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Vulnerability of rural households to climate change and extremes: Analysis of Chepang households in the Mid-Hills of Nepal

Luni Piya

PhD Candidate

739-8529, Hiroshima Ken

Higashi Hiroshima Shi, 1-5-1 Kagamiyama

Graduate School for International Development and Cooperation (IDEC)

Hiroshima University, Japan

loonypiya@hotmail.com

Keshav Lall Maharjan, PhD

Professor

739-8529, Hiroshima Ken

Higashi Hiroshima Shi, 1-5-1 Kagamiyama

Graduate School for International Development and Cooperation (IDEC)

Hiroshima University, Japan

mkeshav@hiroshima-u.ac.jp

Niraj Prakash Joshi, PhD

Assistant Professor

739-8529, Hiroshima Ken

Higashi Hiroshima Shi, 1-5-1 Kagamiyama

Graduate School for International Development and Cooperation (IDEC)

Hiroshima University, Japan

niraj_2008@yahoo.com

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Abstract

Rural communities, who are dominantly dependent upon natural resources, have always been adjusting their livelihood against the vagaries of climate. With the global climate change, these communities have been placed in greater vulnerability as the weather and extreme events have become more unpredictable. In order to formulate suitable policy measures to address their livelihood, assessment of local level vulnerability is very important. This paper analyzes the micro-level vulnerability of rural Chepang community in Nepal utilizing the data collected from 221 Chepang households from four villages located in four different districts. The analysis is based on indices constructed from carefully selected indicators for exposure, sensitivity, and adaptive capacity. The indicators are weighted using Principal Component Analysis. Inter-village analysis of the vulnerability index indicate that the existing exposure in a locality is often modified at the household level depending upon the inherent adaptive capacity of the households to give the picture of overall vulnerability. Using only the biophysical indicators of vulnerability (exposure and sensitivity) can thus lead to an erroneous policy implication. Furthermore, inter-household analysis of vulnerability indicate that poor households with low adaptive capacity are vulnerable anywhere, irrespective of where they are located. Policy measures and development efforts should be focused towards improving the adaptive capacity of the rural households, while keeping the post-disaster emergency relief measures in place for localities with higher exposure to climate extremes. The poorest households should be the primary target of any interventions.

Keywords: Exposure, sensitivity, adaptive capacity, livelihood assets, Principal Component Analysis (PCA)

1. Introduction

Natural climate variability has always been a challenge to human livelihoods. Human-induced climate change has lent a complex new dimension to this challenge. Evidences show that the natural climatic variability, compounded with climate change will adversely affect millions of livelihoods around the world (IPCC, 2007). The rural communities in the developing countries are expected to be affected more due to their extensive dependence on climate sensitive livelihood options, and limited adaptive capacity to adapt to the changes

(UNFCCC, 2009). Nepal, with its fragile geography, predominantly natural resource based livelihoods, and low level of adaptive capacity due to higher incidence of poverty, is placed among the most vulnerable country to climate change (Oxfam, 2009). Nepal is already a country vulnerable to natural disasters particularly floods and landslides. With an increased intensity in monsoon risks, the risk of flash flooding, erosion, and landslides will be increased. The adverse impacts of climate change and extreme events will definitely exacerbate the vulnerability, existing poverty and inequalities in least developed countries like Nepal. Within the country, poor and marginalized communities tend to be those least able to cope with climate-related disasters.

Climate change is a global phenomenon; however its manifestations and impacts vary locally, so do the adaptation capacities, preferences, and strategies. Effective planning for climate change adaptation programming requires an assessment of local vulnerabilities so as to bridge the gap between community needs and priorities at the local level, and policy processes at the higher level. Micro-level studies should form the inputs for formulating relevant policies at the macro level (Burton, Dinniger, & Smith, 2006). Researches done at the national level data fail to capture the location specificity of smaller areas. This calls for the need of detailed explorations at the finer spatial level. Even at the local level, the most marginalized section of the community must be the focus as they are the ones who are the most vulnerable. In this direction, this research focuses on the Chepang community, one of the highly marginalized indigenous nationalities in the rural mid-hills of Nepal. This paper will conduct an in-depth analysis of the local level vulnerabilities by integrating quantitative analysis with qualitative information obtained from primary field survey. The next section of the paper briefly describes the study community. The second section deals with the conceptualization of vulnerability based on literatures followed by a theoretical framework for analyzing adaptive capacity and a brief review of various methodologies followed by researchers to measure social vulnerability. Research design and methodology is discussed in the third part. Results and discussion of data analysis are dealt in the fourth section and the last part concludes the paper.

1.1 Chepangs: The study community

Chepangs are one of the indigenous nationalities¹ of Nepal having a population of 52,237 constituting 0.23% of the total population of Nepal. More than 95% of the Chepangs

¹ According to National Foundation for Development of Indigenous Nationalities Act 2002, indigenous nationalities means tribes or communities having their own mother language and traditional rites and customs, distinct cultural identity, distinct social structure and written or unwritten history. Based on the same Act, Nepal

lives in the hilly villages of Chitwan, Makwanpur, Dhading and Gorkha districts (CBS, 2008). In Nepal, indigenous nationalities represent the marginalized section of the country. Not only do the majority of indigenous people reside in the geographically remote parts of the country, but also their socio-economic and human development indicators lie far below the national average. Based on the Nepal Living Standards Survey 2003/04, hilly indigenous people (besides Newar and Thakali)² have higher poverty incidence of 43% compared to the Tarai indigenous people having poverty incidence of 33% (NIRS, 2006). The Chepang community has been categorized as one of the highly marginalized indigenous nationalities from the hills by National Federation of Indigenous Nationalities (NEFIN) and National Foundation for the Development of Indigenous Nationalities (NFDIN). Although their native area is surrounded by major highways of the country (Figure 1), feeder roads joining the area to the highways are very few. The geographical remoteness is further compounded by constant landslides along the walking trails during the rainy season and poorly developed infrastructures like limited communication facilities, electrification, bridges, health centers, and schools. Literacy rate among this community is very low, which has hampered their representation in the administrative as well as political spheres. As a result, despite being situated geographically quite near to the capital city Kathmandu (Figure 1), they are still marginalized from the mainstream of development of the country. Chepangs thus qualify as an appropriate representative of the marginalized group of people in Nepal and is selected as the study population for this research.

Chepangs are believed to be until the last 100-150 years ago a nomadic group ranging the forests of Nepal as described by Brian Hodgson in his 1848 article ‘On the Chepang and Kusunda Tribes of Nepal’ to be “living entirely upon wild fruit and the produce of the chase” (Hodgson, 1874, p. 45). It is supposed that agriculture is comparatively a newer phenomenon for them. Nearly a century later, a comprehensive study by Rai (1985) reported that though Chepangs still practiced a good deal of hunting and gathering, agriculture formed the mainstay of their livelihood, and they practiced *khoriya*. Under this system, a patch of land was cleared in the forest and cultivated for 2-3 years before the soil became exhausted. It was then left fallow allowing sufficient time for vegetation to regenerate; meanwhile they cleared and cultivated other patches of land. However, introduction of new government policies put

Government has identified 59 Indigenous Nationalities who are classified into five groups viz., endangered, highly marginalized, marginalized, disadvantaged, and advanced group based on a composite index comprising of variables like literacy rate, housing, land holdings, occupation, language, graduates, residence, and population size. The indigenous nationalities are further classified into mountains, hills and tarai based on the geographical location where they form a majority (NIRS, 2006).

² Newars and Thakalis are the only two indigenous nationalities falling under the advanced category.

restrictions on hunting, gathering, and clearing of forest patches (Upreti & Adhikari, 2006), leading to the transition of their livelihood to sedentary rain-fed agriculture (FORWARD, 2001). Due to small parcels, the rugged topography and stony nature of the land, only a small percentage of Chepang households are fully food self-sufficient (Piya, Maharjan, & Joshi, 2011a). Though agriculture forms the mainstay of their livelihood, Chepangs still depend upon forest resources to a large extent and the contribution of wild and uncultivated edible plants play an important role in their subsistence economy. Chepangs also depend upon livestock, wage laboring, collection and sale of forest products, handicrafts, skilled non-farm jobs, salaried jobs, and remittance for cash income (Piya, Maharjan, & Joshi, 2011b).

They live in areas most at risk to floods and landslides, are more reliant on local natural resources and would therefore suffer most from the drying up of local water resources or changes in vegetation cover. Even small changes in rainfall patterns can have devastating consequences on their crops. They are vulnerable to extreme weather events; have poor access to information and lack resources to cope with and recover from weather-related disasters. Their vulnerability is further compounded by geographic isolation poorly served by roads and other infrastructure, often isolated by landslides and floods. Studies related to the vulnerabilities of climate change and extremes should focus on such poor and marginalized communities because they are the most vulnerable and least able to cope with the adverse impacts. Studies based on the livelihood of these vulnerable communities will help to draw the attention of the government and development agencies to this issue. This paper is an attempt towards this direction.

2. Theoretical framework of the paper

2.1 Conceptualizing vulnerability to climate change

Vulnerability is the susceptibility of a system to disturbances determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adapt (Nelson et al., 2010a). Cutter et al. (2009) defines vulnerability as the susceptibility of a given population, system, or place to harm from exposure to the hazard and directly affects the ability to prepare for, respond to, and recover from hazards and disasters. Both these definitions agree that vulnerability refers to the susceptibility to harm, rather than the measure of harm itself, which may be due to exposure to threats or drivers of change.

The Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity but also on its ability to adapt to

new climatic conditions (Watson, Zinyowera, & Moss, 1996). IPCC Third Assessment Report (TAR) refined its earlier definition of vulnerability as ‘the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity’ (IPCC, 2001). IPCC Fourth Assessment Report (AR4) is consistent with the definition of vulnerability given by TAR.

The definition given by IPCC SAR views vulnerability as the ‘end point’ of a sequence of analyses starting with projection of future climate trend, development of possible climate scenarios, studying the biophysical impacts of such climate changes, identification of adaptive options, and finally any residual (adverse) consequences that remain after adaptation define the level of vulnerability (Kelly & Adger, 2000). Most climate change studies have often followed the end-point analysis in assessing the vulnerability which conceptualizes vulnerability as the impact on the system after a hazard incident. Such analysis puts hazard in the center of analysis focusing on the biophysical drivers such as temperature, precipitation, and extreme climatic events which cannot be influenced by policy makers. It tends to rely on projections using biophysical models which itself has a lot of uncertainties (Nelson et al., 2010a). In the recent years, climate change studies have recognized that vulnerability is not only defined by the characteristics of the hazards, but rather by the emergent property of human-environmental systems that enable them to cope with changes, thereby linking vulnerability to their adaptive capacity (Vincent & Cull, 2010; Vincent, 2004; Adger & Kelly, 1999; Adger, 1999). This approach puts vulnerability as the ‘starting point’ of analyses, a state that exists within a system before it encounters a hazard, therefore refers to the present day vulnerability. In this approach, vulnerability is determined by the existing capacity to respond to that hazard. Such differences in the approach have led to the coining of the terms ‘Biophysical’ vs. ‘Social’ vulnerability (Vincent, 2004; Brooks, 2003). End-point analyses tend to view vulnerability as a linear impact of hazards, referring to the exposure and sensitivity of natural environments to projected changes in climate, therefore referring to the biophysical vulnerability. This approach is often criticized for taking humans as passive receivers of hazards, failing to account for the interactions of humans to cope with such hazards. In the starting point approach, emphasis is placed on “social vulnerability” concerning more with the social system. Social vulnerability approach recognizes that the physical phenomena are mediated by the particular human context in which they occur. While biophysical studies have contributed to our understanding of the physics of climate

change and its impact on biophysical environments; it has less implications on policy making since variables like temperature and precipitation are not under the immediate control of the policy makers. Social vulnerability studies focuses on the analysis of drivers of current adaptive capacity, thereby providing insights on the type of information required to prioritize adaptation. Such types of studies are more relevant to policy makers as it focuses on the socio-economic drivers like poverty, and access to resources that are under their direct influence.

Though theoretically, social and biophysical approaches to vulnerability studies present two divergent schools of thoughts, social vulnerability assessments cannot be complete without taking hazards into considerations since vulnerability is always hazard specific. Some studies have therefore, tried to form a compromise between the two approaches by considering an integrated approach for vulnerability assessments, combining social vulnerability (adaptive capacity) with the biophysical aspects of climate change (exposure and sensitivity) to give a complete picture of vulnerability (Nelson et al., 2010b; Gbetibouo & Ringler, 2009; Cutter, 1996).

2.2 Theoretical framework for analyzing adaptive capacity

The substantial works on adaptive capacity is done after the publication of IPCC third assessment report in 2001, which identified adaptive capacity as a component of vulnerability. Many of the initial studies have focused on the adaptive capacity at the national level (Haddad, 2005; Adger & Vincent, 2005; Brooks et al., 2005; Adger et al., 2004; Yohe & Tol, 2002) and few of the latter studies have been focused at the subnational level (Jakobsen, 2011; Nelson, et al., 2010b; Gbetibouo & Ringler, 2009). The earlier national level studies are aimed at comparative assessment of adaptive capacity at the national level to identify the countries with lowest adaptive capacity, thereby assisting in the adaptation related investment decisions under the United Nations Framework Convention on Climate Change (UNFCCC). The subnational studies are done with the objective of identifying the regional variations within the country, thereby facilitating specific target-group oriented resource allocations. All of these studies have contributed to form a conceptual basis for defining adaptive capacity by throwing an insight on the possible social and economic indicators of adaptive capacity. They conclude that many of these variables are not quantifiable and can only be qualitatively described. The earlier studies select the indicators of adaptive capacity based on subjective judgments while the latter ones promoted selection of indicators based on some theoretical underpinnings. Following Jakobsen (2011) and Nelson et al. (2010b), this paper uses the

sustainable rural livelihoods framework given by Ellis (2000) and DFID (1999) to analyze the adaptive capacity of the study community. The sustainable livelihoods approaches which views livelihood outcomes as a function of the ownership or access to livelihood assets is principally based on Nobel Laureate Amartya Sen's entitlements approach, where by households with sufficient range of entitlements, capabilities or assets have more choices of adopting strategies suitable to cope during the periods of adversities or minimize the associated risks (Jakobsen, 2011; Ludi & Slate, 2008). The lack of or limited access to livelihood assets increases the defenselessness or incapacity to avoid risks as well as increases the shocks and stresses to which an individual or household is exposed to (Shahbaz, 2008). On the other hand, households with diversified asset portfolio are more capable to reduce risks and to cope with or adapt to increased level of risks. Such households will have more options to substitute among alternative livelihood activities during the times of stress, thereby having more adaptive capacity. For instance, households with access to irrigation (physical assets) will face less risks of crop damage during droughts compared to those households depending entirely on rainfed agriculture. Similarly, households with higher savings (financial assets) or memberships in saving and credit institutions (social assets) have greater capability to minimize livelihood risks posed by crop failure due to bad weather. Finally, households having some non-farm sources in addition to farming will improve the adaptive capacity of the households against the climatic stresses through distribution of risks across various livelihoods sources.

2.3 Measuring social vulnerability to climate change

Adger (1999) borrows the concept of entitlements from Nobel Laureate Amartya Sen, and proposes the infrastructure of entitlement as a measure of social vulnerability. Measurements of poverty incidence, inequality and institutional settings have been used as proxy indicators to assess the social vulnerability in a coastal village in Vietnam. It was found that the vulnerability at the community level is affected by the broader institutional changes at the sub-national or national level. Adger opines that vulnerability is location specific and the indicators cannot be generalized to other localities or cannot be aggregated from one level to the other. This concept has further been consolidated in his subsequent works (Kelly & Adger, 2000; Adger & Kelly, 1999).

Deressa et al. (2009) employed the 'vulnerability as expected poverty' approach given by World Bank (Hoddinott & Quisumbing, 2003) to measure the vulnerability of households to climate extremes in Nile Basin of Ethiopia. This approach is based on the estimation of

probability that a household will fall below a given standard of minimum daily consumption requirement or a standard poverty line, or the probability that it will remain below the minimum standard level if it is already there. Using a combination of socio-economic data and frequency of extreme climate events to estimate the probability of being vulnerable, it was found that the farmers' vulnerability was extremely sensitive to the minimum consumption requirement or poverty line and also on the agro-ecological setting.

Vulnerability has been equated as a function of access to various assets categories by some social vulnerability studies (Vincent & Cull, 2010; Vincent, 2004). These studies choose proxy indicators of the determinants of vulnerability based on a theoretical framework, and come up with weighted aggregate index. Vincent (2004) determines the index for national level, while Vincent & Cull (2010) applies the same exercise to compute the index for the household level. They conclude that the determinants of vulnerability is scale specific; indicators used for assessing national scale adaptive capacity may not be representative at the regional or local level.

Cutter (1996) proposes a synthesis of biophysical and social vulnerability under the hazards of place model, where the geographical contexts cover biophysical vulnerability and the socio-economic factors cover social vulnerability. This model does not consider the climate variables or extremes under its biophysical component. This model was applied by Cutter, Boruff, & Shirley (2003) to create a social vulnerability index for United States based on county level socio-economic and demographic data. They found that the factors that contributed to the overall vulnerability were different for different counties.

A more integrated framework encompassing both biophysical components (exposure and sensitivity) and the socio-economic component (adaptive capacity) has been followed by Gbetibouo & Ringler (2009) and Nelson et al. (2010b). These studies cover all three components of vulnerability and adopts rural livelihoods framework developed by DFID (1999) and Ellis (2000) to measure the adaptive capacity. These studies view adaptive capacity as an emergent property of human, social, natural, physical and financial assets possessed by the community. Both studies integrate biophysical models with household survey data to assess the vulnerability at the sub-national level. Nelson et al. (2010b) demonstrate that using biophysical modeling alone, without incorporating the socio-economic determinants (adaptive capacity) leads to entirely erroneous results, thereby giving wrong message to the policy makers.

3. Research Design

3.1 Study area and data source

To ensure representativeness of the sample selected, this study covers all four districts that form the native area of the Chepangs, i.e. Chitwan, Makawanpur, Dhading and Gorkha districts. One Village Development Committee (VDC³) from each district was selected based on the dominance of Chepang population. Kaule VDC from Chitwan district, Kankada VDC from Makawanpur district, Mahadevsthan VDC from Dhading district, and Bhumlichowk VDC from Gorkha district form the four study VDCs (Figure 1). Chepangs form the most dominant population in Kaule and Kankada VDC, and second most dominant population in Mahadevsthan VDC. In Gorkha district, Chepangs do not form a clear majority in any of the VDCs; thus, Bhumlichowk VDC is selected as this VDC accommodates the highest Chepang population within Gorkha district.

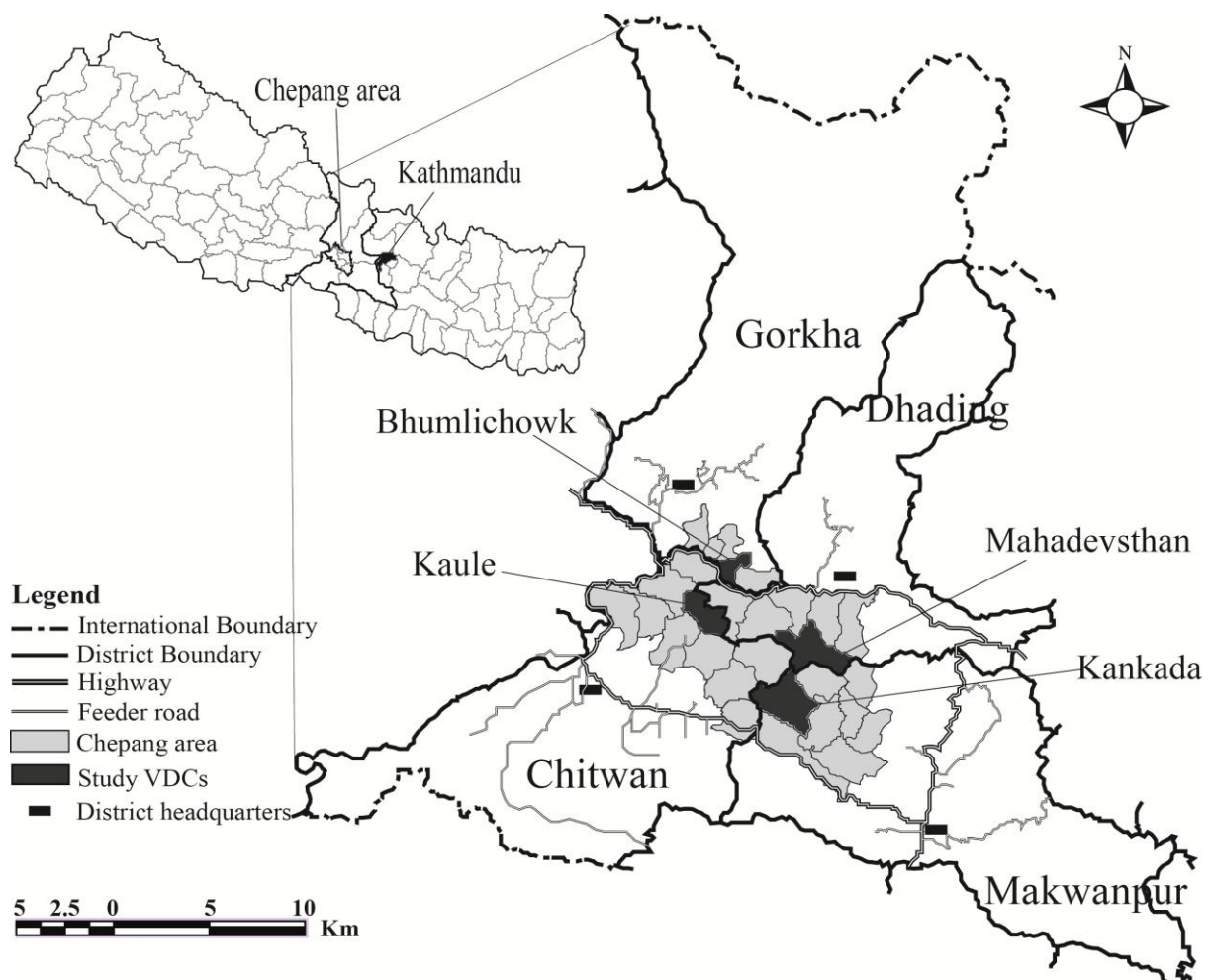


Figure 1. Map of study districts showing native areas of the Chepangs and the study VDCs

³ VDCs are the lowest administrative tiers in Nepal, composed of 9 wards.

Chepong settlements are situated along the geographically fragile and steep Mahabharata Hills within these districts. Few of the Chepong settlements in Chitwan and Makwanpur districts can be found at lower altitude of around 250 meters above sea level (masl). However, majority of the settlements are found at altitudes higher than 1000 masl, ranging up to 1920 masl represented by the Siraichuli peak located in Kaule VDC of Chitwan district, which is also the highest point along the whole of Mahabharata range. The Chepong settlements on hill tops are scattered and connected by narrow foot-trails. One Chepong settlement is separated from the other by a rivulet that flows in the groove between the ridges so that in order to go from one settlement to another, one has to climb down the groove, cross the rivulet, and again climb up the ridge. During monsoon, the rivulets are flooded, and the ridges are very slippery which makes movements across the settlements very difficult; the trails are covered by bushes with plenty of leeches, and falling stones with constant danger of landslides.

This study is based on the primary data collected by household survey conducted in two phases. The first phase of household survey was conducted in February-March 2010 and the second phase in May-June 2011. Sixty randomly selected households from each VDC form the sample for the household survey. Household survey was conducted using semi-structured interview schedule. The researchers visited the selected households and face-to-face interviews were conducted with the household members on the selected household's premises. All the households covered by the survey were untouched by roads and not connected to the central electricity grid. The first phase of the household survey was focused on collection of data related to demographics, livelihood assets (landholdings, livestock holdings, savings, loans, education, trainings, membership to CBOs, infrastructure, and physical assets), livelihood activities, income sources, and expenditures. Besides the household survey, group discussions were carried out to assess the general changes in climate variables and obtain a timeline of climate related disasters like floods, landslides, droughts, and hailstorms. Based on the overall general information obtained from the group discussion in 2010, semi-structured interview schedule was designed and follow-up field visit was made in May-June 2011. This time the same households covered in 2010 were revisited for gathering supplementary data. Out of the total 240 households covered in 2010 field survey, 58 households in Chitwan, 56 households in Makwanpur, 54 household in Dhading, and 53 households in Gorkha could be revisited in 2011 survey; thus the final sample constitutes a total of 221 households. The main purpose of this household survey was to find out whether individual households perceived any changes in climate, and if they did, what were the

changes perceived, adaptation strategies adopted, and the impacts of extreme climatic events on the crop production and livelihood assets. The latitude, longitude and altitude of the sample households were recorded during the second phase of field visit.

This paper also makes use of raw monthly minimum and maximum temperature and monthly precipitation data obtained from Department of Hydrology and Meteorology (DHM) in Kathmandu, Nepal for the time period of 32 years, from 1977-2008. Temperature data was obtained from 49 stations and precipitation data from 218 stations distributed all over the country. The temperature and precipitation at the household level was interpolated for each year from the weather stations using the latitude-longitude-altitude information of each household by ordinary kriging method in ArcGIS 10.

3.2 Choosing the vulnerability indicators

Vulnerability to climate change is multidimensional and is determined by a complex inter-relationship of multiple factors. Many variables representing components of vulnerability are not directly quantifiable. Nevertheless, devising an index to measure vulnerability is helpful to compare similar systems and provide insights into the underlying processes and determinants of vulnerability that is of relevance to policy makers. The first step in constructing the index comprises of the selection of indicators, then weights are assigned to these indicators, and finally these indicators are aggregated to form an index. Indicators and indices are useful in representing a complex reality into simpler terms. However, the methodology adopted in the choice of indicators is very crucial, since choice of wrong indicators may lead to a construction of an invalid index. Choice of indicators to represent the index for vulnerability is constrained by the fact that vulnerability itself has no tangible element. There are two approaches in the selection of indicators, data-driven and theory-driven (Vincent, 2004). The selection of suitable indicators can best be done based on some theories that provide insight into the nature and causes of vulnerability. However, even theory-based deductive approaches are constrained by data-limitations due to which subjectivity enters in the process of indicator selection. The best option is to verify the representativeness of the theory-based indicators with insights gained from focus group discussion conducted at the local level. This approach was adopted while selecting the indicators used in this paper.

Following the definition of vulnerability given by IPCC (2001), vulnerability in this study is taken to be a function of exposure, sensitivity, and adaptive capacity. Exposure is the nature and degree to which a system is exposed to significant climatic variations. Sensitivity

is the degree to which a system is affected, either adversely or beneficially by climate-related stimuli. Adaptive capacity is the ability of a system to adjust to climate change including climate variability and extremes, to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences. Selection of indicators for adaptive capacity is based on the DFID sustainable livelihoods framework, whereby adaptive capacity is taken to be a function of asset possession by the households (Jakobsen, 2011; Nelson, et al., 2010b).

3.2.1 Exposure

For this study, historical changes in climate variables and occurrence of extreme climatic events are taken as indicators of exposure (Table 1). Rate of change in average annual maximum temperature, average annual minimum temperature and average annual precipitation for the time period of 1977–2008 represent the historical climate changes. The temperature and precipitation for individual household was interpolated for each year from the station level data (49 temperature stations and 218 precipitation stations) using the latitude, longitude, and altitude information of the stations and the households by ordinary kriging method in ArcGIS10. The coefficient of the trends of climate variables is calculated separately for each household. Floods/landslides, droughts and hailstorms are the most commonly occurring natural disasters in the study area. Number of occurrence of these extreme events for the last ten years was obtained for each household from the household survey (Appendix 1). It was hypothesized that higher the rate of change of the climate variables and higher the frequency of natural disasters, higher will be the exposure of the households to climate change and extremes.

Table 1. Indicators for exposure

Component Indicators	Description of the Indicators	Unit	Hypothesized relation
Historical change in climate variables	Rate of change in average annual minimum temperature (1977 – 2008)	Coefficient of trend	+
	Rate of change in average annual maximum temperature (1977 – 2008)	Coefficient of trend	+
	Rate of change in average annual precipitation (1977 – 2008)	Coefficient of trend	+
Extreme climate events	Frequency of climate related natural disasters (floods, landslides, droughts and hailstorms) over the last 10 years	Number	+

3.2.2 Sensitivity

Sensitivity is given by the degree to which a system is modified or affected by an internal or external disturbance or set of disturbances (Gallopín, 2003). Livelihood impacts of

climate related disasters were taken as the sensitivity indicator following Daze, Ambrose, & Ehrhart (2009) and Marshall et al. (2009). Deaths of family members and loss of properties (viz. land, livestock, and crop) due to climate related disasters over the last ten years represent the sensitivity for the purpose of this study. It is hypothesized that higher impacts of past climatic hazards will increase the sensitivity of the households to such events. The income structure will also determine the household sensitivity. Higher share of natural resource based income (composed of agriculture, livestock, forest, honey and handicrafts) will increase the sensitivity of the household as these sources are more dependent on climate; while higher share of non-natural resource based remunerative income sources (composed of salaried jobs, non-farm skilled jobs, and remittances from abroad) will reduce the sensitivity. These three income sources are categorized as remunerative sources because the return from these sources is comparatively higher than other sources of income. It was found that the annual income of the households having any of these three sources is higher compared to other households with no income from any of these three sources (Piya, Maharjan, & Joshi, 2011b). The detailed breakdown of the share of various income sources are given in Appendix 2.

Table 2. Indicators for sensitivity

Component Indicators	Description of the Indicators	Unit	Hypthesized relation
Fatalities	Death of family members due to climate related disasters (floods, landslides) over the last 10 years	Number of family members	+
Damage to properties	Total land damaged by flood/landslides over the last 10 years	Area in local units (<i>Kattha</i> ⁴)	+
	Total livestock death due to flood/landslides/drought/hail over the last 10 years	Livestock Standard Unit (LSU ⁵)	+
	Total crop damage due to flood/ landslides/ drought/ hail over the last 10 years	Value in Nepali Rupees (NRs ⁶)	+
Income structure	Share of natural resource based income (agriculture, livestock, forest, honey, and handicraft) to total income	%	+
	Share of non-natural based remunerative income (salaried job, remittance, skilled non-farm job) to total income	%	-

3.2.3 Adaptive capacity

As described in the theoretical framework, adaptive capacity of a household is taken to be an emergent property of the five types of livelihood assets viz. physical, human, natural,

⁴ 1 Kattha = 0.033 ha

⁵ LSU is aggregates of different types of livestock kept at kept at household in standard unit calculated using the following equivalents; 1 adult buffalo = 1 LSU, 1 immature buffalo = 0.5 LSU, 1 Cow = 0.8 LSU, 1 calf = 0.4 LSU, 1 pig = 0.3 LSU, 1 sheep or goat = 0.2 LSU and 1 poultry = 0.1 LSU (CBS, 2003; Baral, 2005).

⁶ 73 NRs = 1 US \$ at the time of field survey.

financial, and social. These indicators are not necessarily specific to climate shocks only but are also relevant in addressing other shocks like food shortages. Although only few of the selected indicators like house types and irrigation facilities have a direct role in minimization of risks from climate shocks, all of these indicators do assist households to combat climate shocks through risk pooling, risk distribution or as buffer during extreme climatic events. The relevance of each indicator in building household adaptive capacity in the face of climate related risks is discussed hereafter.

Table 3. Indicators for adaptive capacity

Component Indicators	Description of the Indicators	Unit	Hypothesized relation
Physical Assets	Type of house (1 = thatch roof, thatch/wooden wall; 2 = thatch roof, stone+mud wall; 3 = stone/tin/tile roof, stone/wood/brick+mud wall)	Ordinal value	+
	Have devices to access information (mobile, radio) (0 = No, 1 = Yes)	Ordinal value	+
	Walking distance to nearest motor road	Hours	-
	Irrigated land	% of total	+
Human Assets	Highest qualification in the family	Number of schooling years	+
	Dependency Ratio	-	-
	Trainings or vocational course attended by family members	Number	+
Natural Assets	Share of more productive land (<i>khet + bari</i>) possessed	% of total	+
	Share of less productive land (<i>khoriya</i>) possessed	% of total	-
	Have bullock (0 = No, 1 = Yes)	Ordinal	+
Financial Assets	Gross household annual income	NRs	+
	Livelihood Diversification Index	-	+
	Total household savings	NRs	+
	Ownership of goat, poultry, and pig	LSU	+
Social Assets	Memberships in CBOs	Number	+
	Access to credit (1 = needed, but no access; 2 = credit used only for subsistence purposes; 3 = credit used for productive investment +/- subsistence; 4 = no need)	Ordinal Value	+

Indicators for the physical assets are type of house, ownership of devices to access information (mobile phone and radio), walking distance to the nearest road, and irrigated land. Out of these, only house quality and irrigation are directly related to climate risks. Possession of better quality house will improve the capacity to withstand the risks from extreme climate events. Type of house was indicated from a value of 1-3, 3 indicating the most durable type of house (see Table 3). Ownership of mobile phone and radio will increase the adaptive capacity through access to weather related information. Better access to information enables a household in planning proactive adaptation measures against climate risks. Walking distance to the nearest motor road, which in this case is also equivalent to the nearest marketplace, is

assumed to be inversely related to adaptive capacity as household located far away from the markets will be in a disadvantageous position for lacking the opportunity of income generation from alternative sources like non-farm labor, which help in securing livelihoods during the periods of food shortage or crop failure. Farther distance from the roads also symbolizes poor access to inputs as the service centers are located at the road-heads. In addition, greater distance from the motor roads also means limited access to information as the marketplace acts as informal gathering centers where information exchange takes place, and also the formal institutions providing extension services are located there. Irrigation is directly related to climate shocks as it minimizes risks posed by droughts. Higher percentage of irrigated land means lesser dependence on natural rain for agricultural purposes, which is becoming more unpredictable with climate change.

Human asset is represented by highest qualification in the family; trainings or vocational courses attended by the family members; and dependency ratio. These indicators are not directly related climate shocks; however they are still relevant because development of human capabilities through vocational trainings or formal education enable households to increase their income by undertaking skilled non-farm activities, which are less climate-sensitive compared to farming and gathering, thereby helping the households to avert climate risks. Furthermore, it also diversifies household livelihood sources which help to buffer the risks posed by climate on farm income. Households with higher dependency ratio will have more burdens on the earning members thereby reducing the adaptive capacity. The implication of dependency ratio is common to any types of shocks including climate.

The quality of land possessed by the households is taken as an indicator of natural assets. Chepangs possess three categories of land. Paddyland (*khet*) is the most productive category of land, usually having an irrigation source. *Bari* is terraced upland, which may or may not be irrigated, and is less productive than *khet*, but more productive than the third category, *khoriya*, which is unterraced sloppy land-plot. Natural assets, by their own nature, are more vulnerable to climate shocks than other types of assets. While terraced land types (*khet* and *bari*) are less prone to erosion, *khoriya* face greater risks of landslides and loss of top-soil due to run-off during rains. Households possessing higher share of *khet* and *bari* compared to *khoriya* will suffer less from climate disasters. Higher share of more productive land (*khet* and *bari*) also means higher food self-sufficiency, thus higher adaptive capacity. Higher share of *khoriya* indicates the opposite. Besides land, possession of bullock, which is the only means of ploughing fields in the hills, is another indicator of household natural assets.

Gross household annual income, livelihood diversification index, household savings, and ownership of small livestock (goat, poultry, and pig) are taken as the indicators of financial assets. These indicators of financial assets are not specific to climate shocks only. Gross annual income of the household is the sum total of the cash and non-cash income from 11 different sources shown in Appendix 2. Higher income means greater availability of resources at disposal to maximize positive livelihood outcomes. Besides the amount of annual income, the sources from which the income is derived also need to be considered. If all of the income is derived from farming alone, then such income will be adversely affected during the years of bad weather. On the other hand, if the income is derived from more than one source, then risk will be distributed among the sources. In order to capture this aspect of income, Livelihood Diversification Index (LDI) is calculated; higher diversification indicating better ability of the household to switch among the activities when needed. Herfindahl index of diversification is used (Kimenju & Tschirley, 2009), which is calculated as

$$D_k = 1 - \sum_{i=1}^N (S_{i,k})^2$$

where, D_k is the diversification index, i is the specific livelihood activity, N is the total number of activities being considered, k is the particular household, and $S_{i,k}$ is the share of i^{th} activity to the total household income for k^{th} household (see Appendix 2). In addition to income at disposal, households which are able to make some savings out of their income will be able to make productive investments like family education or use the savings as buffer during the times of need. For Chepangs, small livestock are also important sources of cash income; they keep these livestock as buffer to sell during the times of stress or to pay back the loan that they take from moneylenders.

Finally, social asset is represented by the number of membership in formal community based organizations (CBOs) and access to credit. Membership in CBOs will improve the households' social networks and access to information through their constant contact with the outsiders during the meetings in CBOs. Also, management of resources like water collection tanks and forests is done jointly by the members of these CBOs. Such activities help in pooling risks across the households in a community. Access to credit is also taken as social assets because for the Chepangs, taking loans from social contacts is one of the most important strategies to cope with seasonal food shortages, which they repay by selling agricultural produce, livestock, or forest products. Thus, access to credits in this community is equivalent to the social safety nets against all types of shocks. Also, some

semi-formal saving and credit organizations in the community have recently started providing interest-free loans for productive investment like vegetable farming, and rearing cattle. Thus, access to productive loans denotes the access of the households to existing credit providing organizations in the locality. Better the access to credit, higher will be the adaptive capacity of the households.

3.3 Calculation of the vulnerability index

Having chosen the suitable indicators, now these need to be normalized so as to bring the values of the indicators within the comparable range (Nelson, et al., 2010b; Gbetibouo & Ringler, 2009; Vincent, 2004). Normalization is done by subtracting the mean from the observed value and dividing by the standard deviation for each indicator.

$$\text{Normalized value} = \frac{\text{Observed Value} - \text{Mean}}{\text{Standard Deviation}}$$

Next, weights should be assigned to these indicators. Some research follows equal weighting (Nelson et al., 2005; Vincent, 2004), however it may be too arbitrary and lead to overweighting of some less important indicators, while underweighting the important ones. Weighting can also be based on expert judgement (Vincent, 2007; Adger & Vincent, 2005; Vincent, 2004), however this approach is often criticized for being too subjective, and is often constrained by the availability of subject matter specialists or lack of consensus among the experts themselves (Gbetibouo & Ringler, 2009). Assigning weight by Principal Component Analysis (PCA) following Filmer and Pritchett (2001) is thus preferred compared to the former two methods (Nelson et al., 2010b; Gbetibouo & Ringler, 2009; Cutter, Boruff, & Shirley, 2003). PCA was run for the selected indicators of exposure, sensitivity, and adaptive capacity separately in Data Analysis and Statistical Software (STATA10) software for assigning the weights. The loadings from the first component of PCA are used as the weights for the indicators. The weights assigned for each indicator varies between -1 and +1, sign of the indicators denoting the direction of relationship with other indicators used to construct the respective index. The magnitude of the weights describes the contribution of each indicator to the value of the index. PCA was run separately for the indicators of exposure, sensitivity and adaptive capacity. Stepwise PCA was run for the indicators of adaptive capacity. The first-step PCA was run for the indicators of each asset group separately to observe the relative importance of indicators within each asset category. From the weights obtained from first-step PCA, individual index values for each asset type was calculated. Second-step PCA was run using the index values for each of the five asset types

to analyze which asset group contributes the most to the total adaptive capacity. Overall adaptive capacity index was calculated using the weights (loadings) obtained from the second step PCA run for the five asset categories.

The normalized variables are then multiplied with the assigned weights to construct the indices (for exposure, sensitivity, and adaptive capacity separately) using the following formulae:

$$I_j = \sum_{i=1}^k b_i \left[\frac{a_{ji} - x_i}{s_i} \right]$$

where, 'I' is the respective index value, 'b' is the loadings from first component from PCA (PCA1) taken as weights for respective indicators, 'a' is the indicator value, 'x' is the mean indicator value, and 's' is the standard deviation of the indicators. Finally, vulnerability index for each household is calculated as: $V = E + S - AC$, where, V is the vulnerability index, E the exposure index, S is the sensitivity index and AC is the adaptive capacity index for respective household. The overall vulnerability index facilitates inter-household comparison within the VDCs and inter-VDC comparison as well. Higher value of the vulnerability index indicates higher vulnerability. However negative value of the index does not imply that the household is not vulnerable at all. This index does not give the absolute measurement of vulnerability; rather the index values give a comparative ranking of the sampled households and/or study VDCs. Tests of analysis of variance (ANOVA) was conducted to compare the means among the four study sites and four vulnerability quartiles.

4. Results and discussion

The weights obtained from PCA analysis is given in Tables 4 and 5 for the indicators of exposure and sensitivity respectively, along with the average values of the indicators across the four study sites. The weights for the indicators of exposure are all positive as hypothesized except for maximum temperature trend. This shows that while minimum temperature trend, rainfall trend and number of natural disasters contribute positively to the exposure index, maximum temperature contributes in the opposite direction. As revealed by the absolute value of the weights, temperature and rainfall trends contribute more to the exposure index compared to the incidence of natural disasters. Both minimum and maximum temperature coefficients show a slow increasing trend for all the study VDCs. Precipitation also shows an increasing trend; the rate for Kaule and Bhulichowk VDC being significantly higher compared to the other two VDCs. The number of natural disasters over the last ten years is highest for Mahadevsthan, followed by Bhulichowk, Kaule, and Kankada.

Table 4. Weights and VDC wise mean values for indicators of exposure

Indicators	Weight	Aggregate (n=221)	Kaule (n=58)	Kankada (n=56)	Mahadevsthan (n=54)	Bhumlichowk (n=53)	P-value
Minimum Temperature	0.58	0.04 (0.00)	0.05 (0.00)	0.05 (0.00)	0.04 (0.00)	0.05 (0.00)	0.00***
Maximum Temperature	-0.59	0.03 (0.00)	0.03 (0.00)	0.04 (0.00)	0.04 (0.00)	0.03 (0.00)	0.00***
Rainfall	0.56	5.87 (1.04)	7.00 (0.23)	4.46 (0.01)	5.45 (0.41)	6.59 (0.20)	0.00***
Natural disasters	0.09	2.65 (1.18)	2.66 (1.43)	2.05 (0.92)	3.00 (1.05)	2.92 (1.00)	0.00***

Source: Interpolated raw data from DHM; Field Survey 2010/11

Note: Figures in parenthesis indicate standard deviation

*** indicate significant at 1% level of significance

Table 5. Weights and VDC wise mean values for indicators of sensitivity

Indicators	Weight	Aggregate (n=221)	Kaule (n=58)	Kankada (n=56)	Mahadevsthan (n=54)	Bhumlichowk (n=53)	P-value
Fatalities	0.52	0.09 (0.91)	0.00 (0)	0.36 (1.79)	0.00 (0)	0.00 (0)	0.09*
Land affected	0.42	5.45 (12.55)	1.23 (3.33)	17.64 (19.79)	1.79 (4.68)	0.90 (1.73)	0.00***
Livestock affected	0.51	0.28 (1.34)	0.13 (0.5)	0.87 (2.48)	0.08 (0.54)	0.02 (0.16)	0.00***
Crop affected	0.53	17,958.5 (32,521.7)	6,628.8 (7,549.5)	35,329.6 (51,563.6)	17,202.3 (31,026.1)	12,773.1 (11,081.1)	0.00***
Share of natural resource based income	0.09	60.24 (26.71)	51.98 (25.35)	61.10 (28.30)	61.29 (28.59)	67.32 (22.50)	0.02*
Share of remunerative income	-0.06	11.21 (21.20)	9.56 (18.50)	14.60 (23.91)	10.67 (23.16)	9.99 (18.93)	0.57

Source: Field Survey, 2010/11

Note: Figures in parenthesis indicate standard deviation

***, * indicate significant at 1% and 10% level of significance respectively

The indicators of sensitivity are contributing to sensitivity index in the direction as hypothesized (Table 5). Among the weights for sensitivity indicators, livelihood impacts due to natural disasters are seen to influence more to the overall sensitivity index compared to the income structure. Share of remunerative income assist to decrease the overall household sensitivity (as shown by negative sign of the weight), while higher share of natural resource based income makes the household more sensitive to climate change and extremes. Although the number of natural disasters was least reported in Kankada (Table 4), the damage caused by the natural disasters is highest in Kankada for all the indicators (Table 5). This can be related to the incidences of very intensive and destructive rainfall over the last decade, thereby causing more landslides in the area. Second highest crop damage was reported in

Mahadevsthan followed by Bhumlichowk because of higher occurrences of drought over the last 10 years in these two VDCs. Higher share of natural resource based income compared to non-natural resource based income for all the study VDCs show that Chepang livelihoods is predominantly based on natural-resource based activities most notably agriculture, livestock, and forestry (Appendix 2).

Table 6. VDC wise mean values for indicators of adaptive capacity

Indicators	Aggregate (n=221)	Kaule (n=58)	Kankada (n=56)	Mahadevsthan (n=54)	Bhumlichowk (n=53)	P-value
House type	2.24 (0.48)	2.16 (0.45)	2.23 (0.47)	2.20 (0.49)	2.38 (0.49)	0.09*
Have device to access information (mobile, radio)	0.69 (0.46)	0.47 (0.50)	0.73 (0.45)	0.78 (0.42)	0.81 (0.39)	0.00***
Walking distance to nearest road	2.12 (2.62)	3.09 (0.82)	3.15 (0.69)	1.39 (4.76)	0.72 (0.33)	0.00***
Irrigated land	13.06 (21.9)	7.72 (19.8)	2.94 (13.34)	22.45 (24.85)	20.03 (22.32)	0.00***
Highest qualification	4.62 (2.90)	4.36 (2.76)	4.88 (2.94)	3.74 (3.08)	5.51 (2.58)	0.01**
Dependency Ratio	1.21 (0.76)	0.93 (0.65)	1.42 (0.84)	1.11 (0.68)	1.40 (0.75)	0.00***
Trainings / vocational course	0.52 (0.78)	0.41 (0.62)	0.48 (0.74)	0.56 (0.88)	0.62 (0.86)	0.52
Share of productive land type	74.49 (25.46)	77.11 (20.97)	61.64 (33.34)	84.43 (23.24)	75.07 (15.66)	0.00***
Share of less productive land type	25.02 (25.03)	22.88 (20.98)	36.58 (32.65)	15.46 (23.27)	24.88 (15.64)	0.00***
Have bullock	0.66 (0.47)	0.64 (0.48)	0.71 (0.46)	0.59 (0.50)	0.70 (0.46)	0.51
Gross household annual income	87,973.3 (59,252.8)	61,193.0 (35,826.2)	89,695.1 (51,915.4)	76,820.7 (52,118.5)	126,823.5 (73,191.1)	0.00***
Livelihood Diversification Index	0.53 (0.14)	0.54 (0.17)	0.54 (0.14)	0.54 (0.13)	0.52 (0.13)	0.82
Savings	2,136.9 (9,469.9)	1,119.9 (4,554.1)	1,822.3 (10,660.1)	1,481.7 (4,678.5)	4,249.6 (14,419.4)	0.30
Ownership of goat, poultry, and pig	1.93 (1.35)	1.61 (1.07)	2.22 (1.47)	1.87 (1.22)	2.03 (1.56)	0.09*
Membership in CBOs	1.11 (1.15)	0.88 (1.11)	1.05 (1.24)	1.41 (1.30)	1.11 (0.87)	0.1*
Access to credit	2.65 (0.95)	2.31 (0.86)	2.77 (1.06)	2.74 (0.85)	2.79 (0.95)	0.01**

Source: Field Survey, 2010/11

Note: Figures in parenthesis indicate standard deviation

***, **, * indicate significant at 1%, 5%, and 10% level of significance respectively

In general, the mean value of the assets reveals that Bhumlichowk has comparatively higher asset possession while Kaule has the least asset possession among the study VDCs as shown in Table 6. First step PCA was run separately for the five groups of indicators for each asset type, based on which separate index score for each-asset class was calculated. These index scores for the five types of assets was taken as the inputs for second step PCA, based on which aggregate adaptive capacity index score was computed. First step PCA shed light on the comparative contribution of individual indicators within each asset category. Second step PCA shows relative importance of the five types of assets that determine the total adaptive capacity. The index developed in this study makes use of both composite and aggregate index types. A single aggregate score of adaptive capacity index is computed while maintaining the transparency in the composite make-up of that score (Figure 2).

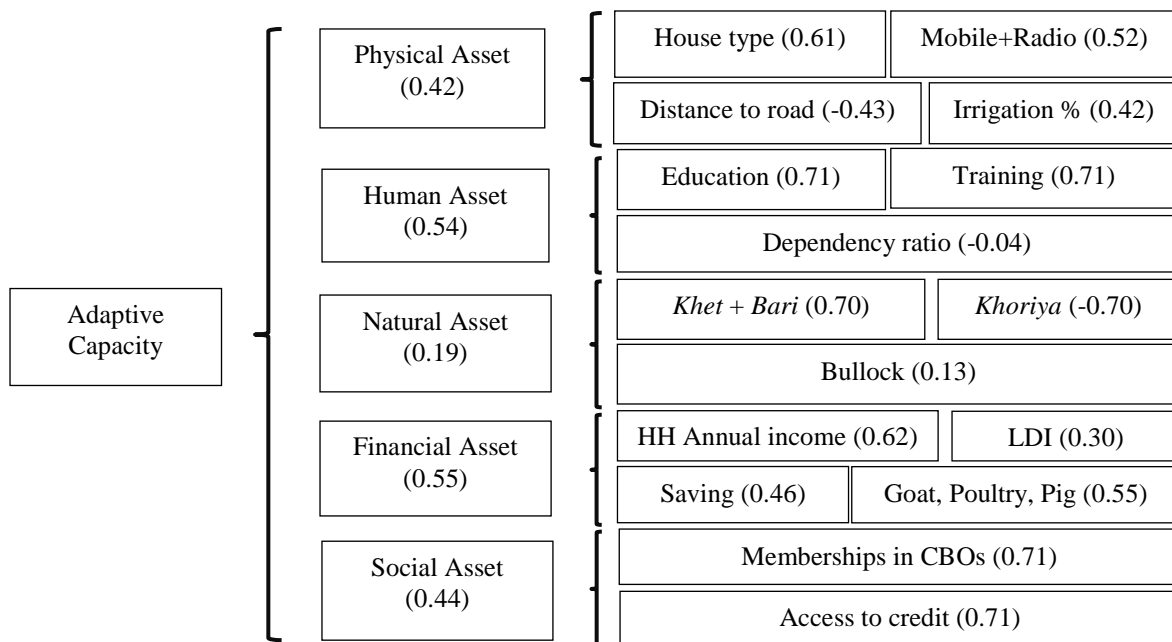


Figure 2. Structure of aggregate adaptive capacity index, composite sub-indices, and component indicators

Note: Figures in parenthesis are the loadings obtained from first principal component taken as weights for the respective indicators (b_i)

For physical assets, house type and the information devices have the highest influence followed by distance to road and percentage of irrigation. Walking distance to the nearest road negatively impacts the adaptive capacity as hypothesized. For the human assets highest qualification and training received higher weights; dependency ratio decreases the adaptive capacity as shown by the negative sign of the weight. Under natural assets, quality of land owned has higher impact in determining the adaptive capacity, while higher share of *khoriya*

land decreases the adaptive capacity as hypothesized. Among the financial assets, household annual income receives the highest weightage followed by small livestock, saving, and diversification index. For the social assets, both the indicators have equal weights.

Second-step PCA shows that financial assets and human assets are the two most important determinants of overall adaptive capacity followed by social and physical assets. Financial asset is important as it is the most convenient form of asset that can be converted into other forms of asset when needed. Development of human assets in terms of education and skill development trainings is a must in order to be able to properly utilize the existing physical and financial assets. Furthermore, local institutions and social networks are equally crucial as demonstrated by the importance of social assets. Natural assets receives the least weightage, which is quite relevant given the fact that natural resources are more impacted upon by climate change and related disasters compared to the other asset types. Thus improving the adaptive capacity against climate extremities requires diversification to livelihoods that is less dependent on natural resources.

As shown by the weights obtained from PCA analysis for asset categories, the first and foremost policy focus in the Chepang community should be to increase their access to financial assets and improve human assets. This does not imply that the remaining asset categories are not important at all. Social networks and physical assets are equally important as well. Financial assets enable households to make investment in education and the savings can be used as capital for investments like buying good quality land or buying necessary inputs for cash crop cultivation. However, financial asset is very limited in the remote rural areas that are far from the market due to fewer opportunities that generate cash income. Development supports that create employment opportunities for cash income generation in the area is recommendable. Highest qualification among the Chepang community is less than 5 years on average (Table 6), which is very low thus having several negative consequences in their livelihoods. Illiteracy, for example, hinders them from attaining the skills required to make more productive use of the available natural and physical resources. Policies should be geared towards improving the literacy rate of the community, and also towards providing trainings and vocational education for capacity building and skills development, so that they can diversify their livelihoods to more remunerative sources.

Figure 3 shows the index values for adaptive capacity and its components across the four study sites (values given in Appendix 3). Bhumlichowk fares the best in three of the asset categories (physical, human and financial) and second-best in social assets, thereby scoring the highest in overall adaptive capacity. The mean values of individual indicators in

Table 6 shows that Bhumlichowk ranks the first in terms of possession of physical assets (house type, information devices), is nearest to the road, has comparatively higher percentage of irrigated land, highest education and training, highest annual income, highest saving and best access to credit. Kaule stands the last in terms of all the asset categories (except natural assets) and thus has the least adaptive capacity. Mahadevsthan ranks the second and Kankada third in terms of adaptive capacity index.

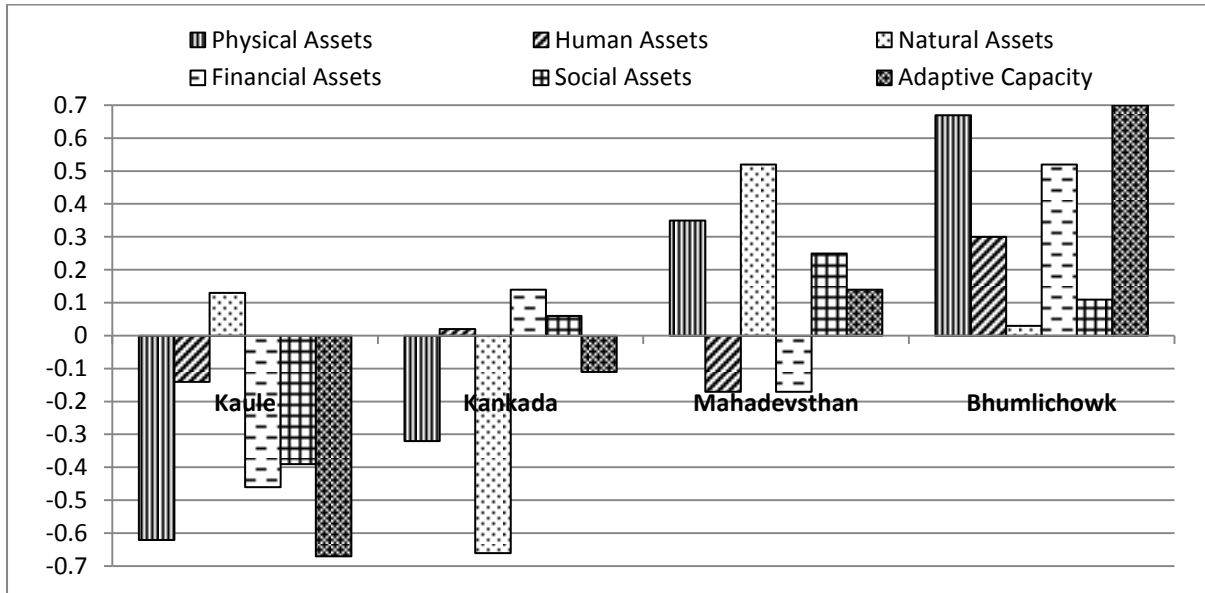


Figure 3. Index scores for adaptive capacity and its components in the four study sites

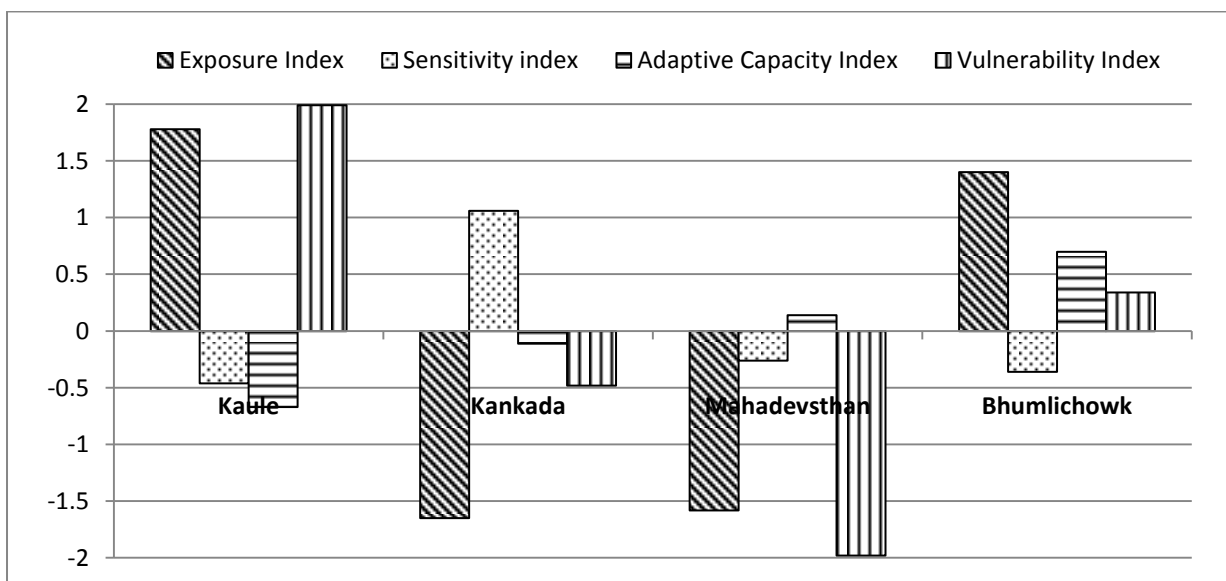


Figure 4. Index scores for vulnerability and its components for the study VDCs

Indices for exposure, sensitivity, and adaptive capacity were separately calculated as described in the methodology section. Overall vulnerability index was calculated as the subtraction of adaptive capacity index from the sum of exposure and sensitivity index. This paper assumes a linear relationship between the three components of vulnerability, however further works in depicting the exact relationship existing among these components is recommended. The average index values for the four study VDCs is presented in Figure 4 (also see Appendix 4). VDC with higher value of vulnerability index is more vulnerable; however negative value of vulnerability index does not mean that the VDCs are not vulnerable at all; it just means that these VDCs are comparatively less vulnerable. According to the value of the vulnerability index, Kaule is the most vulnerable VDC while Mahadevsthan is the least vulnerable. Bhumlichowk and Kankada rank the second and third in terms of vulnerability index. Kaule has the highest exposure coupled with lowest adaptive capacity as a result of which, it is the most vulnerable VDC. Bhumlichowk on the other hand, despite having the highest adaptive capacity ranks the second most vulnerable VDC owing to its high exposure index. Despite having comparatively lower adaptive capacity than Bhumlichowk, Kankada and Mahadevsthan VDC fares better in terms of overall vulnerability as these VDCs face lesser exposure. Comparing between the two least vulnerable VDCs, both are similar in terms of exposure, however higher sensitivity and lower adaptive capacity in Kankada results in higher vulnerability there compared to Mahadevsthan. However, Kankada and Mahadevsthan VDCs have quite low adaptive capacity, which means that the livelihood impacts of sudden extreme climatic events will be quite high in these VDCs. This fact is demonstrated in Table 5, where the livelihood impacts of extreme climatic events is the highest in Kankada VDC (thereby having the highest sensitivity index). This is because Kankada VDC faced a big landslide in 2001, which claimed several more than 60 human lives and enormous property damage. This implies that it is very important to build the adaptive capacity of the community to enable them to face the risk of sudden natural disasters. Besides, relief measures to support the community during emergencies must be put in place for all the VDCs having both higher exposure as well as lesser adaptive capacity.

Next for inter-household analysis, all the sample households from all four VDCs were categorized into four vulnerability quartiles, the first quartile representing the most vulnerable and fourth quartile representing the least vulnerable households. The index values for the quartiles are presented in Figure 5 (also see Appendix 5). Index for exposure and sensitivity is the highest for the first quartile and least for the last quartile as expected. Similarly, adaptive capacity follows the expected order, with the value being lowest for the first quartile

and consecutively higher for the subsequent quartiles. This shows that irrespective of the locations, households with lower adaptive capacity are faced with higher exposure and higher sensitivity to climate change and extreme events. Poorer households are thus vulnerable anywhere irrespective of their locations.

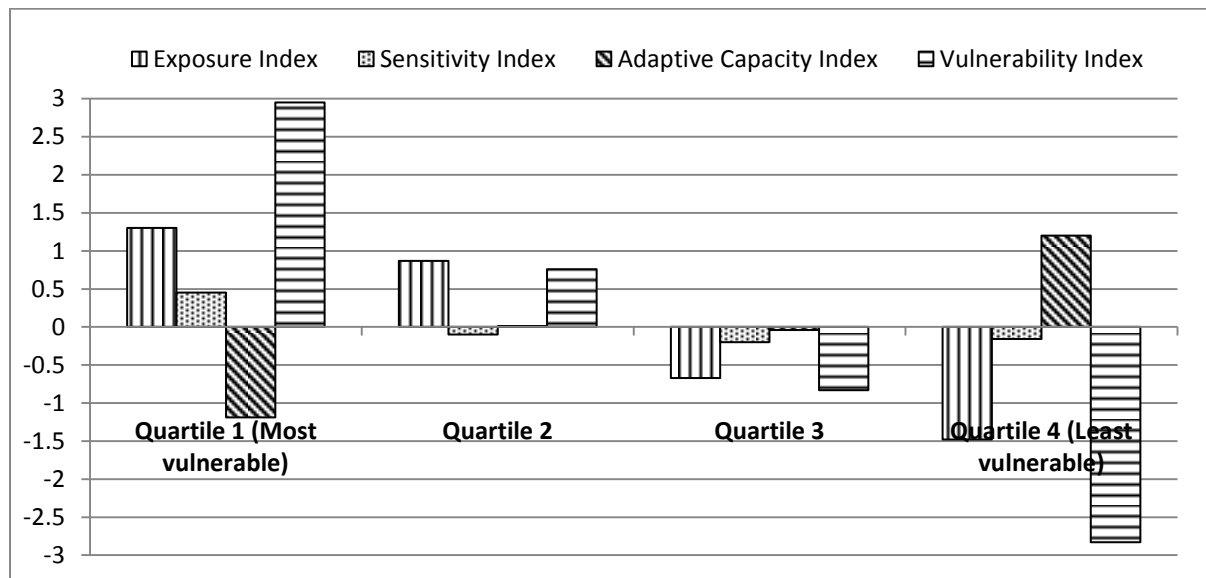


Figure 5. Index scores for vulnerability and its components by vulnerability quartiles

5. Conclusion and policy implications

The results imply that exposure of a locality to long term changes in climate variables and occurrences of natural disasters is the most important component to determine the overall vulnerability of the locality. However, biophysical elements determining the exposure like temperature, rainfall and natural disasters are beyond the immediate influence of the policy makers. Out of the three components of vulnerability, adaptive capacity is the component having direct policy implications. Improving the adaptive capacity also has indirect implications on improving the sensitivity of the community. For example, improving the irrigation facilities (physical assets) in the locality decreases the sensitivity of crops to droughts. Similarly, creating opportunities for non-farm income reduces the extensive dependence of the community on natural resource based livelihoods, thereby reducing their sensitivity towards climate change and extremes. Inter-VDC comparison of vulnerability shows that despite having higher adaptive capacity, such capacity may not be fully realized in the face of higher exposure (e.g. Bhumlichowk). On the other hand, even in VDCs with comparatively lower exposures, sudden onset of extreme events can result in significant property loss if the community does not possess sufficient adaptive capacity. Thus, policy

measures should be in place for the arrangement of activities like provision of post-disaster relief measures, maintaining buffers (like food stores), establishment of early warning systems, and evacuation centers in localities having both higher exposure and lower adaptive capacity. Inter-quartile analysis of the components of vulnerability shows that the most vulnerable households are the ones with the lowest adaptive capacity and they are the ones facing highest exposure and sensitivity irrespective of the locality. Thus, improving the adaptive capacity of these vulnerable households also reduces their sensitivity and finally decreases their overall vulnerability. Among the various components of adaptive capacity, the foremost policy emphasis should be placed to create opportunities for non-farm livelihoods options, which will not only improve the cash income of the community, but also reduce their dependence on natural resources. Higher financial assets at hand mean more choices for productive investments. However, this has to be backed-up by educating the community and providing relevant trainings and vocational education so as to develop the human capacity able to utilize the existing opportunities and assets. As agriculture still forms the mainstay of the community, development of basic infrastructure like irrigation facilities is a must. Finally, construction of all-weather roads linking the settlements to the nearest market centers will help to create markets for their farm outputs, and also improve their access to inputs, information, and off-farm employment opportunities.

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Appendix 1. Number of reported natural disasters by the households for the last 10 years

Natural Disasters	Aggregate (n=221)	Kaule (n=58)	Kankada (n=56)	Mahadevsthan (n=54)	Bhumlichowk (n=53)	P-value
Floods/Landslides	0.79 (1.18)	0.52 (0.88)	1.34 (0.48)	0.59 (0.71)	0.70 (0.72)	0.00***
Drought	1.01 (0.78)	0.93 (0.65)	0.52 (0.69)	1.35 (0.55)	1.28 (0.45)	0.00***
Hailstorm	0.85 (0.68)	1.21 (0.67)	0.20 (0.40)	1.06 (0.45)	0.94 (0.5)	0.00***

Source: Field survey 2010/11

Note: Figures in parenthesis indicate standard deviation

*** indicates significant at 1% level of significance

Appendix 2. Share of different income sources to total income (%) in the study VDCs

Income source	Aggregate (n=221)	Kaule (n=58)	Kankada (n=56)	Mahadevsthan (n=54)	Bhumlichowk (n=53)	P-value
Natural resource based sources						
Agriculture	40.85 (22.51)	30.29 (20.32)	40.28 (22.45)	41.99 (21.74)	51.87 (20.67)	0.00***
Livestock	11.65 (14.13)	15.46 (17.21)	11.45 (14.82)	9.88 (11.06)	9.51 (11.75)	0.09*
Forest	6.84 (10.40)	5.23 (9.56)	8.80 (9.75)	7.60 (11.37)	5.74 (10.78)	0.23
Honey	0.32 (0.99)	0.50 (1.60)	0.44 (0.89)	0.20 (0.58)	0.15 (0.33)	0.17
Handicraft	0.58 (2.19)	0.51 (1.79)	0.13 (0.47)	1.63 (3.82)	0.05 (0.20)	0.00***
Non-natural based remunerative sources						
Salaried job	4.95 (15.53)	0.81 (6.17)	13.35 (24.03)	1.79 (9.20)	3.84 (13.22)	0.00***
Remittance	1.38 (8.36)	0.66 (5.02)	0.00 (0.00)	2.08 (11.96)	2.91 (10.81)	0.24
Skilled non-farm job	4.88 (14.64)	8.09 (17.45)	1.25 (5.31)	6.81 (19.23)	3.23 (11.58)	0.04**
Other less remunerative sources						
Wage labor	26.3 (25.85)	35.46 (30.0)	21.3 (25.23)	25.65 (24.89)	22.21 (19.94)	0.01**
Old age allowance	1.51 (5.9)	2.03 (6.07)	2.19 (8.39)	1.52 (5.29)	0.21 (1.12)	0.28
Petty business	0.73 (5.25)	0.97 (7.36)	0.81 (3.38)	0.86 (6.32)	0.28 (2.01)	0.90

Source: Field survey 2010/11

Note: Figures in parenthesis indicate standard deviation

***, **, * indicate significant at 1%, 5% and 10% level of significance respect

Appendix 3. Mean values of sub-indices for adaptive capacity for the study VDCs

Indices	Kaule	Kankada	Mahadevsthan	Bhumlichowk	P-value
Physical Assets	-0.62 (0.86)	-0.32 (0.90)	0.35 (1.32)	0.67 (0.95)	0.00 ^{***}
Human Assets	-0.14 (0.96)	0.02 (1.18)	-0.17 (1.23)	0.30 (1.07)	0.10 [*]
Natural Assets	0.13 (1.21)	-0.66 (1.81)	0.52 (1.31)	0.03 (0.89)	0.00 ^{***}
Financial Assets	-0.46 (0.79)	0.14 (1.13)	-0.17 (0.93)	0.52 (1.40)	0.00 ^{***}
Social Assets	-0.39 (0.95)	0.06 (1.03)	0.25 (1.02)	0.11 (0.93)	0.00 ^{***}
Adaptive Capacity	-0.67 (1.07)	-0.11 (1.42)	0.14 (1.47)	0.70 (1.44)	0.00 ^{***}

Note: Figures in parenthesis indicate standard deviation

^{***}, ^{*} indicates significant at 1%, and 10% level of significance respectively

Appendix 4. VDC wise mean values of indices of vulnerability and its components

Indices	Kaule	Kankada	Mahadevsthan	Bhumlichowk	P-value
Exposure	1.78 (0.18)	-1.65 (0.46)	-1.58 (0.32)	1.40 (0.15)	0.00 ^{***}
Sensitivity	-0.46 (0.30)	1.06 (2.80)	-0.26 (0.70)	-0.36 (0.25)	0.00 ^{***}
Adaptive capacity	-0.67 (1.07)	-0.11 (1.42)	0.14 (1.47)	0.70 (1.44)	0.00 ^{***}
Vulnerability	1.99 (1.09)	-0.48 (3.26)	-1.98 (1.50)	0.34 (1.50)	0.00 ^{***}

Note: Figures in parenthesis indicate standard deviation

^{***} indicates significant at 1% level of significance

Appendix 5. Mean values of indices of vulnerability and its components for the vulnerability quartiles

Indices	Quartile 1 (Most vulnerable)	Quartile 2	Quartile 3	Quartile 4 (Least vulnerable)	P-value
Exposure	1.30 (1.11)	0.87 (1.23)	-0.67 (1.43)	-1.48 (0.99)	0.00 ^{***}
Sensitivity	0.45 (2.92)	-0.10 (0.73)	-0.20 (0.74)	-0.16 (0.53)	0.10 [*]
Adaptive capacity	-1.19 (0.67)	0.01 (0.85)	-0.04 (1.30)	1.20 (1.60)	0.00 ^{***}
Vulnerability	2.95 (2.21)	0.76 (0.50)	-0.83 (0.45)	-2.83 (1.09)	0.00 ^{***}

Note: Figures in parenthesis indicate standard deviation

^{***}, ^{*} indicates significant at 1%, and 10% level of significance respectively