.716) than female headed (0.296) and (0.549) households, respectively. The differences were mainly due to a lower percentage of landlessness among male-headed households and higher percentages of households involved in social organizations. Similarly, a higher percentages of female-headed households (66.66%) reported increasing number of insects/health problem, higher food-insufficient months (4.1 months), a higher percentage of households (3.5%) with food accessibility decreased.

Overall, Khudi had a higher LVI than the Kunchha and Ilampokhari VDCs, indicating greater vulnerability to climate change impact. The results of the major component calculations are presented collectively in a spider web diagram (Fig. 3). The scale of the diagram ranges from 0 (less vulnerable) to 0.8 (most vulnerable). Similarly, very poor and poor households are more vulnerable, followed by medium and well-off households. Female-headed households are more vulnerable than male-headed households due to the higher exposure and sensitivity and lower adaptive capacity.

6 Discussion

The households in the rural mountainous areas of Nepal are already experiencing the impacts of climate change on their livelihoods. The research applied LVI composite index and VI-IPCC approaches to identify the contributing factors for vulnerability and the most vulnerable households in the studied areas. The households that depend only income source or rain fed agriculture were more vulnerable. The trend of drying water resources, erratic rainfall, and increasing numbers of pests showed that subsistence farming and livelihoods in the Kunchha and Khudi VDCs of Lamjung are becoming more challenging with the impacts of climate change than Ilampokhari. Similar to other researches, the overall vulnerability greatly varies according to gender of the household head and well-being status of the households within the study areas (Gentle et al. 2014; Gentle and Maraseni 2012; Panthi et al. 2015). Because of the higher sensitivity of the very poor, poor households to the food, water, and health components and the lower adaptive capacity in terms of poor sociodemographic status, limited livelihood diversification strategies create large differences in vulnerability. Female-headed household had higher livelihood strategies because of earning from the male counterpart outside the villages. However, because of the low ownership on land, overall adaptive capacity of the female-headed households was lower than male-headed households. Several researchers Gentle et al. (2014), Gentle and Maraseni (2012) and Ribot (2009) show similar results that describe the socioeconomic, institutional, and policy dimensions of the households and communities govern sensitivity and adaptive capacity as components of vulnerability. The major determining factors causing vulnerability are access to resources and services, access to and control over natural resources such as land and water, as well as affordability of basic services such as food, water, and health. The outcomes of this research are consistent with previous research (Adger et al. 2003; Gentle et al. 2014; IISD 2003; Paavola and Adger 2005), which indicates that the poor within the communities are affected more by the impacts of climate change.

Despite the useful explorations conducted by this research, there are still some limitations to be overcome. For instance, this study focuses only on the livelihood vulnerability of residents in the mountainous areas and thus lacks comparison with residents of other areas of the country. This study cannot cover the natural capital, fixed assets value, physical capital to determine the coping capacity of the households. With a single mountainous region as the focus, the study's results may be limited. Additionally, challenges prevail in terms of selecting suitable indicators and assigning appropriate weights to them. The weakness of the indicator approach is that there is some level of subjectivity in choosing indicator (Etwire 2013; Panthi et al. 2015). Further study is required to determine if the research results can be applied to other mountainous regions. Similarly, further comparison is needed with respect to the differences in household's livelihood vulnerability conditions in other regions. This method can be applied to calculate the vulnerability of sectors, regions and communities by increasing the sample size and covering different climatic zones in subsequent studies going forward.

7 Conclusion and implication of the findings

The LVI and VI–IPCC are related methods for assessing the aggregate relative vulnerability of communities to the impacts of climate change. Both approaches provide a detailed depiction of several factors affecting household livelihood vulnerability. The LVI composite index analyzed the overall vulnerability of the households and explained the contributing factors to vulnerability. VI-IPCC showed the dimensions of vulnerability from exposure, sensitivity, and adaptive capacity analytical framework. And the results showed similar type of vulnerability among three VDCs. This helps to set the priority areas of intervention for adaptation plan at the local level from community and government perspective. Both of these indices varied across the three VDCs, different well-being groups, and gender of the household head. The results indicate that the households of the Khudi VDC, very poor households, and female-headed households in Lamjung were the most vulnerable to climate change. The indexed values for each component and sub-component varied notably across sites, which provided insights for the design and implementation of site-specific coping strategies for the rural households.

The findings of this research can help to understand the contributing factors to vulnerability and enhance adaptive capacity of the rural households. Income and livelihood diversification options are essential for reducing the vulnerability of the local community (Ghimire et al. 2010; Panthi et al. 2015). This method can also be applied to calculate and compare vulnerable communities in other rural areas because the method is flexible, and indicators and sub-components can be changed or replaced to calculate the vulnerability of sectors, regions, or communities (Aryal et al. 2014). This type of research is very important for focusing on reducing the impacts of climate change and vulnerability (Rosenzweig and Wilbanks 2010). In determining the vulnerability of rural and remote areas in Nepal, it is important to consider the role of socioeconomic changes, such as changing professions from agriculture to business or food crops to cash crops, and labor migration.

The findings have an implication for Nepal's climate change policies and programs, such as national adaptation programs of action (NAPA) 2010, local adaptation programs of action (LAPA) 2011, and climate change policy 2011, which ignored the concept of differential vulnerability in terms of analysis and adaptation planning. The findings suggest that the local communities as a unit of vulnerability analysis and the most vulnerable communities should be prioritized as groups for adaptation planning. Similarly, the findings have practical implications in vulnerability analysis and adaptation planning in consideration of geographical area, well-being status, and gender of the household head. Both NAPA and LAPA are oriented toward addressing climate hazards, overlook sociopolitical and underlying causes of vulnerability, and lack a process to identify and address the most vulnerable populations (Gentle et al. 2014). This process may result in inaccurate vulnerability analysis and further hinder identification of the adaptation needs of the most vulnerable communities. A micro-level analysis of vulnerability may help in understanding the complexities and in designing adaptation plans at the local level. However, the accuracy is based on the relevancy of indicators and the reliability of local responses, including well-being ranking and stratification of households.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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