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ORIGINAL ARTICLE

Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal

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Abstract Climate change vulnerability depends upon various factors and differs between places, sectors and communities. People in developing countries whose subsistence livelihood depends mainly upon agriculture and livestock production are identified as particularly vulnerable. Nepal, where the majority of people are in a mixed agro-livestock system, is identified as the world's fourth most vulnerable country to climate change. However, there is limited knowledge on how vulnerable mixed agro-livestock smallholders are and how their vulnerability differs across different ecological regions in Nepal. This study aims to test two vulnerability assessment indices, livelihood vulnerability index and IPCC vulnerability index, around the Gandaki River Basin of central Nepal. A total of 543 households practicing mixed agro-livestock were surveyed from three districts, namely Dhading, Syangja and Kapilvastu representing three major ecological zones: mountain, mid-hill and Terai (lowland). Data on socio-demographics, livelihood determinants, social networks, health, food and water security, natural disasters and climate variability were collected and combined into the indices. Both indices differed for mixed agro-livestock smallholders across the three districts, with Dhading scoring as the most vulnerable and Syangja the least. Substantial variation across the districts was observed in components, sub-components and three dimensions (exposure, sensitivity and adaptive capacity) of vulnerability. The findings help in designing site-specific intervention strategies to reduce vulnerability of mixed agro-livestock smallholders to climate change.

Keywords Climate change · Mixed agro-livestock · Nepal · Smallholders · Vulnerability

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Introduction

Although climate change is a global problem, its impacts differ from region to region, country to country, sector to sector and community to community (Adger et al. 2004; Kasperson and Kasperson 2001). Poor and agrarian communities of the developing countries are affected most by the climate change because they have poor adaptive capacity and limited access to alternate means of production (IPCC 2007; Skoufias et al. 2011). Climate change is a major concern for the entire Himalayan region because the rate of increase in temperature is significantly higher than the global average (IPCC 2007) and the presence of sensitive sectors (water, biodiversity, agriculture) and potential impacts on ecology, economy and society (Ives et al. 2000; Liu and Rasul 2007). Nepal lies in the central Himalaya and has been rated the world's fourth most vulnerable country to climate change (Maplecroft 2011). The fragile ecosystems, unstable geology and complex topography of mountain countries such as Nepal are highly sensitive to slight changes in natural climate and are susceptible to disasters (Barry 1990; MOHA 2013; Rangwala and Miller 2012). Maximum temperature in Nepal has shown an increasing trend of 0.06 °C per year (MOEST 2010; Shrestha et al. 1999), and the annual mean temperature is increasing at a rate of 0.04°C per year with a higher rate of increase at higher altitudes (Baidya et al. 2007; Shrestha and Aryal 2011). Frequency of high-intensity rainfall has also increased (Chalise and Khanal 2001), leading to more flash floods and landslides. In the high-elevation areas where snowfall is the current norm, there will be increasing precipitation in the form of a rain (IPCC 2007).

Agriculture is one of the most susceptible sectors to climate change (Kurukulasuriya and Rosenthal 2003), and within the agricultural sector, livestock production is the most climate-sensitive economic area (IPCC 2007). Climate change may adversely affect different aspects of livestock production system including animal health and productivity, fodder production, water availability, pests and diseases (Thornton et al. 2009), thereby increasing vulnerability of people involved in the system (Pradhanang et al. 2015). Although numerous local factors affect vulnerability to climate change (Wooda et al. 2014), livestock smallholders in developing countries are highly affected and most vulnerable to such changes (Heltberg et al. 2009). Livestock is an integral part of the farming system and socioeconomical life in Nepal, where the population remains largely rural. The livestock sector contributes nearly 26 % to the total agricultural gross domestic product (MOAD 2012) in Nepal. About 87 % of the households in the country keep some kind of livestock (IRIN 2013). Grain cultivation and livestock production are inseparable livelihood activities in Nepal. These activities complement each other, and the majority of households combine subsistence crop production with small numbers of livestock and thus are referred to as mixed agro-livestock smallholders. However, there is little information on how vulnerable mixed agro-livestock smallholders are to climate change and how vulnerability differs across different agro-ecological zones of Nepal. Therefore, this study aims to construct and interpret vulnerability for mixed agro-livestock smallholders from three districts representing different agro-ecological zones in and around the Gandaki River Basin (GRB), which includes much of central Nepal and has previously been shown to be undergoing warming and change in precipitation pattern (Panthi et al. 2015).

Climate change vulnerability is dynamic and depends upon both biophysical and social processes (IPCC 2014; O'Brien et al. 2005). The assessment of factors contributing to vulnerability is the initial step to develop adaptation strategies (Ford and Smit 2004) and inform policies and programs to reduce risks associated with climate change (Fussel and Klein 2006). Vulnerability is not easily reduced to a single metric and is not easily quantifiable (Alwang et al. 2001). The challenge of vulnerability research is to develop robust and credible measures (Adger 2006). Vulnerability assessment must integrate and examine interactions between humans and their physical and social surroundings. There is not a consensus on methods to assess vulnerability, but most assessments entail considering one or more of exposure to risks, susceptibility to damage and capacity to recover (Cutter 2003; Eakin and Luers 2006). A pragmatic approach to vulnerability assessment involves studying how vulnerable a community is compared to others and which component pushes up the level of vulnerability within the community. Most researchers rely on the IPCC working definition of vulnerability as a function of exposure, sensitivity and adaptive capacity (IPCC 2001). The vulnerability framework (Turner et al. 2003) based on the IPCC definition is considered as a powerful analytical tool for assessment. Within this broader framework, Hahn et al. (2009) developed an indicator-based vulnerability assessment that has been used by many scholars in different contexts (Aryal et al. 2014; Etwire et al. 2013; Pandey and Jha 2012; Shah et al. 2013). Here, two types of indices are developed and compared based on different indicators. The livelihood vulnerability index (LVI) is a composite index of all major parameters, while the IPCC vulnerability approach frames the major parameters into three contributing factors to vulnerability: exposure, sensitivity and adaptive capacity. This study computes and compares these indices for livestock smallholders in the GRB, which includes all Nepal's major physiographic regions and ecological zones for livestock and agriculture.

Methods

Concept of livelihood vulnerability index (LVI)

The LVI was originally designed to provide development organizations, policy makers and planners with a practical tool to understand contributions of demographic, social and physical factors to climate vulnerability. This provides a flexible approach where development planners can refine and focus their analysis to suit the needs of each geographical location. In addition to the overall composite index, sectorial vulnerability indices can be segregated to identify potential areas for intervention (Hahn et al. 2009). The sustainable livelihood approach combines five types of household assets: natural, social, financial, physical and human capital (Chambers and Conway 1992), to which vulnerability assessment also adds consideration of exposure to climate hazards.

The LVI takes into consideration earlier methods of estimating the differential impacts of climate change. This index uses primary data from households and combines them with data obtained from secondary sources for variables such as risks from landslides, flooding, temperature and rainfall (Etwire et al. 2013; Hahn et al. 2009). The formulation for LVI developed for this study is based on the livelihood vulnerability analysis technique developed by Hahn et al. (2009), with replacements of some indicators to suit the local context in Nepal and to be more relevant for mixed agro-livestock smallholders. It makes use of eight major components: socio-demographic profile, livelihood strategies, social networks, health, access to food, access to water, natural disaster risks and climate variability. Selection of indicators was based on review of the literature and stakeholder (development and extension workers and agro-livestock smallholders) consultation. The monthly standard deviations of temperature and precipitation used in the climate variability component of LVI in Hahn et al. (2009) were replaced with climate-extreme indicators developed by WMO (2009) as these were more relevant to the daily activities of livestock smallholders, and a flood indicator was also included under the natural disaster component because flooding is a major natural disaster attributed to climate change in the study areas. Some other indicators were modified (Table 1) to make them more relevant to mixed agro-livestock smallholders. The 'natural disasters' and 'climate variability' components are reported separately. Climate variability, even if it does not reach the level of a natural disaster, increases the vulnerability of rural livelihoods and reduces the ability of households to deal with risks.

LVI calculation

Each of the eight major components of the LVI comprises several indicators or sub-components (Table 1). Sub-components considered under each major component, the source of information, and their functional relationship with vulnerability are also presented (Table 1). The sub-components within the major components of the vulnerability were customized to the local context in consultation with field-level stakeholders.

The mathematical approach to constructing the LVI was drawn from Hahn et al. (2009) and is summarized here for completeness. Many authors (Aryal et al. 2014; Etwire et al. 2013; Shah et al. 2013) have used a similar approach in various contexts because this assessment tool is accessible to a diverse set of users in resource-poor settings. The LVI uses a simple approach of applying equal weights to all major components. Each of the sub-components was measured on a different scale; therefore, it was first necessary to standardize them for comparability. The equation for standardizing numerical values is the same as that used in constructing the Human Development Index—HDI (UNDP 2007):

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

Here, $S_{\rm d}$ is the original sub-component for district d, and $S_{\min}$ and $S_{\max}$ are its minimum and maximum values reflecting low and high vulnerability, respectively, for each sub-component determined using data from all three districts surveyed. For example, the 'average number of months household struggle for food' sub-component ranged from 0 to 12. These minimum and maximum values were used to transform this indicator into a standardized value between 0 and 1 so that it could be integrated into the food component of the LVI. For variables that measure frequencies, such as the 'percent of households reporting conflicts in their community', the minimum value was set at 0 and the maximum at 100 %. Some sub-components such as the 'average livestock diversity index' were constructed as the inverse of the crude indicator because it was assumed that increase in the number of livestock species raised by households decreases vulnerability. By taking the inverse, we created an index that, for example, assigns greater vulnerability for households with a low number of livestock species. The expression for the livestock diversity index is [1/(number of livestock species + 1)]. The maximum and minimum values were also transformed following this logic, and Eq. (1) was then used to standardize this sub-component.

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

Table 1 Major components and sub-components, information sources and their functional relationship with vulnerability

Major components	Sub-components	Data source	Assumed functional relationship
Socio-demographic profile	Percentage of dependent people (<15 years and >60 years)	CBS, 2011	Higher percentage reflects less capacity to adapt
	Percentage of female-headed households	Survey	Women typically have less adaptive capacity (Mainaly and Tan 2012) Most households in Nepal are male-headed; female-headed means males are outside home
	Percentage of household heads who have not attended school	Survey	Education makes people more aware and able to adjust to change in environmental condition
Livelihood strategies	Percentage of households with family member not working outside their community for job	Survey	Income diversification increases adaptive capacity
	Average livestock diversification index	Survey	Diverse species of livestock reduces the risk of major losses
Social network	Percentage of households not having access to communication media (TV/radio, telephone)	Survey	Communication media make people aware of hazard occurrence and preparation
	Percentage of households not having access to local government service (veterinary)	Survey	These services strengthen adaptive capacity
	Percentage of households not having access to institution to purchase fodder seed/seedlings	Survey	Seed sources strengthen adaptive capacity
	Percentage of households not associated with any organization (cooperative/group)	Survey	Group insurance and information sharing increases adaptive capacity
	Average borrow: lend money ratio	Survey	High amount of borrowing indicates financial stress, less capacity to adapt
Health	Average time to health facility	Survey	The shorter this time, the less vulnerability
	Percentage of households with family member chronically illness	Survey	Family with illness are more sensitive
	Percentage of households with a family missing work in the last 2 weeks due to illness	Survey	This is to assess how illness is impacting family; higher percentage implies higher sensitivity
Food	Percentage of households depending solely on family farm for food	Survey	High sensitivity because limited source for food
	Percentage of households saving seeds	Survey	Lower level implies higher sensitivity to disasters
	Average number of month household struggling for food	Survey	More months imply more sensitivity
Water	Percentage of households reporting water conflict in past year	Survey	This is to assess how water scarcity is affecting community. Higher percentage implies higher the sensitivity
	Average time to water source	Survey	The shorter the time, the less sensitivity
	Percentage of household having consistent water supply	Survey	Family with consistent water supply are less sensitive
Natural disaster	Average number of flood events in the past 10 years	(UNISDR 2014)	More reflects higher exposure
	Average number of landslide events in the past 10 years	(UNISDR 2014)	More reflects higher exposure
	Average number of drought events in the past 10 years	DHM	More reflects higher exposure
Climate variability	Average number of consecutive (3 days) dry spells from 2002 to 2011	DHM	Higher variability implies higher exposure
	Average number of consecutive (3 days) wet spells from 2002 to 2011		
	Average number of warm days ($T_{max} > 90$th percentile) from 2002 to 2011		
	Average number of cold nights ($T_{min} < 10$th percentile) from 2002 to 2011		

CBS Central Bureau of Statistics, Government of Nepal, *DHM* Department of Hydrology and Meteorology, Government of Nepal, *Survey* Household survey carried out from May to October 2013 as a part of this study, *UNISDR* United Nations Disaster Information Center

$$M_{\mathrm{d}} = \frac{\sum_{i=1}^{n} \mathrm{index} S_{\mathrm{d}_i}}{n} \quad (2)$$

Here, M_{d} is one of the eight major components for district d, the S_{d_i} represent 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 a district were calculated, they were averaged using Eq. (3) to obtain the district-level LVI:

$$\mathrm{LVI}_{\mathrm{d}} = \frac{\sum_{i=1}^{8} W_{m_i} M_{\mathrm{d}_i}}{\sum_{i=1}^{8} W_{m_i}} \quad (3)$$

Equation 3 can be expressed in expanded form as

$$\mathrm{LVI}_{\mathrm{d}} = \frac{W_{\mathrm{sdpSDPd}} + W_{\mathrm{lsLSd}} + W_{\mathrm{snSNd}} + W_{\mathrm{hHd}} + W_{\mathrm{fFd}} + W_{\mathrm{wWd}} + W_{\mathrm{ndNDd}} + W_{\mathrm{cvCVd}}}{W_{\mathrm{sdp}} + W_{\mathrm{ls}} + W_{\mathrm{sn}} + W_{\mathrm{f}} + W_{\mathrm{w}} + W_{\mathrm{nd}} + W_{\mathrm{cv}}} \quad (4)$$

SDP = socio-demographic profile, LS = livelihood strategy, SN = social network, H = health, F = food, W = water, ND = natural disasters and CV = climate variability.

Here, $\mathrm{LVI}_{\mathrm{d}}$ is the LVI for district d, equals to the weighted average of the eight major components. The weights of each major component, W_{m_i}, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI (Sullivan et al. 2002). The LVI is scaled to range from 0 (least vulnerable) to 0.5 (most vulnerable).

Calculating the livelihood vulnerability: IPCC framework approach

We applied an alternative method developed by Hahn et al. (2009) for calculating the LVI based on the IPCC vulnerability definition which highlights exposure, adaptive capacity and sensitivity. Natural disasters and climate variability were framed under 'exposure'; water, food and health sectors under 'sensitivity'; and socio-demographic profile, livelihood strategy and social network under 'adaptive capacity'. The reasoning behind this categorization is that exposure of the study population is measured by the number of natural disasters as well as climate variability in the last 10 years using meteorological data from stations located in the selected districts. Adaptive capacity is quantified by the demographic profile of a district (e.g., percentage of female-headed households), the types of livelihood strategies employed (e.g., percentage of household working outside for income) and the strength of social networks (e.g., borrow/lend ratio; percentage of household having communication media like television, radio, telephone). The sensitivity is measured by assessing the current state of a district's food and water security and health status. The same subcomponents outlined in Table 1 as well as Eqs. 1, 2 and 3 were used to calculate the VI-IPCC. The index diverges from the LVI in how the major components are combined. Rather than merging the major components into the LVI in one step, they are first combined according to the categorization into exposure, sensitivity and adaptive capacity.

$$\mathrm{CFd} = \frac{\sum_{i=1}^{n} W_{m_i} M_{\mathrm{d}_i}}{\sum_{i=1}^{n} W_{m_i}} \quad (5)$$

Here, CFd is one of the contributing factors to VI-IPCC (exposure, sensitivity and adaptive capacity) for district d, W_{m_i} is the weightage of one of the major contributing factors and M_{d_i} is the major component for district d indexed by i. In this paper, equal weight was given to all the components as we did not have detailed information to justify assigning different weights. After calculating the contributing factors, the vulnerability is calculated using the following formula:

$$\text{VI-IPCC} = (\text{Exposure} - \text{Adaptive capacity}) * \text{Sensitivity} \quad (6)$$

The VI-IPCC index ranges from −1 (least vulnerable) to 1 (most vulnerable).

Study area

The study area lies in and around the GRB in Nepal. The GRB (Fig. 1) lies in central Nepal and is one of the three major basins in Nepal. The elevation of the basin ranges from 60 m above sea level (m asl) in southern lowlands to more than 8000 m asl in the north (Shrestha et al. 2011) and covers all physiographic regions of Nepal: the Terai (southern lowland), Siwalik (low Hills), Hill, Middle Mountain and High Mountain. The GRB, together with adjacent areas, includes nineteen districts of the central and western development regions of Nepal. Three districts, namely Dhading, Syangja and Kapilvastu (Fig. 1) representing Mountain, mid-Hill and Terai, respectively, were selected for the study. These districts were the working

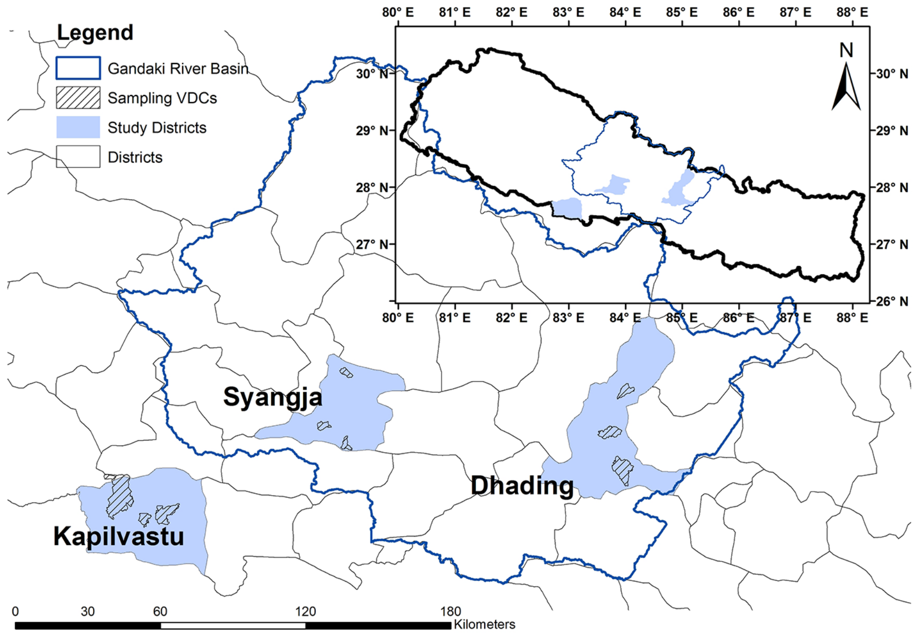

Fig. 1 Districts and sampling VDCs around the Gandaki River Basin

areas for a multi-year USAID Innovation Lab funded project 'Adaptation to climate change by livestock smallholders in GRB, Nepal' in which the first author has been involved for 3 years and was familiar with the social–cultural hindrances to data collection. Previous research has indicated that most smallholders in GRB districts had observed the variation of weather patterns and experienced increased temperature, decreased but erratic precipitation and delayed summer monsoon (Dhakal et al. 2013). The identification and implementation of adaptation options for mixed agro-livestock smallholders is crucial for this basin, which must start with an assessment of vulnerability (Ford and Smit 2004) to design effective adaptation strategies.

Data sources and sampling procedure

Three village development committees (VDCs) as shown in Fig. 1 were selected from each of the case study districts for the household survey (9 VDCs total). The VDCs were selected based on temperature, precipitation, socio-ethnic settlement, livestock types and accessibility for household survey. The VDCs and the total number of households sampled in each district are given in Table 2. National census 2011 data (CBS 2012) from each VDC and the percentage of households engaged in subsistence farming and livestock occupation were used to calculate the sampling frame. The sample size for VDCs in each district was determined using the probability proportional to size method (UNICEF 2008; WHO 2005).

The survey was conducted from May to October 2013. Household heads or other senior members of the selected households were considered for the survey. Prior verbal consent was obtained from each respondent for the interview. Each interview lasted on average 1 h. Surveys were carried out in Nepali language, except that in Kapilvastu, a local interpreter was assigned because most of the respondents preferred to speak in the local language (Hindi). The survey instruments were prepared and approved by the human subject research ethics section of Tribhuvan University, Nepal. The survey was administered by interviewers who were trained before the survey and who selected households within each VDC randomly using the guidelines suggested by UNICEF (2008). Internal quality control procedures were established during orientation training of the interviewers. For example, where survey questions might lead to different answers depending on respondent interpretation, all interviewers agreed upon a common definition. Surveys consisted of several sections intended to get information on indicators mentioned in Table 1. Data were coded and checked in MS Excel, and data analysis was carried out using SPSS 16.0

Secondary data were collected and analyzed for indicators of natural disasters and climate variability. Records of landslides and flooding events at a district level were collected from the UNISDR (Desinventer 2014). Temperature and rainfall data for the nearest meteorological station in each district were collected from the Department of Hydrology and Meteorology (DHM), Kathmandu, Nepal. These data were collected for Taulihawa for Kapilvastu (station index: 716), Putalibazar for Syangja (station index: 805) and Dhunibeshi for Dhading (station index: 1038). Three-monthly drought events were calculated with the monthly precipitation data using the Standardized

Table 2 Sampling VDCs and the sample size taken from each of the districts for household survey

District	VDCs selected for the survey	Elevation range of VDCs (m)	Sample size (household)
Dhading	Baireni, Nilakantha and Darkha	412–2615	192
Syangja	Chapakot, Setidobhan and Tindobate	338–1668	171
Kapilvastu	Hariharpur, Jayanagar and Shivapur	90–746	180
Total	9 VDCs	90–2615	543

Precipitation Index (SPI) developed by World Meteorological Organization (WMO 2012). The number of cold nights and warm days were calculated using the daily observation of minimum and maximum temperature, respectively. The nights having minimum temperature that is below the 10th percentile of each station's climatology were considered as cold nights, and the days having maximum temperature that exceeded the 90th percentile were considered as warm days (WMO 2009). The number of consecutive dry days (CDD) and consecutive wet days (CWD) was calculated using the daily precipitation data. Here, we considered a continuous 3-day period for the calculation of 'consecutive'.

Results

Livelihood vulnerability index (LVI)

Overall, Dhading (0.2889) and Kapilvastu (0.2883) had a higher LVI than Syangja (0.2592), indicating relatively greater vulnerability of mixed agro-livestock smallholders of these districts to climate change. The results for major components are presented in a spider diagram (Fig. 2). Dhading smallholders were rated more vulnerable in the socio-demographic profile, water, natural disaster and climate variability sub-components. Meanwhile, Kapilvastu showed more vulnerability in the livelihood strategies, social networks, and health and food sub-components. None of the sub-components had the highest value for Syangja.

Vulnerability index: IPCC

The overall VI-IPCC scores, on a scale of −1 to 1, indicate that the mixed agro-livestock smallholders of Dhading (−0.0767) are most vulnerable which is followed by Syangja (−0.1205) and Kapilvastu (−0.1538) (Table 3). A vulnerability triangle diagram showing scores for exposure, adaptive capacity and sensitivity illustrates that Dhading (0.375) is more exposed to climate change impacts than Kapilvastu (0.240) and Syangja (0.216). However, accounting for the current health status as well as food and water security, Kapilvastu (0.331) is more sensitive to climate change impacts than Dhading (0.249) and Syangja (0.225). Syangja has a higher adaptive capacity than the Kapilvastu and Dhading districts (Table 3; Fig. 3).

Discussion

Vulnerability assessment of the case study sites

Mixed agro-livestock smallholders of Dhading and Kapilvastu districts were found to be more vulnerable to climate

Fig. 2 Vulnerability spider diagram for the major components of the livelihood vulnerability index (LVI) for Dhading, Syangja and Kapilvastu districts of Nepal

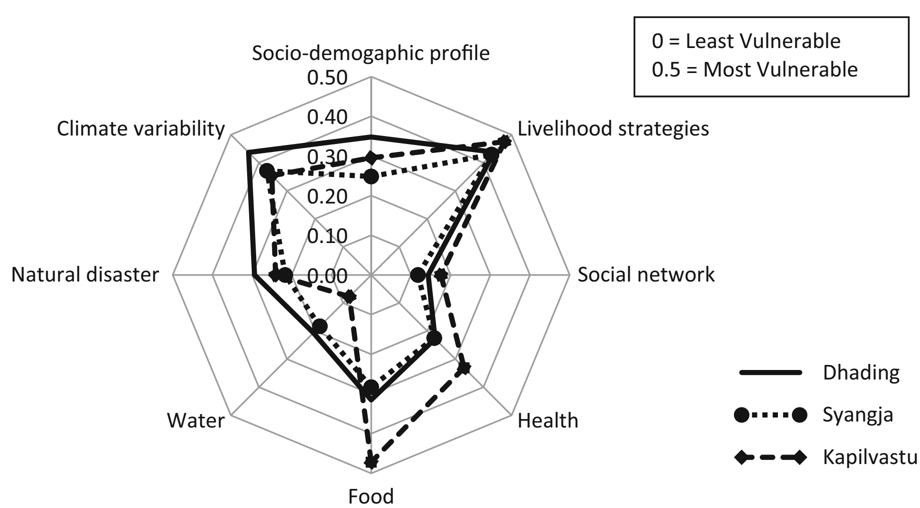

Table 3 VI-IPCC contribution factors in the three districts around the GRB

Contributing factors	Dhading	Syangja	Kapilvastu
Adaptive capacity	0.683	0.752	0.704
Sensitivity	0.249	0.225	0.331
Exposure	0.375	0.216	0.240
Overall VI-IPCC	−0.0767	−0.1205	−0.1538

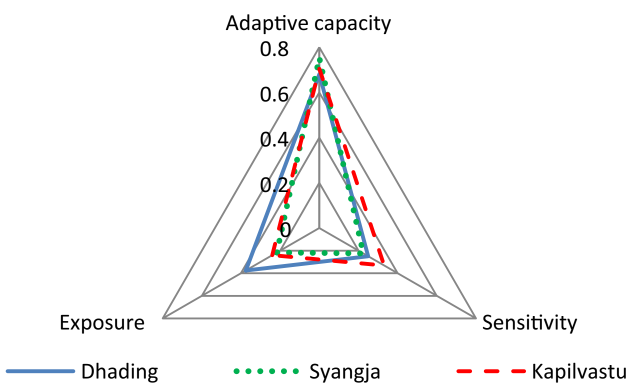

Fig. 3 Vulnerability triangle diagram of the contributing factors of the livelihood vulnerability index-IPCC (VI–IPCC) for Dhading, Syangja and Kapilvastu Districts, Nepal

change than those of the Syangja district as measured by LVI, although different components predominated in each district. The overall LVI was slightly higher for Dhading than Kapilvastu district. The Dhading district is more exposed to extreme climate conditions such as consecutive wet days and consecutive dry days that result in the natural disasters like droughts, landslides and floods. In general, climatic variation in mountain region of the GRB is very high (Panthi et al. 2015). This district is also listed as one of the most drought-prone areas in Nepal by the National Adaptation Programme of Action (MOEST 2010). It has also been reported that natural springs, wells and water sources of the Dhading district have dried up (SAGUN 2009) as in other hilly districts of Nepal such as Lamjung (Gentle et al. 2014). Dhading district, although adjacent to Kathmandu, the capital city of Nepal, is underdeveloped in many infrastructures, and many respondents from this district mentioned that they have to walk for an hour to fetch drinking water and that the availability of water in the source is also inconsistent. In Dhading, 29.3 % of the respondents reported that they knew water conflict in past 6 months; most of those conflicts were at the community drinking water taps. Water vulnerability of rural households is caused particularly when there is a high dependency of agriculture on water and the existing infrastructure is poor (Pandey et al. 2014). However, we considered only water availability for drinking purpose in the water component of vulnerability. Low level of education of household head is another major contributing factor for the higher LVI of smallholders in Dhading district. Furthermore, there was low diversification of income sources as majority of respondents in Dhading (52.6 %) report no additional outside income. On the climate variability side, the highest numbers of warm days and cold nights were found for Dhading, which particularly can impact livestock health and productivity. More than half of the respondents in Dhading (51.9 %) reported that they do not have access to the local government veterinary service to care for their livestock. There are a few service and sub-service centers, but due to steep topography and ruggedness, the reach of those services is very limited.

Mixed agro-livestock smallholders of Kapilvastu district were vulnerable almost to the same extent as those of Dhading district (as indicated by LVI value). Food, health and social network were major contributing components for high vulnerability. Most of the farmers in the district solely rely on their farm for their food. Although the district is in the Terai (southern plain) region where the agricultural productivity is high and which is considered the granary for the whole country, the majority of respondents reported that they struggle for food for much of the year. This is because they own very small pieces of land and the family size is big compared to respondents from two other districts. There is also a lack of family income diversification that limits ability to buy food. Health and veterinary centers are not well distributed, and many farmers do not have access to them. Communication media and local government services have not well penetrated in the district's rural areas, and therefore, social networking was weak. More than one-third of total households had no access to communication (TV/radio, telephone); even in the village with coverage of telephone network, people were unable to use it due to lack of money. Community practices such as exchange of goods and help, information sharing and networking constitute part of social capital and have implications for vulnerability. A social network is a social structure made of nodes that are tied by one or more specific types of interdependency, such as values, visions, ideas, financial exchange, friendship, sexual relationships, kinship, dislike, conflict or trade (Armah et al. 2010). Both formal and informal institutions that exist at the local level can play important roles in managing natural resources and supporting livelihood. They can be effective in handling environmental risks and sometimes seen as most pertinent in the area of climate change adaptation (Adger 2010). However, it is important to note that community institutions can also impose some social and cultural barriers to adaptation (Jones and Boyd 2011). Farmers were reluctant to undertake vegetable farming and livestock rearing in commercial ways due to lacking water availability for irrigation, subsidized insurance, financial support and access to market. Meteorological records showed that over the last 10 years, Kapilvastu had maximum number (89.62) of average consecutive dry days (CDD) per year but minimum number (7.75) of consecutive wet days (CWD). Rain-fed and subsistence agriculture are heavily impacted by these climatic factors together with other non-climatic factors (Gentle et al. 2014).

As compared to Dhading and Kapilvastu district, the LVI of mixed agro-livestock smallholders was lower in Syangja district, indicating that they were less vulnerable to climate change. The most promising result was that none of the components had the highest index value for this district. Even at sub-component level, only two sub-components, 'average number of months household struggle for food' and 'average number of consecutive wet days', had highest value for this site. The first sub-component mentioned reflects the fact that agriculture production from household farms was sufficient to feed the family only for a short period of time (about 7 months), whereas they had to struggle to get food for remaining 5 months. The fact that this district had the highest consecutive wet days correlates with increased number of landslides there. National Adaptation Programme of Action (NAPA) to climate change (MOEST 2010) has listed Syangja district as 'high risk' for landslides. All other sub-components were relatively good in this district. For example, government services such as schools and colleges, health and veterinary centers, drinking water facilities and communication facilities were well penetrated in the district.

In the VI-IPCC approach, the adaptive capacity is higher than the exposure of, and sensitivity to climate change and variability in all the three districts (Fig. 3). Interestingly, the three districts each lead in one major factor contributing to vulnerability: Dhading in exposure, Kapilvastu in sensitivity and Syangja in adaptive capacity. As discussed above, natural disaster and climatic variability components come under exposure. At sub-component level, both the consecutive dry days and consecutive wet days were highest in Dhading compared to two other districts. This indicates that Dhading is experiencing more extreme climatic events, leading to a high exposure value. The high sensitivity in Kapilvastu was mainly attributed to health and food components. There were large numbers of families with chronically ill members who cannot work. Since groundwater was extracted through hand pumps at the household or community level, the water component was fairly good. However, the presence of arsenic could be a problem associated with the use of ground water in some districts in the Terai of Nepal (Thakur et al. 2011) which could be worth considering by future studies. The adaptive capacity was highest in the Syangja district, whereas exposure and sensitivity were least.

Implications of findings and recommendations

Our study reveals general as well as site-specific factors contributing to different components of vulnerability (exposure, sensitivity and adaptive capacity) for mixed agro-livestock smallholders. The findings can be instrumental to reduce vulnerability and enhance adaptive capacity. Income and livelihood diversification options are essential to reduce vulnerability in all districts (Ghimire et al. 2010). The integration of crops and livestock by smallholders helps for such diversification and spreads risk for systematic threats such as climate change. The removal of disparities in infrastructure development within and across districts would help to reduce vulnerability. In Dhading, rainwater harvesting and water storage for livestock and agriculture could be one of the best solutions to reduce water problems (Aryal et al. 2013). In Kapilvastu and other lowland areas, drip irrigation systems could be effective to increase agricultural productivity (Saussa 2010). Periodic agriculture and veterinary camps could be cost-effective ways for penetrating villages with government services to reduce vulnerability to livestock loss (Aryal et al. 2014). In Syangja, though vulnerability is lower overall in comparison with the other two districts considered, landslide control mechanisms like bioengineering technologies could be particularly helpful to initiate. Plantation of nutritional fodder tree and forage species as a social forestry adaptation by communities will not only provide diversity of nutrition to livestock but also help in controlling soil erosion and recurrent landslides in the region. Microfinance can help communities through livelihood support and risk management instruments (Heltberg et al. 2009). Livestock and agriculture insurance can be initiated to protect against heavy losses from unfavorable climate; this is still at an early stage in Nepal (Dhakal et al. 2013; Hallegatte 2009). Community cooperatives and other formal and informal groups such as community forestry groups, mothers' groups and farmers' groups make the community network stronger, thereby reducing vulnerability. Links and shared values, understandings and trust among community members are community social capital, which strengthens community's capability to deal with emergency situations (Castle 2002). Multi-layered and multifaceted social ties and everyday social interaction are a community's assets for collective direction (Pelling and High 2005). They are useful to strengthen bonds among the households in a community which is important to reduce vulnerability (Thomas et al. 2005). Therefore, strengthening social capital in forms such as those considered under the social network indicators is also critically important.

Limitations

As noted earlier, vulnerability assessment is not simple and needs to consider wider socio-political factors. While there is a lack of credible measures to assess vulnerability, the indicator-based vulnerability assessment as used in this study provides a customizable approach. These methods can be replicated in many sectors and geographical areas. 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 indicators (Etwire et al. 2013) and the local environment plays a significant role in framing and designing the indicators. Extensive review of the literature, consultation of subject experts and engagement of stakeholders, as done in this study, would be expected to lead to good results. In addition, the LVI differs within a community since different households have unequal vulnerability. Because the LVI indicators typically vary between studies, numerical values of LVI can be used to compare the level of vulnerability within a study, for example between districts in our sample, but cannot be readily compared with other studies as the indicators and context vary. Further, it appears that while the adaptive capacity, sensitivity and exposure factors may be meaningfully compared between districts, the formula for the overall VI-IPCC score should be used with caution, as it leads to the counterintuitive result that if the adaptive capacity factor is numerically greater than the exposure factor, increased sensitivity actually reduces vulnerability.

Conclusion

The LVI and VI–IPCC are related methods for assessing the aggregate relative vulnerability of communities to climate change impacts. Each approach provides a detailed depiction of several factors affecting household livelihood vulnerability. The values for both of these indices varied across three districts and indicate that the mixed agro-livestock smallholders of Dhading, which is a mountain district, were the most vulnerable to climate change. The indexed values for each component and sub-component varied noticeably across sites, which provided insight into the design and implementation of site-specific coping strategies for smallholders. Among the three districts, Dhading could be developed using a number of strategies to reduce vulnerability, especially in water availability along with socio-economic variables such as education and awareness. Kapilvastu needs income and livelihood diversification together with food security. The level of vulnerability of mixed agro-livestock smallholders did not show a clear dependence on altitude in the basin. Overall, this research has extended LVI developed by Hahn et al. (2009) and IPCC vulnerability (VI-IPCC) index to the context of rural Nepal where livestock is an integral component of livelihood. With the VI-IPCC, one can compare the level of contribution from factors (exposure, sensitivity and adaptive capacity) for the overall vulnerability, but LVI distinguishes different sectors/aspects of vulnerability. VI-IPCC explicitly distinguishes household exposure to climatic risks, capacity to cope the impacts and sensitivities to various risks associated with climate change and variability. This approach can be used to other communities and sectors and also to evaluate the performance of programmatic interventions that aim to reduce vulnerability and highlight potential areas for interventions.

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Compliance with Ethical Standards

Conflict of interest The authors declare no conflict of interest.

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